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27	28	29	30			

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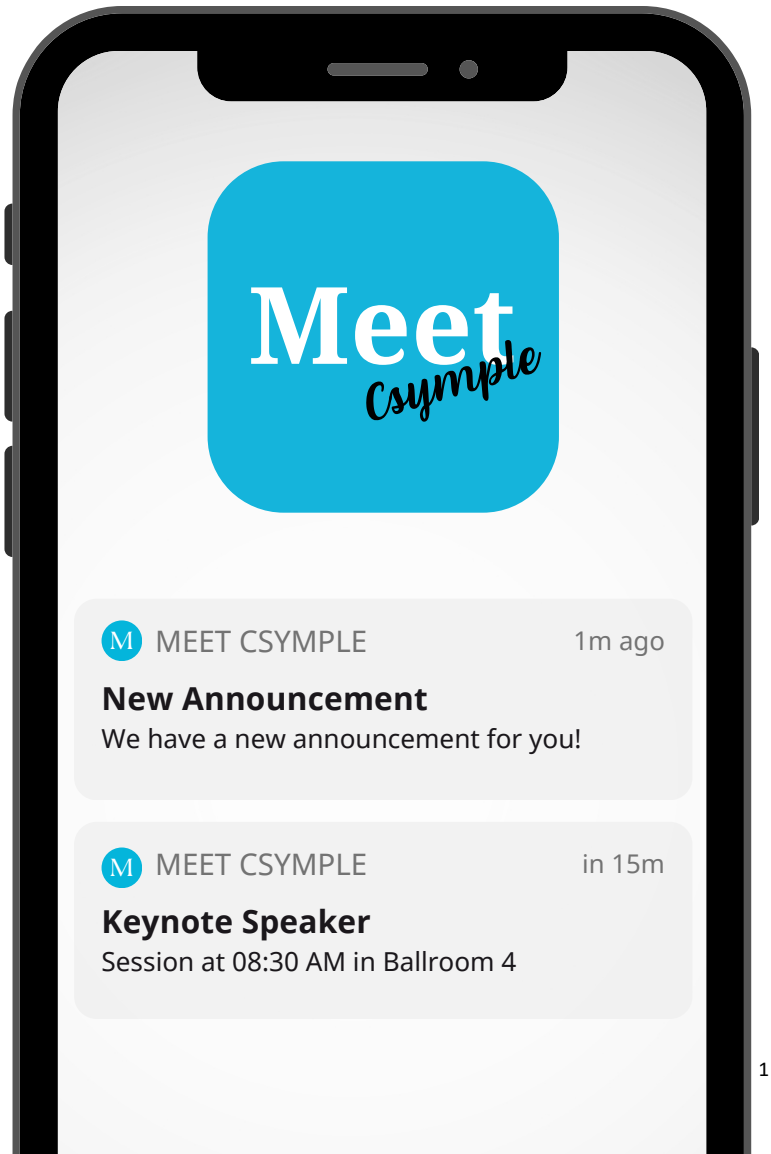

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CONTINUING MEDICAL EDUCATION CREDIT INFORMATION

Accreditation
The American College of Surgeons is accredited by the Accreditation Council for Continuing Medical Education (ACCME) to provide continuing medical education for physicians.

AMA PRA Category 1 Credits™
The American College of Surgeons designates this live activity for a maximum of 25.0 *AMA PRA Category 1 Credits™.* Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Of the *AMA PRA Category 1 Credits*™ listed above, a maximum of **25.0** hours meet the requirements for **Emergency General Surgery**.*

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Of the *AMA PRA Category 1 Credits*™ listed above, a maximum of **3.50** hours meet the requirements for **Geriatric Surgery**.*

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ACS AMERICAN COLLEGE OF SURGEONS

ACCME ACCREDITED WITH COMMENDATION

Successful completion of this CME activity, which includes participation in the evaluation component, enables the learner to earn credit toward the CME of the American Board of Surgery's Continuous Certification program.

PROGRAM OBJECTIVES

1) Describe innovative, appropriate techniques and technology for optimal care of the injured or seriously ill patient in urban and rural environments
2) Apply concepts from urban and rural trauma and acute care surgery cases to the practice setting
3) Describe practical exposure techniques and guidelines for management and early control of injuries and acute surgical conditions
4) Identify the dilemmas, ethics, and solutions relative to managing critically ill and injured patients
5) Discuss care issues particular to the surgical intensive care unit, including TBI, fluid administration, nutrition, timing of tracheostomy, renal replacement therapies, delirium, and pulmonary contusion
6) Discuss how to manage complications relative to operative approaches and specific organ injuries
7) Discuss evolving nonclinical issues, including second victim phenomenon, organ donation, trauma center proliferation, and human trafficking
8) Identify the pros and cons of trauma transfer policies and safety and efficacy of interosseous fluid resuscitation

DISCLOSURE INFORMATION

Ineligible Company: The ACCME defines an "ineligible company" as any entity producing, marketing, re-selling, or distributing health care goods or services used on or consumed by patients. Providers of clinical services directly to patients are NOT included in this definition.
Financial Relationships: Relationships in which the individual benefits by receiving a salary, royalty, intellectual property rights, consulting fee, honoraria, ownership interest (e.g., stocks, stock options or other ownership interest, excluding diversified mutual funds), or other financial benefit. Financial benefits are usually associated with roles such as employment, management position, independent contractor (including contracted research), consulting, speaking and teaching, membership on advisory committees or review panels, board membership, and other activities from which remuneration is received, or expected.
Conflict of Interest: Circumstances create a conflict of interest when an individual has an opportunity to affect CME content about products or services of an ineligible company with which he/she has a financial relationship.

The ACCME also requires that ACS manage any reported conflict and eliminate the potential for bias during the educational activity. Any conflicts noted below have been managed to our satisfaction. The disclosure information is intended to identify any commercial relationships and allow learners to form their own judgments. However, if you perceive a bias during the educational activity, please report it on the evaluation.

Speakers / Moderators / Discussants / Authors	Nothing to Disclose	Disclosure		
		Company	Role	Received
Hamed Amani	No			
Jayson Aydelotte	No			
Elizabeth R. Benjamin	No			
Andrew C. Bernard	No			
Carlos V.R. Brown	No			
Andre R. Campbell	No			
Bryan J. Cotton	Yes	Haemonetics Corp (TEG, CellSaver)	Scientific Advisory Board	Honorarium
Chris Cribari	No			
Demetrios Demetriades	No			
Marc de Moya	Yes	Boston Scientific	Consultant	Consultant Fee
Jay J. Doucet	No			
Alexander Eastman	No			
Tanya Egodage	No			
Patrick Georgoff	No			
Jennifer Gurney	No			
R. David Hardin, Jr	No			
Eliott R. Haut	No			
Kenji Inaba	No			
Jay A. Johannigman	No			
Bellal A. Joseph	No			

Speakers / Moderators / Discussants / Authors	Nothing to Disclose	Disclosure		
		Company	Role	Received
Mark J. Kaplan	No			
James Kempema	No			
Natasha Keric	No			
Meghan R. Lewis	Yes	Pfizer	Surgical Advisory Board	Financial Compensation
Matthew J. Martin	No			
Kenneth L. Mattox	No			
R. Todd Maxson	No			
Rakesh Navuluri	No			
Jigarkumar A. Patel	No			
Purvi P. Patel	No			
Ali Salim	No			
Michael A. Samotowka	No			
Martin A. Schreiber	Yes	Haemonetics	Consultant & Research PI	Financial Compensation
		CSL Behring	Consultant & Research PI	Financial Compensation
		Tricol	Consultant	Financial Compensation
Jeffrey J. Skubic	No			
Jason W. Smith	No			
Jason L. Turner	No			
Sydney J. Vail	No			
Matthew J. Wall, Jr.	No			
Alison Wilson	No			
Kenneth L. Wilson	No			
D. Dante Yeh	Yes	Takeda Pharmaceuticals	Consultant	Consultant Fee
		UpToDate	Author	Author royalties
		Irrimax Corporation	medical advisory board	Honorarium
		American Society of Parenteral and Enteral Nutrition (ASPEN)	medical advisory board	Honorarium
		Society of Critical Care Medicine	Speaker	Honorarium

Program Committee	Nothing to Disclose	Disclosure		
		Company	Role	Received
Mary Allen	No			
Patrick Georgoff	No			
Matthew J. Martin	No			
Kenneth L. Mattox	No			
Purvi Patel	No			
Martin A. Schreiber	Yes	Haemonetics	Consultant & Research PI	Financial Compensation
		CSL Behring	Consultant & Research PI	Financial Compensation
		Tricol	Consultant	Financial Compensation
Jason L. Turner	No			
Alison Wilson	No			
D. Dante Yeh	Yes	Takeda Pharmaceuticals	Consultant	Consultant Fee
		UpToDate	Author	Author royalties
		Irrimax Corporation	Medical Advisory Board	Honorarium
		American Society of Parenteral and Enteral Nutrition (ASPEN)	Speaker	Honorarium
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IN MEMORIAM

DAVID V. FELICIANO, MD, FACS, MAMSE

Hawthorne, New Jersey
Nov 23, 1944 – Jan 4, 2024

David Vincent Feliciano, MD, FACS, MAMSE, 79, of Edgewater, Maryland passed away on Thursday, January 4, 2024 in his home with his wife by his side. Born in New York City, New York, he was the son of the late Dr. Vincent and Anita (Hessler) Feliciano. David was a graduate of Hawthorne High School, received his undergraduate and medical degrees (cum laude) from Georgetown University and his training in general surgery at the Mayo Clinic. He also had training in trauma at Detroit Receiving Hospital/ Wayne State University, and in vascular surgery (six month Fellowship) at Baylor College of Medicine. Dr. Feliciano was a Lieutenant in the U.S. Navy Medical Corps Reserve (Port Hueneme, California). He was Surgeon-in-Chief at Grady Memorial Hospital and a Professor of Surgery at Emory University in Atlanta from 1992-2011 and then was Chief of General Surgery at Indiana University and Chief of Surgery at Indiana University Hospital from 2013-2017. In 2018, he became a Clinical Professor of Surgery at the University of Maryland and an Attending Surgeon (recently emeritus) at the Shock Trauma Center/ Department of Surgery. A pioneer in trauma surgery, Dr. Feliciano became world renowned in vascular trauma and emergency general surgery. He published almost 700 articles/chapters/books and served on numerous prestigious Editorial Boards including having served as an Associate Editor of The American Surgeon. He has been Co- Editor of the textbook TRAUMA through all nine editions and was lead Co-Editor for the 3rd, 6th, and 9th editions. Dr. Feliciano was a member of 25 surgical or medical organizations including the American Surgical Association, Southern Surgical Association, and the American Association for the Surgery of Trauma. He was President of the Priestley Society (Mayo Surgeons), 1991-1992; President of the Southwestern Surgical Congress, 1991-1992; President of the Western Trauma Association, 1992-1993; President of the Panamerican Trauma Society, 1999-2000; President of the Atlanta Surgical Association, 2004-2005; President of the American Association for the Surgery of Trauma, 2006-2007; President of the Georgia Surgical Society, 2009-2010; President of the Southeastern Surgical Congress, 2016-2017; was Chair of the Advisory Council for General Surgery, American College of Surgeons, 2007-

2011; and was a Director, American Board of Surgery, 2001-2007. Besides being a gifted and dedicated surgeon, one of his greatest legacies was his 49 Teaching Awards which deemed him a master educator. In 2016, he received the Distinguished Alumnus Award from the Mayo Clinic and, in 2021, he received a Distinguished Service Award from the Southeastern Surgical Congress. He and his wife, Grace loved living on the water and enjoyed boating and kayaking on the Chesapeake. They were members of the Holy Family Catholic Church in Davidsonville, Maryland. He was a man of the highest character and deep faith who, as a beloved surgeon, teacher, mentor, and father will be missed by many. Dr. Feliciano was preceded in death by his parents and brother, Donald. Surviving are his wife of 22 years, Grace (Grace F. Rozycki, MD); his greatest legacy his two sons, (David Feliciano in Houston, Texas and Douglas Feliciano, JD in Mountain View, California), sister (Joan DeFreest, Hewitt, New Jersey), his former spouse, Barbara Feliciano (Waimea, Hawaii) several nieces, nephews, and cousins. The family wishes to thank Dr. Thomas Scalea, Physician-in-Chief, R Adams Cowley Shock Trauma Center; System Chief for Critical Care Services, University of Maryland Medical System along with his superb team for the extraordinary care provided to Dr. Feliciano over several years.

Rao Ivatury, MD, FACS

February 24, 1947 - February 27, 2024

It is with sadness that we announce the passing of Dr. Rao R. Ivatury, a loving father and husband, committed educator and mentor, and pioneer in the field of trauma surgery and critical care.

Modest and unassuming, his kindness and respect extended equally to his most accomplished surgical colleagues as it did to the nurses, service staff and technicians he knew were the unsung heroes of excellent patient care. This humility and generosity of spirit inspired love and affection in all who knew him, in particular his beloved family.

Born in 1947 in Kakinada, India, Dr. Ivatury hailed from a family deeply-rooted in the medical profession, guided by the influence of his father, a highly-respected surgeon. His journey in medicine began at P.R. Government College, Kakinada, India, and he later graduated from Andhra Medical College in 1969. He completed surgical residencies at the All India Institute of Medical Sciences in New Delhi (1974) and Misericordia Hospital in the Bronx, New York (1980).

As Director of Trauma and Co-Director of the SICU at Lincoln Medical & Mental Health Center (1987-1997), Dr. Ivatury developed a profound love for trauma and critical care rooted in his experiences caring for patients during a violent time in the south Bronx. His work laid the foundation for groundbreaking concepts in trauma care, such as "damage-control" surgery and the management of open abdomen cases.

n 1998, Dr. Ivatury became a Professor of Surgery at Virginia Commonwealth University (VCU) Medical Center, where he served as Chief of Trauma, Critical Care, and Emergency Surgery until his retirement in 2012. During his tenure, he transformed the VCU Trauma Center into an internationally-recognized institution, leading an expansion of the full-time trauma faculty and guiding it to recognition as a Level 1 Trauma Center.

Dr. Ivatury's impact extended beyond the operating room. His dedication to developing the next generation of surgeons led his students and residents to refer to him as "Trauma Master Jedi Yoda," reflecting his humility, wisdom, and kindness as an educator. Esteemed globally, he was frequently sought

after for his expertise, especially in Latin America, where he invested considerable time and energy assisting other surgeons as a leader of the Panamerican Trauma Society.

A prolific author and editor, Dr. Ivatury leaves behind an impressive body of work with some 350 publications, 100 abstracts, thirty chapters, and five books. Dr. Ivatury's contributions to medicine were recognized with awards such as the Fred Parker Award and the Arnold M. Salzberg Award in Surgery, and in 2019 he was named a Master Surgeon Educator by the American College of Surgeons.

Beyond his professional achievements, Dr. Ivatury was a loving husband to Dr. Leela Kriplani for 48 years until her passing in 2023. He was a proud father to two sons, Gautam and Arun, and a doting grandfather to five grandchildren, in whom his love of music and his dedication to helping others lives on. Dr. Ivatury will be remembered not only as an icon in the field of trauma surgery but as a loving and compassionate teacher, mentor, husband, and father. His legacy will continue to inspire future generations and his kind and humble leadership will continue to serve as a model for all.

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MATTOX VEGAS TCCACS™ 2024 PROGRAM AT A GLANCE		
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	TITLE	SPEAKER
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7:45 – 8:00	Massive Transfusion - When it is too much?	Kenji Inaba
8:00 - 8:15	Meshing Around: Mesh Selection and Utilization in High Risk Hernias	Natasha Keric
8:15 – 8:30	Just Say No to Angio: The Dark Side of Angioembolization for Solid Organ Injury	Matthew J. Martin
8:30 – 8:45	Scan Them All? Selective versus Universal Screening for Blunt Cerebrovascular Injury	Tanya Egodage
8:45 – 9:00	Pelvic Fractures: Pelvic Binders, Preperitoneal Packing, and Other Myths!	Demetrios Demetriades
9:00 – 9:15	Pediatric and Adult High Grade Pancreatic Injuries: Is to Cut Still to Cure?	R. Todd Maxson
9:15 – 9:30	The K-Hole: Prehospital and ER Ketamine Indications and Complications	Zaffer A. Qasim
9:30 – 10:00	PANEL DISCUSSION	
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10:30 – 12:00	Panelists: Elizabeth R. Benjamin — R. David Hardin, Jr. Alexander L. Eastman — Martin A. Schreiber Jennifer M. Gurney — Jason W. Smith Matthew J. Wall, Jr.	

	SESSION 3 KENNETH L. MATTOX ANNUAL DISTINGUISHED LECTURESHIP Moderator: Martin A. Schreiber	Augustus Ballroom Palace Tower Emperors Level – 4th Floor
	TITLE	SPEAKER
12:00 – 1:30	"Necessity As The Mother of Invention: Innovation And Health Challenges From COVID-19 To 'Bionic' Arms"	Albert Chi
1:30 – 3:45	SESSION 4 SEE ONE, DO ONE - HOW I DO IT Moderator: Elliott R. Haut	Palace Ballrooms 1-2 Palace Tower Emperors Level – 4th Floor
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1:45 – 2:00	Take Back the Duct: Laparoscopic Common Bile Duct Exploration	Marc de Moya
2:00 – 2:15	Complicated Diverticulitis: Cut to Cure?	Jay A. Doucet
2:15 – 2:30	Initial Burn Resuscitation	Hamed Amani
2:30 – 2:45	Battle of the Bulge: Lumbar and Flank Hernias	Meghan R. Lewis
2:45 – 3:00	Dangerous Passage: Penetrating Neck Injuries and the "No-Zone" Approach	Kenji Inaba
3:00 – 3:15	Fasciotomy: Start to Finish – Avoiding the Pitfalls	Jason W. Smith
3:15 – 3:30	Rib Plating: Is It Time to Slow Your Roll?	Patrick Georgoff
3:30 – 3:45	Bleeding Kids: Optimal Resuscitation for Pediatric Patients in Hemorrhagic Shock	R. Todd Maxson
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4:10 – 5:10	SESSION 5 NEW TECHNIQUES AND TECHNOLOGY Moderator: Kenji Inaba	Palace Ballrooms 1-2 Palace Tower Emperors Level – 4th Floor
	TITLE	SPEAKER
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4:22 - 4:34	Plasma in Burns - What's Old is New Again	Jennifer M. Gurney
4:34 – 4:46	New Airway Tools and Techniques: Prehospital and Emergency Department	James Kempema
4:46 – 4:58	Cell Salvage in Damage Control Resuscitation	Martin A. Schreiber
4:58 – 5:10	Surgical Nostradamus: The Future of AI and Machine Learning in Acute Care Surgery	Bellal A. Joseph

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7:42 – 7:54	**Dry Land Drownings: Fluid Overuse in Sepsis Resuscitation**	**Bryan A. Cotton**
7:54 – 8:06	**Managing Severe Pulmonary Contusions**	**Carlos V.R. Brown**
8:06 – 8:18	**Trach or Wait? Early vs. Late Tracheostomy in the Trauma ICU**	**Jayson Aydelotte**
8:18 – 8:30	**Failing Kidneys: Renal Replacement Therapies in the ICU**	**Purvi P. Patel**
8:30 – 8:42	**Chill Out: Delirium & Sedation in the Critically Ill Acute Care Surgery Patient**	**Andrew C. Bernard**
8:42 – 8:54	**Updates in TBI Management: Brain Oxygenation, MMA Embolization, and New Protocols**	**Tanya Egodage**
8:54 – 9:06	**ICU Nutrition: Stuff Em or Starve Em!**	**Andre' R. Campbell**
9:06 – 9:18	**Ethical Challenges in the ICU**	**Jay J. Doucet**
9:18 – 9:30	**Double Jeopardy - Billing for ICU Consults**	**Jason W. Smith**
9:30 – 10:00	**PANEL DISCUSSION**	
10:00 – 10:30	**Break/Visit Exhibits**	**Palace Ballroom 3 Palace Tower Emperors Level – 4th Floor**

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10:45 – 11:00	Ventral Hernia and the Hostile Abdomen: Robotic eTEP to the Rescue!	Matthew J. Martin
11:00 – 11:15	When To Call IR	Rakesh Navaluri
11:15 – 11:30	Cut to the Core: Pulmonary Hilar Injuries	Matthew J. Wall, Jr
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11:45 – 12:00	Biliary Obstruction: Surgical Options When ERCP Fails	Mark J. Kaplan
12:00 – 12:15	Backed Into a Corner: Damage Control Surgery in the Rural or Austere Setting	Jason L. Turner
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2:08 – 2:16	TXA: Is the Story Complete?	Sydney J. Vail
2:16 – 2:24	Stop the Clot: VTE Prophylaxis Update	Elliott R. Haut
2:24 – 2:32	Incisional Wound Vacs: Do They Live Up to the Hype?	Marc A. de Moya
2:32 – 2:40	Perianal Emergencies for the Acute Care Surgeon	Chris Cribari
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	TITLE	**SPEAKER**
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5:00 – 5:15	**Infected Hardware and Vascular Prostheses**	**Ali Salim**
5:15 – 5:30	**Taming the Beast: How to Approach EC Fistulas**	**D. Dante Yeh**
5:30 – 5:45	**Bowel Obstruction in the Post Bariatric Surgery Patient**	**Kenneth L. Wilson**
5:45 – 6:00	**REBOA Complications and Pitfalls**	**Demetrios Demetriades**
6:00 – 6:30	**PANEL DISCUSSION**	
7:00 – 9:30 PM	**SESSION 12** **MEET THE PROFESSOR / DISCUSS THE ISSUES RECEPTION / DANCE**	**Augustus Ballroom** **Palace Tower** **Emperors Level – 4th Floor**
WEDNESDAY, APRIL 17, 2024		
Time	**Activity**	**Location**
6:30 – 8:30	**Continental Breakfast Served in Exhibit Hall**	**Palace Ballroom 3** **Palace Tower** **Emperors Level – 4th Floor**
7:00 – 8:30	**SESSION 13** **HENRY C. CLEVELAND FORUM ON CONTEMPORARY ISSUES IN TCCACS** **Moderator: Jay A. Johannigman**	**Palace Ballrooms 1-2** **Palace Tower** **Emperors Level – 4th Floor**
	TITLE	**SPEAKER**
7:00 – 7:10	**You've Been Served - Dealing with Malpractice Issues and Lawsuits**	**Sydney J. Vail**
7:10 – 7:25	**How to Recruit, Retain, and Compensate in the Rural Setting**	**Jeffrey J. Skubic**
7:25 – 7:40	**Entrustable Professional Activities: Ready or Not, Here they Come**	**D. Dante Yeh**

7:40 – 7:55	Use of APPs to Strengthen the Practice and Continuum of Care	Chris Cribari
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	Pro Position	Carlos V.R. Brown
	Con Position	Matthew J. Martin
9:00 – 9:30	Resolved: Intraosseous is the safe, effective method for initial administration of fluid and blood	
	Pro Position	Zaffer A. Qasim
	Con Position	Bellal A. Joseph
9:30 – 10:00	Break & Visit Exhibits	Palace Ballroom 3 Palace Tower Emperors Level – 4th Floor
10:00 – 11:25	SESSION 15 WE HAVE MET THE ENEMY… Moderator: Kenneth L. Wilson	Palace Ballrooms 1-2 Palace Tower Emperors Level – 4th Floor
	TITLE	SPEAKER
10:00 – 10:15	Human Trafficking: How to Detect? What to do?	Alexander L. Eastman
10:15 – 10:30	Second Victim Phenomenon	Alison Wilson
10:30 – 10:45	Facing Futility: When to Say When in Kids and Adults	Bryan A. Cotton
10:45 – 11:00	Three's a Crowd: Proliferation of Trauma Centers	Natasha Keric
11:00 – 11:15	Victory out of Tragedy: Organ Donation Challenges	Ali Salim
11:15 – 11:30	PANEL DISCUSSION	
	SESSION 16 MATTOX COMMENTARY	Palace Ballrooms 1-2 Palace Tower Emperors Level – 4th Floor
11:25 – 1:00	Commentary On Lessons Learned	Kenneth L. Mattox

GENERAL COURSE INFORMATION

Trauma, Critical Care & Acute Care Surgery 2024 is a two-and one-half-day course focusing on treatment of critically ill and injured patients, stressing current basic and cutting-edge guidelines and technology for evaluation, diagnosis, and management. The course is designed to enhance the skills of those caring for ill and injured patients in rural, urban, and suburban hospitals.

CONFERENCE REGISTRATION

Early registration is 3:00-5:30 p.m., Sunday, April 14, Palace Tower, 4th floor immediately outside the General Session Room, the Palace Ballrooms 1 & 2. General registration opens at 6:45 a.m., Monday, April 15th and is in the same location.

GENERAL SESSIONS

All general sessions are held in Palace Ballrooms 1 & 2 on the 4th floor of the Palace Tower. You must have a *TRAUMA, CRITICAL CARE & ACUTE CARE SURGERY* badge to enter the General Session. The General Session begins at 7:30 a.m, Monday, April 15th.

CONTINENTAL BREAKFAST

Continental breakfast will be served in the Exhibit Hall in Palace Ballroom 3, immediately adjacent to the General Sessions. Hours for continental breakfast are Monday 7:00-8:30 a.m., Tuesday 7:00-8:30 a.m., Wednesday 6:30-8:30 a.m.

On Tuesday, you will have two satellite breakfast program options offered by independent providers. The programs are offered at no charge to you, and if you did not register prior to the conference and space is available, registration may be done with the provider on-site.

These independent satellite breakfast programs are not accredited by or affiliated with the American College of Surgeons or Trauma, Critical Care and Acute Care Surgery 2024.

LUNCH SESSIONS

On Monday at 12:00 noon, the luncheon session will be held in the Augustus Ballroom, 4th floor, Palace Tower. Your badge will serve as your ticket for this session and admits one person. Doctor Albert Chi is presenting, "*Necessity as The Mother of Invention: Innovation and Health Challenges From COVID-19 To 'Bionic' Arms.*"

On Tuesday, you will have free time to attend one of three satellite luncheon programs offered by independent providers. These programs are offered at no charge to you, and if you did not register prior to the conference and space is available, registration may be done with the provider on-site.

These independent satellite luncheon programs are not accredited by or affiliated with the American College of Surgeons or Trauma, Critical Care and Acute Care Surgery 2024.

CLAIMING YOUR CME CREDITS

This is accomplished online, optimally done during the conference. We have provided complimentary Wi-Fi in the convention general session and Exhibit Hall, as well as in your Caesars Palace hotel room.

Instructions for accessing CME Claiming site while at the conference:

1. Go to Wi-Fi list on your phone, laptop, etc.
2. Click on our SSID (network name), which is **MattoxTCCACS2024**
3. Then it will prompt you to put in the password, which is **Tccacs!!**
4. Then it will take you to the internet
5. Next go to Conference URL to CLAIM CME: WWW.LVTRAUMACME.COM

BADGES

All registrants will be provided a name badge for use during the meeting. For security purposes, name badges are required at all times in the convention area. Individuals without a badge will not be admitted into the course room or exhibit hall. Lost badges will be replaced with a $20 fee.

MATTOX/VEGAS TCCACS 2024

April 15-27, 2024
Caesars Palace, Las Vegas

SCHOLARSHIP RECIPIENTS
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Emily W. Baird, MD, University of Alabama at Birmingham

Sarah Hatfield, MD, MPD, Weill Cornell Medicine

Lindsey Loss , MD, Oregon Health and Science University

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Casey Silver, MD, MS, Northwestern University

Sophia M. Trinh, MD, LSU Health, New Orleans

Dana van der Heide, MD, University of Iowa

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Jacoby Bryce, University of Utah School of Medicine

Kristin Ohe, MD, Texas Tech University, El Paso

Nehil Patel, Touro University Nevada College of Osteopathic Medicine

Michael S. Rallo, Rutgers Robert Wood Johnson Medical School

Fariha Tareen, Ross University School of Medicine

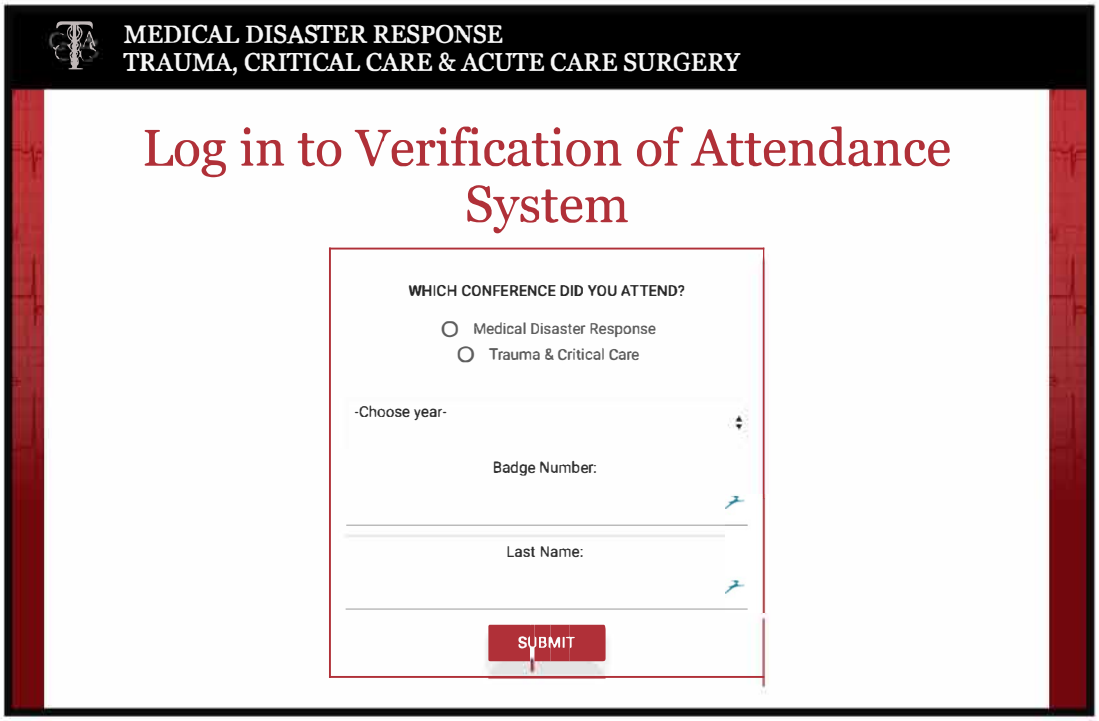
Kaylee Velasquez, Arkansas College of Osteopathic Medicine

ATTENDANCE VERIFICATION, MOC EXAM, & CME CERTIFICATES

TRAUMA, CRITICAL CARE, ACUTE CARE SURGERY 2024

APRIL 15-17, 2024

WWW.LVTRAUMACME.COM



Your USER ID is the ID NUMBER PRINTED ON THE LOWER CORNER OF YOUR BADGE, OPPOSITE THE BARCODE. TAKE A MOMENT NOW TO INPUT YOUR BADGE NUMBER IN THE BLANK ABOVE, AND/OR NOTE IT IN YOUR TELEPHONE OR OTHER ELECTRONIC DEVICE.

CME / MOC Instructions

The link to Step 2 will be available upon submitting Step 1. You can access any of the steps as many times as you wish.

Step #	Description	Completed?
1	Complete Verification of Attendance Form (VOA)	✗
2	Course Evaluation You may SUBMIT this form multiple times.	✗
3	**Download CME Certificate** (must complete VOA form and course evaluation first)	✗

LOG OUT

STEP 1: ACCESS CONFERENCE URL TO CLAIM CME

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- Click on our SSID (network name), which is **MattoxTCCACS2024**
- Then; it will prompt you to put in the password, which is **Tccacs!!**
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- Next go to Confrenece URL to claim one: WWW.LVTRAUMACME.COM

STEP 2: VERIFICATION OF ATTENDANCE

- FREE WI-FI provided in the General Session and your Caesars Palace hotel rooms to facilitate your completing your required forms immediately, during the conference
- You may save and submit this form multiple times
- Once you complete and submit your Verification of Attendance (VOA) Form, you may:
  - Complete the course evaluation (Step 3) REQUIRED

STEP 3: COURSE EVALUATION

- Course evaluation form must be completed for your certificate to be downloaded (Step 4).
- You may complete the forms in stages, following each session (advised), or at the completion of the course

STEP 4: DOWNLOAD CME CERTIFICATE

- PLEASE ENSURE YOU SAVE A COPY FOR YOUR RECORDS
- If you note any errors on your certificates, contact Mary Allen IMMEDIATELY at REDSTART@AOL.COM or Telephone: 713.798.4557

The Verification of Attendance system for submitting requests for CME credit is available via any device connected to the Internet. Should the Wi-Fi network in the meeting room seem slow because of high usage, you may use your data plan's wireless connection or access the system.

www.lvtraumacme.com

SCAN THE ABOVE QR CODE TO GO TO THE TCCAS 2024 DASHBOARD, WHICH ALLOWS YOU TO SIGN IN TO ACCESS REQUIRED CME FORMS, AS WELL AS DOWNLOAD YOUR CME CERTIFICATE.

ALSO, SUBMIT YOUR QUESTIONS TO THE SESSION MODERATORS VIA THIS SYSTEM

2024

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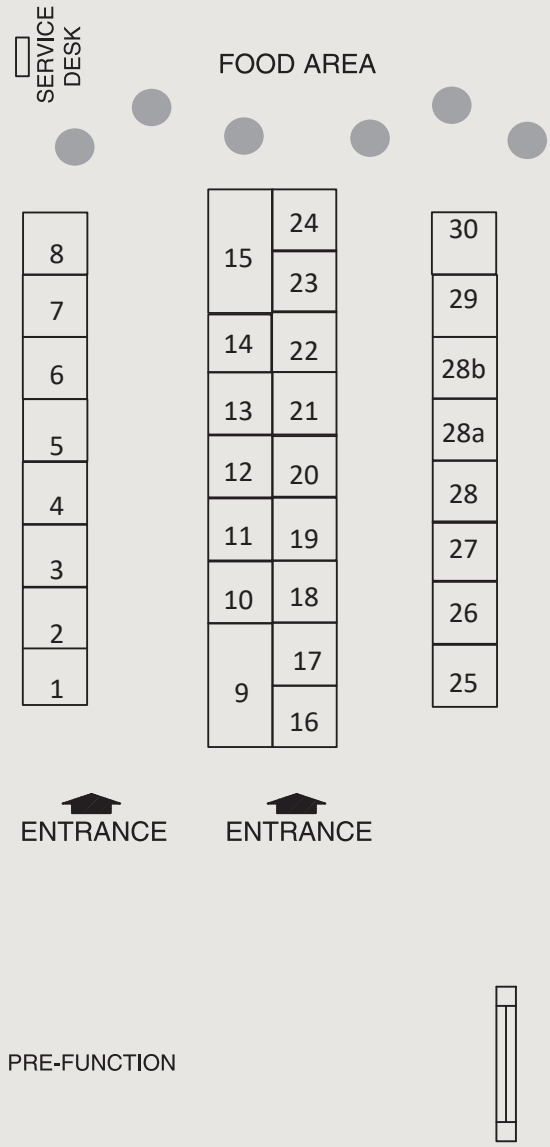

SATELLITE LUNCHEON AND BREAKFAST PROGRAMS

On Tuesday, take advantage of your free time for breakfast and lunch to hear about the following products! Attendance is limited, so, register early.

AROA™

Tuesday, Breakfast Program 6-7:15 AM, Augustus 1-2 Ballroom

HEMOSONICS
A Stago Group Company

Tuesday, 6-7:15 AM Breakfast Program, Augustus 3-4 Ballroom

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Tuesday, Luncheon Program, 12:30-2:00 PM, Augustus 3-4 Ballroom

RECELL® Autologous Cell Harvesting Device | avita medical

Tuesday Luncheon Program, 12:30-2:00, Augustus 1-2 Ballroom

PRYTIME MEDICAL™
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Tuesday Luncheon Program, 12:30 – 2:00 PM, Emperor Ballroom

These independent satellite programs are not accredited by or affiliated with the American College of Surgeons or Trauma, Critical Care and Acute Care Surgery 2024.

SESSION 1

HOT TOPICS

Moderator: Martin A. Schreiber

Monday, April 15, 2024

7:30 – 10:00 AM
Palace Ballrooms 1-2
Palace Tower
Emperors Level – 4th Floor

7:30 – 7:45	**TCCACS Review/Preview 2024** **Kenneth L. Mattox, MD, FACS, MAMSE**
7:45 – 8:00	**Massive Transfusion - When it is too much?** **Kenji Inaba, MD, FRCSC, FACS**
8:00 – 8:15	**Meshing Around: Mesh Selection and Utilization in High Risk Hernias** **Natasha Keric, MD, FACS**
8:15 – 8:30	**Just Say No to Angio: The Dark Side of Angioembolization for Solid Organ Injury** **Matthew J. Martin, MD, FACS, FASMBS**
8:30 – 8:45	**Scan Them All? Selective versus Universal Screening for Blunt Cerebrovascular Injury** **Tanya Egodage, MD, FACS**
8:45 – 9:00	**Pelvic Fractures: Pelvic Binders, Preperitoneal Packing, and Other Myths!** **Demetrios Demetriades, MD, PhD, FACS**
9:00 – 9:15	**Pediatric and Adult High Grade Pancreatic Injuries: Is to Cut Still to Cure?** **R. Todd Maxson, MD, FACS**
9:15 – 9:30	**The K-Hole: Prehospital and ER Ketamine Indications and Complications** **Zaffer A. Qasim, MBBS, FRCEM, FRCPC (EM) Edic**
9:30 – 10:00	**Panel Discussion**
10:00 – 10:30	**Break & Visit Exhibits** **Palace Ballroom 3** **Palace Tower** **Emperors Level – 4th Floor**

MATTOX VEGAS TCCACS – REVIEW/PREVIEW 2024

Kenneth L Mattox, MD, FACS, MAMSE

Course Director, TCCACS
Distinguished Service Professor
Michael E. DeBakey Department of Surgery
Special Advisor to the President and CEO
Baylor College of Medicine
Houston, TX

What has become known as the Mattox-Vegas-Trauma Course has now been held in Las Vegas, Nevada, for **FIFTY-SEVEN (57) consecutive** years, and all but one of these in Caesars Palace. The first TCCACS Vegas Conference was held the same year Caesars Palace opened, so the Mattox Vegas TCCACS is now the "longest running show" at one venue in Vegas. In 2021, in the immediate post COVID era, we were the first conference to hold a safe, "live," large conference, which we also presented virtually, for the first time and have continued.

TCCACS attendees join us each Spring to recharge their clinical batteries and stay abreast of cutting-edge approaches to evaluation and care of the injured and sickest of the sick patients, as well as to network with colleagues. The greatest marketing tool for this conference is word of mouth spread by current and past attendees. We welcome and appreciate your enthusiasm for this conference. Our driving focus continues to be your patients – providing you with current knowledge that helps you provide the very latest and best medical and surgical care. Please let us (redstart@aol.com, kmattox@aol.com) know details of specific cases and managerial tactics for which this course affected your practice. Use your social media sources to transmit real time observations to the world trauma community, as well as using **@kmattox1 on Twitter** or **Kenneth Mattox or TCCACS on Facebook**. Share what you learn with those who are unable to attend! Use your **TCCACS Conference App** to find and communicate with colleagues and exhibitors, post pictures directly to your social media of choice, and get special conference announcements and alerts, among many other applications.

TCCACS CONFERENCE APP
CONFERENCE CODE: TCCACS20249

The meeting organizers carefully select faculty with proven track records. Each year, our faculty ever disappoint and always exceed expectations. Differing views are encouraged among the faculty to inspire you to recognize the differences between dogma and emerging evidence-based issues in the ever changing areas of acute care surgery, surgical critical care, and trauma management.

This conference is a dynamic experience. Take advantage of all aspects – from interacting with colleagues from around the world, to exchanging views with our faculty, to expanding your knowledge by visiting the exhibitors in the Exhibit Hall. Take advantage of the additional vendor sponsored Satellite breakfast and Luncheon Sessions on Tuesday. After two lengthy, exhilarating days of intense learning, relax at the Tuesday evening reception and dance, and take another opportunity to chat with friends, exhibitors, and faculty.

We welcome your suggestions and input on all aspects of the program. Please take time and thought in completing the course Evaluation Tool. We read and collate ALL comments/suggestions, which play a key role in next year's course. You, the attendees, play one of the most important roles of the meeting. Without your interest, participation, and enthusiasm, there would be no conference "energy"-one of the key elements of our success.

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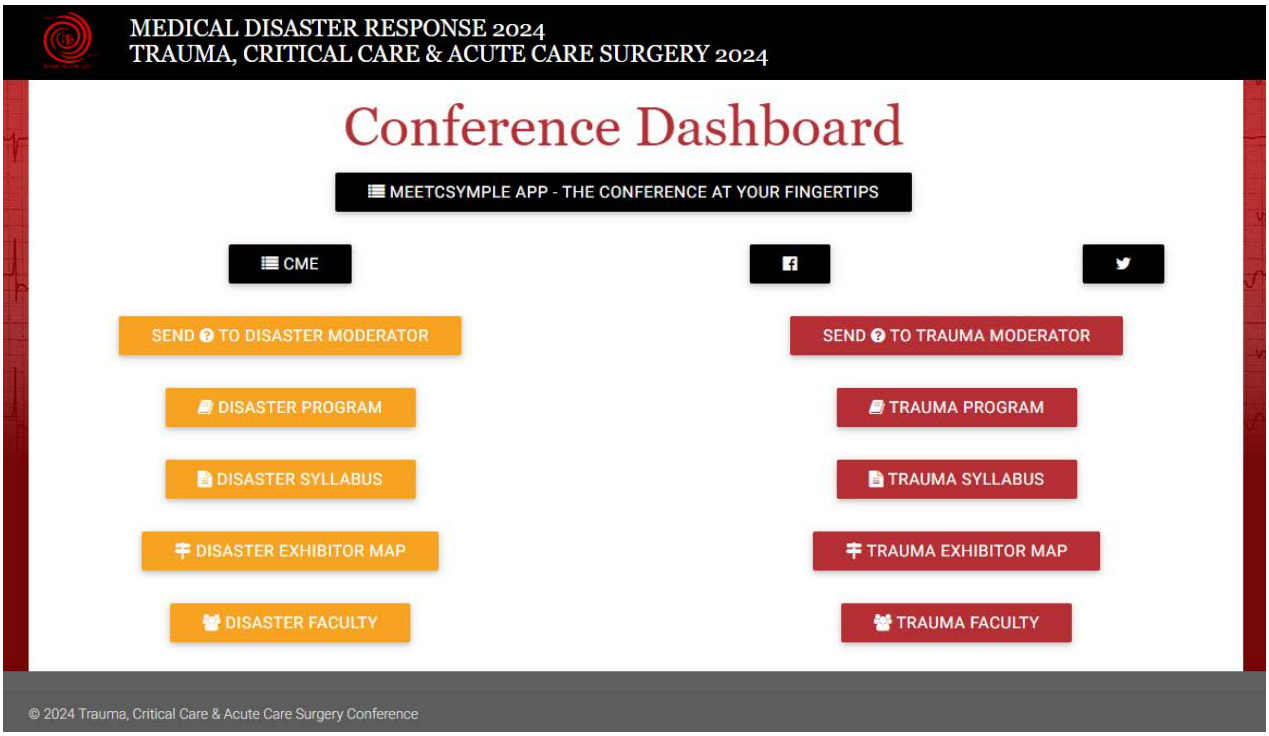

Please take full advantage of opportunities to interact with the other attendees, faculty, and exhibitors. Using the Evaluation Tool, please tell us what you want to hear about and experience in next year's course. Your interest, participation, and enthusiasm are the conference "energy" – a key element to our success.

MTP AND FUTILITY

Kenji Inaba, MD, FRCSC, FACS

Professor and Vice Chair of Surgery
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For the injured patient who survives to reach emergency medical care, bleeding remains the primary cause of preventable death. Consequently, as trauma care providers, our primary goal is to aggressively find and achieve surgical or endovascular control of this bleeding. To optimize the physiologic conditions for this to occur, however, the replacement of lost volume and correction of any systemic coagulation defects remain a critical complementary step. Upward of a quarter of trauma patients will present to the emergency department with a measurable coagulopathy, even in the absence of pharmacologic anticoagulation. Over the last several years, as part of a damage control resuscitation strategy, the efficacy of a balanced approach to the resuscitation of injured patients has been tested, with an emphasis on the use of fixed ratio blood product transfusion in ratios approaching 1:1:1.

The efficacy of this approach to empiric blood product transfusion remains a critical question and was addressed by a Research Outcomes Consortium multicenter prospective trial conducted at 12 centers in Canada and the US. This study called the Pragmatic Randomized Optimal Platelets and Plasma Ratios (PROPPR) study, enrolled patients expected to require a massive transfusion and randomized them to treatment with a 1:1:2 versus a 1:1:1 ratio. In summary, there were no significant differences in the mortality outcomes at the predetermined 24 hour and 30 day endpoints. However, more of the patients in the 1:1:1 group achieved hemostasis, and fewer died due to exsanguination, the critical cause of death targeted by hemostatic resuscitation. Importantly, there were no safety differences noted between the two study arms.

COMPONENTS

How plasma is used during acute resuscitation is one of the major changes to our resuscitation strategies and underpins the 1:1:1 discussion. It is produced from whole blood separation or apheresis and is frozen within 8 hours (FFP) or 24 hours (FP24) of collection and can be stored frozen for up to one year. Each mL by convention contains 1 IU of all factors and can be thawed in approximately 15-30 minutes and dispensed as A, B, O or AB specific without the need for Rh typing or crossmatching. Alternatively, pre-thawed plasma, including the universal donor AB or low titer A, is held refrigerated in liquid form where it can be stored for up to 5 days for immediate access.

For bleeding patients, the transfusion of red cells (PRBC) is a priority; however, if replaced in the absence of the remaining normal constituents of blood, a coagulopathy with the loss of intrinsic clotting efficacy will result. The best available evidence today suggests that a more aggressive approach to plasma replacement is associated with improved outcomes. This is particularly true in that subset of patients who are undergoing massive, rapid hemorrhage and require a massive transfusion. The exact definition of a massive transfusion is elusive. Research studies often use the need for more than 10 PRBC units within a defined time period, such as 24 hours. With the realization that the most critically ill patients who are actively bleeding undergo definitive treatment early, with front-loaded resuscitation, this time interval has been progressively decreasing from 24 hours to 12 and even 6 hours after admission. More recent

definitions advocate the use of rates, such as the Critical Administration Threshold of 3 Units/hour, as described by Savage. For those patients with slow, smaller volume bleeds, lab values can often be used to guide factor replacement. The INR and PTT, as well as platelet count, can be checked and corrected with replacement product. Alternatively, thromboelastography can be utilized. For those being massively transfused, however, even thromboelastography cannot keep up and empiric fixed ratios are used to determine the amount of plasma and platelets that are to be transfused.

The best available evidence that we have at this time supports the use of higher volumes of plasma in ratios that approach 1:1 of Plasma to PRBCs.

Contemporary platelets are available as either random donor pooled units or, increasingly, as a single donor apheresis product. Each apheresis unit is equivalent to approximately 6-8 units of the random donor product and as such, a 1:1:1 ratio when utilizing apheresis platelets actually requires a unit of apheresis platelets to be transfused for every 6-8 units of plasma and 6-8 of PRBC. Platelets, regardless of the source, are stored at room temperature in the blood bank under very stringent storage conditions. They are dispensed as an ABO matched product. The data supporting the use of platelets in the context of a massive transfusion is not as extensive as that existing for plasma. When the existing evidence is summarized however an increasing amount of platelets in relationship to PRBC volume is associated with an improvement in survival.

FUTILITY

While the aggressive transfusion of blood as part of the resuscitation package is clearly associated with a survival benefit, this is not without cost. Our blood supply is not unlimited, and increased use can strain any supply network no matter how redundant, as blood is a time limited product. This problem was made crystal clear during the COVID-19 pandemic, where there was an acute blood product shortage noted across the nation by the Red Cross.

The concept of medical futility for those patients undergoing a massive transfusion is complex, and like every other aspect of medicine, introduces a multitude of subjective factors that make this a difficult concept to grasp, let alone define a transfusion threshold beyond which care becomes “futile”. Furthermore, external factors, such as the impact on society of a massive volume of blood products being used for a single patient who may or may not survive can become critically important when put into context.

With this said, however, several studies have examined patients receiving large volume transfusions in the context of trauma, and several important lessons have been learned.

A recent review of fourteen studies, all retrospective, predominantly trauma, with in excess of 8000 patients was published by Kim. This study clearly demonstrated the weaknesses inherent to the existing literature. The data is all retrospective, with highly variable definitions of what would constitute a large volume “ultra-massive” transfusion. As would be expected, as the volume of blood products increased, the number of patients who received these high volume transfusions, the ones who are truly in question, also decreased, making the true study numbers small. While the studies included in the analysis demonstrated that in addition to the classic risk factors for death after trauma such as injury burden and physiological compromise remained unchanged, again not surprisingly, the more blood product the patient required, the higher the mortality. However, despite there being a clear trend toward an increase in mortality with increasing blood transfusion, the authors were unable to find a cut-off value beyond which transfusion became universally futile.

In another recent large retrospective military study that was not included in the 14 study review, 11,746 combat casualties receiving blood were examined. The median transfusion volume was eight units. Ten patients received a staggering 164 to 290 units of blood product, with seven of these patients surviving to 24 hours. Notably, almost 80% of those receiving in excess of 100 units of blood products under austere conditions survived to 24 hours, again making the concept of a blood transfusion threshold for futility an exceedingly difficult number to capture.

No universally accepted transfusion maximum beyond which survival becomes futile exists. However, because there is not an unlimited supply of blood products, pragmatically, this is still a very important concept to consider for all trauma care providers resuscitating the critically ill trauma patient.

One practical approach is to have a pre-planned "time-out" at regularly scheduled transfusion thresholds decided upon ahead of time. For example, the UK National Blood Transfusion Committee recommends a re-evaluation after the transfusion of every 8 units of blood. At these points during the resuscitation, patient factors such as the injury burden, work effort remaining, physiologic status, as well as system factors such as the institutional capability and blood supply should be considered, with an individualized short term plan created for the patient. This may not be practical if the preplanned transfusion threshold occurs during a critical portion of an operative intervention, but doing this at regularly scheduled intervals will prevent blind transfusion to an expected outcome.

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MESHING AROUND: MESH SELECTION AND UTILIZATION IN HIGH-RISK HERNIAS

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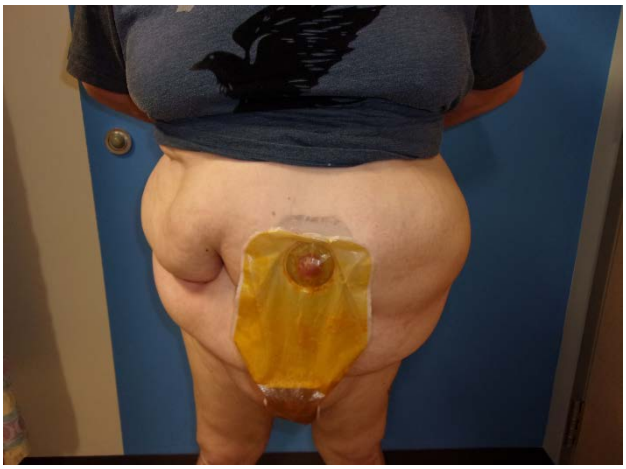
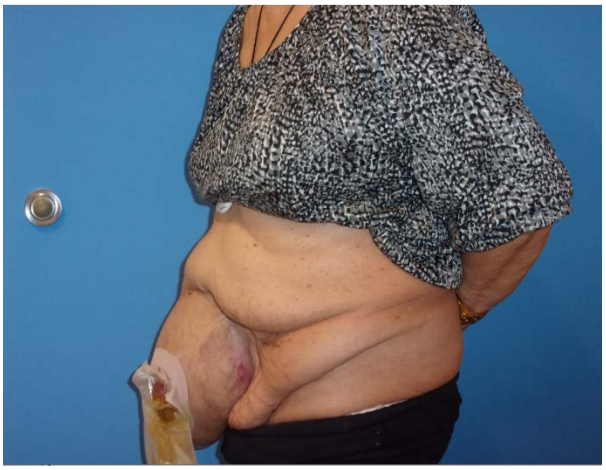
THE SCOPE OF THE PROBLEM

- There are 5 million laparotomies performed annually in the United States with up to a 20% risk of developing an incisional hernia.
- Approximately 400,000 ventral hernia repairs are done each year adding > $15 billion dollars to US healthcare costs.
- Ventral hernia repairs in a contaminated field are challenging and usually not avoidable in the acute care surgery practice.
- Patient comorbidities increase the risk for postoperative complications.
- Mesh requirement and type of mesh to be used for ventral hernias in contaminated fields remain a controversial topic.
- Recent literature is calling into question use and benefit of biologic mesh for high-risk hernia repairs.

DEFINITIONS AND OVERVIEW

1. **High-Risk Hernia:** Hernia in a high-risk patient; BMI > 35, current tobacco user, current diagnosis of diabetes mellitus, immunocompromised state, previous ventral hernia repair, and need for an emergent repair, such as damage control laparotomy.

2. **Contaminated Field:** The CDC wound classification has been found to be a marker for patient readmission with surgical wounds that are anything other than class I (clean) wounds. Most acute care surgeons operate on patients with Class II (clean contaminated), Class III (contaminated) and Class IV (dirty/infected) wounds, which portend a significantly higher risk of infectious complications and 30-day readmission. Surgeons must be familiar with different techniques and risk of mesh utilization to soften the risk that is inherent to the wound even prior to surgical intervention.

Table I. Surgical Wound Classification Grades (I-IV) as Defined by the CDC

CDC Surgical Wound Classification Definitions
Class I/Clean: An uninfected operative wound in which no inflammation is encountered, and the respiratory, alimentary, genital, or uninfected urinary tract is not entered. In addition, clean wounds are primarily closed and, if necessary, drained with closed drainage. Operative incisional wounds that follow no penetrating (blunt) trauma should be included in this category if they meet the criteria.
Class II/Clean-Contaminated: An operative wound in which the respiratory, alimentary, genital, or urinary tracts are entered under controlled conditions and without unusual contamination. Specifically, operations involving the biliary tract, appendix, vagina, and oropharynx are included in this category, provided no evidence of infection or major break in a sterile technique is encountered.
Class III/Contaminated: Open, fresh, accidental wounds. In addition, operations with major breaks in a sterile technique (eg, open cardiac massage) or gross spillage from the gastrointestinal tract, and incisions in which acute or no purulent inflammation is encountered are included in this category.
Class IV/Dirty-Infected: Old traumatic wounds with retained devitalized tissue and those that involve existing clinical infection or perforated viscera. This definition suggests that the organisms causing postoperative infection were present in the operative field before the operation.

CDC = Centers for Disease Control and Prevention.

3. **Types of Mesh:** There is a wide variety of synthetic and biologic mesh. These definitions are foundational.

    a. Synthetic Mesh: Most often categorized as macroporous, microporous, or composite. Microporous mesh includes monofilament and double filament polypropylene with large pore sizes that allow tissue ingrowth (increase in scar tissue). Microporous mesh, which includes ePTFE, does not include tissue ingrowth, and, therefore, has a lower affinity for adhesions. Composite materials combine the different qualities usually on different sides of the mesh to take advantage of the benefits and minimize the side effects of the mesh composition. Mesh can have antiadhesive coatings that are absorbable (i.e., polyurethane) or nonabsorbable (i.e., collagen hydrogel). Synthetic mesh can also be categorized by weight (light, medium, heavy).

Examples of Synthetic Mesh

Name	Company	Features
Soft Mesh	Bard	Lightweight, macroporous, polypropylene
Ventralight ST Mesh	BD	Uncoated medium weight monofilament polypropylene on anterior side with absorbable hydrogel barrier (Sepra Technology) on posterior side
Ultrapro	Ethicon	Macroporous, partially absorbable and lightweight polypropylene

b. Biologic Mesh: Categorized as acellular dermal matrix (ADM) obtained from human (allografts) or non-human (xenografts) sources. Sources of biological mesh include human dermis or fascia lata, porcine dermis or intestine, and bovine dermis or pericardium. Alteration of the extracellular matrix through manufacturing techniques (decellularization, crosslinking and/or sterilization) can impact cellular infiltration and neovascularization.

Examples of Biologic Mesh

Name	Company	Features
Strattice	Life Cell Corp	Non crosslinked, porcine dermis
AlloDerm	Life Cell Corp	Non crosslinked, donated allograft human dermis
Permacol	Medtronic	Cross-linked porcine dermis
Surgimend	Integra Life Sciences	Fetal bovine dermis

OPTIONS FOR VENTRAL HERNIA REPAIR IN AN ACUTE SETTING

1. **Skin Only Closure:** This is a reasonable option for patients with multiple comorbidities and does not impede on future repairs. Skin is the ideal biologic dressing with no extra cost and one stage repair, which allows for earlier extubation and enteral nutrition. Need for subcutaneous flaps and drains can lead to higher morbidity with postoperative pain, infection, seroma, hematoma, or flap necrosis.
2. **Primary Repair:** Primary repair does eliminate the use of mesh but has high recurrence rates. Studies have looked at type of suture and technique to decrease hernia rates. The use of triclosan-coated sutures in emergent surgery has been shown to reduce the incidence of incisional surgical site infections and evisceration when compared with PDS. The small bites versus large bites for closure of abdominal midline incisions (STITCH) trial showed risk of an incisional hernia at 1 year was lower in the small bites group (5mm by 5mm) versus the large bites group (1cm by 1cm). Although the primary repair technique eliminates the use of mesh, it has high recurrence rates. Arroyo et al showed that in the suture only group, there was an 11% hernia recurrence versus the mesh group that had 1%. Similar results were shown in the Burger et al paper. Most experts will agree that mesh repair is superior to primary repair in decreasing hernia recurrence rates.

Table II. Complications after umbilical hernia repair

	Sutures (n = 100)	Mesh (n = 100)
Seroma	5	6
Haematoma	1	1
Wound infection	3	2
Other	2	1
Recurrence	11	1*

*P = 0·0015 *versus* sutures (χ^2 test with Yates' correction)

Arroyo et al., Br J Surg. 2001 Oct;88(10):1321-3

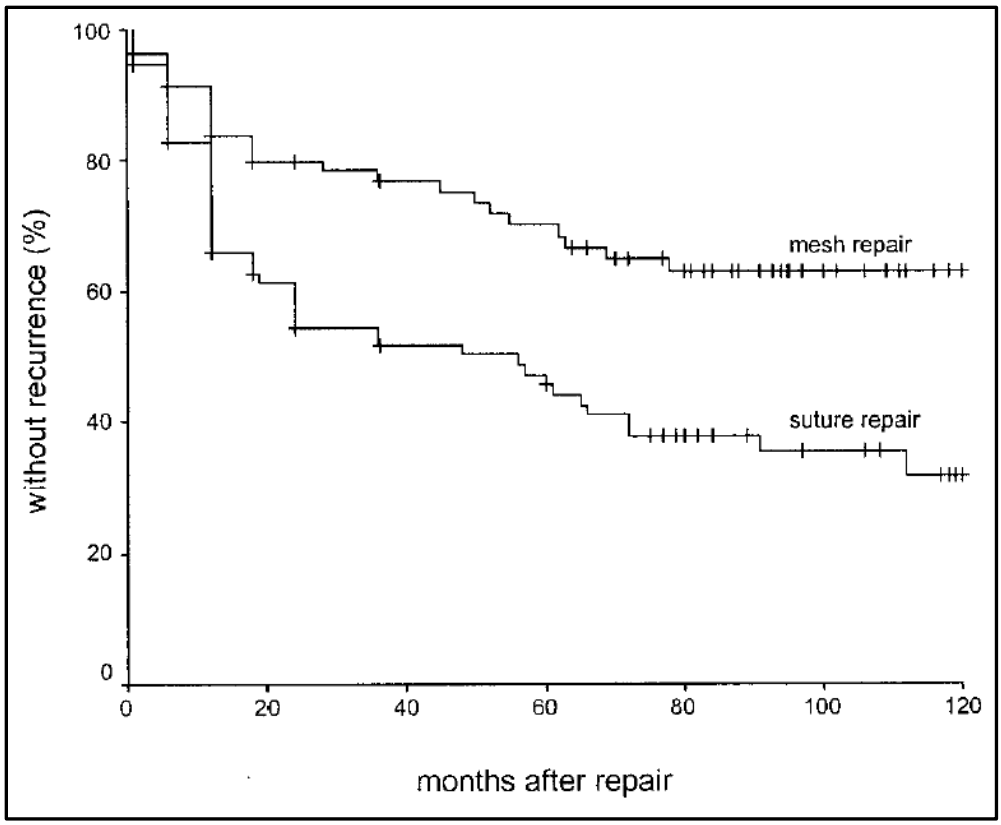
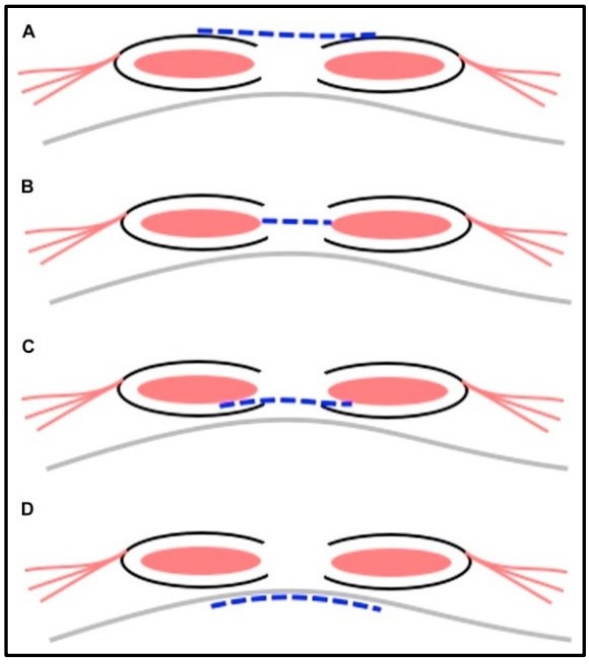


Figure 1. Kaplan-Meier curves for recurrence of hernia after repair of a primary or first recurrent incisional hernia according to whether the patient was assigned to suture repair (97 patients) or mesh repair (84 patients). There were significantly fewer recurrences in patients who were assigned to mesh repair ($P <$ 0.001). Source: *Burger et al, Ann Surg. 2004 Oct;240(4):578-83*

3. **Bridge or Reinforce with Mesh:** There are four classic planes for mesh position in a ventral hernia repair; onlay/overlay (a), bridged/inlay (b), sublay/retromuscular underlay (c) and intraperitoneal/preperitoneal underlay (d).

   Fascial bridge using prosthetic mesh is a reasonable option if there is tension and the abdominal fascia will not come together. Although sublay repair has low surgical site occurrence and recurrence rates, it is a complex procedure that requires high surgical skills and may cause devastating abdominal wall complications. Each mesh plane has advantages and disadvantages and can be legitimate options in proper patient selection.



PLANNED VENTRAL HERNIA AND ABDOMINAL WALL RECONSTRUCTION

Consensus amongst experts is that abdominal wall reconstruction should not be employed in the acute phase, as it might preclude future repair. This is usually attempted in the outpatient setting as a planned ventral hernia repair. Newer techniques, such as the Transverse Abdominus Muscle Release (TAR), to obtain tension free reconstruction with component separation in complex and large abdominal wall hernias are proving to have low morbidity and recurrence rates. Repair in the elective phase still does not eliminate contaminated spaces, as many hernioplasties involve concomitant ostomy takedown and mesh explantation. Studies have shown that even in the contaminated planned herniorrhaphy, the use of synthetic mesh can be employed safely, decrease recurrence rates, and be cost effective when compared to biologic mesh. There is still need for continued research comparing one stage versus two staged abdominal wall reconstruction.

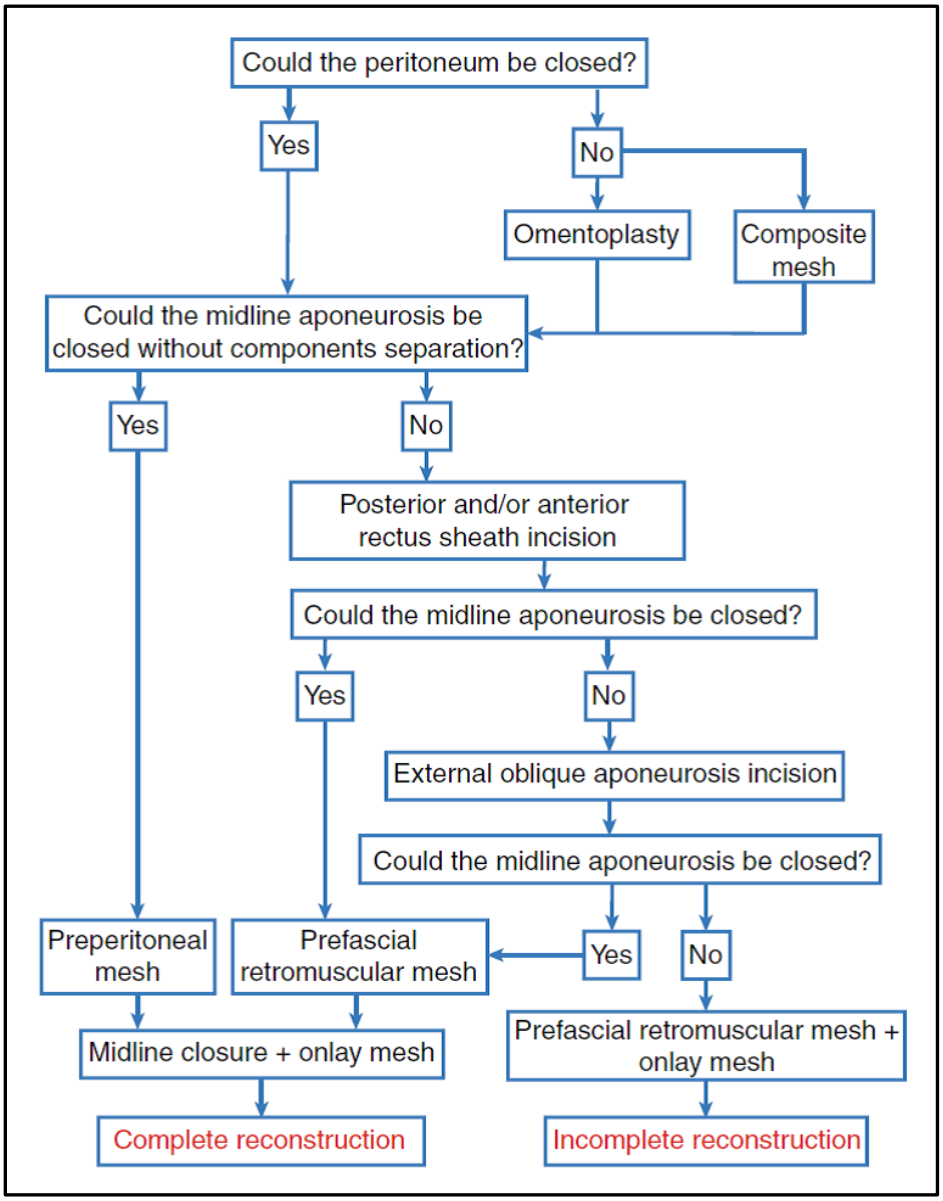


Figure 2. Ventral hernia repair algorithm. Source: *Celdran et al, Hernia. 2016 Apr;20(2):201-7*

SYNTHETIC VERSUS BIOLOGIC MESH IN A CONTAMINATED VENTRAL HERNIA

Inconsistent literature has supported the opinion that synthetic mesh used in a contaminated hernia leads to high rates of surgical site occurrence (surgical site infection, seroma, wound dehiscence and enterocutaneous fistulae) and need for mesh explantation. Common practice has been to implant a biologic mesh in patients with high-risk hernias to reduce the incidence of mesh infection; however, recent literature has shown biologic mesh to have double the rates of recurrence and cost compared to synthetic mesh.

Table III. Recommendations of the VHWG for the technique of repair of incisional ventral hernias[3,6-9,31,32,62]

Recommendation	*Strength of recommendation*	*Level of evidence*	*Evidence*
1. Reinforcement recommended for repair of all incisional ventral hernias	1	A/B	Burger et al[6] Espinosa-de-los-Monteros et al[7] Luijendijk et al[3]
2. Centralize and reapproximate rectus muscles when feasible under physiologic tension	1	C	de Vries Reilingh et al[8] Espinosa-de-los-Monteros et al[7] Kolker et al[9] VHWG opinion
3. Reduce bioburden prior to repair	1	B	Mangram et al[32] VHWG opinion
4. Placement of repair material: Underlay is the recommended technique for the placement of appropriate repair material for open and laparoscopic repairs; overlay placement of repair material should only be considered when complete fascia-to-fascia repair has been achieved	2	B	Awad et al[31] Espinosa-de-los-Monteros et al[7] Korenkov et al[62] VHWG opinion
5. In the setting of gross, uncontrolled contamination, it is appropriate to consider delayed repair	1	C	VHWG opinion

Breuing et al., Surgery. 2010 Sep;148(3):544-58

The PRICE randomized clinical trial by Harris et. al. compared biologic versus synthetic mesh for ventral hernia repair in adults. Eight surgeons performed an open technique of their choice on randomized patients with clean (Class I) and contaminated (Class II-IV) wounds. Risk of recurrence at 2 years was double in the biologic group which was statistically significant. Interesting findings also presented were low rates of mesh explantation in both groups; less than 5% in Class I wounds (all in the synthetic group) and less than 8% in the Class II-IV wounds, with the only enterocutaneous fistula occurring in the biologic group and chronic mesh infection in the synthetic group.

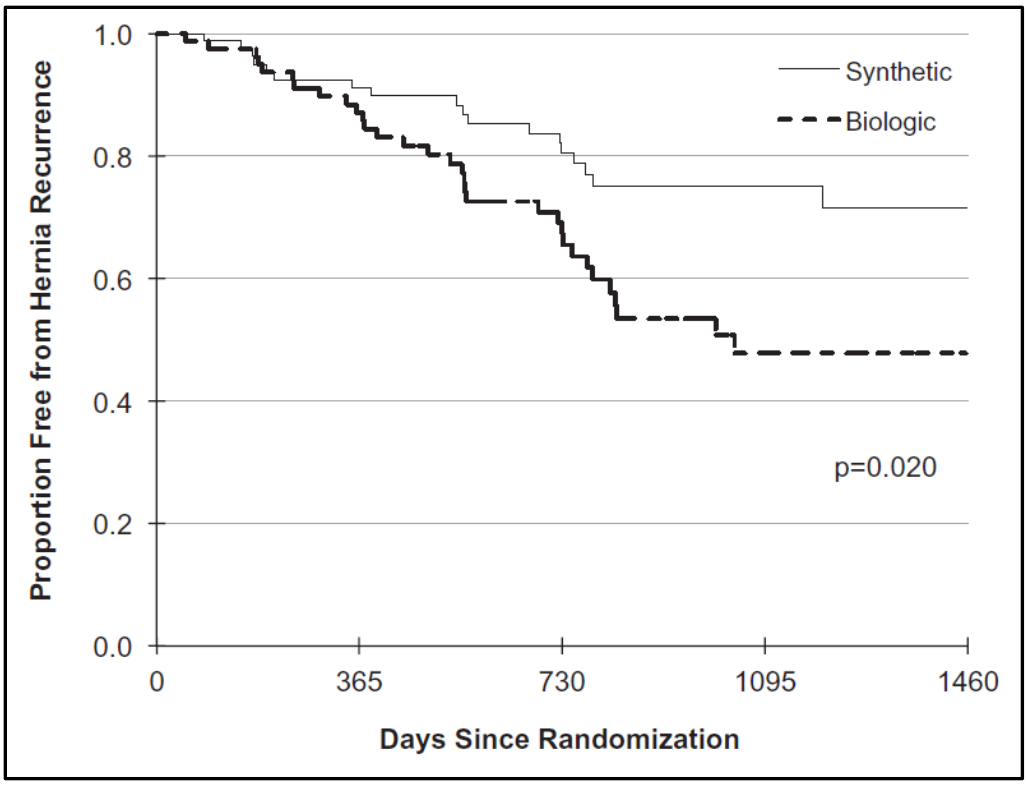


Figure 3. Source: *Harris et al, Ann Surg. 2021 Apr 1;273(4):648-655*

Rosen et. al. performed a similar randomized control trial comparing biologic versus synthetic mesh for contaminated (Class II and Class III) ventral hernia repairs. Eight surgeons, all with fellowship training in abdominal wall reconstruction, performed a retromuscular repair. Recurrence rate at two years was lower in the synthetic group (6%) versus the biologic group (21%), which was statistically significant. There was no major difference in surgical site infection between the two groups. Cost was 200 times higher in the biologic group ($17,000), versus the synthetic group ($105) and the sole driver in doubling the 30-day hospital cost.

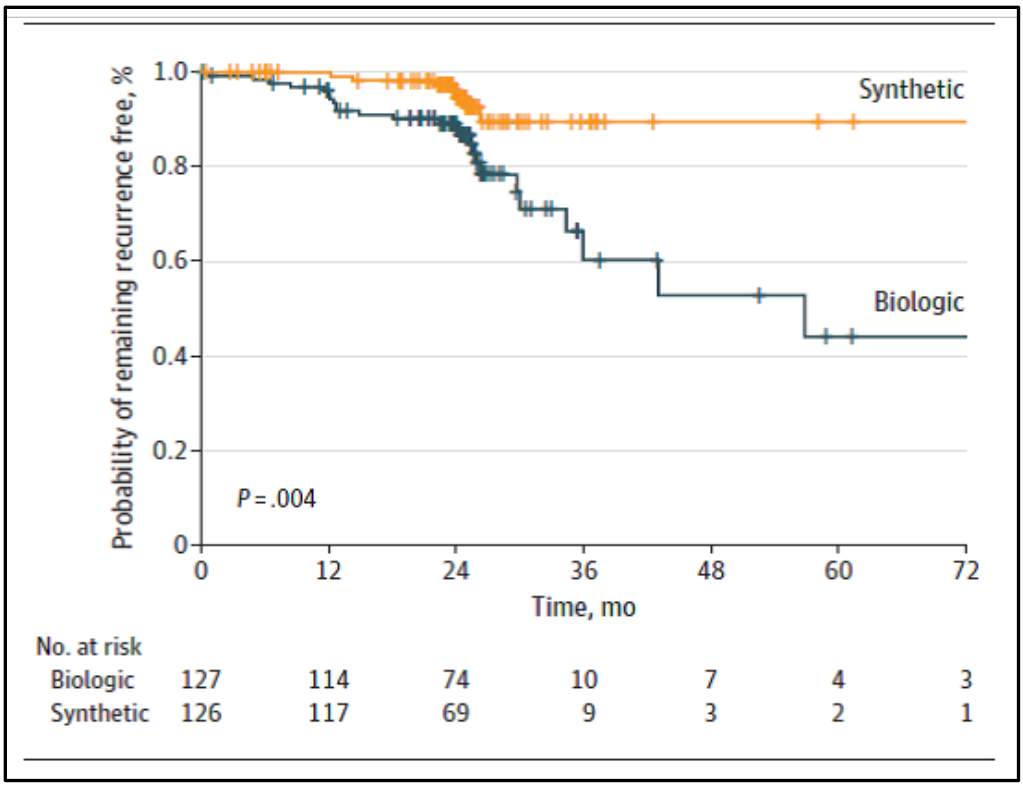


Figure 4. Kaplan-Meier Plot of Time to hernia Recurrence. Source: *Rosen et al, JAMA Surg. 2022 Apr 1;157(4):293-301*

SUMMARY AND BEST PRACTICE

- If you are practicing acute care surgery, you will be dealing with high-risk hernias (most likely in the middle of the night).
- Skin closure is not a bad option if you need to bail and not burn any bridges.
- If you are going to do primary closure, small bites are the way to go.
- Recurrence rates are lower with mesh repair versus primary closure.
- Sublay repair has the lowest rates of surgical site occurrence and recurrence but is technically challenging.
- It is important to get familiar with all types of mesh placement techniques, as each can serve a purpose in different patient selection.
- Mesh explantation due to mesh infection is not a common occurrence, given the number of herniorrhaphies performed in the US
- Synthetic mesh has lower recurrence rates at a fraction of the cost of biologic mesh and is safe to use in contaminated hernias.

JUST SAY "NO" TO EMBO: EFFICACY AND OUTCOMES OF LIBERAL ANGIOEMBOLIZATION FOR SOLID ORGAN INJURY

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"Failure to immediately recognize and treat simple life-threatening injuries is the tragedy of trauma, not the inability to handle the catastrophic or complicated injury."

- F. William Blaisdell

BLUF (BOTTOM LINE UP FRONT)

1. Selective nonoperative management has become the CLEAR standard of care for most blunt solid organ injuries and is associated with improved outcomes. However....
2. The vast majority of these injuries are low grade (AAST-OIS Grades 1-3), and...
3. The vast majority of these injuries are not bleeding or have low volume bleeding that will spontaneously cease without ANY intervention
4. EXTREME nonop management (ENOM) attempts to avoid operation in injuries that are high grade (Grades 4-5), actively bleeding, and/or quasi-stable through the use of angioembolization and/or blood product transfusion
5. There is scant, well-controlled data comparing outcomes of ENOM to immediate operative intervention, but available data shows:
6. A high failure rate of ENOM resulting in delayed treatment and increased morbidity
7. A high short- and longer-term complication and risk profile of ENOM that may exceed that of up-front laparotomy and surgical intervention
8. A significant infection risk associated with ENOM that far exceeds the rates seen with standard nonoperative management
9. The use of terminology like "success" and "failure" of nonop management is misleading, and simple success/failure rates should not be a primary metric for comparing outcomes
10. Minimally invasive techniques may have a role in further reducing morbidity in patients requiring operative intervention

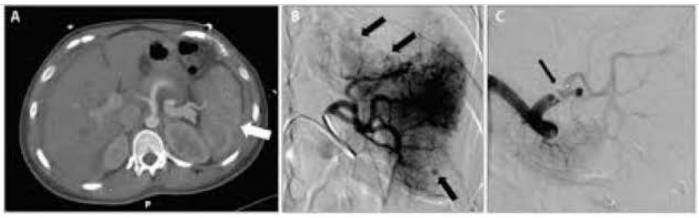
A TALE OF TWO SPLEEN CASES

1. Two 55 yo females in a high speed MVC with abdominal bruising
2. Grade IV splenic lacerations on CT scan, no "blush"
3. Both are hemodynamically stable
4. Both admitted to ICU for nonoperative management
5. Both subsequently drop SBP to 80, heart rate to 130

Patient 1	Patient 2
• Taken immediately to the OR	• Transfusions started – 4U PRBC
• Ex lap, splenectomy, abd closed	• Remains hypotensive w SBP 80
• Uneventful postop recovery	• Angioembolization 2 hrs later
• Receives postop immunizations	• Develops splenic infarct/abscess
• Tolerates diet on day 3	• Perc drains x 2 and IV antibiotics
• D/C home in 4 days	• D/C home in 3 weeks
• **This is the "Failure"**	• **This is the "Success"**

STANDARD VERSUS "EXTREME" NONOP MANAGEMENT

Standard nonop management of splenic injuries is extremely well described and validated, with selection criteria, including hemodynamic stability, no evidence of active bleeding, no transfusion requirement, and no other indication for operation. Although most modern protocols state that this can be applied to all grades of injuries, the data on high-grade (IV and V) is extremely limited. ALL management protocols specify operative intervention for patients who are "unstable" and/or have signs of ongoing rapid bleeding, but none have exactly defined the term "unstable" or exact criteria/transfusion thresholds that should prompt operative intervention. The advent of angioembolization has been generally seen as an advance in management, but data on the actual efficacy and impact on outcomes in splenic trauma is limited and conflicting. As a result, there is significant variability in the management of high-grade injuries or those with signs of active bleeding, ranging from prompt operative intervention to "extreme" nonoperative management approaches involving angioembolization and/or large volume transfusion therapy in the unstable or "quasi-stable" patient. Whether this approach is safe and results in any real or potential benefits to the patient versus operative intervention remains unknown and has accumulating data that it may be ineffective or even harmful.



Potential Benefits

- control active hemorrhage
- minimally invasive
- reduce rebleeding*
- reduce transfusions*
- increase successful NOM*
- allow NOM for high grade inj*
- avoids laparotomy*

Known Complications

- splenic infarction
- splenic abscess
- vascular access site complications
- failure to stop bleeding
- rebleeding
- need for laparotomy
- infections/systemic inflammation

*none of these has been definitively established as a realized benefit, particularly in the extreme non-operative management setting (high grade, hemodynamic abnormalities)

Although it has been demonstrated with a large body of scientific literature that nonoperative management does have clear benefits over routine laparotomy for blunt splenic injuries, this is for "all-comers," the majority of whom have low grade injuries, no active bleeding, and hemodynamic stability. The literature on ENOM is much more limited and has conflicting results, and papers supporting this approach have severe limitations, including selection bias, lack of adequate control groups for comparison, failure to adjust for major confounders, and lack of inclusion of clinically meaningful endpoints. In particular, the complication profile of this approach is either not examined in detail or is lumped in with the larger group of patents who had successful standard nonoperative management. Several key points to keep in mind in evaluating this topic and in reviewing the literature:

1. Comparison of ENOM patients with historic controls is inappropriate for determining whether it is reducing complications or splenic salvage rates
2. Late complications of ENOM, including vascular access site complications, are often not included
3. The systemic, inflammatory, and infectious implications of embolizing the spleen are not well studied, but appear to have independent adverse effects
4. There are multiple additional confounders that must be parsed, such as the timing and method of angioembolization, whether proximal or distal AE was done, and whether outcomes like ICU/hospital length of stay were due to associated injuries or to the splenic injury and splenic injury management approach

SOME INCONVENIENT TRUTHS FROM THE LITERATURE

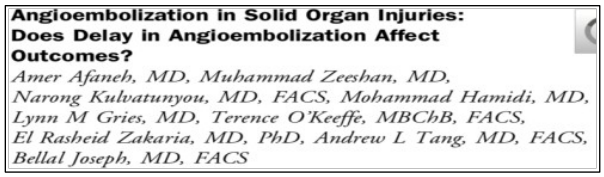
- 105 patients with blunt splenic injury
- Grade III or higher and >1 unit PRBC were independent risk factors for failure of NOM
- If both present, failure rate = 97%
- ? if angioembolization would improve this?


Nonoperative Management of Splenic Injuries

Have We Gone Too Far?

George C. Velmahos, MD, PhD; Linda S. Chan, PhD; Eman Kamel, MD; James A. Murray, MD; Nabil Yassa, MD; Deborah Kahaku, RN; Thomas V. Berne, MD; Demetrios Demetriades, MD, PhD

- 92% took >1 hour to start
- Increase in mortality for each hour delay
- More transfusions needed with delay


Angioembolization in Solid Organ Injuries: Does Delay in Angioembolization Affect Outcomes?

Amer Afaneh, MD, Muhammad Zeeshan, MD, Narong Kulvatunyou, MD, FACS, Mohammad Hamidi, MD, Lynn M Gries, MD, Terence O'Keeffe, MBChB, FACS, El Rasheid Zakaria, MD, PhD, Andrew L Tang, MD, FACS, Bellal Joseph, MD, FACS

- NOM supported for Grade 1 and 2 injuries
- Could NOT support for higher grades
- Literature highly biased and confounded
- Reported mortality differences between operative and NOM mainly due to associated injuries


Is non-operative management safe and effective for all splenic blunt trauma? A systematic review

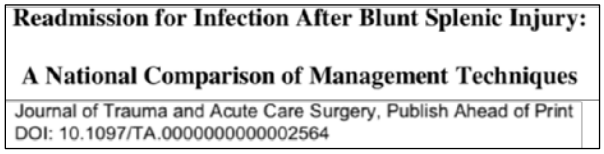
Roberto Cirocchi[1], Carlo Boselli[2], Alessia Corsi[2*], Eriberto Farinella[3], Chiara Listorti[2], Stefano Trastulli[1], Claudio Renzi[2], Jacopo Desiderio[1], Alberto Santoro[4], Lucio Cagini[5], Amilcare Parisi[1], Adriano Redler[4], Giuseppe Noya[2] and Abe Fingerhut[6]

- Pts with splenic inj + contrast extrav on CT
- Splenectomy or angioembolization (AE)
- No difference in mortality
- ARDS 4-fold higher in AE group
- Failure rate 53% for Grade IV & 100% for Grade 5 injuries


Proximal Splenic Angioembolization Does Not Improve Outcomes in Treating Blunt Splenic Injuries Compared With Splenectomy: A Cohort Analysis

Juan C. Duchesne, MD, Jon D. Simmons, MD, NREMT-P, Robert E. Schmieg, Jr., MD, Norman E. McSwain, Jr., MD, and Charles F. Bellows, MD

- Analysis of 38,000 patients w spleen inj
- Operative vs NOM vs AE
- AE had highest rates of deep space SSI
- AE higher risk infection, sepsis at one year


Readmission for Infection After Blunt Splenic Injury:

A National Comparison of Management Techniques

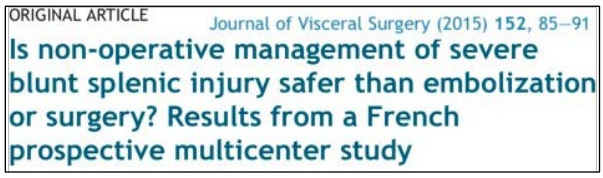
Journal of Trauma and Acute Care Surgery, Publish Ahead of Print
DOI: 10.1097/TA.0000000000002564

- Systematic literature review of AE
- Significant complication rate with AE
- Improved salvage rates from retrospective studies NOT confirmed in prospective studies

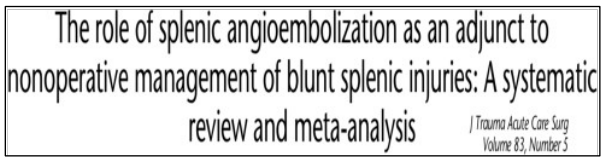

Splenic artery embolization: technically feasible but not necessarily advantageous

F. Van der Cruyssen[1*] and A. Manzelli[2]

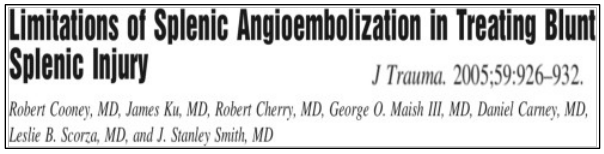
- Prospective study, 91 pts with splenic inj
- AE had same total morbidity as splenectomy
- Specific morbidity (related to intervention) was **15% for surgery vs 47% for AE**



- 23 studies, 6684 patients with blunt splenic inj
- No difference in NOM failure, mortality, length of stay with vs without AE
- Morbidity 38% with AE vs 19% without

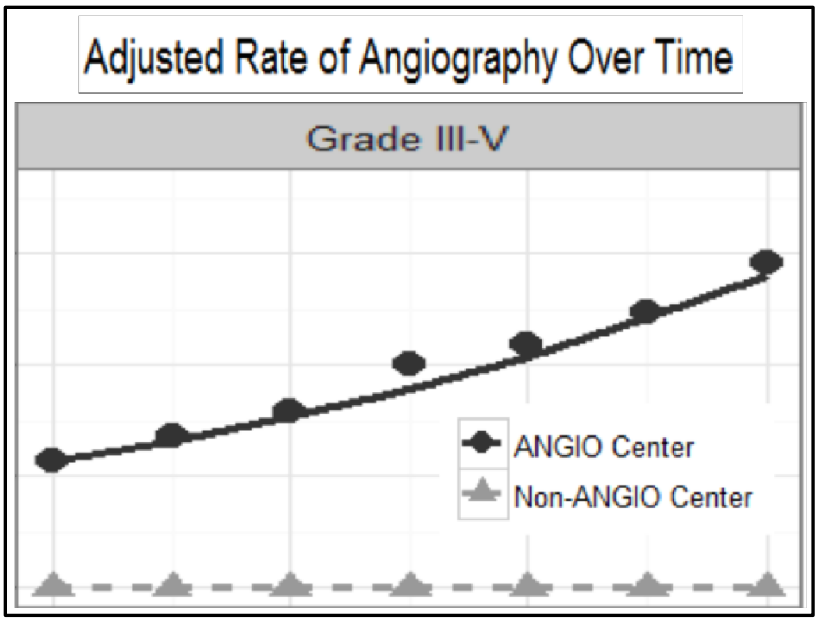


- 194 patients with blunt splenic injury
- Only 5% required AE
- 33% failure rate of angioembolization

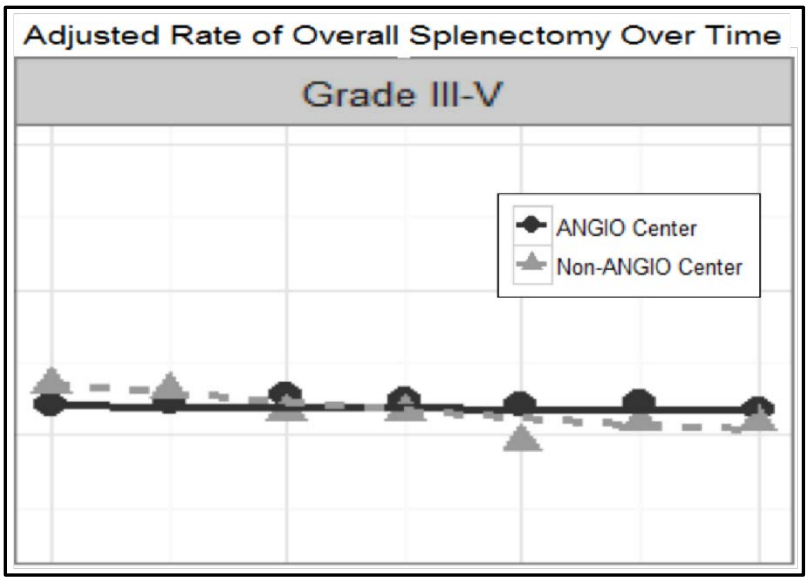


A RECENT NATIONAL ANALYSIS: ARE WE DOING BETTER?

- National Trauma Data Bank analysis of high grade blunt splenic injuries over 6 years
- Identified 53,689 patients treated at Level 1 or 2 trauma centers
- Overall there was NO DIFFERENCE in adjusted rates of splenectomy over time
    - 24.3% in 2008 and 24.3% in 2014
- This was despite the fact that angioembolization use increased significantly over time
    - 5% in 2008 and 14% in 2014 ($p<0.01$)
- However, as shown in the following figure, there was significant variability in the use of AE, with some centers rarely or never using it versus centers that utilized AE.



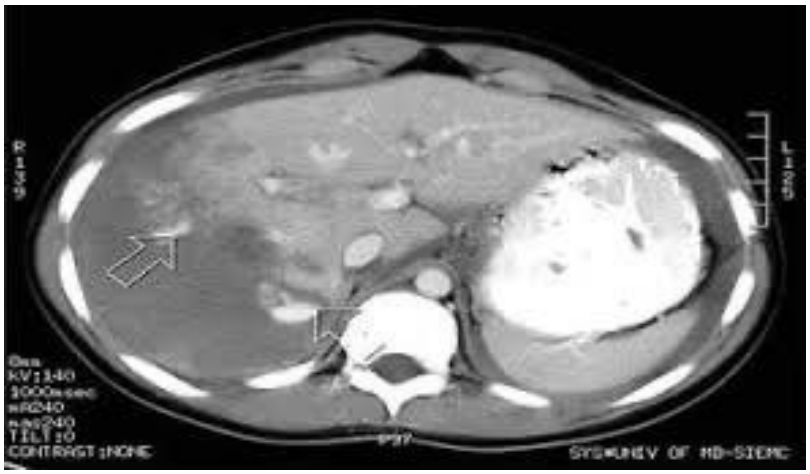
- Interestingly, the adjusted splenectomy rate was no different between angio and non-angio centers (Figure below) and did not change over time.



- There was no change in mortality over time or difference in mortality between angio and non-angio centers.
    - even when adjusted for spleen injury grade and total injury severity
    - similar findings when broken down by individual injury grades
- Of additional concern – the rates of late splenectomy (>6 hrs from admission) declined to a greater degree in the non-angio centers compared to angio centers

- Main conclusions related to angioembolization for high grade injuries:
    - AE had little to no impact on overall splenic salvage rates
    - success/failure of nonoperative management not improved
    - may result in more late splenectomies versus those managed nonoperatively without angioembolization
- Limitations of this analysis include the lack of granular patient-level data, the possibility of unmeasured confounders, and the lack of data on the exact angioembolization technique and timing of intervention

WHAT ABOUT HIGH-GRADE LIVER INJURIES?



- The most recent update of the AAST-OIS grading system for both liver and splenic injuries now upgrades any injury with contrast extravasation to at least Grade 3
- The calculus regarding SNOM and interventions for liver injuries are different and more complex compared to the spleen, given the critical function of the liver, the increased technical difficulty of operative hemorrhage control, and the lack of complete organ resection as an option
- The increased adoption of SNOM, hepatic angioembolization, and damage control surgery if laparotomy is required has led to a marked decrease in trauma surgeon experience and comfort with major operative liver surgery
- Although AE seems ideal for major liver injuries, there is an increasing body of literature demonstrating numerous risks, complications, and major morbidity/mortality associated with AE
- AE associated complications include hepatic ischemia and necrosis, hepatic abscess, bile leaks, systemic inflammatory response syndrome, hepatic dysfunction or failure, access site complications, and failure to control bleeding
- Longer term complications include biliary duct structuring and need for major hepatic resection or even liver transplantation
- These complications will vary widely based on the injury location and severity, the need for operative intervention, the site of AE (non-selective vs selective), and the type of AE performed (coil versus gelfoam)

- The managing trauma surgeon should always consider the wisdom and advisability of adding the additional insult of AE to an already injured liver
- Routine or "prophylactic" AE based solely on the grade of injury or the presence of a blush without other clinical indicators should be avoided

SOME SELECTIVE DATA ON LIVER AE

A modern, multicenter evaluation of hepatic angioembolization – Complications and readmissions persist

Jason M. Samuels [a,*], Shane Urban [b], Erik Peltz [a], Thomas Schroeppel [c], Holly Heise [c], Warren C. Dorlac [d], Linda J. Britton [d], Clay Cothren Burlew [a,e], Caitlin Robinson [e], Megan L. Swope [e], Robert C. McIntyre Jr. [a]

The American Journal of Surgery 219 (2020) 117–122

- Multicenter study of 1319 patients, with N=30 patients underwent AE
- High complication rate associated with hepatic AE
- 43% incidence of liver-related complications (table)
- 35% thirty-day readmission rate

Table III. Liver-related and unrelated complications N = 30 patients

AE related Complications (N = 23)	Number of Patients (%)
Liver-related	
Hepatic necrosis	1 (4)
Peri- or Intra-hepatic abscess	5 (22)
Bile leak	6 (26)
Gallbladder Infarction	0
Biloma	2 (9)
Any complication	10 (43)
30-day readmission	8 (35)
Endoscopic Retrograde Cholangiopancreatography	4 (17)

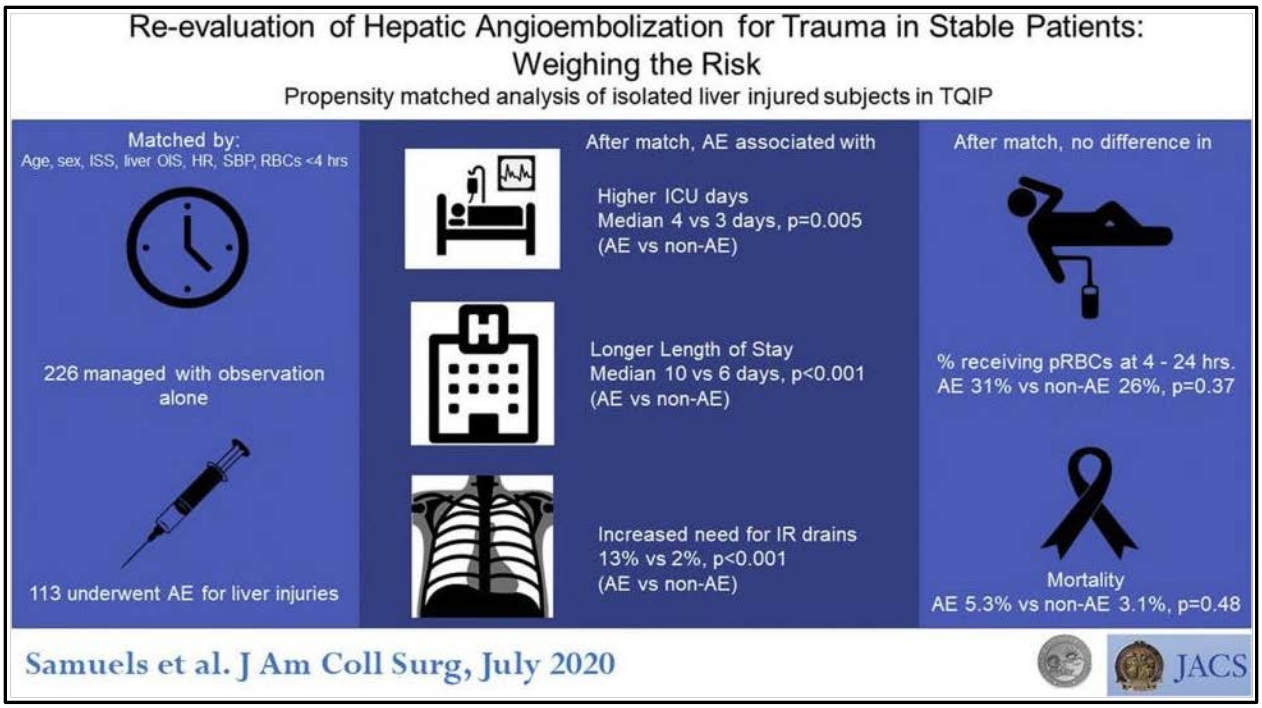
Trauma Surgery & Acute Care Open

Decreased mortality, laparotomy, and embolization rates for liver injuries during a 13-year period in a major Scandinavian trauma center

Iver Anders Gaski,[1] Jorunn Skattum,[2] Adam Brooks,[3] Tomohide Koyama,[2] Torsten Eken,[4] Paal Aksel Naess,[1] Christine Gaarder[2]

. *Trauma Surg Acute Care Open* 2018;**3**:e000205.

- 583 patients with liver injuries over 12 year period
- Significant decrease in AE use from 11% to 5% over time
- Associated with DECREASED need for laparotomy and 50% reduction in mortality
- Among Grade IV and V injuries, similar reduction in AE use and trends toward decreased mortality and deaths from hemorrhage
- Period of reduced AE utilization independently associated with improved outcomes on multivariate regression



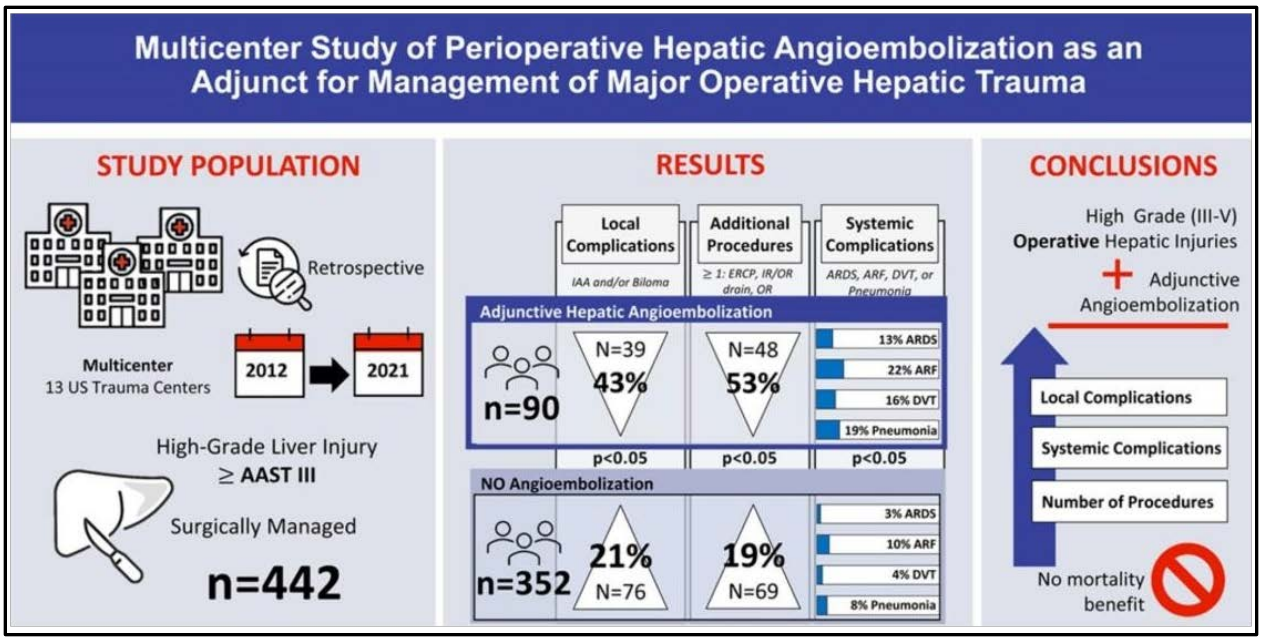
- TQIP nationwide analysis using propensity matched controls
- Hemodynamically stable patients with Grade 3 or higher liver injuries
- AE utilization associated with numerous adverse outcomes (see figure above) and no identification of a benefit

Multicenter Study of Perioperative Hepatic Angioembolization as an Adjunct for Management of Major Operative Hepatic Trauma

J Am Coll Surg
Vol. 237, No. 5, November 2023

Paige E Deville, MD, Alan B Marr, MD, FACS, Jennifer T Cone, MD, FACS, MHS, Lea E Hoefer, MD, Delbrynth P Mitchao, MD, Kenji Inaba, MD, FACS, FRCSC, Ryan Kostka, DO, Jennifer L Mooney, MD, FACS, Allison G McNickle, MD, FACS, Alison A Smith, MD, PhD, FACS; for the MIT Liver Study Group

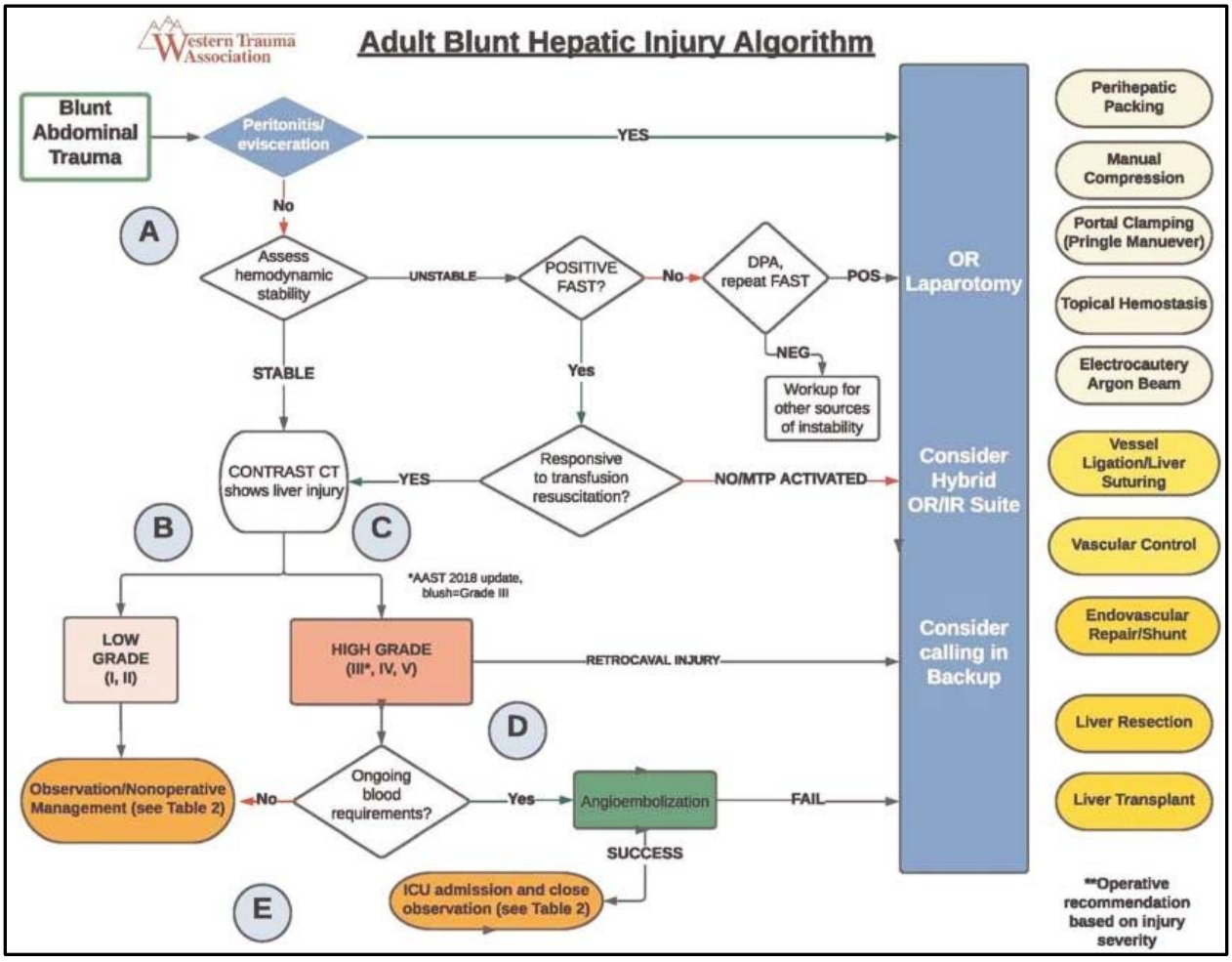
- U.S. multicenter study of high grade hepatic trauma patients (N=442 total, N=90 underwent adjunctive AE)
- Unique study that focuses solely on high grade liver injuries that required operative intervention
- Similar ISS but AE group with higher grade injuries vs no-AE group
- Significantly increased liver-specific and systemic complications in the AE group versus no-AE (see visual abstract below)
- AE independently associated with intra-abdominal abscess formation (adjusted odds ratio = 1.9)



SUMMARY AND TAKE-HOME POINTS

- The majority of blunt splenic and liver injuries can be managed without surgery OR angioembolization
- Increasing trends of extreme nonoperative management – extending NOM to high grade injuries, those requiring transfusion, and those with concerning hemodynamics
- Splenic and Liver AE has a well-defined and not insignificant complication profile and failure rate that can require surgery and result in a much more difficult operation due to splenic/hepatic infarction and/or abscess
- A significant body of literature raises concerns about the short- and long-term complication profile of splenic/hepatic angioembolization, including a significantly increased risk of infectious complications
- No clear data defines the optimal threshold or risk:benefit of operating versus continuing to transfuse blood products for bleeding spleen/liver injuries

NEWLY PUBLISHED WTA ALGORITHM FOR HEPATIC INJURY MANAGEMENT



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SCAN THEM ALL? SELECTIVE VERSUS UNIVERSAL SCREENING FOR BLUNT CEREBROVASCULAR INJURY

Tanya Egodage, MD, FACS

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Associate Program Director
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Blunt cerebrovascular injury (BCVI) is a potentially devastating complication of blunt cervical trauma involving damage to the vertebral or carotid vessels. Although initially characterized in the 1870's, its epidemiology, diagnosis, and management were increasingly described in the literature in the late 1900's.[1-5] Since then, a great deal of literature has been published to challenge our knowledge of BCVI. The reported incidence, initially thought to be far lower, is now reported as up to 7.6% of all blunt trauma patients in some papers, with a stroke rate of up to 40% if untreated.[3,4,6] Although generally associated with high-energy mechanisms, BCVI may occur in the setting of low-energy injuries as well.[7] Criteria for the diagnosis and management of BCVI have evolved over decades of investigation and with the progression of technology, although grading nomenclature has remained unchanged. Despite the relatively low incidence of stroke with low-grade injuries, the potential for the devastating sequelae of stroke in a previously functional patient has resulted in arguments for more ubiquitous screening. Furthermore, improvements in technology and increased detection of BCVI have called into question accepted screening criteria and management strategies. This review presents the arguments for both selective and universal screening for BCVI.

GRADING

Grading of BCVI was initially described by Biffl et al., and stratified into five grades with increasing severity and greater risk of complications. Whereas grade 1 injuries describe a luminal irregularity or dissection <25% of the circumference of the vessel, a grade 5 injury describes a complete transection of the vessel with active extravasation. Historically, grade 1 carotid injuries have been associated with a stroke rate of as low as 3%, whereas grade 4 injuries portend a stroke rate of 44%, and grade 5 a rate of 100%. The full grading classification is enumerated below.[8]

Grade	Description
I	Luminal irregularity or dissection with <25% luminal narrowing
II	Dissection or intramural hematoma with >25% luminal narrowing, intraluminal thrombus, or raised intimal flap
III	Pseudoaneurysm
IV	Occlusion
V	Transection with free extravasation

Figure 1. Grading classification of BCVI

SCREENING

Historically, BCVI was diagnosed with digital subtraction angiography (DSA). Despite its specificity, DSA is invasive and resource-intensive. Improvements in high resolution computed tomography angiography (CTA), with broader use of CT scans have increased the rate of diagnosis of asymptomatic BCVI. Several screening criteria exist, the most common being the Denver and Memphis criteria, which incorporate mechanism, physical examination and injury pattern to determine patients at high risk for BCVI. Iterations to the Denver screening criteria include the modified Denver Criteria and the expanded Denver Criteria.[9] The expanded Denver Criteria, the most contemporary iteration, include thoracic vascular injuries, scalp degloving, and additional injuries associated with high-energy. The Memphis and Expanded Denver Criteria are delineated below.

Memphis Criteria
Unexplained neurologic deficit
Horner's syndrome
LeFort II or III (unilateral or bilateral)
Cervical spine injury
Skull base fractures involving the foramen lacerum
Neck soft tissue injury (e.g., seatbelt injury or hanging)

Figure 2. Memphis Criteria

Denver Criteria
Signs/symptoms of BCVI
Potential arterial hemorrhage from neck/nose/mouth
Cervical bruit in patient <50 y old
Expanding cervical hematoma
Focal neurologic defect: TIA, hemiparesis, vertebrobasilar symptoms, Horner's syndrome
Neurologic deficit inconsistent with head CT
Stroke on CT or MRI
Risk factors for BCVI
High-energy transfer mechanism
Displaced midface fracture (LeFort II or III)
Mandible fracture
Complex skull fracture/basilar skull fracture/occipital condyle fracture
Severe TBI with GCS <6
Cervical spine fracture, subluxation, or ligamentous injury at any level
Near hanging with anoxic brain injury
Clothesline type injury or seat belt abrasion with significant swelling, pain, or altered mental status
TBI with thoracic injuries
Scalp degloving
Thoracic vascular injuries
Blunt cardiac rupture
Upper rib fractures

Figure 3. Expanded Denver Criteria

MANAGEMENT

Patients with confirmed BCVI require one of a range of therapeutic interventions from medical therapy to more invasive interventions. Most patients are commenced on antithrombotic or antiplatelet for up to several months, depending on resolution of the injury and each center's algorithm for management. Some studies have found that a percentage of grade 1 injuries resolve spontaneously; however, there is a large cohort who do not. A review by Murphy et al., reported that those who received antithrombotic treatment had lower stroke rates than those who did not.[10] Endovascular interventions, including thrombectomy or stenting, are considered for patients with higher grade injuries. Both of these therapies are not without risk, however.

SELECTIVE SCREENING

Proponents of selective screening point to the potential risks of identifying and treating indeterminate or low-grade injuries. Hiatt et al., recently evaluated liberal use of CTA versus selective screening for BCVI. Indeterminate CTA results were present in 11% of patients receiving CTA of the neck. Of those indeterminate findings, 68% were noted to be false positive results when evaluated by confirmatory DSA.[11] Additional studies have documented that the overall rate of false positivity in identifying BCVI with multi-detector CTA may range up to 48%.[12,13] The implications of this are not benign. Patients with positive CTA findings would be either treated empirically with antiplatelet or antithrombotic therapy, or receive a confirmatory DSA. In fact, despite transition from DSA to CTA for screening, substantial use of DSA remains, specifically up to 33% of injuries who demonstrate positive results on CTA.[14] Furthermore, CTA may be inaccurate in 62% of vessels imaged, warranting DSA.[13] DSA carries significant risks including vessel injury, pseudoaneurysm formation, dissection, stroke, hematoma formation, need for sedation, and is resource heavy. Rates of complications range from 0.3 to 5%, with a reported stroke risk of up to 0.5% following intervention.[15] Anyone who has witnessed a devastating stroke in a previously healthy patient receiving empiric DSA will caution you of its use if not absolutely required. Likewise, antiplatelet and antithrombotic therapy are fraught with risks in trauma patients who may have concomitant traumatic brain injury (TBI), spinal cord injury (SCI), solid organ injury (SOI), or active hemorrhage. Despite some literature to demonstrate the safety of antithrombotic in the acute setting of SOI, clinicians may be slow to adopt anticoagulation for fear of patient deterioration. Three-month maintenance dosing upon patient discharge increases the risk of post-discharge complications, such as bleeding following any interval trauma. Interval imaging conducted in a delayed fashion confers additional radiation to the patient, and, perhaps more importantly, increased use of limited resources in an already burdened healthcare system.

UNIVERSAL SCREENING

On the other hand, there are several arguments for broader screening. First and foremost, BCVI is often asymptomatic, but may lead to the devastating complication of stroke if left untreated. Especially in young, otherwise healthy injured patients, this is life-altering. Despite an initial reported incidence of 0.38%, liberal screening has demonstrated an incidence of up to 7.6%.[6] Even with low-risk spinal injuries, concomitant BCVI rates range up to 9%. Selective screening misses between up to 34% of BCVI, even by broad screening mechanisms.[7,16] In fact, almost 25% of injuries grade three or higher may be missed.[16] So the true incidence of BCVI may be far greater than initially quantified.

What are the documented complications of treating these injuries? Studies demonstrate that thrombotic events occur within 72 hours of injury, during which time patients have competing injury priorities.[9] Even so, the evidence demonstrates that early antiplatelet or antithrombotic therapy does not worsen TBI or SOI.[12] A recent meta-analysis similarly demonstrated low overall risk of hemorrhagic complications with a 34% stroke rate in those untreated.[17] These once-feared complications are not as grave as previously anticipated. An EAST practice management guideline evaluating management of grade 2-3 injuries stated

that stenting was not recommended, therefore, DSA may not be required for grade 1-3 injuries, in favor of antiplatelet therapy which has been demonstrated as safe in the early post-traumatic time period.[18] Furthermore, the theoretical risk of DSA has been disproven. Recent post-hoc analysis of an EAST multicenter trial determined that stroke and pseudoaneurysm formation was not significantly higher in patients undergoing DSA following blunt internal carotid artery injury.[14,19] Additionally, technology has improved precipitously, with many hospitals utilizing 128-slice or even 256-slice CT scanning. This will, no doubt, improve the quality of injury detection, as we have seen with improved sensitivity from the 32-slice to 64-slice scanners.[20]

Reliance on clinical deterioration for detection of BCVI will invariably result in undue morbidity and mortality, and universal screening can improve care for this subset of patients. The discussion of cost-effectiveness and resource utilization is valid, however, early identification and intervention can potentially reduce long-term healthcare costs associated with stroke care and rehabilitation.[21]

CONCLUSIONS

Despite ongoing controversy, in well-resourced environments, clinicians are trending toward more universal screening. In light of literature demonstrating increased efficacy of CTA, with minimal adverse outcomes related to BCVI treatment, this approach may be adopted. However, further investigation is required to amend national guidelines.

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PELVIC FRACTURES: PELVIC BINDERS, PREPERITONEAL PACKING AND OTHER MYTHS!

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The management of bleeding from severe pelvic fractures remains a major challenge and a controversial issue. One third of pelvic fracture mortality has been attributed to inadequate control of hemorrhage. Currently, modalities for bleeding control from pelvic fractures include application of a pelvic binder, angioembolization, preperitoneal pelvic packing (PPP), resuscitative endovascular balloon occlusion of the aorta (REBOA), and open occlusion of the internal iliac arteries with packing. Most of the available evidence supporting some of these approaches is of very poor quality, and there is newer evidence that they might be associated with worse outcomes.

PELVIC BINDER

Pelvic binders are frequently used in the prehospital environment and in the emergency room to stabilize the fracture, decrease the pelvic hematoma volume, and achieve hemorrhage control. There is no doubt that application of basic orthopedic principles, such as reducing and immobilizing a fracture reduces bleeding. Patients with pubic symphysis diastasis would certainly benefit from reduction and application of a properly placed pelvic binder. However, liberal use of the binder before radiological confirmation of the type of pelvic fracture may be harmful and might even worsen the pain and bleeding. Application of a binder in certain types of pelvic fractures, such as lateral compression fractures, iliac wing fractures, severe acetabular fractures, hip dislocations, and fractures of the femoral neck, may be harmful by increasing the fracture displacement. In an analysis of 713 pelvic fractures from the Los Angeles Trauma Center, only 3% had pubic symphysis diastasis and would have benefited from binder application, and 37% would have potentially been harmed. It is prudent not to apply a pelvic binder before radiological evaluation of the type of fracture and reserve the application only in patients with pubic symphysis diastasis.

PREPERITONEAL PELVIC PACKING (PPP)

PPP has been promoted as an effective damage control procedure in the management of bleeding in severe pelvic fractures, and it is included in the treatment algorithms by major trauma organizations, including the Eastern Association for the Surgery of Trauma, Western Trauma Association, and the World Society of Emergency Surgery,[9–11] and many courses and workshops teaching the procedure are taught nationally and internationally.

Pelvic packing was first reported in 2002, and it involved extraperitoneal packing of the presacral and paravesical regions using between four and eight swabs through a lower abdominal incision without entering the peritoneum.[1]

The evidence supporting the effectiveness of the PPP is very weak and based on small, retrospective and poorly done observational series. In the updated practice management guideline from the Eastern

Association for the Surgery of Trauma in 2020, there is a conditional recommendation for PPP in hemodynamically unstable patients if angioembolization is not immediately available. If both PPP and angioembolization are readily available, the guideline states that it cannot recommend for or against initial use of PPP versus pelvic angioembolization. The authors emphasized the very low quality of available evidence, which included only small observational studies.[2]

PPP theoretically works by direct compression of the bleeding source in the pelvis. However, a recent human cadaver study showed that with the standard PPP technique, the packs were significantly away from potential sources of pelvic fracture bleeding, such as the sacroiliac joint and common, external, and internal iliac vessels.[3]

It has been suggested that PPP produces tamponade, which controls bleeding. However, it is unlikely that packing that does not compress directly the bleeding site will produce an effective tamponade, especially for bleeding from a major vascular laceration. In addition, as shown in another human cadaver study, it was shown that PPP increased the pelvic pressure by only 12.3±4.5 mm Hg, which is highly unlikely to produce tamponade and bleeding control, especially in arterial bleeding.[4]

Another recent study that included 139 patients with pelvic fractures who underwent angiographic intervention, with or without prior PPP, concluded that PPP was not an effective method for arterial hemorrhage control in pelvic fractures.[5]

Recent studies reported that PPP was independently associated with an increased risk of venous thromboembolic complications[6,7] and no improved survival or reduced complications or hospital stay.[8]

REBOA

Severe pelvic fracture remains one of the strongest and most common indications for REBOA use. However, the quality of data supporting REBOA use is very poor, and more recent large studies reported contradictory results. In a joint statement from the American College of Surgeons Committee on Trauma, the American College of Emergency Physicians, the National Association of Emergency Medical Services Physicians, and the National Association of Emergency Medical Technicians regarding the clinical use of REBOA in civilian trauma centers in the USA, it is stated that the quality of clinical evidence to support REBOA use in trauma patients is poor, with no Class I or II data, and, thus, the existing data must be interpreted with caution.[9]

Matusmoto et. al., in a retrospective study from the Japanese Trauma Data Bank, analyzed 3149 multitrauma patients with severe pelvic trauma patients, 256 of whom underwent REBOA, reported that the REBOA group had worse mortality, despite adjusting for major comorbidities.[10]

In another retrospective study, Mikdad et. al. compared preperitoneal packing (PPP) to REBOA use in pelvic trauma using propensity score matching. They found that mortality was higher in patients treated with REBOA compared to PPP.[11]

Several other studies have also reported worse outcomes with REBOA use in severe multitrauma patients. In a TQIP study by Joseph et. al., trauma patients who underwent REBOA placement in the ED were matched with a similar cohort of patients with no-REBOA. There was no significant differences between groups in 4-hour blood transfusion, and the mortality and acute kidney injury rates were significantly higher in the REBOA group.[12]

In a recent TQIP study, which included isolated severe pelvic fractures, 93 REBOA patients were matched with 279 without. The REBOA groups had significantly higher rates of in-hospital mortality (32.3% vs 19%, p=0.008) and higher rates of venous thromboembolism (14% vs 6.5%, p=0.023). In multivariate analysis, REBOA use was independently associated with increased mortality and venous thromboembolism.[13]

Other recent studies reported that REBOA application in severe pelvic fractures was associated with increased risk of extremity compartment syndrome and need for fasciotomy[14] and venous thromboembolic complications.[15]

In summary, on the basis of the currently available evidence, liberal REBOA use in pelvic fractures may be associated with worse outcomes and caution is adviced!

BILATERAL INTERNAL ILIAC ARTERY OCCLUSION

For select patients with severe hemodynamic instability, those in need of an immediate laparotomy for severe associated intra-abdominal injuries or those in austere environments with no angiointerventional capabilities, exploration of the pelvic hematoma with bilateral internal iliac artery occlusion (BIIAO) and direct packing of the bleeding site has been used in some trauma centers.[16] Multiple reasons for an exploratory laparotomy and BIIAO, have been described by the proponents of this approach: First, patients with severe pelvic fractures have a high incidence of associated intra-abdominal injuries. In a NTDB study, severe pelvic fracture (AIS score of 4 or 5), 33.7% had an associated abdominal injury, including 12.5% with bowel injury.[17] This is particularly important in severe hemodynamic instability, which may not allow CT scan evaluation. A second reason supporting exploratory laparotomy and exploration of the pelvic hematoma is the significant incidence of injuries to the major iliac vessels in severe pelvic fractures. In a NTDB study of 3,221 patients with severe pelvic fracture (AIS score of 4 or 5), 10.7% had common or external iliac vessel injury.[18] A third reason for exploring the pelvic hematoma is the direct visualization of the bleeding areas and application of local hemostatic agents.

CONCLUSIONS

a) Liberal application of a pelvic binder may be harmful in certain types of pelvic fractures.

b) Preperitoneal packing is not supported by anatomical studies on human cadavers or by clinical studies.

c) Liberal application of REBOA may be harmful.

d) Exploratory laparotomy with BIIAO and direct packing of the bleeding site is another proposed approach, but there is no class 1 or 2 evidence to support its efficacy

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HIGH-GRADE PANCREATIC INJURY IN PEDIATRIC AND ADULT PATIENTS: IS "TO CUT" STILL "TO CURE"?

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"Everything old is new again." From Johnathan Swift from Political Lying 1710

As I began my Pediatric Surgical training in 1996, papers were being published announcing the END of operative management for pediatric pancreatic trauma. The papers extolled the benefit of not F….. with (touching) the pancreas, and simply draining lesions. The challenges were that few of these injuries were graded according to a unified grading system, and almost none, except those directly explored, had definitive determination of pancreatic ductal injury (PDI). Therefore, 1990s reports talked about the success of the 50% of injuries that had no pancreatic complications (PC), the 50% that had PC, or the 10 % that died. It was concluded that non-operative management was a success. Operations were performed then for concomitant injuries that today would be managed non-operatively. Interestingly, those percentages correlate well the percentages of the AAST grades of injury seen today, where 30% are AAST graded I or II, 55% grade III and 15% grade IV or V. Fortunately, within the next decade, surgeons began to question the failures of these non-operative approaches, and further defined, with the help of a standardized AAST grading scale, those at risk for failure of this approach. As a result, it was determined that AAST grades III and V were at high risk of failure.[1,2,3]

The adult trauma literature was less divergent in its recommendation for treatment. The conventional wisdom was to do nothing for AAST grades I and II, drain AAST grade IV, have a variety of surgical and drainage techniques in your arsenal for AAST grade V, and do a distal pancreatic resection for AAST grade III. Other pearls were to sew the duct with absorbable rather than non-absorbable suture and to place a closed suction drain rather than a Penrose.[4,5,6]

Over the next two decades, the advancements in adult management centered more on advances in imaging techniques, endoscopy, and the further options for management of the complex pancreatic-duodenal-biliary injuries. The conversations for the pediatric patients seemed to quiet during this time until the emergence of advanced endoscopy and interventional radiology for young children in the early 2000s and 2010s.[7] As these two resources have become more ubiquitous, there is "de ja vue, all over again". (Yogi Berra & John Fogerty) The Pediatric Pancreatic Trauma Study Group published in 2018 that CT and MRI were poorly suited to discern the status of the pancreatic duct. The same was claimed in another report from Canada.[8,9] The most definitive determination of ductal integrity is the endoscopic retrograde cholangio-pancreatography (ERCP). This is often readily available for adults, but for children, ERCP remains variably available and frequently not therapeutic. When successful, however, ERCP provides definitive determination of main pancreatic duct integrity and leads to earlier surgical intervention for higher-grade injuries.[10] When the initial CT "suggests" a pancreatic transection and when ERCP is not available, I have found that a repeat IV contrasted, venous phase, thin-cut, limited CT 12 hours later (or

the next morning) very frequently shows a very clear transection of body (inferred duct) leading to early intervention. The downside, obviously, is the radiation risk for the developing child, but this is less of a concern in the adult population. Early intervention is important because the success of the operation is inversely proportional to the time from injury. Operations done early (24-36 hours following injury) have significant technical advantages. Distal pancreatic resection is substantially more difficult when the transection is greater than 48hours old. I find it considerably more likely that the distal pancreatic resection also leads to a splenectomy when the resection is delayed.

The evolution in the management of pancreatic injury in both pediatric and adult patients now includes minimally invasive techniques, such as laparoscopic and robotic techniques. I find using a laparoscopic approach straightforward to access the pancreas behind the stomach, evaluate for major ductal injury, and then perform a distal pancreatectomy is effective.

The algorithm for pancreatic injury management that I recommend begins with hemodynamic stability. Unstable patients must go to the OR! The control of bleeding and contamination takes priority, but when able, a systematic evaluation of the entire pancreas, including an assessment of the biliary tree, is required. A simple cholangiogram through the gallbladder will suffice. One is simply assessing the distal bile duct and ampullary integrity. If there is significant destruction of the main pancreatic duct, bile duct/ampulla, and the patient has a duodenal injury, then a pancreatico-duodenectomy is warranted. The temporizing maneuver is to widely drain with closed suction drains following control of bleeding and contamination. The definitive operation is best done when stable and in a high volume, hepato-biliary center. Despite advances in management, morbidity and mortality remain as high as 25% for these injuries.[11,12]

Next in the algorithm, stable patients need to have a CT to assess for location of pancreatic injury and to assess for other injuries. CT “suggested” Grade V injuries are then further assessed operatively. A CT “suggested” injury to a part of the pancreas other than the head is further evaluated for ductal integrity. Options here are MRCP or ERCP or repeat thin cut CT. Ductal injury is then defined as proximal or distal (patient right or left of the superior mesenteric vein). Anecdotally, I have found that the few times I have had a CT or MRCP reading of “Right of the SMV,” the injury is, in fact, a grade III right over the spine. So, “proximal” means really proximal. (i.e. not enough remaining pancreas to preserve endocrine or exocrine function if the distal segment is resected). TRUE grade IV injuries, while rare, should be managed with drainage and potential stenting, when amenable. If ERCP is not possible, MRCP will provide more information and has a higher sensitivity for identifying ductal injury but is still not perfect. For me, laparoscopy would be next in the evaluation algorithm.

The surgeon is then left with patients that are stable with injuries to the pancreas that:

a. Involve the duct at or distal to the SMV
b. Do not involve the duodenum
c. Are within 48-72 hours from injury

Grade III injuries should be managed with a spleen preserving distal pancreatectomy, a stapled transected distal duct and (until ongoing trials inform us differently) a closed suction drain.

Grade III injuries that have had a distal pancreatectomy or Grade IV or V injuries that have been drained still have a risk of pancreatic complications such as fistula or pseudocyst formation. ERCP with/without stenting and IR drainage should be available to deal with these potential pancreatic complications.

In conclusion, eat when you can, sleep when you can, and for high grade lesions, be prepared to operate on the pancreas.

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THE K-HOLE: PREHOSPITAL AND ER KETAMINE INDICATIONS AND COMPLICATIONS

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SUMMARY POINTS

1. Ketamine is a non-barbiturate dissociative anesthetic medication
    a. It has both anesthetic and analgesic properties
    b. It is a noncompetitive antagonist of N-methyl-D-aspartate (NMDA) and glutamate receptors. These receptors are primarily excitatory.
    c. In addition, ketamine is a partial agonism on the opiate mu-receptor, facilitating its analgesic properties
    d. It maintains normal airway reflexes allowing for spontaneous respiration to continue
    e. It is a cardiovascular and respiratory stimulant through skeletal muscular tone enhancement, providing a degree of hemodynamic stability and bronchodilation
2. Dosing
    a. Can be IV or IM
    b. Elderly patients metabolize ketamine more slowly and need lower doses
    c. Typical sedation/analgesia dose
        i. 0.2-0.75mg/kg IV or 2-4mg/kg IM
    d. Typical anesthesia induction dose
        i. 0.5-1.5mg/kg IV or 4-10mg/kg IM
    e. Typical dose for hyperactive delirium syndrome
        i. 3-5mg/kg IM (max does 500mg) or 0.5-1mg/kg IV (max dose 200mg)
3. Indications
    a. General anesthesia
    b. Analgesia for severe pai
    c. Hyperactive delirium with severe agitation
    d. Depression management (off-label)

4. Potential adverse effects include
    a. Allergic reactions
    b. Tachycardia and hypertension
    c. Anorexia
    d. Nausea/vomiting
    e. Muscle stiffness
    f. Confusion
    g. Diplopia
    h. Amnesia and confusion
    i. Emergence phenomenon
    j. Laryngospasm
    k. Note: Ketamine does not raise intracranial pressure
5. Contraindications
    a. Known allergy to ketamine
    b. Known pregnancy or breast feeding
    c. Known schizophrenia

DEEPER DIVE

Ketamine is a highly effective medication that has been in use for over 50 years. It has uses in the anesthesia, emergency medicine, critical care, and prehospital care realms.

Pharmacology

Ketamine is classified as a dissociative anesthetic agent. It essentially makes the patient feel "detached" from their pain and environment.

The active isomer is S(+)-ketamine. It is metabolized primarily to its active metabolite, norketamine. Ketamine enhances the descending inhibiting serotonergic pathway and exerts antidepressive effects. Analgesia occurs at much lower doses than the hypnotic effects.

Antagonism of the N-methyl-D-aspartate (NDMA) receptor is the primary target for ketamine. This is further potentiated by glutamate binding – patients who are "dependent" on ketamine often have this additional binding which opens the NDMA receptor. Since glutamate is the most prevalent amino acid in the body, its liberation activates multiple pre- and post-synaptic receptors.

Ketamine binds with many sites, including opioid, monoaminergic, muscarinic, nicotinic, and cholinergic receptors. However, even though ketamine binds to opioid receptors, it is not reversed by naloxone.

The action at monoaminergic receptors is most likely responsible for the sympathetic properties of ketamine. It stimulates noradrenergic receptors and inhibits catecholamine uptake, leading to a hyperadrenergic state.

Ketamine's psychologic effects are primarily mediated by affecting the release of acetylcholine from cholinergic receptors. These are activated by nicotinic and muscarinic receptors, and ketamine effectively directly inhibits these.

Uses of Ketamine

Procedural Sedation and Anesthesia

The primary use of ketamine has been for anesthesia. It was found to be extremely useful for short procedures, especially when there was no need for muscle relaxation and a desire to maintain airway reflexes. It is also relatively hemodynamically stable, allowing its use in patients who may be at higher risk of developing hypotension. This is particularly of use in trauma patients with hemorrhagic shock, and in patients with traumatic brain injuries (TBI), as the preservation of blood pressure allows by extension the preservation of cerebral perfusion pressure.

Ketamine is also useful in severe asthma, as the bronchodilator properties can assist in overall management, should these patients require intubation.

Analgesia

Ketamine, administered either IM or IV, can be a useful adjunct for pain management. Prehospital, this may be administered in the setting of major trauma when, for example, the patient's airway is not immediately accessible and the patient needs to be either extricated or moved. This use can be extended to the emergency department if analgesia is needed to facilitate assessment and management.

Chronic neuropathic pain also has been treated with ketamine and can counteract the spinal sensitization that may occur in these patients. In addition, there are potential roles for use in complex regional pain syndrome and sickle cell disease. The use of ketamine allows for a sparing of the overall dose of opiates, as well as limiting some of the side-effects of the latter class of medications.

Hyperactive delirium syndrome with severe agitation

This is a potentially life-threatening clinical condition that can be encountered in the prehospital or emergency department setting. The patient shows abnormal vital signs (e.g. raised temperature, heart rate, and blood pressure), significant agitation, change in mental status, and often metabolic derangements. Patients with this condition can pose a threat to their own and others' lives, especially during attempts to restrain the patient to allow for safety of those around them. Of note, the term "excited delirium" has been deemed inappropriate to describe this condition.

Despite some high-profile news stories on this condition, ketamine has been used safely in many prehospital and in-hospital systems. It has the advantage of rapid onset, even by IM administration. with the maintenance of airway reflexes. Unlike earlier studies of prehospital ketamine use for this indication, the adverse event rate (specifically emergency department intubation need) is about 1.8%. Although there is some concern of exacerbation of pre-existing psychiatric conditions, this has not borne out in clinical studies.

Depression

Ketamine can provide rapid-acting antidepressant activity, though this is not sustained unless administered as an infusion. A Cochrane review has shown that patients with major depressive disorder can experience reduction or remission of symptoms lasting 1- 7 days. However, due to a high dropout rate of included studies, longer-term benefit (or lack thereof) has not yet been elucidated.

DOSAGE

a. Can be IV or IM
b. Elderly patients metabolize ketamine more slowly and need lower doses
c. Typical sedation/analgesia dose
    i. 0.2-0.75mg/kg IV or 2-4mg/kg IM
d. Typical anesthesia induction dose
    ii. 0.5-1.5mg/kg IV or 4-10mg/kg IM
e. Typical dose for hyperactive delirium syndrome
    iii. 3-5mg/kg IM (max does 500mg) or 0.5-1mg/kg IV (max dose 200mg)

ADVERSE EFFECTS

Potential side effects are listed below:

a. Allergic reactions
b. Tachycardia and hypertension
c. Anorexia
d. Nausea/vomiting
e. Muscle stiffness
f. Confusion
g. Diplopia
h. Amnesia and confusion
i. Emergence phenomenon
j. Laryngospasm

Emergence phenomenon is a state of agitation and hypervivid sensation that can occur more commonly in adults than children. This can be avoided by ensuring recovery occurs in a quiet, dark environment. A lower dose of ketamine may also reduce this risk. Co- administration of a short-acting benzodiazepine, such as diazepam or midazolam, may also reduce the incidence. Route of administration does not affect the incidence of emergence.

Laryngospasm is a rare occurrence with ketamine use, occurring in about 4.2 per 1000 cases. Rapid bolus administration may precipitate this. The majority of cases respond to simple airway maneuvers and bag-valve-mask ventilation. Rarely, advanced airway management will be required.

COMMON MYTHS

Ketamine has long been thought to be contraindicated in patients with raised intracranial pressure (ICP). This was based on studies that are now several decades old, that often used lumbar area pressures as surrogates for ICP. More recent studies have failed to show evidence of harm in patients with TBI. In contrast, the elevation of blood pressure and maintenance of relative hemodynamic stability during induction of anesthesia may actually benefit the brain through the maintenance of cerebral perfusion pressure and prevention of secondary brain injury.

While ketamine is often labeled as a “cardiostable” agent and is preferred in patients with hemodynamic instability, recent studies do highlight the possibility of worsening hypotension in patients with pre-existing low blood pressure. This may be related to such patients being at the end of their physiologic reserve, and, therefore, the usual increase in catecholamine effect may not be able to be reproduced. Therefore, it is recommended that in patients with a high shock index (heart rate/systolic blood pressure) >0.9 be administered a lower induction dose of ketamine for intubation.

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SESSION 2

CASE MANAGEMENT

Moderator: Alison Wilson

Monday, April 15, 2024
10:30 – 12:00 PM
Palace Ballrooms 1-2
Palace Tower
Emperors Level – 4th Floor

Panelists: **Elizabeth R. Benjamin**
Alexander L. Eastman
Jennifer M. Gurney
R. David Hardin, Jr.
Martin A. Schreiber
Jason W. Smith
Matthew J. Wall, Jr.

SESSION 3

KENNETH L. MATTOX ANNUAL DISTINGUISHED LECTURESHIP

Moderator: Martin A. Schreiber

Monday, April 15, 2024
12:00 – 1:30 PM
Palace Ballrooms 1-2
Palace Tower
Emperors Level – 4th Floor

"Necessity As The Mother of Invention: Innovation And Health Challenges From COVID-19 To 'Bionic' Arms"

Albert Chi, MD, FACS
Associate Professor of Surgery
Division of Trauma, Critical Care and Acute Care Surgery
Oregon Health & Science University
Portland, OR
Research and Exploratory Development,
Johns Hopkins Applied Physics Lab
Commander, Medical Corps, IRR USN

SESSION 4

SEE ONE, DO ONE - HOW I DO IT

Moderator: Elliott R. Haut

Monday, April 15, 2024

1:30 – 3:45 PM
Palace Ballrooms 1-2
Palace Tower
Emperors Level – 4th Floor

1:30 – 1:45	**Open Exposure - Popliteal Vessel** **Elizabeth R. Benjamin, MD, PhD, FACS**
1:45 – 2:00	**Take Back the Duct: Laparoscopic Common Bile Duct Exploration** **Marc A. de Moya, MD, FACS**
2:00 – 2:15	**Complicated Diverticulitis: Cut to Cure?** **Jay J. Doucet, MD, FACS**
2:15 – 2:30	**Initial Burn Resuscitation** **Hamed Amani, MD, FACS**
2:30 – 2:45	**Battle of the Bulge: Lumbar and Flank Hernias** **Meghan R. Lewis, MD, FACS**
2:45 – 3:00	**Dangerous Passage: Penetrating Neck Injuries and the "No-Zone" Approach** **Kenji Inaba, MD, FRCSC, FACS**
3:00 – 3:15	**Fasciotomy: Start to Finish - Avoiding the Pitfalls** **Jason W. Smith, MD, PhD, MBA, FACS**
3:15 – 3:30	**Rib Plating: Is It Time to Slow Your Roll?** **Patrick Georgoff, MD, FACS**
3:30 – 3:45	**Bleeding Kids: Optimal Resuscitation for Pediatric Patients in Hemorrhagic Shock** **R. Todd Maxson, MD, FACS**
3:45 – 4:10	**Break & Visit Exhibits** **Palace Ballroom 3** **Palace Tower** **Emperors Level – 4th Floor**

OPEN EXPOSURE – POPLITEAL VESSEL

Elizabeth R. Benjamin, MD, PhD, FACS

Professor of Surgery
Emory University School of Medicine
Trauma Medical Director
Grady Memorial Hospital
Atlanta, GA

OVERVIEW

Popliteal artery injuries can be some of the most complicated injuries to manage, both technically in the short term, due to the often-difficult exposure, and long term due to the high risk of complications and association with limb loss. Factors that influence outcome after injury include time to revascularization, mechanism of injury, associated soft tissue and venous or nerve injury, and chronic underlying disease. Posterior dislocation of the knee is a classic risk factor for blunt injury, with an approximately 20% incidence of popliteal injury. Although small or simple injuries may be repaired primarily, the majority of injuries require interposition or bypass graft and patients with associated orthopedic injuries may be shunted during orthopedic fixation followed by definitive repair. Liberal use of angiography is recommended, if there is not a palpable pulse at the conclusion of the reconstruction. The popliteal artery should not be ligated given the high rate of associated limb loss. After any period of ischemia, the lower leg should be evaluated for compartment syndrome with a low threshold for fasciotomy in the setting of concern. Prophylactic fasciotomies are not recommended.

SURGICAL ANATOMY

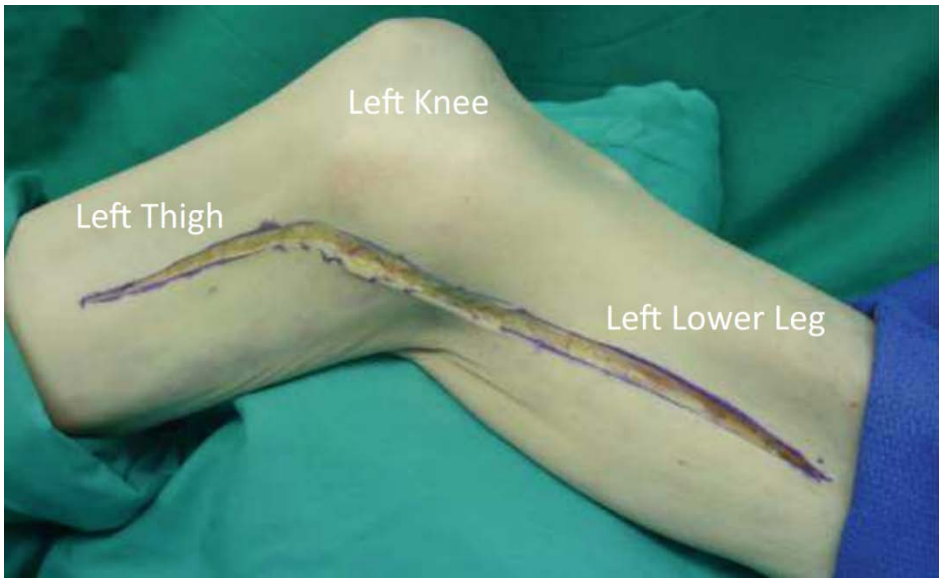
- The popliteal vessels, tibial nerve, and common peroneal nerves traverse the popliteal fossa, a diamond shaped area behind the knee bordered inferiorly by the medial and lateral heads of the gastrocnemius, and superiorly by the biceps femoris (lateral) and the semitendinosus and semimembranosus muscles (medial).
- The popliteal artery is a continuation of the superficial femoral artery and divides into the anterior tibial artery and tibioperoneal trunk that ultimately provides the peroneal and posterior tibial arteries.
- The popliteal artery is divided into three (3) segments: the suprageniculate (above the knee), mid (behind the knee) and infrageniculate (below the knee).
- The origin of the popliteal artery is as the superficial femoral artery passes through the adductor (Hunter's) canal in the adductor magnus and enters the lower third of the thigh. From this medial position, it travels posterolaterally, traversing the knee in a directly posterior position.
- Unlike the superficial femoral artery, the popliteal artery has several branches, the superior and inferior geniculates, that provide collateral circulation and blood supply to the knee joint.
- Below the knee, the anterior tibial artery branches off anteriorly, through the interosseus membrane, to run with the deep peroneal nerve, alongside the lateral edge of the tibia in the anterior compartment of the lower leg and ultimately becomes the dorsalis pedis artery.

- The tibioperoneal trunk then branches approximately 2-3 cm distal to the takeoff of the anterior tibial artery into the peroneal and posterior tibial arteries within the deep posterior compartment. The posterior tibial artery continues down to the foot behind the medial malleolus, while the peroneal artery transitions more laterally.
- While the femoral vein is medial to the artery, the popliteal vein is lateral to the popliteal artery in the mid fossa before resuming it's more medial position below the fossa. The tibial nerve is lateral and posterior to the artery at the mid fossa, making it a more superficial structure relative to the vessels.

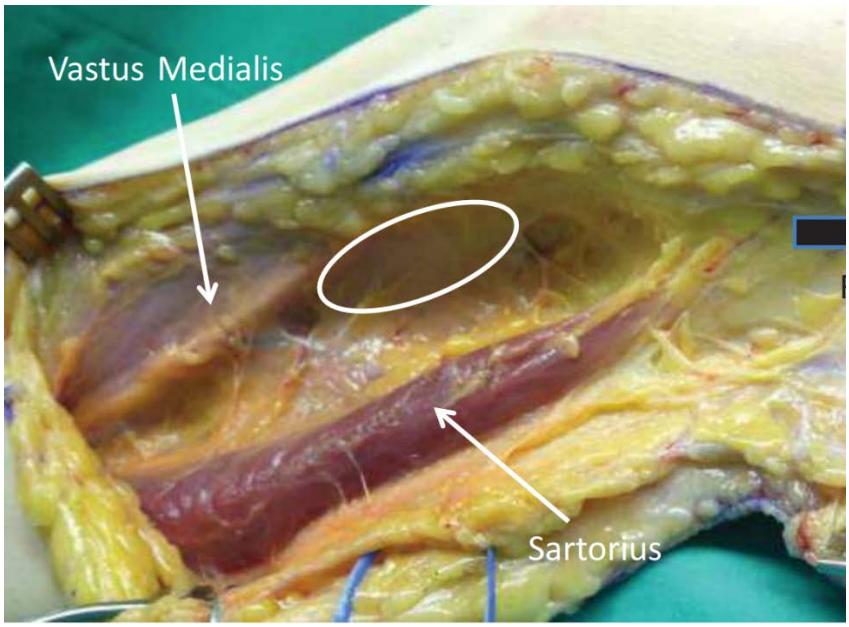
POSITIONING AND APPROACH

Ideally, the patient is placed in a supine position with the leg externally rotated and the knee flexed, supported by a sterile bump. Skin preparation should include the contralateral groin in anticipation a saphenous vein graft will be needed.

The incision is based on suspected level of injury, with access to the suprageniculate popliteal artery approached from a medial longitudinal incision in the groove between the vastus medialis and the sartorius muscles, just posterior to the femur. The infrageniculate popliteal is approached also through a medial longitudinal incision posterior to the tibia. The mid popliteal can be most easily accessed by a posterior prone approach, but for trauma, a medial approach is preferred with access obtained directly between the incisions for the supra and infrageniculate popliteal artery.



Care must be taken to preserve the saphenous vein. For proximal exposure, retract the sartorius inferior or posteriorly to expose the fat pad just posterior to the femur, where the popliteal vessels run. The popliteal artery will be the most medial structure, followed by the popliteal vein, and then the tibial nerve. In the setting of trauma, this space can be filled with dense hematoma, and the posterior aspect of the femur and the anterior border of the sartorius can be used to maintain the spacial relationship of the vessels. Should additional exposure be needed, the incision can be carried proximally, with release of the adductor canal to expose the superficial femoral artery. Distally, the tendons of the semimembranosus, semitendinosus, and gracilis muscles may be divided to gain better exposure to the popliteal fossa on the posterior aspect of the knee. These tendons should be tagged and reapproximated to maintain joint stability at the end of the case.

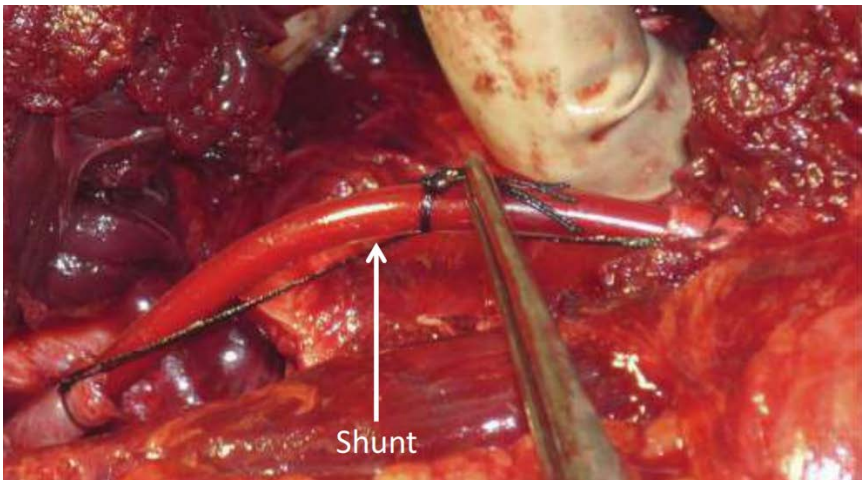


Extending the incision distally allows exposure of the infrageniculate popliteal artery with posterior retraction of the gastrocnemius muscle and division of the tibial attachments of the soleus. The anterior tibial artery branches early and traverses laterally through the interosseus membrane into the anterior compartment, and the tibioperoneal trunk ultimately divides into the posterior tibial and peroneal arteries that run posterior to the tibia and fibula respectively. Be aware of the multiple geniculate branches of the popliteal artery, as maintaining these is important due to their role in collateral circulation.

As with all vascular injuries, obtain proximal and distal control around the injury with vessel loops or noncrushing clamps. Small injuries may be repaired without narrowing the artery using 5-0 or 6-0 prolene suture; however, care must be taken not to create or leave a dissection flap. Any concern for intimal injury or poor post repair pulse should be followed with an on-table angiogram. For most injuries, resection and interposition graft will be needed.

- Trim the ends of the artery using Potts scissors and bevel the edges slightly.
- Use of a Fogarty balloon is likely needed to remove clot, both proximally and distally, and the artery should be injected with heparinized saline.
- If appropriate with associated injuries, systemic heparinization is recommended.
- First choice option is to use saphenous vein from the contralateral leg for a reverse saphenous vein graft.
- Use 5-0 or 6-0 prolene to create a tension free anastomosis, passing the needle from the intima to the adventitia on the artery side to minimize the risk of intimal dissection. Create the proximal anastomosis first to allow flow through the graft prior to performing the distal anastomosis.
- Take care to place the knee in a slightly flexed position when measuring graft length to allow for appropriate measurement. A long graft can kink once the knee is in anatomic position, and a short one can be placed on undue tension in full extension.
- Debride all devitalized tissue and provide soft tissue coverage for the anastomosis prior to closure to minimize the infection risk.

In patients that are profoundly unstable or need orthopedic fixation prior to anastomosis, a shunt may be temporarily placed to restore flow. The knee should be maintained in a 30-degree flexion with the external fixator to allow easier access to the vessels. If Argyle shunts are used, resist trimming the shunt to maintain the atraumatic ends, and secure the shunt using an 0 silk tie on the proximal and distal ends, secured to a midpoint tie on the shunt for stabilization. Confirm flow after placement with a pulse or signal check.



In patients with concomitant arterial and venous injuries, management of the venous injury should be based on the overall clinical picture, nature of the injury, and projected need for venous drainage based on soft tissue injury. Contemporary literature shows no difference in limb swelling, DVT, PE, amputation, or mortality rates. However if the vein is ligated, compression wraps should be applied to the leg with elevation, and in all patients, venous thromboembolism prophylaxis (VTEp) should be initiated as soon as possible.

CONCLUSIONS

Popliteal injuries carry a high risk of amputation, both in the acute and delayed settings. The popliteal artery is effectively an end artery, and injuries should be addressed expeditiously. Patients in extremis or with combined orthopedic injuries may require a temporary shunt prior to definitive repair. Repair of the popliteal artery commonly requires an interposition graft, and the ideal conduit is the contralateral saphenous vein. Patients should be monitored closely postoperatively to assess graft patency and for early signs of infection. VTEp should be started early, and patients with venous ligation should undergo leg wrapping and elevation.

TAKE BACK THE DUCT: LAPAROSCOPIC COMMON BILE DUCT EXPLORATION

Marc A. de Moya, MD, FACS

Professor and Chief of Trauma, Acute Care Surgery
Lunda/Apprahamian Chair of Surgery
Medical College of Wisconsin/Froedtert Trauma Center
Milwaukee, WI

Over the last several decades with the advent of improved endoscopic technology, general surgeons have abdicated exploration of the common bile duct for the less invasive and successful endoscopic approach. However, in parallel, our skills as laparoscopic/robot-assisted surgeons have also significantly increased. Over time, we have become more dependent on the endoscopic approach to clearing the common bile duct for presumed choledocholithiasis, and despite our increased laparoscopic skills, have not applied that knowledge to clearance of the common bile duct. There has been mounting evidence to suggest that a direct to operating room approach with intra-operative cholangiograms and laparoscopic trans-cystic common bile duct exploration (LTCBDE) is associated with improved patient length of stay, improved outcomes, and time to definitive treatment. The landscape of choledocholithiasis management has witnessed a transformative shift with LTCBDE as a first-line treatment option, and general surgeons are at the forefront of this change. As a result, it is time for general surgeons and acute care surgeons to reclaim the common bile duct.

EVIDENCE

There are a number of studies that suggest that a one stage approach is associated with decreased length of stay, decreased number of imaging studies, and no increase in complication rate. As far back as 1999, Cuschieri, et. al. found that the two-staged approach was associated with twice the number of imaging studies. This study was later repeated with the same results by Bansal, et. al. in 2010. A later meta-analysis done in 2018 by Singh and Kilambi was performed that also demonstrated that the single-stage approach is superior to the two-stage for the reasons mentioned above. Murphy, in 2022, developed an online tool to evaluate the value of a single stage approach (see QR code). This clearly demonstrates how a one-stage approach increases the value of care for the hospital and patient.

TECHNIQUE

Those general surgeons who perform intra-operative cholangiograms, particularly in those with acute cholecystitis, have the skills needed to perform LTCBDE. The technique can be broken down into the following steps;

1. Identification of choledocholithiasis with intra-operative cholangiogram, preferably via Olson clamp trans-cystic. Via cholangiocatheter placement of wire beyond the sphincter of Oddi, preferably under fluoroscopy. The wire should be advanced with plenty of redundancy in the GI tract
2. Sheath is placed via the 5mm trocar. This effectively elongates the reach of the port, alternatively bariatric 5mm trocar may be used

3. Balloon dilation is placed over the wire to dilate the cystic duct to 5mm (this is an optional step as some cystic ducts do not require dilation)
4. Placement of choledoscope over the wire with continuous or intermittent irrigation for visualization
5. Visualization of the common bile duct lumen and obstructing stone(s). One may attempt to push smaller stones through the spincter of Oddi with the camera
6. Passage of basket if stones are less than 7-8mm, if larger than 7-8mm would break them with lithotripsy
7. Removal of stones or stone fragments with basket until clear
8. Completion cholangiogram
9. Completion of Cholecystectomy
10. If unable to remove stones then clip duct and complete the cholecystectomy and arrange post-operative ERCP

EQUIPMENT NEEDED (APPROPRIATE REPLACEMENTS CAN BE USED AS LOCAL RESOURCES DICTATE)

Lawson	Description	Catalog	Count	Open	Location
107321	Spyglass scope	M00546780	1	1	RG29D
013743	Pulmonary jagwire .035x180cm	1517	1	1	CT09B14
059869	Klein injector tubing	AFTD	1	1	SB65A04
087640	Suction tubing	OR610	1	1	SB61C01
083042	Armada 35 6.0 mmx40 mmx80 cm	B1060-040	1	0	RG29E
014086	Encore inflation device 26 mL	M0067101140	1	0	RG29E
057513	Cook common bile duct exploration kit	C-CDES-100	1	(see note below) 1	G29E
	Duct introducer sheath	c-cdis-4.0-15-berci g08297	1	1	(part of kit)
	NCompass Nitinol Stone Extractor	c-ntse-2.4-115-nct4 g36251	1	1	(part of kit)
028645	Zerotip basket	M00513210	1	0	CT9A12
028029	Cook 2.4 Compass Basket	NCT4-024115	1	0	RG29E
009453	Device multi-torque for 0.38 GW	TD01	1	0	IPP30 ALCOVE
	IV pressure bag available				

EXAMPLE OF OUR CART

ESTABLISHING A NEW PROGRAM

It is necessary to have a surgical champion and a nursing champion. This pair can lead the education and follow the outcomes of the patients. In groups that are able to coordinate, it is helpful to have two surgeons scrubbing with LTCBDE to more rapidly increase the group's level of expertise and comfort with the steps. It is important to have a nursing champion to ensure that all nurses involved in the cases are familiar with the equipment and that there is a cart built to house all the necessary instruments/catheters.etc. A partnership with the local choledochoscope representative can also help to facilitate availability of equipment and help to troubleshoot any issues that may arise.

CONCLUSION

The paradigm shift toward LTCBDE as a first-line treatment for choledocholithiasis led by skilled general surgeons is a testament to the continuous evolution of surgical techniques. This innovative approach offers a host of benefits for both patients and healthcare systems, promising improved clinical outcomes, reduced costs, and an enhanced quality of care. As this technique becomes more widely adopted, ongoing research and advancements will likely refine and further solidify its place as a cornerstone in the management of choledocholithiasis.

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COMPLICATED DIVERTICULITIS: CUT TO CURE?

Jay J. Doucet, MD, FACS

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Medical Director, Emergency Management
UC San Diego Health
San Diego, CA

OBJECTIVES

- Definitions/Pathogenesis
- Incidence and risk factors
- Emerging Concepts
- Diagnostic tools
- Treatment options
    - Medical
    - Surgical
        - Open/laparoscopic/robotic
- Timing/Flow of interventions

DEFINITIONS/PATHOGENESIS

- Diverticular disease and diverticulitis are the most common non-cancerous pathology of the colon.
- **Traditionally** been considered a disease of aging and associated with cultural and dietary habits: “Western diet”
- Pathogenesis of diverticular disease is still not completely understood – its complex!
- **Traditional** theory of the pathophysiology of diverticulosis is linked to long-term constipation, leading to in mucosal and submucosal herniation at the entry sites of the penetrating blood vessels (vasa recta), increased intraluminal pressure, and colonic muscular hypertrophy, especially in left colon.
- By age 40, 5% of the population has **diverticulosis**, while the prevalence may be as high as 60–80% by age 80.
- The **term "symptomatic uncomplicated diverticular disease" (SUDD)** was coined for diverticulosis with non-specific symptoms of pain and constipation – maybe overlaps with constipation-predominant irritable bowel syndrome. Patients with SUDD may also exhibit gut hypersensitivity while their bowel compliance is normal.
- Diverticulitis is caused by changes in the gut microbiota and microenvironment, stasis or obstruction within a diverticulum, .local tissue ischemia, and **microperforation**.

- **Acute diverticulitis (AD)** usually a triad of abdominal pain, fever and elevated inflammatory parameters (white blood cells, C-reactive protein) with varying degrees of aggravated symptoms.
- **Chronic diverticulitis** manifest as continuing diverticulitis and possible fibrostenotic stricture, large bowel obstruction, or of fistulae to bladder, vagina, small bowel, skin.
- **Warning – in 1%-5% of patients**, the suggestive clinical and even radiological features are in fact caused by a **locally advanced malignancy** with incipient of micro/macro-perforation.
- **SCAD:** small subset of patients with "segmental colitis associated diverticulitis", can have pathologic features of inflammatory bowel disease and rarely even progress to Crohn's or ulcerative colitis.

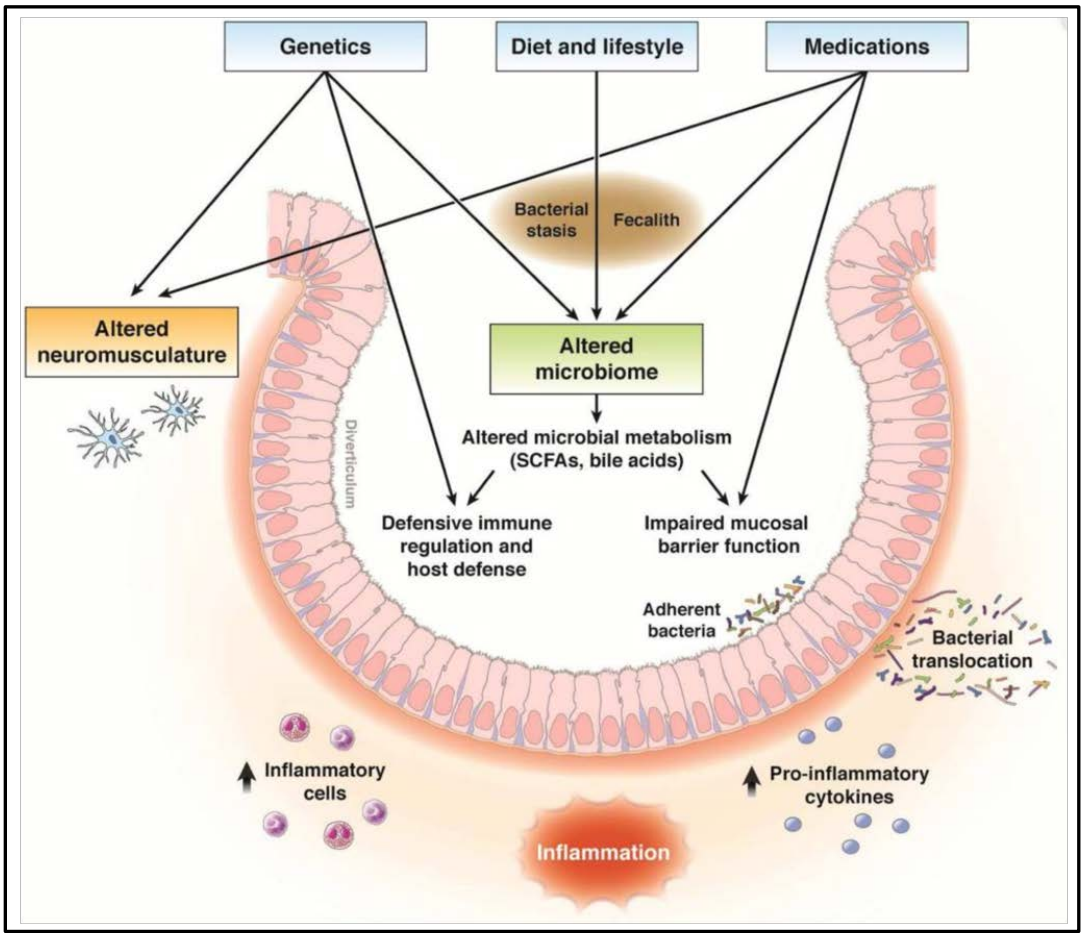

Figure 1. Etiology of Diverticulitis

INCIDENCE AND RISK FACTORS

- In 1890's diverticular disease **was a rarely diagnosed medical curiosity!**
- AD causes over 300000 hospital admissions resulting in 1.5 million days of inpatient care, diverticulitis places significant economic burden on the US healthcare system at 2.4 billion dollars annually.
- 1947 review suggested that 10-25% of patients with diverticulosis will develop diverticulitis. More modern studies suggest a 1-4.3% risk at 7-11 years.

- But – **increasing incidence in younger patients under 40**, traditionally was 1-2% incidence, but now in California 1995-2006 **Incidence in those under 18-44 years doubled** while no change in those 75 years and older
- Risk factor – **low dietary fiber** – An inverse relationship between fiber consumption and the onset of diverticular illness was discovered in a prospective study involving 47888 American men over a 4-year period (relative hazards risk ratio 0.58, CI: 0.41-0.83, P = 0.01). Similar studies overseas.
- Additional environmental factors implicated in diverticulitis include **smoking, corticosteroids and non-steroidal anti-inflammatory medications (NSAIDs), and obesity**.
- Increased incidence in monozygotic twins suggests genetic effects, and **increasing incidence in younger patients with shorter exposure to low fiber diet suggests intrinsic, non-dietary risk factors**.

Table I. Hinchey classification and modified Hinchey classification of acute diverticulitis

Hinchey classification and modified Hinchey classification of acute diverticulitis			
Classic Hinchey class (1999)		**Modified Hinchey Class (2005)**	
I	**Pericolic abscess or phlegmon**	**0**	**Mild clinical diverticulitis**
		IA	**Confined pericolic inflammation: Phlegmon**
		IB	**Confined pericolic abscess**
II	**Pelvic, intra-abdominal or retroperitoneal abscess**	**II**	**Pelvic, distant intra-abdominal, or retroperitoneal abscess**
III	**Generalized purulent peritonitis**	**III**	**Generalized purulent peritonitis**
IV	**Generalized fecal peritonitis**	**IV**	**Fecal peritonitis**
		SMOL	**Smoldering diverticulitis/peridiverticulitis**
		FIST	**Colovesical/vaginal/enteric/cutaneous fistula**
		OBST	**Large and/or small bowel obstruction**

EMERGING CONCEPTS

- **Incidence - exaggerated?**
    - Although a common EGS presentation, **most people with diverticulosis will never develop symptoms or problems.**
- **Not just low fiber diet – but genetics too?**
    - **Increasing incidence in those 20-40 years** old, but not in elderly.
- **Effect of gut microbiome?**
    - **DIABOLO trial**, fecal samples from 31 patients with left-sided AD were compared to 25 control subjects using PCR. There was a higher diversity of Proteobacteria ($p < 0.00002$) and all phyla combined ($p = 0.002$) in AD patients

- **Routine Antibiotics - not mandatory?**
    - **DIABOLO trial/AVOD trials** in "non-severe" Hinchey 1A, 1B – no antibiotics non-inferior versus conventional therapy for morbidity, unplanned surgery, hospital stay duration, subsequent abdominal pain or transit impairment, or recurrent acute diverticulitis. LOS 1 day shorter without antibiotics.
- **Secondary prophylaxis – use antibiotics?**
    - Weak data for **rifaximin as a candidate for secondary prevention** of recurrent acute diverticulitis – 9% less recurrence of AD at 1 year.
- **Hinchey no longer king?**
    - While some Hinchey 1B and II (abscesses) do well with IR drainage versus surgery in initial trials, some trials suggest high rates of recurrence, ASCRS 2022 suggest consideration of elective surgery in these grades.
- **Hartmann procedure – should be avoided?**
    - Factors associated with Hartmann include non-elective surgery, modified Hinchey class 3 or 4, poor performance index, immunosuppression, and obesity. **30%-45% of patients with an end colostomy never have their stoma reversed**. Despite evidence of safety of primary resection and anastomosis +/- diverting ileostomy, and of increased morbidity of Harttmann, over 50% of US surgeons perform Hartmann's as emergent surgery for AD despite.
- **Good-bye Laparoscopic Lavage?**
    - After initial enthusiasm, laparoscopic lavage for AD has been shown in multiple trials to be inferior to surgical resection for localized abscesses and appears to be an inferior tool for diffuse peritonitis.

DIAGNOSTIC TOOLS

- CT scans are the main tool in the diagnosis of diverticulitis and classification of diverticular disease severity. CT carries prognostic and potentially therapeutic significance.
- Interval colonoscopy is advised after an acute attack, particularly after complicated diverticulitis to rule out malignancy or significant adenomas in the colon, this is usuallt deferred to 6 weeks post attack.

TREATMENT OPTIONS

- **Medical**
    - Most presentations of new AD are uncomplicated. Initial conservative management is typical – large studies show only 6.9-7.3% of AD presentations will need colectomy over next 7-10 years.
    - **For low risk, Hinchey 0 and IA presentations**, a no-antibiotic protocol may be non-inferior.
    - **Abscesses** (Hinchey 1B, II) can be managed by antibiotics and percutaneous drainage has long term success. However abscess patients literature has reported significantly higher recurrence rates (up to 40%-61%), particularly in patients with a pelvic abscess (modified Hinchey II). ASCRS practice guidelines recommend **consideration of an elective colectomy** in these patients.

- **Surgical**
    - Up to 20% of hospitalized patients with AD fail non-operative management
    - Three groups of indications for emergency surgery:
        1. **Signs of diffuse peritonitis and/or free perforation**
        2. **Suspicion of underlying malignancy; and,**
        3. **Failure of medical management or IR drainage**
    - The continuation of SIRS or sepsis symptoms at 72 hours is considered by mant surgeons as failure of medical management.
    - Since 2000, strict criteria such as age and number of attacks are no longer considered absolute indications for prophylactic elective colectomy (ASCRS).
    - Younger patients (< 50 years) were historically thought to have a more severe form of AD and hence elective surgery was needed to avoid recurrence. However, now known younger patients having similar rates of recurrence and subsequent need for colectomy as older patients
    - **DIRECT trial** in patients with ongoing symptoms or at least 2 attacks suggested that offering surgery was associated with improved cost and quality of life in patients undergoing surgery.
    - **Resection is the principal aim of surgical therapy**. Resection typically begins in the healthy, non-thickened bowel proximal to the target area and distally should include the high-pressure zone of the rectosigmoid junction as identified by the coalescence of the teniae. In general, oncological principals should be employed unless a malignant cause of the inflammation has been ruled out.
    - **Reconstruction vs diversion: Three options to consider:**
        1. **A primary anastomosis,**
        2. **A primary anastomosis with upstream diversion; and**
        3. **Creation of an end colostomy (Hartmann procedure).**
    - A small, randomized study comparing rates of ostomy closure in patients with an end colostomy vs a diverting ileostomy demonstrated significantly higher reversal rates the latter group (58% vs 90%, respectively), and the post-operative morbidity was higher in the former (20% vs 0%). Hartmann is not considered primary surgical therapy except in cases of modified Hinchey class 3 or 4, poor performance index, immunosuppression, and obesity (Body mass index > 30. (Table 2).
    - However, in 2012-2016 in the United States, **more than 90% of surgeons performed a Hartmann resection in the acute setting**, and only 7.6% of patients had a primary anastomosis with diverting loop ileostomy performed.
    - **Damage control EGS approaches work in unstable patients** - A systematic review revealed a 62% rate of restored intestinal continuity during damage-control surgery
    - How I do it (Figure 2)

- Outcomes data after damage-control surgery for AD: a 9.2% risk of mortality and high morbidity of close to 50% including a 7.4% leak rate. Wound infection reported at 10%-20% was the most common morbidity with mortality rates being < 5%. P
- **Patient comorbidities and need for emergent surgery** were the two main contributing factors to patient mortality.
- Long term follow up data demonstrate low recurrence rates (6%-8%) and a long median time to recurrence at 29 months.
- 3 randomized trials show that **minimally invasive surgery** (laparoscopic, robotic) for diverticular has lower short term morbidity in terms of lower blood loss, decreased post-operative pain and shorter hospital stay compared to open surgery.
- Three prospective randomized controlled multicenter trials on laparoscopic **peritoneal lavage** were launched and resulted in high-quality evidence - a systematic review concluded that the preservation of diseased bowel by laparoscopic lavage was associated with an approximately 3 times greater risk of persistent peritonitis, intraabdominal abscesses and the need for emergency surgery compared to a resection.

Table II. Rise and Fall of the Hartmann procedure for complicated diverticulitis

Rise and Fall of the Hartmann procedure for complicated diverticulitis	
1907	Mayo described the 3-stage technique for perforated diverticulitis in a 5-case series, the first documentation of a surgical treatment for diverticular disease
1925	Hartmann describes procedure for rectal cancer – no intent to reverse stoma
1950	Boyden suggests immediate resection with Hartmanm procedure for AD + peritonitis
1962	Staunton advocates Hartmann in AD when a Mikulicz procedure not possible.
1973	Labow - Hartmann's operation for AD with obstruction or abscess, whether or not there is peritonitis.
1979	Nunes - 25 AD patients - 8 % mortality, shorter LOS, removes source of infection and avoidx primary anastomosis – "a reasonable option in these patients".
1984	Krukowski stated "Hartmann's should be done in most cases".
1998	Desai et al - 185 patients with Hartmann's: 9 % morbidity /14 % mortality rate with reversal of stoma in 57 % of patients no mortality at second operation; they concluded that the procedure was safe.
2000	American Society of Colon and Rectal Surgeons (ASCRS), Hartmann is the optimal management for perforated diverticular disease.
2006	ASCRS revised its guidelines to be more patient specific, encouraging conservative approaches for the management of diverticulitis.
2014	ASCRS encouraged decision making by case but Hartmann's operations were less likely to have stoma reversal than those with resection, primary anastomosis and proximal diversion; thus, **primary resection and anastomosis was recommended** pver Hartmann.
2020	ASCRS most patients with diverticulitis will respond to non-surgical treatments. In the 15–32 % who need emergency surgery, of data **shows improved mortality and morbidity rates with resection and primary anastomosis with or without a stoma**. While a Hartmann's operation can be done in select patients, most patients report a poorer quality of life due to the end colostomy

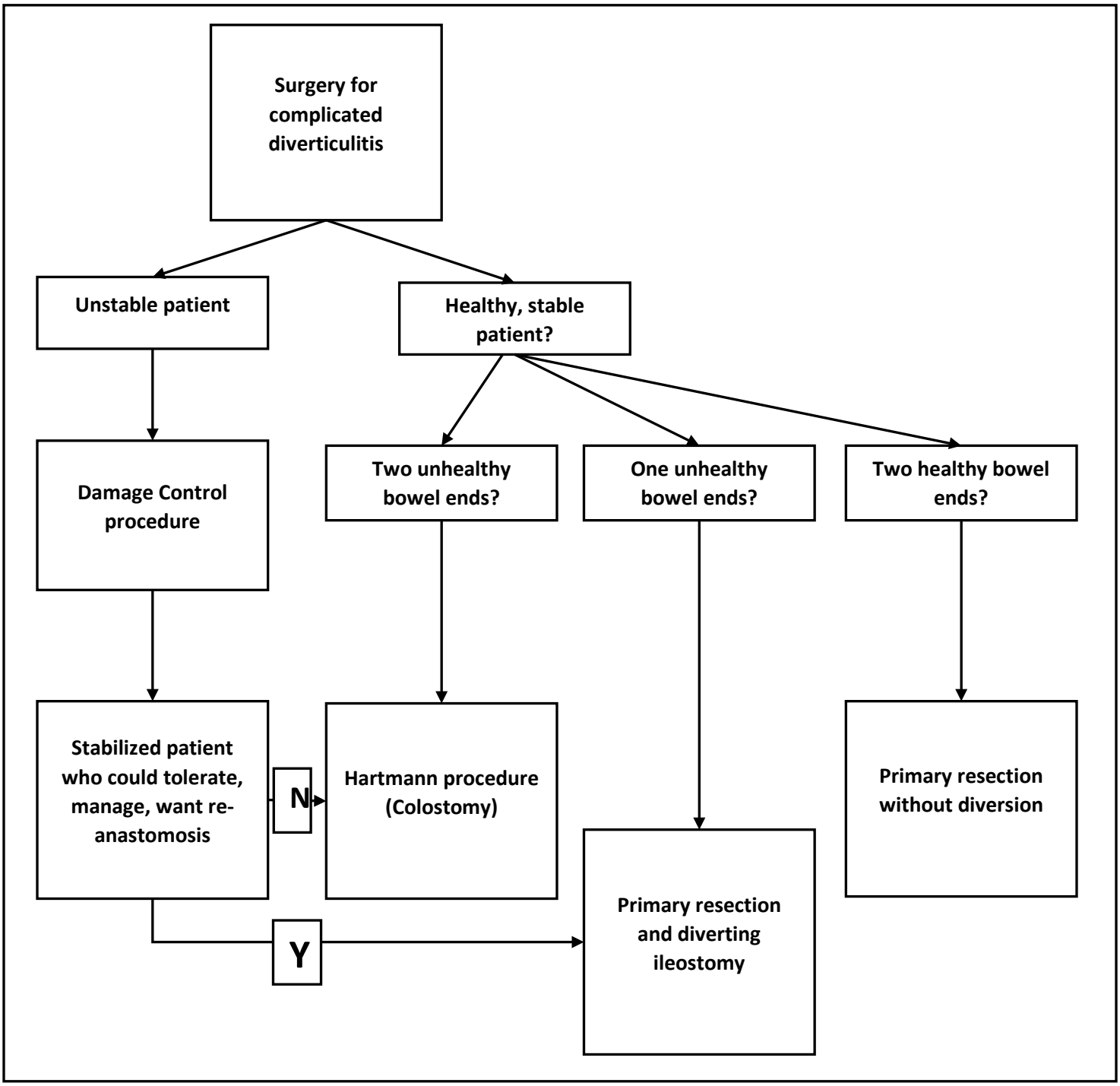

Figure 2. Surgical algorithm for complicated diverticulitis

CONCLUSION

- Diverticulitis is expected to increase substantially in the future as the population ages and the disease becomes more prevalent in younger patient populations.
- Dietary fiber, genetics, and microbiome have roles in pathogenesis.
- CT scan is the investigation of choice
- Medical management succeeds in most cases, but there is a defined role for surgery
- The surgical procedure of choice is primary resection with or without proximal diversion. The Hartmann procedure is obsolete except for specific indications.
- Damage control procedures are warranted, with reasonable results, in unstable patients.

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INITIAL BURN RESUSCITATION

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One of the early articles on burn resuscitation was published in the Journal of the American Medical Association (JAMA) in 1905. In the landmark article, Haldor Sneve introduced techniques aimed at averting shock following severe burns, involving the application of salt solutions through oral ingestion, enemas, and intravenous infusion.[1] It was understood early in the 20th century that burn injury produces a state of physiologic derangement akin to volume loss. Despite the significance of his findings, Sneve's recommendations encountered limited acceptance over an extended period.

Next few decades saw incremental advancement in understanding of burn physiology. Some of the noteworthy ones are:

- 1919, Fauntleroy, et. all, - salt solution with added sodium bicarbonate through proctolysis and oral fluid administration, along with addition of Whisky, a concoction he termed “eggnogs”.[2]
- 1921, Underhill, et. all, - described the burn edema fluid as filtrate of plasma.[3]
- 1931, Blalock, et. All, - described the relationship of blood pressure and burn edema formation. He showed that as edema increased, blood pressure decreased. This backed Underhill’s understanding that burn edema was a filtrate of blood.[4]

World War II marked a turning point in burn resuscitation history. In 1942, the National Research Council recommended a standardized approach based on the surface area of burn. Dr. H. Harkins proposed burn resuscitation, using plasma administration based on the extent of surface area burned.[5] This formula laid the foundation for subsequent developments.

Cope and Moore, in 1947, recognized the limitations of surface area-based formulas and proposed the 'Body-Weight Burn Budget,' incorporating colloid and electrolyte solutions based on anticipated interstitial space expansion according to body weight.[6] Prior proposals did not account for patient’s weight. They only accounted for extent of the burn.

Modern era of burn resuscitation started in the ‘60s and ‘70s. These decades brought the Parkland Formula and Brooke Formula to the burn world. The 1960s and 1970s witnessed the emergence of the Parkland formula, proposed by Baxter and Shires. This formula consisted of purely crystalloid fluids and calculated, as will be discussed below.[7]

Another competing formula that persists until today was first developed by Artz, et al., at the Army Medical Center (now called Brooke Army Medical Center). In this formula, Artz, et al. advocated for resuscitation using a combination of colloid and crystalloid.[8] This formula proved cumbersome. An update was introduced by Pruitt et al., “Modified Brooke Formula” in 1979, eliminating colloids in the first 24 hours. Subsequent years saw variations in resuscitation formulas, including Monafo's use of hypertonic saline in 1970.

Despite a surge in mid-century research and the introduction of various formulas, the Parkland formula persisted as the mainstay for severe burn resuscitation. The complexity of burn pathophysiology and therapy hindered the development of a quick and easy solution. Understanding the historical evolution is crucial to designing novel approaches while maintaining current standards for burn resuscitation outcomes.

In 1968, Baxter and Shires pioneered the development of the Parkland formula, a foundational approach for managing severe burns. Their work stemmed from a comprehensive study on fluid dynamics in individuals experiencing severe burns, aiming to understand the intricate physiological responses to such injuries.[7] Despite the formula's widespread adoption, there are problems which arise if the clinician solely relies on this formula. It is entirely conceivable that Parkland Formula has enjoyed such widespread acceptance because of its simplicity. It is based on patient's weight and % TBSA. The formula is as follows:

> Calculate total fluid need for the first 24 hours. Start with patient's initial time of injury. Determine weight. Determine % TBSA. Multiply by 4. Divide by 2. Give the first half of the fluids in 8 hours. Give the second half of fluid in the next 16 hours.
>
> **Total Fluid = (Wt (kg) * % TBSA) *4**
>
> **1st 8 hours = Total Fluid/2**
>
> **Next 16 hours = Total Fluid/2**

Parkland Formula and the Modified Brooke Formula have become the mainstay of burn resuscitation. However, they both suffer from one major drawback. They both are very prone to "Fluid Creep". This term was coined by Pruitt to describe the interval need for more and more fluid to maintain desired patient physiologic parameters. However, this tendency soon metastasizes to out of control over-resuscitation, which could lead to abdominal compartment syndrome.[9] Other practical issue stems from the often-inaccurate estimation of burn size, a critical parameter for fluid volume calculations.

Addressing this need, the 'Rule of Ten' (ROT), a simplified resuscitation formula aligned with ABA guidelines, has been implemented at the USAISR. Consisting of two straightforward steps, ROT eliminates the complexities associated with recalling intricate formulas. It involves multiplying the estimated burn size in %TBSA by 10 to determine the initial fluid rate in ml/h, with additional adjustments for patients above 80 kg.[10] Although this formula is simple, it has not gained wide acceptance.

CURRENT, REAL-WORLD PRACTICE

Despite the advances made in over a century of work, no simple mechanism or formula exists to resuscitate a burn patient. Each patient poses a challenge unique to his/her physiology. The burn surgeon is left to determine how to effectively resuscitate the patient. The author takes a bit from each formula and "concocts" a denovo strategy for the patient at hand. The strategy is as follows:

Start with the Parkland formula, should the patient's injuries necessitate fluid resuscitation. If so, determine parameters for Parkland Formula, i.e., patient weigh, % TBSA, Time of Injury. Determine baseline blood indices, such as, Hemocrit (Hct), INR, Sodium, Creatinine, etc. Note patient hemodynamics, blood pressure, pulse rate and central venous pressure (CVP). Lastly, monitor urine output.

Based solely on these parameters, the resuscitation is tailored to the individual. A combination of hypertonic Lactated Ringers' solution (HLR), Vitamin-C infusion and Fresh-frozen Plasma (FFP) and/or Albumin are administered in various proportions. Careful study of patient hemodynamics, CVP, Hct and urine output are noted. Of these, least attention is paid to urine output in the first 24 hours.

We have noted the first 24 hours of resuscitation reveals little correlation between urine output and effective resuscitation. "Chasing urine output" often results in under, and most often, over resuscitation. More emphasis is placed on hemoconcentration, as measured by serial Hct and CVP measurement. Fluid increase/decrease and addition of colloid (FFP or Albumin) is guided by these two parameters. The roles of Vit-C and HLR are beyond the scope of this discussion but pose interesting physiologic underpinnings. This individualized tailoring of fluid resuscitation is more cumbersome for the practitioner. However, in the author's opinion, it is essential to ensure proper resuscitation. Simple "protocol-driven strategies" may not yield optimum results. Such individualized resuscitation model has resulted in no abdominal compartment syndrome complication to date.

Regardless of which formula is used, the practitioner must have an adequate understanding of its use and its limitation. It is also crucial to remember; no formula is fool-proof. Each one needs to be adjusted based on patient dynamics. Parkland Formula is a good start. If the reader gravitates to a different formula, fine. Use what you like. Just remember, a formula does not resuscitate your patient. Your effort, diligence and understanding of patient physiology does!

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BATTLE OF THE BULGE: LUMBAR AND FLANK HERNIAS

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"Lateral" hernias refer to primary or acquired hernias originating from the lateral abdominal wall, limited superiorly by the twelfth rib, inferiorly by the iliac crest, posteriorly by the erector spinae muscle, and anteriorly by the ipsilateral linea semilunaris. They are subclassified according to location: subcostal (L1), flank (L2), iliac (L3), and lumbar (L4).[1,2]

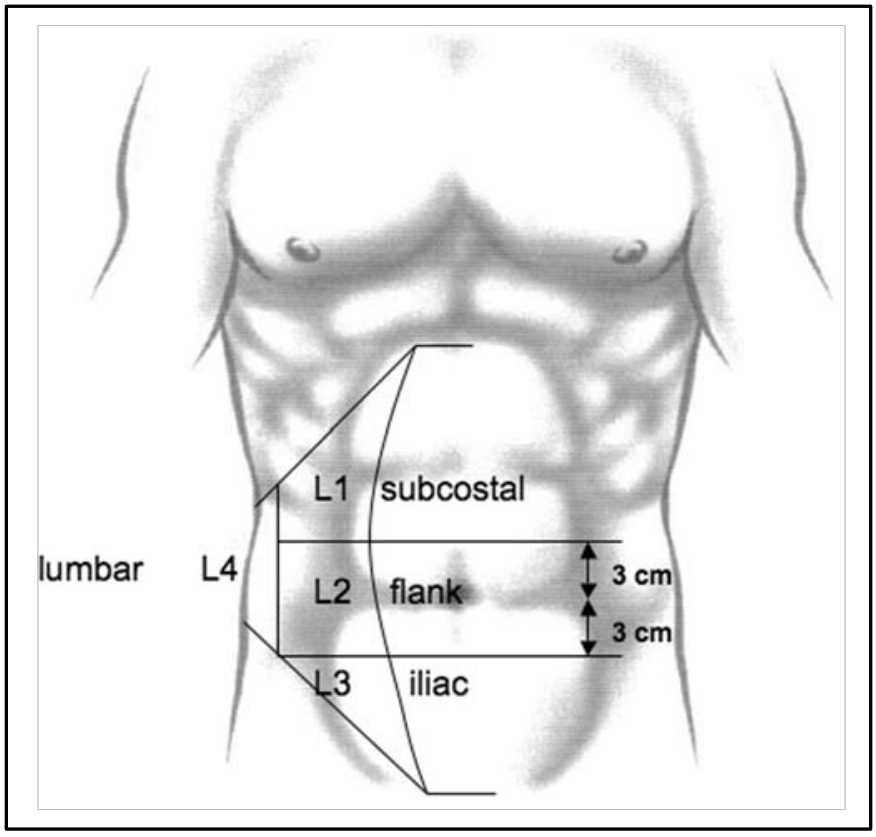

Figure 1. Lateral Hernia Classification
From Muysoms, et al. Classification of primary and incisional abdominal wall hernias. *Hernia*.

Lateral hernias are much less common than ventral hernias, with only about 350 cases reported in the literature.[3] They are also not always described according to the specific nomenclature or can occur across multiple of the described spaces. As a result, there are no randomized controlled trials comparing repair technique and no guidelines for management. Repair is particularly challenging due to their proximity to bony prominences and important neurovascular structures, limiting space for placement and fixation of mesh.

Secondary lateral hernias can be caused by trauma, though incisional are much more common.[4] The traumatic type occur in <1% of blunt trauma cases, but diagnosis has increased over the years due to increased CT scanning. Traumatic hernias are caused by a sudden significant impact, with an increase in intra-abdominal pressure, such as from a seatbelt after a high-speed motor vehicle collision.[5] In some cases, the oblique musculofascial complex may be detached from the iliac crest or the costal margin, resulting in a floating abdominal wall.[6] In addition to the difficulty of repair, this pattern is at risk for early recurrence if repaired improperly.

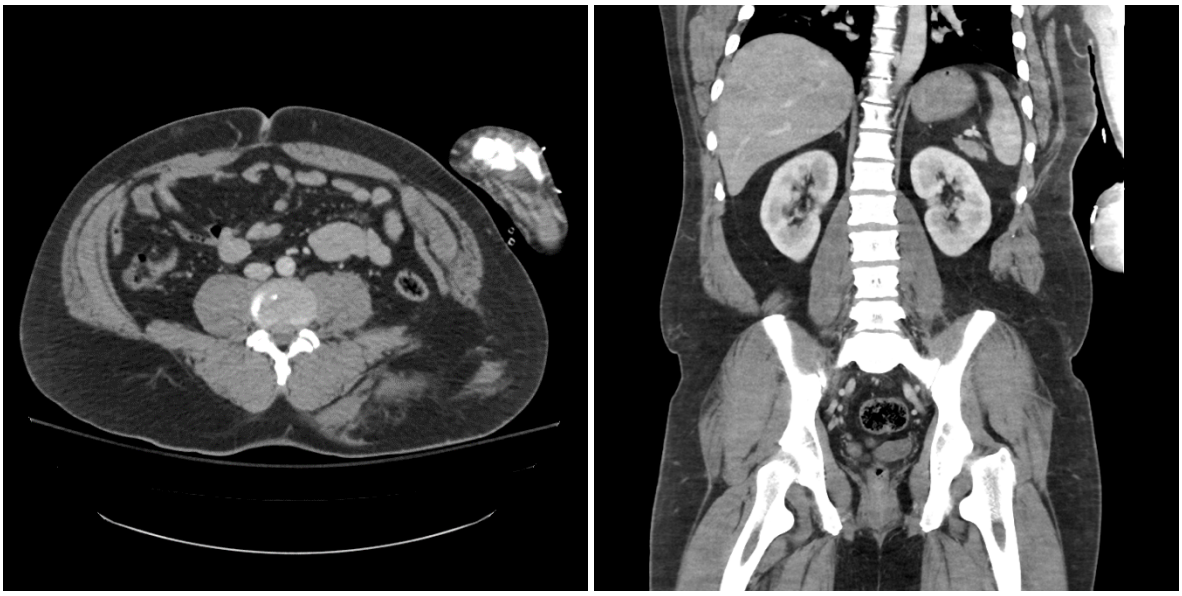

Figure 2. Flank hernia with muscle detached from iliac crest: axial (a) and coronal (b)

EVALUATION

A thorough medical and surgical history will ascertain whether the hernia is primary or secondary, and whether the patient is symptomatic with pain or signs of incarceration. Patients should also be evaluated for significant co morbidities. A CT scan should be performed to assess the defect size, location, hernia contents, and the presence or absence of muscle atrophy.

MANAGEMENT

Symptomatic lateral hernias should be repaired. A 25% risk of incarceration and 8% risk of strangulation have been reported.[7] Asymptomatic hernias may be managed expectantly, if desired, particularly if the patient has high-risk co morbidities.

Due to the rarity of traumatic hernias, their management remains controversial. Most patients have concomitant injuries, though not always requiring surgical management.[8] There can be varying degrees of abdominal wall muscle disruption[9], and there may or may not be herniation of abdominal contents into the hernia space.

Trauma patients should undergo emergent laparotomy if they present with hemodynamic instability or peritonitis, not for treatment of a traumatic hernia alone. Patients with traumatic abdominal wall hernias who are stable without peritonitis can be monitored with serial abdominal examinations. Their concomitant injuries should be addressed, beginning with those that are most life-threatening or disabling. A traumatic hernia can be fixed acutely (at initial hospitalization) or can be managed expectantly. Acute repair prevents subsequent incarceration; however, some studies have reported a higher failure/recurrence rate associated with acute repair.[10] For those that undergo repair, the defect can be repaired primarily or with mesh. Repair should be tension free, and contamination with enteric contents is a relative contraindication for use of synthetic mesh. For those patients managed expectantly, they can undergo subsequent elective repair at a later date, if indicated.

Bender et al. evaluated acute and chronic management of traumatic flank hernias.[11] They used the trauma registry at their level I trauma center from 2001 through 2007. Their report included 25 patients (0.2% of all blunt trauma patients). Ninety-six percent were due to a motor vehicle crash and all patients had at least 1 associated traumatic injury. Eleven patients underwent immediate surgery, 8 patients underwent delayed repair (after day of admission), and 3 patients underwent late repair (4.5-10 years after injury). The remaining 3 patients were managed expectantly. There were 3 total recurrences. The sole mortality occurred in a patient who underwent immediate primary repair, then had an unrecognized recurrence causing bowel incarceration, sepsis, and death. The authors concluded that repair of these defects is technically difficult, and the hernias can be managed expectantly, or repair delayed if diagnosed on CT scan with no associated injuries.

In 2016, Coleman et al. published the largest single institution series of traumatic abdominal wall hernias.[8] They performed a retrospective review of 80 patients from their trauma registry from 2002 to 2014. Patients were moderately to severely injured (mean ISS 22). Thirty-five patients (44%) underwent urgent laparotomy or laparoscopy, and 10 of these (29%) were nontherapeutic except for hernia repair. Hernia repair was performed in a total of 23 patients, most (78.3%) within 5 days of injury. There were 6 recurrences (26%). Over 70% of the hernias were not repaired, and none developed any symptoms or complications during the follow up period.

In 2019, Karhof et al. performed a literature review regarding timing of repair and use of mesh for traumatic hernias.[5] Six retrospective articles were selected. None of the studies reported significant differences in hernia recurrence with regard to the timing of repair. Only one study described the decision between primary and mesh repair.[12] Defects were repaired primarily if there was sufficient tissue for a tension-free repair, otherwise a mesh was used. The use of a mesh was also sometimes by surgeon preference and was only contraindicated in the setting of abdominal contamination at the time of repair. There was no significant difference in recurrence rates between patients with mesh repair and no mesh repair (pooled OR 0.55 [95% CI 0.17–1.80]; p = 0.32). In aggregate, there were 229 patients with traumatic abdominal wall hernias, and just over half underwent surgical repair. Twenty-three of 172 patients (13%) who had repair developed a recurrence. Almost 70% of the patients who recurred had primary repair at initial hospitalization. Pooled analysis did not show any statistically significant favor for the use of mesh augmentation or the timing of surgical repair.

OPERATIVE REPAIR

As with other types of hernias, repair of lateral hernias has traditionally been performed in open fashion, with a trend in recent years toward minimally invasive repair for select candidates. For all elective repairs, preoperative antibiotics should be administered, antithrombotic devices should be utilized, general anesthesia is required, and mesh should be used with wide overlap. Mesh can be placed intraperitoneal, partially extraperitoneal, or extraperitoneal. If mesh is fixated, it can be anchored to the bone or transfascial sutures can be placed. A large number of techniques have been advocated, often with only small series to support.

OPEN TECHNIQUES

Open repair has demonstrated feasibility and durability, even for patients with extremely large defects and/or muscular atrophy. Disadvantages of an open technique include the need for a large incision, long hospital length of stay (LOS), complication rates from 3 to 42%, including seromas, hematomas, flap necrosis, chronic pain, and infection, as well as recurrence rates up to 11%.[1,4,11,13,14,7]

Phillips et al. performed a retrospective analysis of 16 patients who underwent open flank hernia repair with a retromuscular preperitoneal approach with iliac bone fixation between 2007 and 2011.[13] Mean operating room (OR) time was 178 min. One intraoperative complication, ureteral injury in a transplant recipient, occurred and was primarily repaired without sequela. Two patients developed wound complications, one requiring superficial debridement and another requiring partial excision (<5 %) of the mesh with secondary healing. With a mean follow-up of 16.8 months (range 2–49), no recurrent hernias were noted.

Renard et al. described a retrospective series of 31 consecutive open retro-muscular repairs for large lateral hernias with muscular atrophy between 2009 and 2015.[15] Mesh was inserted into the retroperitoneal space posteriorly, placed with the largest overlap inferiorly and posteriorly, and fixed through the contralateral abdominal wall muscles under strong tension to correct the flank bulging. The mesh was placed totally extraperitoneal in 65% of cases. They reported no postoperative mortalities, a rate of surgical complications of 32.3%, and a rate of overall postoperative morbidity (Clavien-Dindo classification) of 38.7%. After a median follow-up of 27.5 months, their recurrence rate was 6.5% and reported rate of chronic pain was 9.7%.

Katkhouda et al. also reported a series of 8 (7 flank and 1 thoracoabdominal) open preperitoneal repairs with muscle plication.[16] The median OR time was 185 min. There were no major complications. One patient who was repaired without mesh attachment to bony landmarks developed a recurrence at ten months and subsequently underwent reoperation. Patients with mesh secured to bony landmarks were recurrence free at a median follow-up of 171 days.

In 2020, Cavalli et al. described their open extraperitoneal approach for repair of complex flank, lumbar, and iliac hernias in 22 patients.[3] They used a large polypropylene mesh covering all the lateral abdominal wall, regardless of defect size. They reported a LOS of 4.8 days with no major complications, though 2 patients had hematomas/seromas and 1 skin dehiscence. There was only 1 recurrence after a mean follow up of 44.8 months.

LAPAROSCOPIC TECHNIQUES

Several case series have demonstrated the safety and feasibility of laparoscopic repair. The laparoscopic series demonstrate average OR times of 2-4 hours, hospital stays of a week or less, and low complication rates, though chronic pain from fixation may be a concern. The disadvantages of laparoscopic repair include that it is not always feasible (such as with very large hernias), it can be technically difficult, the peritoneal layer may tear during dissection (precluding coverage of the repair), and the fascial defect may not be able to be closed.[4] Conversion rates to open procedure may also be common.[4]

The laparoscopic techniques share the same critical steps:

1. Takedown of adhesions and hernia sac/contents
2. Dissection of the pre/retroperitoneum to expose the psoas/paraspinous muscles (with caution not to injure ureters, vessels, nerves)
3. Measurement of defect size and selection of appropriate mesh for at least 5-cm overlap. Meshes for intraperitoneal placement should have an adhesion barrier.
4. Defect closure
5. Wide mesh overlap
6. Fixation of mesh to healthy tissue with tacks, sutures, glue, +/- use of bone anchors

Edwards et al. published a retrospective review of 27 laparoscopic transperitoneal repairs from 2002 to 2006 at two university hospitals.[7] Mean OR time was 144 min and mean LOS was 3.1 days. There were no flank hernia recurrences at a mean follow up of 3.6 months, however, 3 patients were treated for chronic pain (1 with reoperation to remove a previously placed mesh).

Novitsky et al reported a retrospective series of 14 laparoscopic repairs of traumatic lateral hernias from 2 hernia centers from 2007-2013.[6] The mean OR time was 174 min and mean LOS was 3.1 days. There were no peri-operative complications and all patients returned to full activities by 6 weeks. At a mean follow-up of 35 months, there were no recurrences.

Zhao et al. retrospectively reported on their prospective database of laparoscopic transabdominal partial extraperitoneal (TAPE) technique between 2017 and 2020.[17] OR time was 1-4 hours long. Hospital stay was 6-9 days, and there were no major complications. At a mean follow up of 20 months, there were no recurrent hernias.

LAPAROSCOPIC VERSUS OPEN

Moreno-Egea et al. performed a prospective nonrandomized study of 16 patients who underwent operation for secondary lumbar hernia between 1997 and 2003.[18] Nine were treated via the laparoscopic approach and 7 with an open technique. The clinical data, hospital data (OR time and LOS), patient comfort (consumption of analgesics and time to return to normal activities), recurrences, and hospital costs were reported. There were no differences between the two groups in terms of age and medical history, however, the defects of the patients in the laparoscopic group were smaller. Mean OR time, postoperative morbidity, mean LOS, consumption of analgesics, and time to return to normal activities were significantly lower in the laparoscopic group ($p < 0.01$). There were no statistical differences in hospital costs. However, the final cost did show differences favoring the laparoscopic group when expenses for readmissions and recurrences were taken into account ($p < 0.01$).

ROBOTIC TECHNIQUES

Robotic repair techniques have been increasingly utilized for ventral hernia repair.[18-20] This data is also being extrapolated to repair of lateral hernias.

Advantages of robotic repair over laparoscopic include improved visualization and range of motion, which may decrease conversions to open procedure.[4] Robotic repairs involve the same key steps as laparoscopic.

Di Giuseppe et al. reported on their robotic extraperitoneal repair of 7 patients with flank hernias from 2018-2019.[4] Patients were followed up at 1 and 6 months. Median OR time was 137 minutes, and LOS was 4.0 days. No intraoperative complications occurred, and there were no conversions to open surgery. Postoperatively, one patient developed a pneumonia, which required antibiotics. Six months after surgery, neither recurrence nor chronic pain were recorded. Due to no conversions to open procedure, the authors believe reduced length of stay may offset the increased cost of robotic surgery.

SUMMARY

Lateral hernias are rare and difficult to repair. Traumatic lateral hernias can be managed expectantly or with delayed repair, depending on the patient's condition and concomitant injuries. As with other hernia types, symptomatic lateral hernias should be repaired to prevent incarceration and strangulation. All patients should have a preoperative evaluation/risk assessment and CT scan prior to repair. These hernias can be approached with open, laparoscopic, or robotic techniques. Large defects with significant muscular atrophy should be preferentially repaired open, while small defects are more amenable to minimally invasive repair. Laparoscopic repair is associated with decreased morbidity and LOS compared to open repair. Robotic repair may allow for improved visualization and range of motion, which may decrease conversion to open procedure.

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PENETRATING NECK TRAUMA

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Contemporary ATLS principles apply to all patients sustaining a penetrating neck injury. And, as for all patients with a penetrating injury, they should be rolled early to identify all external wounds. This, combined with plain radiographs, will provide a map of all body regions at risk of injury. This is critical, as the neck is a small area, easy to traverse, and a penetrating injury to the neck may result in a brain, thoracic, or even intra-abdominal injury requiring surgical intervention. Likewise, an external injury to the thorax may exit the chest and cause an injury to the neck.

The focus of this talk will be on the initial resuscitation, evaluation, and decision-making process for penetrating injuries to the neck.

INITIAL STEPS

There has been significant evolution of the initial diagnostic evaluation of penetrating injuries to the neck over the last two decades. Predicated on the ease of access to structures in the neck, the initial evaluation was based on anatomic boundaries. Classically, the neck was broken into three anatomic zones, I-III. Zone II, which extends from the cricoid cartilage to the angle of the mandible, contains structures that are relatively easily amenable to surgical exploration. Consequently, injuries to Zone II were preferentially explored. For Zones I and III, because of the increased difficulty in accessing any of the potentially injured structures contained in these Zones, an imaging first approach was taken. This was, of course, problematic because of the burden of negative explorations conducted in Zone II, as well as the time and resources required to run the full battery of tests required to exclude injuries to the vasculature and aerodigestive tract in Zones I and III. This would include a combination of catheter based angiography, duplex, endoscopic evaluation, and contrast swallow. It was also problematic because the presence of an external injury in one “Zone” does not mean that the actual injured structure would also be in that underlying area. So, for example, a GSW with an external wound in Zone II could actually cause an injury in Zone I or Zone III. Perhaps, most importantly, however, was the evolution of screening CTA as a method of tracing the trajectory of the injury. As a result of this, the contemporary management of penetrating neck injuries has changed to focus on the clinical examination, de-emphasizing the importance of the anatomic Zones of the neck. This “no-Zone” approach is now the de facto standard for penetrating neck injury evaluation. Based on the physical examination, the neck injury can be compartmentalized into three categories; those with Hard Signs, Soft Signs, and No Signs of vascular or aerodigestive tract injury.

HARD SIGNS OF INJURY

Patients with hard signs of injury require immediate operative exploration. Hard signs of vascular injury include arterial bleeding, an expanding or pulsatile hematoma, bruit or thrill, or shock attributed to the neck injury. Hard signs of aerodigestive tract injury are air bubbling, hemoptysis, or hematemesis. Occasionally, a direct laryngotracheal injury will be visible and also warrants operative exploration.

For these patients, there are several other considerations while in the resuscitation bay prior to proceeding to the OR. First, as for all trauma patients, external hemorrhage must be stopped as early as possible, in concert with blood product resuscitation. In general, the bleeding from neck wounds can be controlled easily with direct digital pressure. If it is a larger wound, packing may be required. While the risk of airway compromise with packing is practically very low, just enough packing to control the bleeding is the goal. For small external wounds with significant bleeding, a large foley catheter inflated with water or saline can be effective for controlling the bleeding. For single provider scenarios, this will also allow you to free up your hands to deal with other issues while maintaining the hemorrhage control.

For the airway, in general, all airway manipulations are ideally performed in the OR. If the patient is maintaining an effective airway with acceptable oxygen saturations, the patient can be moved rapidly to the OR where any further invasive procedures can be performed under ideal conditions. If the patient will not tolerate transport to the OR, then endotracheal intubation or direct intubation of a visible airway defect can be performed. For infants and children, and even in adults, a compromised airway can be temporized with trans-tracheal needle jet insufflation. This will allow sufficient oxygenation for transport to the OR for definitive airway management.

As discussed above, prior to leaving the resuscitation bay, a quick evaluation of the entire torso, and, ideally, a plain film survey will make the operative planning much easier, especially if there are potential injuries to the other major body cavities that will require intra-operative evaluation.

SOFT SIGNS OF INJURY

Patients with soft signs of injury require screening imaging. The contemporary evidence based approach to screening utilizes multi-detector CT Angiography. Soft signs of vascular injury include small volume oozing and small, non-expanding hematomas. Soft signs of aerodigestive tract injury include subcutaneous emphysema, dysphagia, hoarseness, and minor hemoptysis or hematemesis. Multi-detector CT Angiography is highly sensitive and specific for the detection of vascular injuries. For the aerodigestive tract, while it is highly sensitive with a positive test, unless a tract can clearly be seen traversing a critical structure, a confirmatory test using endoscopy or a contrast swallow in the awake and alert patient may be required prior to operative intervention.

NO SIGNS OF INJURY

In the asymptomatic patient with a normal physical examination, the likelihood of injury is exceedingly low, approaching zero, and only observation is required.

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INDICATIONS FOR UPPER AND LOWER EXTREMITY FASCIOTOMY FOLLOWING TRAUMA: A REVIEW

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ABSTRACT

This review summarizes and analyzes fasciotomy indications for trauma, concentrating on upper and lower extremity injuries. Because compartment syndrome from traumatic injuries requires prompt and adequate treatment, this review provides clear, evidence-based guidance for acute care providers.

A comprehensive literature review included peer-reviewed publications, clinical recommendations, and meta-analyses from the past decade. Medical resources, including PubMed, MEDLINE, and Cochrane Library, were searched for trauma-induced compartment syndrome and fasciotomy research. Case studies gave unique insights into complicated trauma scenarios and management in this review.

The research notes that acute compartment syndrome, which causes higher intra-compartmental pressures and ischemia, is the main reason for fasciotomy in trauma. Key findings show that compartment pressures needing fasciotomy are lower in the lower extremities. Clinical indicators, including pain out of proportion, paresthesia, pallor, paralysis, and pulselessness (the "5 Ps"), were regularly used to determine fasciotomy requirement, although their absence did not rule out compartment syndrome. Several studies stressed constant pressure monitoring in high-risk individuals. Fasciotomy timing was critical, with earlier intervention improving limb salvage and functional recovery. The research also stressed the need for postoperative treatment to reduce infection and long-term functional damage.

Trauma-induced compartment syndrome must be diagnosed and treated quickly to avoid tissue damage and improve patient outcomes. This study emphasizes the requirement for a strong index of suspicion and clinical judgment and objective diagnostic markers for choosing fasciotomy. Early surgical intervention and excellent postoperative care are also stressed. Individualized patient assessment is essential for compartment syndrome after trauma due to its variable presentations and progressions. Future research should enhance diagnostic criteria and develop creative monitoring approaches to improve acute trauma surgical decision-making by enabling early and accurate diagnosis.

INTRODUCTION

Compartment syndrome, a severe condition often encountered in traumatic injuries to the extremities, represents a surgical emergency. The pathophysiology of compartment syndrome involves increased pressure within a closed osseofascial compartment, leading to decreased perfusion and potential ischemic damage to enclosed tissues. Fasciotomy, the surgical decompression of these compartments, is a critical intervention to prevent irreversible tissue damage. However, determining the precise indications for fasciotomy, particularly in the context of trauma to the upper and lower extremities, is complex and requires a nuanced understanding of various clinical and diagnostic criteria. This review aims to elucidate these indications, drawing from current literature and best practices, to improve outcomes in trauma care.

PATHOPHYSIOLOGY AND CLINICAL SYMPTOMS OF COMPARTMENT SYNDROME

Due to increased pressure in a confined muscle compartment, compartment syndrome can cause limb-threatening tissue ischemia and blood flow problems. Trauma care requires understanding its pathogenesis, clinical presentation, and consequences for prompt intervention. Compartment syndrome occurs when muscle compartment pressure exceeds capillary perfusion pressure, decreasing tissue oxygenation and blood flow. Without immediate treatment, this can cause cellular death and tissue necrosis. Traumatic compartment syndrome has a complex etiology. Acute trauma, including fractures, crush injuries, and severe bruising, can cause it. Possible reasons include post-surgical problems, constrictive casts or dressings, and prolonged limb compression. Reperfusion damage, which occurs when blood flow returns to a limb after ischemia, can cause compartment syndrome.

PATHOGENESIS

The pathogenesis of compartment syndrome in trauma revolves around the concept of a vicious cycle. Trauma leads to tissue injury and inflammation, which results in edema and increased interstitial fluid within the confined space of a muscle compartment. The rigid fascial boundaries of these compartments do not allow for significant expansion, causing a rise in intra-compartmental pressure. This elevated pressure compromises the circulation, reducing arterial blood flow and venous return and exacerbating the ischemic process. As ischemia progresses, cellular metabolism shifts from aerobic to anaerobic, accumulating lactic acid and further swelling, perpetuating the cycle of increased compartment pressure and ischemia.

SYMPTOMS AND PHYSICAL EXAMINATION FINDINGS

The common symptoms of compartment syndrome are often summarized as the "5 Ps": pain, paresthesia (tingling or prickling sensation), paralysis, pallor, and pulselessness. However, these symptoms might not all be present in every case. The most consistent and early symptom is pain disproportionate to the injury, often not relieved by analgesics and exacerbated by passive stretching of the muscles within the compartment. Paresthesia is an early sign of nerve involvement, while paralysis and loss of pulses are late and ominous signs indicating advanced ischemia.

Physical examination is pivotal in diagnosing compartment syndrome. Clinicians look for pain by passive stretching of the muscles within the affected compartment, a reliable and early sign. The affected limb might appear swollen and tense. Palpation may reveal a firm, wooden feeling of the compartment. However, the absence of noticeable swelling does not exclude the diagnosis. A high index of suspicion is necessary, especially in unconscious or sedated patients who cannot report pain.

Pulselessness is a late finding and indicates a critical level of ischemia; thus, its presence or absence should not be solely relied upon to rule in or out compartment syndrome. Decreased capillary refill, skin coolness, and skin color changes can also be observed but are vague signs.

In the context of trauma, the need for fasciotomy is often determined based on clinical judgment, supported by objective measurements of compartment pressures. An intra-compartmental pressure within 30 mmHg of the patient's diastolic blood pressure is commonly used as a threshold for surgical intervention. However, reliance on absolute pressure measurements alone is inadequate; clinical correlation is essential.

Upper Extremity: Indications for Fasciotomy

In the upper extremities, fasciotomy is primarily indicated in the presence of acute compartment syndrome following trauma. Specific scenarios include:

1. **Fractures**: Especially supracondylar humerus fractures in children and forearm fractures in adults.
2. **Crush Injuries**: Such as those sustained in industrial accidents or severe falls.
3. **Burns and Electrical Injuries**: Leading to edema and increased compartmental pressures.
4. **Revascularization after Prolonged Ischemia**: Where the restoration of blood flow can lead to reperfusion injury and swelling.
5. **Intravenous Drug Injection**: Accidental injection into a compartment can cause rapid swelling and compartment syndrome.

Lower Extremity: Indications for Fasciotomy

In the lower extremities, indications for fasciotomy are similar but also include:

1. **Severe Leg Trauma**: Including tibial fractures and soft tissue injuries.
2. **Prolonged Limb Compression**: As seen in unconscious patients after falls or in drug overdose cases.
3. **Vascular Injuries**: Particularly in cases of limb reperfusion after acute arterial occlusions.

OBJECTIVE MEASURES: PRESSURE MEASUREMENT TECHNIQUES AND THRESHOLD VALUES

The key to identifying compartment syndrome is measuring intra-compartmental pressure. Injecting a needle with a pressure transducer into the afflicted compartment is normal. Slit catheter, side-ported needle, and Wick catheter are methods. Slit catheters are favored for their precision and less tissue impact. Interpreting intra-compartmental pressures is critical. Intervention is often recommended at 30 mmHg absolute compartment pressure. This figure should be regarded in the patient's total blood pressure context. The differential pressure (ΔP) is increasingly employed, computed as diastolic blood pressure minus compartment pressure. A ΔP below 30 mmHg suggests compartment syndrome and requires attention. This method adjusts for patient blood pressure differences and delivers a more tailored evaluation.

In high-risk patients, including those with severe trauma or postoperative edema, continuous monitoring is crucial.

IMAGING AND OTHER DIAGNOSTIC TOOLS

While the diagnosis of compartment syndrome is primarily clinical, supplemented by pressure measurements, imaging, and other diagnostic tools can play a supportive role, particularly in atypical cases or when clinical assessment is challenging.

MRI and Ultrasound: Magnetic Resonance Imaging (MRI) can help identify edema and muscle swell indicative of compartment syndrome. However, its use is limited in the acute setting due to accessibility and time constraints. Ultrasound can help assess compartmental swelling and guide needle placement for pressure measurements, although its utility in directly diagnosing compartment syndrome is limited.

Near-Infrared Spectroscopy (NIRS): NIRS is a non-invasive method that measures tissue oxygenation and can indicate compromised blood flow in a compartment. While promising, its role in the routine diagnosis of compartment syndrome is still being explored.

Other Methods: Techniques such as laser Doppler flowmetry and tissue oxygen tension measurement are research tools that have been investigated for their potential in diagnosing compartment syndrome. However, they are not widely used in clinical practice due to their complexity and lack of standardization.

SURGICAL TECHNIQUES AND CONSIDERATIONS

Procedure Overview

Upper Extremity Fasciotomy: Involves incisions along the arm or forearm to decompress the involved compartments. In the forearm, two standard incisions (medial and lateral) are often used to relax the flexor and extensor compartments, respectively.

Surgical Steps

1. **The incision for Forearm Fasciotomy**:
    - **Two-Incision Technique**: Generally, two longitudinal incisions are made – one on the medial (ulnar) side and one on the forearm's lateral (radial) side.
    - **Medial Incision**:
        - **Location**: Extend from the elbow to the wrist along the medial border of the forearm.
        - **Structures to Avoid**: Be cautious of the ulnar nerve and artery near the elbow and the median nerve and radial artery at the wrist.
        - **Compartments Released**: The incision allows for decompression of the flexor compartment.
    - **Lateral Incision**:
        - **Location**: Along the line between the biceps brachii tendon and the lateral epicondyle, extending to the wrist.
        - **Structures to Avoid**: The superficial branch of the radial nerve must be protected.
        - **Compartments Released**: This incision allows for decompression of the extensor compartment.
2. **Incision for Arm (Upper Arm) Fasciotomy**:
    - **Single Longitudinal Incision**: Usually, a lateral longitudinal incision is made.
    - **Location**: Extend from the deltoid insertion to the lateral epicondyle.
    - **Structures to Avoid**: Care should be taken to avoid the radial nerve, which spirals around the midshaft of the humerus.
    - **Compartments Released**: This incision decompresses the anterior and posterior compartments of the arm.

Anatomical Considerations

- **Nerves**: The radial, ulnar, and median nerves are at risk during forearm fasciotomy. In the arm, the radial nerve is particularly vulnerable as it courses in the radial groove of the humerus.
- **Vessels**: The brachial artery in the arm and the ulnar and radial arteries in the forearm must be protected.

- **Muscles and Tendons**: Care should be taken not to damage the muscle bellies and tendons, which are essential for functional recovery.

Decompression

- **Fascial Release**: Use blunt dissection to open the fascia of the affected compartments.
- **Inspection of Muscle Viability**: Check for muscle color, contractility, and bleeding to assess viability.
- **Hemostasis**: Achieve meticulous hemostasis to prevent postoperative complications.

Closure and Postoperative Care

- **Temporary Closure**: The wounds may be left open initially, covered with sterile dressings, or temporary skin closure devices.
- **Secondary Closure**: Wounds can be closed secondarily or with skin grafts once the swelling has subsided and the tissues are healthy.
- **Monitoring**: Regular postoperative monitoring for signs of infection, compartment syndrome recurrence, and neurovascular status is crucial.
- **Rehabilitation**: Early physical therapy is vital for functional recovery.

Lower Extremity Fasciotomy: The leg has four compartments that may require decompression. Two incisions (medial and lateral) are typically made to access these compartments. Care is taken to avoid injury to the saphenous vein and superficial peroneal nerve.

Surgical Steps

1. **Incisions for Leg Fasciotomy**:
    - **Two-Incision Technique**: Commonly, two incisions are made to decompress the four compartments of the leg – the anterior, lateral, superficial posterior, and deep posterior compartments.
    - **Lateral Incision**:
        - **Location**: The incision is made along the line midway between the fibula and the tibial crest.
        - **Structures to Identify and Avoid**: Care should be taken to avoid the superficial peroneal nerve.
        - **Compartments Released**: This incision allows the anterior and lateral compartments to decompress.
    - **Medial Incision**:
        - **Location**: Extend from the knee to the ankle, along the posteromedial border of the tibia.
        - **Structures to Identify and Avoid**: The saphenous vein and nerve near the medial malleolus must be protected.
        - **Compartments Released**: This incision decompresses the superficial and deep posterior compartments.

2. **Technique for Fascial Release**:
    - **Careful Dissection**: Use careful dissection to expose the fascia overlying each compartment.
    - **Fascial Incisions**: Longitudinally incise the fascia of each compartment to ensure adequate decompression.
    - **Inspection of Muscle Viability**: Assess the muscles' color, consistency, and contractility to evaluate their viability.

Anatomical Considerations

- **Nerves**: Protection of the superficial peroneal nerve during the lateral incision is crucial. In the medial incision, care must be taken to avoid the saphenous nerve.
- **Vessels**: The great saphenous vein, running along the medial aspect of the leg, is at risk during the medial incision.
- **Muscles and Tendons**: Identify and avoid damage to the muscle bellies and tendons for preserving functionality post-recovery.

WOUND CLOSURE IN FASCIOTOMY

The primary challenge in fasciotomy wound closure is managing the significant tissue edema that often precludes immediate primary closure. The current trends in management include:

1. **Delayed Primary Closure**: Once the swelling subsides, the edges of the fasciotomy wound can often be approximated and closed primarily. This method is preferred for its simplicity and effectiveness in promoting wound healing.
2. **Negative Pressure Wound Therapy (NPWT)**: NPWT, or vacuum-assisted closure, has become a cornerstone in fasciotomy wound management. It helps reduce edema, promotes granulation tissue formation, and can decrease the time to wound closure. NPWT systems have become more user-friendly and portable, increasing patient comfort and mobility.
3. **Skin Grafting**: Split-thickness skin grafting is often necessary for large or non-healing wounds. Recent advancements in skin graft harvesting and meshing techniques have improved the success rates of this approach.
4. **Dynamic Closure Systems**: These systems use a gradual, controlled tension to approximate wound edges, allowing for primary closure of wounds that would otherwise require skin grafting. This method reduces patient morbidity associated with grafting.

POSTOPERATIVE CARE

Minimizing problems, facilitating recovery, and promoting healing are all imperative objectives of postoperative care. Initiating physical therapy and mobilization at the earliest opportunity when it is medically feasible is becoming an increasingly important practice. Improved circulation, functional recovery, and a reduction in joint stiffness can all result from early activity. Effective pain management is of the utmost importance. In order to maximize pain treatment while reducing the need for opioids, contemporary trends support multimodal pain management approaches that combine regional anesthetic procedures, such as nerve blocks, with systemic analgesics. Preventing and Controlling Infections: In situations involving trauma, fasciotomy wounds provide a substantial risk of infection. Prophylactic antibiotics and wound care regimes are frequently employed to reduce the likelihood of infection. Utilization is increasing of sophisticated dressings with antibacterial and moisture-regulating

characteristics. Compartment Syndrome Observation Especially in the initial few days following surgery, it is critical to conduct ongoing surveillance for indications of recurrent compartment syndrome. This sometimes entails using compartment pressure monitoring in addition to routine clinical examinations. Education and psychological support have become essential components of postoperative treatment since they assist patients in understanding the recovery process. The dissemination of information on wound care, the significance of physical therapy, and the establishment of practical recovery goals can enhance patients' happiness and results.

CONCLUSION

Fasciotomy is a lifesaving procedure in the context of compartment syndrome following trauma. The indications for fasciotomy in both the upper and lower extremities are based on clinical findings and objective measures of compartment pressure. The timing of surgery is critical, with early intervention leading to significantly better outcomes. The surgical technique must be meticulous, and postoperative care is essential in ensuring optimal recovery and minimizing complications. Understanding these aspects is vital for healthcare **p**roviders managing patients with trauma-related compartment syndrome.

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RIB PLATING: IS IT TIME TO SLOW YOUR ROLL?

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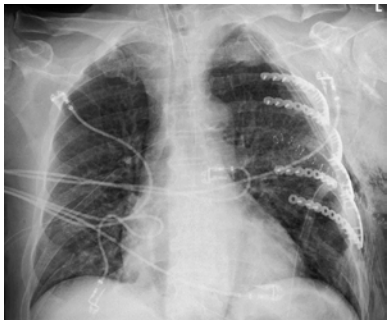

KEY POINTS

- Identifying patients who will benefit from surgical stabilization of rib fractures (SSRF) remains a challenge.
- To optimize treatment of rib fractures, many institutions and some organizations have developed comprehensive treatment guidelines that include risk stratification, disposition recommendations, multimodal pain control, regional anesthesia, pulmonary therapy, non-invasive ventilation, and SSRF.
- While there are no prospectively validated models that can be used to predict which patients will fail non-operative management, recent randomized controlled trials may help with patient selection.
- In general, patients with chest wall instability including flail chest should be considered for rib plating. If they have actual or impending respiratory failure, then plating is indicated.
- In general, patients with multiple displaced rib fractures without chest wall instability should be considered for rib plating if they have actual or impending respiratory failure. Pain alone is not an indication.

INTRODUCTION

As the pendulum swings, it is worth checking in on the topic of rib plating in 2024.

SSRF remains an important part of the trauma surgeon's armamentarium. Still, patient selection remains challenging. How do we know who will benefit? Fortunately, we have new data to help us decide.

Before diving into the deep end, it is important to establish the standard of care for patients with rib fractures. For years now, the significance of rib fractures in trauma patients has been recognized. Rib fractures can increase the risk of pneumonia, ventilator dependence, length of stay, and mortality. The more ribs that are broken, the higher the risk of complications.[1] Recognizing this, many institutions and organizations have developed comprehensive, multidisciplinary guidelines to optimize the treatment of patients with rib fractures.

RIB FRACTURE MANAGEMENT GUIDELINES

While no gold standard exists, most guidelines share the following features:

- Risk stratification
    - Considerations include age, frailty, patient-reported pain level of pain, maximum incentive spirometry volume, oxygen requirements, pre-existing pulmonary disease, the presence of pulmonary contusions, and the number and distribution of rib fractures.
    - There are countless scoring systems out there, some more extensively validated than others. This includes the RibScore[2], PIC Score[3], Rib Fracture Score[4], and the Chest Trauma Score.[5]
- Disposition recommendations
    - Using the risk stratification tools described above, disposition recommendations are made to ensure optimal patient care (e.g., discharge from the ED vs. admission to the floor, step-down, or ICU).
- Multimodal pain control with consideration for regional anesthesia
    - Multi-modal and opioid-sparing pain control is the gold standard for trauma patients.
    - Regional anesthesia including epidural, paravertebral, erecter spinae, and serratus anterior blocks are an important adjunct in managing pain from rib fractures.
    - The American College of Surgeons Trauma Quality Program published a comprehensive best practice guideline for acute pain management in trauma patients in 2020.[6]
- Pulmonary therapy
    - Aggressive pulmonary toilet including incentive spirometry, the use of flutter valves, and early mobilization are an important part of a patient's recovery.
- Non-invasive ventilation
    - The use of BiPAP in high-risk patients has been shown to improve outcomes.[1]
- Monitoring for complications and evolution of injury
    - Early in a patient's course daily chest x-rays are recommended to assess for pneumothorax, hemothorax, atelectasis, and worsening fracture displacement.
- Patient education
    - Knowledge is power! Patients should understand the significance of their injury and the role they play in their recovery.

Note, there is no widely accepted system for describing rib fractures. This includes location of the fracture, degree of comminution, and extent of displacement. This is unfortunate, as it makes it difficult to standardize research and communication between providers.

RIB PLATING: SHOW ME THE DATA

So, where does SSRF fit in? Unfortunately, there are no prospectively validated models that can be used to predict which patients will fail optimal non-operative management. Fortunately, we have new data to help us decide.

Flail Chest

There are countless non-randomized trials that study SSRF in patients with flail chest. Most of these are low quality and impaired by bias. When it comes to randomized control trials, there are only 4 (see table below). Three of these are small, single institution studies completed between 2000 and 2013 and the fourth is a larger study that was published in 2022. A Cochrane analysis reviewed the three small trials and determined that "surgical treatment was preferable to nonsurgical management in reducing pneumonia, chest deformity, tracheostomy, duration of mechanical ventilation, and length of ICU stay." And that "Further well-designed studies with a sufficient sample size are required to confirm these results and to detect possible surgical effects on mortality."[7] It should be noted that one of these studies used Judet struts to fix the ribs and another wires. Both techniques for rib fixation have been largely replaced by rib plating.

FLAIL CHEST								
Author	**Title**	**Year**	**N**	**Inclusion**	**1^0**	**2^0**	**Limitations**	**Notes**
Dehghan et. al.[8]	Operative vs. Nonoperative Treatment of Acute Unstable Chest Wall Injuries: A Randomized Clinical Trial	2022	207	16 to 85 years old w/ displaced rib fractures & either flail chest or non-flail chest w/ severe chest wall deformity, including any of the following: severe greater than 100% displacement of three or more ribs, marked loss of thoracic volume (>25% volume loss of the involved a lobe), overriding of 3 or more rib fractures by a minimum of 15 millimeters each, & 3 or more rib fractures w/ ribs protruding into the lung parenchyma.	No diff in ventilator free days (VFD) in the first 28 days following injury (22.7d SSRF vs. 20.6 non-op, p=.09)	Diff in mortality (favors SSRF, 0% vs. 6%, p=.01), no diff in LOS or complications (pneumonia, tracheostomy)	No long-term follow-up, pts w/ severe pulmonary contusions excluded	Subgroup analysis of pts on the vent at time of randomization showed 2.8 more VFD & shorter LOS in SSRF, the # of pts requiring the vent after randomization was 2x higher in SSRF

Marasco et. al.[9]	Prospective Randomized Controlled Trial of Operative Rib Fixation in Traumatic Flail Chest	2013	46	18 to 80 years old w/ flail chest (3+ consecutive rib fxs in >1 place), receiving mechanical ventilation w/ "no prospect of weaning w/in the next 48 hrs,"	No diff in total vent time in hrs. (151 SSRF vs. 181 non-op, p=.37), diff in ICU LOS in hrs. (favors SSRF, 324 vs. 448, p=.03)	No diff in pneumonia, failed extubation, readmission to ICU, hospital LOS, or mortality; more tracheostomy in non-op (39% vs. 70%, p=.04); no diff in maximum IS @3m, CT scan @3m, or SF-36 at 6m		Resorbable rib plates used for fixation, total vent time assessed at time of surgery is significantly less in surgery group
Granetzny et. al.[10]	Surgical versus conservative treatment of flail chest. Evaluation of the pulmonary status	2005	40	Flail chest with paradoxical movement	Not specified	Not specified	Many	Vent days & ICU LOS significantly less in SSRF, PFTs significantly better in SSRF, no diff mortality, non-op RX included "strapping and packing," SSRF performed w/ Kirschner or stainless-steel wires

The most informative trial was published in JAMA last year by Dehghan et al.[9] Results showed a trend towards more ventilator free days in the operative group, but this was not significant. Subgroup analysis of patients who were mechanically ventilated at the time of randomization showed significantly more ventilator free days in the operative group. Mortality was also significantly lower in the operative group, although numbers were small (6 patients died without plating and none with). And finally, rates of complications like pneumonia and length of stay were similar between the two groups.

These results are *somewhat* contradictory to the previous literature in that there was no significant difference in time spent on the ventilator, length of stay, or rates of pneumonia. In fact, if you look at *non-ventilated* patients, there was no difference in ANY outcomes when comparing operative versus non-operative intervention. So, does this prove plating is less helpful for flail chest injuries than previously thought? Or was the study just underpowered?

There are two other findings from this study that are important to mention. First, patients who required early mechanical ventilation had worse outcomes and higher complications compared with nonventilated patients, regardless of the treatment they received. This underscores the importance of a patient's respiratory status when evaluating them for injury severity and when thinking about SSRF. And second, operative treatment was generally associated with a low rate of complications. In fact, the operative and nonoperative groups had an equivalent rate of reoperation. This is in line with previous literature and demonstrates the safety of SSRF.

Non-Flail Chest

When looking solely at prespecified primary and secondary outcomes these trials are not exactly ringing endorsements of SSRF. Outcomes including pain, disability, length of stay, ventilator free days, pneumonia, tracheostomy, and mortality were not reliably different between operative and non-operative groups. It is important to note that these trials were performed in the modern era of rib fracture treatment, used thoughtful inclusion criteria, and studied clinically relevant outcomes. The studies also demonstrate the difficulty of conducting a randomized surgical trial in trauma patients. Enrollment was challenging and crossover was an issue. Both issues degrade the power of a randomized trial and the ability to identify differences between treatment arms. Furthermore, only one trial used derangements in pulmonary physiology as an inclusion criterion. While only conjecture, a patient's pulmonary status may be one of the most important features when it comes to identifying patients who will benefit from SSRF. Finally, the trial by Pieracci et al. contained both randomized and observational arms that were combined for data analysis making interpretation of the results difficult.

The table below summarizes the most impactful studies that explored SSRF for patients without flail chest.

NON-FLAIL CHEST								
Author	**Title**	**Year**	**N**	**Inclusion**	**1^0**	**2^0**	**Limitations**	**Notes**
Meyer et. al.[12]	Randomized Controlled Trial of Surgical Rib Fixation to Nonoperative Management in Severe Chest Wall Injury	2023	84	Any of: 1) Radiographic (but not clinical) flail chest 2) 5 or more consecutive rib fractures 3) Any single rib fracture with bicortical displacement	Hospital LOS sig longer in SSRF (10d vs 15, p=.046)	Opioid exposure greater in SSRF (349mg vs. 177, p=.001), worse QOL indices @ 1m in SSRF No diff in mortality, ICU LOS, vent days, tracheostomy, PNA, need for regional analgesia, intubation, return to work, or EQ5D5L QOL @ 3 & 6m	Underpowered due to difficult enrollment, no data on pulmonary physiology (e.g., IS), over half of eligible patients chose not to participate	Included Bayesian analysis, clinical flail chest excluded, protocolized non-op management, groups evenly matched (including fracture pattern)

Marasco et. al.[13]	Rib Fixation in Non-Ventilator-Dependent Chest Wall Injuries: A Prospective Randomized Trial	2022	124	1) ≥3 rib fxs b/w ribs 3-10 2) Ongoing pain or displaced rib fractures * Only patients in whom enrolling MD felt there was clinical equipoise were enrolled	No diff in pain rating index @3m	No diff in hospital LOS, complications, mortality, disability @3m via SF12, pain at 0/3/7d. More pts in SSRF returned to work at 6m.	16% crossover in SSRF group & 30% in non op group	
Pieracci et. al.[14]	A Multicenter, Prospective, Controlled Clinical Trial of Surgical Stabilization of Rib Fractures in Patients with Severe, Nonflail Fracture Patterns (CWIS NONFLAIL)	2019	110	1) ≥3 ipsilateral, bicortical, severely displaced (>50% rib width) fxs of ribs 3-10 2) ≥2 pulmonary physiologic derangements after initiation of locoregional analgesia (RR >20, IS <50% predicted, numeric pain score >5/10, poor cough) 3) SSRF expected in <72 hrs	Numeric pain score less in SSRF @2 wks (but not at other time points)	No diff in narcotic requirements, IS, pleural space complications, hospital LOS, ICU LOS, and mortality.	Randomized and observational arms combined for data analysis (no baseline differences between groups)	

PRACTICAL RECOMMENDATIONS

Assuming medical treatment is optimized and there are no contraindications to surgery then the following ***general*** recommendations may be reasonable:

1. Patients with chest wall instability including flail chest should be considered for rib plating. If they have actual or impending respiratory failure, then plating is indicated.
2. Patients with multiple displaced rib fractures without chest wall instability should be considered for rib plating if they have actual or impending respiratory failure. Pain alone is not an indication.
3. Patients with non-displaced fractures should not undergo plating.

Remember, these are ***general*** recommendations. Deciding who to plate is complex and requires experience. There are countless patient specific factors to consider. Reviewing difficult cases with experienced colleagues is highly recommended.

Other less common but legitimate indications for plating include patients with shards of bone sticking into their lung and those with non-union[15]. It is also reasonable to have a lower threshold for performing rib plating if you are already in the OR for something like hematoma evacuation.

WANT TO LEARN MORE?

Scan the QR below to listen to Behind the Knife's BIG T TRAUMA series episode 19: Rib Plating Update.

Behind the Knife

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BLEEDING KIDS: OPTIMAL RESUSCITATION FOR PEDIATRIC PATIENTS IN HEMORRHAGIC SHOCK

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Major differences in the mechanisms of injury and the causes of mortality complicate the research of hemorrhagic shock in the pediatric patient. In both the US and Europe, more than 90% of injuries are blunt, and over 60% of patients with significant hemorrhage also suffer from traumatic brain injury. The fact that the anatomy, physiology, mechanism of injury and incident of penetrating injury varies so significantly across the "pediatric" age spectrum further compounds the ability to make definitive statements about appropriate treatment.[1]

Initial treatment of hemorrhage on the scene is with direct pressure, packing, and tourniquet use in both pediatric and adult patients. The Pediatric Trauma Society has endorsed the use of these techniques in the early treatment of extremity injuries in children. The use of tourniquet and packing for extremity wounds should be no different than for the adult trauma patient. The use of permissive hypotension is a difficult point to declare definitively. While its principles should apply equally well to the pediatric patient, the fact that almost 60% of patients with hemorrhagic shock have concomitant TBI may change the risk: benefit ratio of this practice. Further research is needed, but for now, the recommendation is for the child with hemorrhagic shock and TBI is to maintain a normal BP.[7] For children with hemorrhagic shock without TBI, my practice is to allow modest hypotension until hemorrhage control is achieved.

The pediatric patient, unlike the adult patient, does not have a linear relationship between blood loss and vital signs. It is very difficult to determine when intravascular volume repletion is actually needed in the severely injured pediatric patient. Tachycardia is an unreliable sign in the awake pediatric patient and increases in sympathetic tone will allow a pediatric patient to lose 35-40% of circulating blood volume prior to demonstrating hypotension. (2 Georgette, 3 Russell) Obtaining adequate intravenous access is a "first start" in volume resuscitation, and this can be a challenge. The early use of intraosseous access in the tibia, femur, and humerus is advocated when a pediatric patient in shock does not have access within 90 seconds of attempts.[4,5,6,7]

The indiscriminant use of crystalloid has a significant detrimental effect on children similar to adults. There is a strong correlation in mortality between the use of high volumes of crystalloid compared to a balanced resuscitation with blood and blood components. In addition, the initial use of high volume crystalloid prior to a balance resuscitation with blood actually negates the positive effects of the appropriate blood resuscitation.[8]

Pediatric trauma patients are more likely to be transported longer distances compared to adults, and are often transferred to a tertiary center after receiving initial care at a local facility. It is less likely that the EMS services or small local hospitals have either whole blood or adequate stores of platelet and FFP, let alone whole blood. There is good evidence that the pediatric patient who has had bleeding that has

stopped and is now stable, should be transfused with either whole blood or component therapy based on a the presence of a TBI and a low hemoglobin level. The Pediatric Critical Care Blood Research Network recommends RBC transfusion for children with TBI and a hemoglobin level between 5-7gm/dl. Biologic markers of a clinically significant deficiency in the coagulation cascade, such as with rotational thromboelastometry, should be used to determine the need for additional blood components.[9] The pediatric patient who has had bleeding that has stopped but who is hypotensive, should be resuscitated with blood and/or blood components. "Clean-up" of the coagulation derangement should be done with thromboelastometry driven data.[3,6,7]

The pediatric patient who is hypotensive from blood loss and continues to experience hemorrhagic shock and ongoing blood loss should have a massive transfusion protocol initiated. The protocol should be weight based, with at least three stratifications: neonatal (less than 10 Kg), children (10kg-40kg) and adolescents (> 40 kg). Similarly, when a child meets an accepted "adult" trigger for MTP activation, it should be started.

The next question surrounds the appropriate make-up of the MTP. Nationally, the most common will be component therapy. A 1:1 goal of plasma to red cells is optimal. The MATIC investigators demonstrated that the greater the plasma deficit, the higher the odds ratio of dying. Every 10ml/kg of plasma deficit increases mortality by 10%.[10,11,12,13] A similar decrease in the odds of survival was seen with incremental deficits in platelets in the MTP.[10]

In keeping with a promising trend in adult trauma care, whole blood administration obviates the need for component therapy, and ensures a balanced resuscitation. Excellent work published by Morgan, Leeper, Yazer Spinella and Gaines discuss the safe and appropriate use of cold-stored, low-titer O-negative whole blood (LTOWB) with emerging evidence that there is a survival advantage to its administration when compared to component therapy. There is also a good discussion on the rational for use of RhD-positive and negative blood in this group, with compelling case made for standard use of RhD-positive for all patients.[13]

The routine use of cryoprecipitate is discussed by the Russel, et al. and the Pediatric Traumatic Hemorrhagic Shock Consensus Group. There was, in their consensus, not enough evidence to recommend the empiric use of prothrombin concentrates or fibrinogen in a pediatric MTP.

The use of these intravenous hemostatic agents was better reserved for use with documented deficits on thromboelastometry or direct fibrinogen levels. While there was not enough evidence for the consensus group to recommend routine thromboelastometry, the reality of how so many pediatric patients come from greater distances and are more likely to be transferred from local hospitals makes it, again, more likely that they have received partial component therapy prior to arriving at the trauma center. For this reason, I believe it is warranted to do routine thromboelastometry on patients with significant blood loss.[3,7]

There is evidence from Lucisano, Leeper and Gaines that trauma induced coagulopathy (TIC) is impactful in pediatric trauma, and that it may well vary by developmental stage of the child. While perhaps less common than in adults, there were certain types of injury that altered the expression of TIC in children, such as TBI, and particularly abusive TBI. It is still not totally clear whether or not there are there exist the three distinct phenotypes of fibrinolysis in children, but there does appear to exist a phenotype of both sever fibrinolysis and fibrinolytic shutdown in the pediatric population. These findings suggest that the use of tranexamic acid should have a similar effect in the pediatric population. The safety profile has been established in children for the use of TXA, but to date, results from two large trials, MATCI and The Israeli Defense Forces Medical Corps, were mixed on the efficacy. It does seem to be a benefit for the use of TXA when pediatric patients were given the drug within three hours of injury. The Consensus Group was only

able offer a conditional recommendation for the use of TXA given within three hours of injury. The upcoming MATIC-II trial from Leeper and Spinella should shed more light on this subject.[3,7,14]

The administration of calcium seems based on a finding that a significant percentage of adults with hemorrhagic shock are hypocalcemic. There have not been good published studies that demonstrate survival benefits of replacement of calcium. There is no recommendation for its use in children with hemorrhagic shock and studies are warranted.[15]

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SESSION 5

NEW TECHNIQUES AND TECHNOLOGY

Moderator: Kenji Inaba

Monday, April 15, 2024

4:10 – 5:10 PM
Palace Ballrooms 1-2
Palace Tower
Emperors Level – 4th Floor

4:10 – 4:22	**Fluorescence Imaging for the Acute Care Surgeon: Biliary, Bowel, and Beyond** **Mark J. Kaplan, MD, FACS**
4;22 – 4:34	**Plasma in Burns - What's Old is New Again** **Jennifer M. Gurney, MD, FACS**
4:34 – 4:46	**New Airway Tools and Techniques: Prehospital and Emergency Department** **James Kempema, MD, FACEP**
4:46 – 4:58	**Cell Salvage in Damange Control Resuscitation** **Martin A. Schreiber, MD, FACS, FCCM**
4:58 – 5:10	**Surgical Nostradamus: The Future of AI and Machine Learning in Acute Care Surgery** **Bellal A. Joseph, MD, FACS**

FLUORESCENCE IMAGING FOR THE ACUTE SURGEON: BILIARY, BOWEL, AND BEYOND

Mark J. Kaplan, MD, FACS

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Fluorescence imaging has emerged as a valuable tool in various surgical specialties, revolutionizing the way surgeons visualize and interact with tissues during operative procedures. This paper provides an overview of the use of fluorescence in surgery, discussing its advancements, applications, and future perspectives. The paper highlights the benefits of fluorescence imaging, its role in enhancing surgical precision, and its potential impact on patient outcomes. Additionally, it explores the incorporation of fluorescent probes, such as Indocyanine Green (ICG), and the integration of near-infrared imaging systems for real-time visualization. Overall, fluorescence imaging holds significant promise in improving surgical outcomes and expanding the boundaries of surgical practice.

The history of fluorescence imaging in surgery dates back several decades. The concept of using fluorescence to aid in surgical procedures emerged as researchers recognized the potential of fluorescent dyes to selectively mark and evaluate tissue physiology, blood flow, and anatomy to reduce complications. Identification of viable tissue is crucial in any surgical procedure. A surgeon's eye is limited in determining bowel viability and tumor invasion. There is a need for enhanced diagnostic tools to improve outcomes.

In the 1940s and 1950s, researchers began experimenting with the use of fluorescent dyes, such as fluorescein, in various medical applications. Fluorescent surgery dates to 1947 in the identification of intraoperative brain tumors. Fluorescein was also used initially as a diagnostic tool in ophthalmology to visualize blood vessels in the eye. In the 1960s and 1970s, the use of fluorescence imaging expanded to other medical fields, including dermatology and urology. Researchers explored the application of fluorescent dyes to visualize tumors and sentinel lymph nodes. The introduction of light emitting diodes in the 1970s expanded more wavelengths of light allowing for the developing advanced imaging tools important diagnostic tool. One of the most significant advantages of the florescence-based techniques is to provide real-time information that cannot be visualized by the eye alone.

Fluorescent probes are used to provide contrast for Fluorescent Guided Surgery (FGS) between the target of interest and the surrounding tissue. While many fluorescent probes have been researched and developed for use in FGS, very few are routinely used. Today intrinsic probes refer to fluorophores that naturally fluoresce in their native form.

Indocyanine green (ICG) emerged as a prominent fluorescent dye probe in the 1980s. ICG fluorescence angiography (FA) is an emerging technology, which has been used to decrease the incidence of anastomotic leaks, identify poorly perfused tissue, and identify critical anatomy. ICG is a safe and FDA-approved dye that emits near-infrared light when excited by specific wavelengths. ICG is a water soluble, tricabonate dye that remains in the intravascular compartment until excretion and has a plasma half-life of 3 to 5 minutes. Importantly, ICG absorbs light at an excitation wave emission wavelength of 830 nm or

more. Using near-infrared image, NIF systems will convert the excited light from the tissue, measuring vascular perfusion at colorectal anastomosis. This light is viewed intraoperatively, allowing surgeons to anastomose well-perfused bowel or to refashion a poorly perfused anastomosis. Also, anatomic structures not visualized well by the naked eye are observed. ICG will accumulate in the hepatobiliary system over a longer period and will illuminate biliary structures such as the common bile duct, cystic duct, and surrounding biliary structures.

ICG's unique properties, including rapid clearance from the body and minimal tissue autofluorescence, make it suitable for clinical applications. The development of ICG paved the way for significant advancements in fluorescence imaging, particularly in surgical procedures. ICG's near-infrared fluorescence allowed for deeper tissue penetration and reduced background noise, enabling better visualization of structures during surgery. The introduction of light emitting diodes in the 1970s allowed for many more wavelengths of light to become visible, evolving this device into a crucial diagnostic tool.

In the late 1990s and early 2000s, fluorescence imaging began gaining traction in various surgical specialties. It was used in procedures such as sentinel lymph node mapping, breast cancer, melanoma surgeries, and vascular surgeries to assess tissue perfusion and anastomotic leaks. Over time, fluorescence imaging expanded to other fields, including gastrointestinal surgery, neurosurgery, and minimally invasive procedures. It has been used to aid in the identification of tumors, lymph nodes, blood vessels, and nerves, improving surgical precision and reducing complications. The development of near-infrared imaging systems and specialized surgical cameras further optimized fluorescence imaging in surgery.

There are approximately 20 fluorescence-guided clinical imaging systems that the FDA has approved. They typically fall into the categories of handheld imaging systems, laparoscopic based systems, and surgical microscopes. These systems allowed for real-time visualization of fluorescence signals and provided surgeons with enhanced imaging capabilities during procedures. In recent years, advancements in imaging technology, such as multispectral imaging and three-dimensional reconstruction, have further expanded the applications of fluorescence imaging in surgery. Today, fluorescence imaging is an established technique used in a wide range of surgical procedures. It continues to evolve with ongoing research and technological advancements, including the development of novel fluorescent probes and instrumentation. The integration of fluorescence imaging into routine clinical practice holds significant potential for improving surgical outcomes and advancing patient care across various specialties.

In the simplest form, a FGS system consists of a light source with accompanying filters for excitation of the fluorescent contrast agent. The emitted fluorescent signal from the probe is collected by removing unwanted signals such as excitation light and autofluorescence. The light passes through appropriate emission filters, followed by collection optics to focused signal on the detector. The signals are transferred to a screen for visualization.

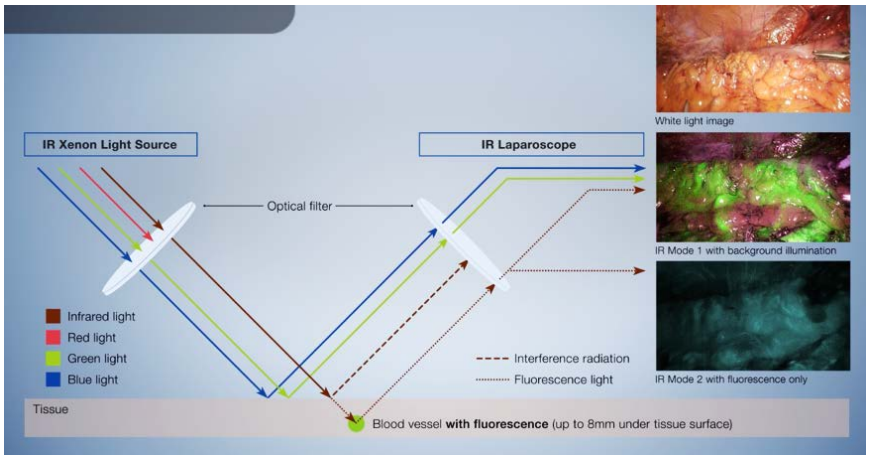


Figure 1. Olympus user's manual

There are 4 visual modes that filtered out to enhance the visibility of the florescent image and are controlled by the Pinpoint Central Image Processor. These enhanced images will have specific ranges for Near Infrared imaging for perfusion, structural analysis (gallbladder surgery, parathyroid surgery), and both sentinel node biopsy and lymphatic mapping. Variations in visual image is dose, time, and filter are settings dependent.

WHITE LIGHT MODE

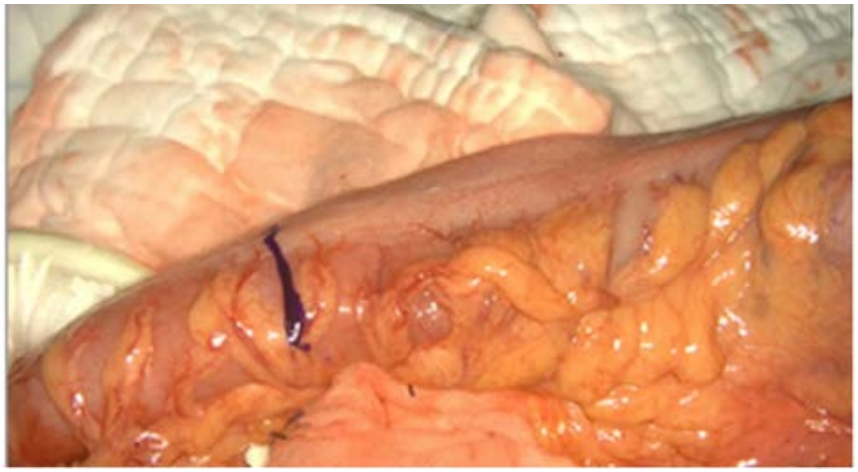


Figure 2. This is the initial display at the start of the study. This is unfiltered light to allow for focus and positioning

OVERLAY MODE

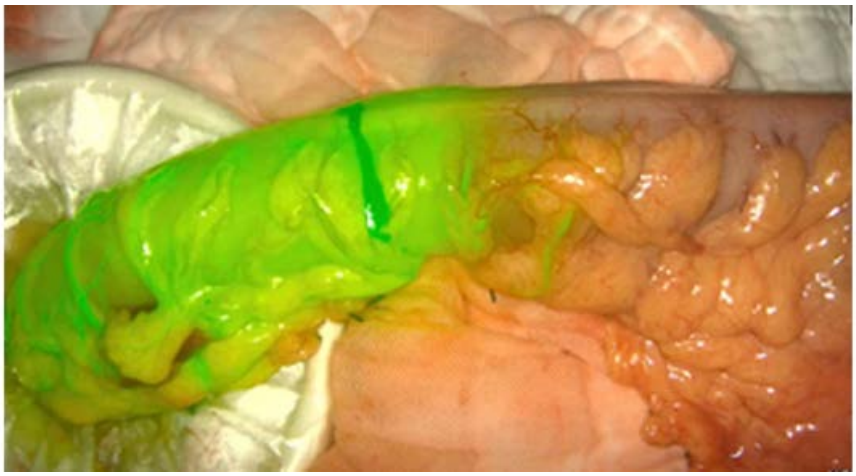


Figure 3. This mode places a green overlay mode to define areas of perfusion. Areas that are perfused will light up green, and areas under perfused will remain dark. Programs are now available to quantitate perfusion for a more accurate assessment of flow.

SPY MODE

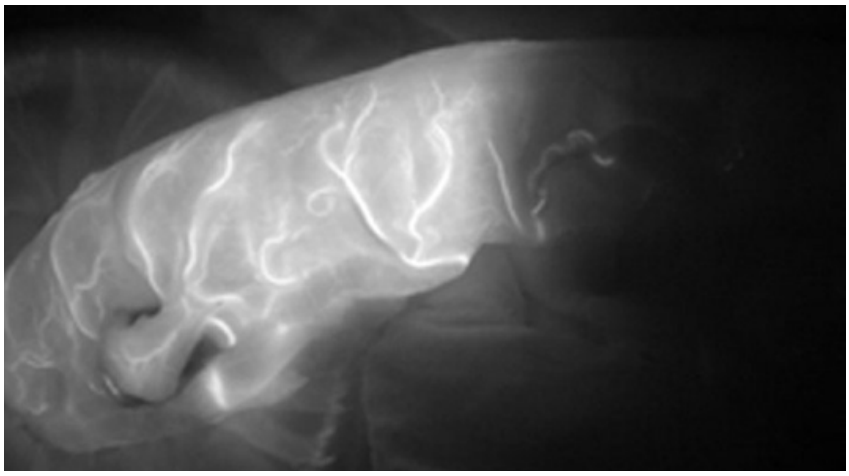
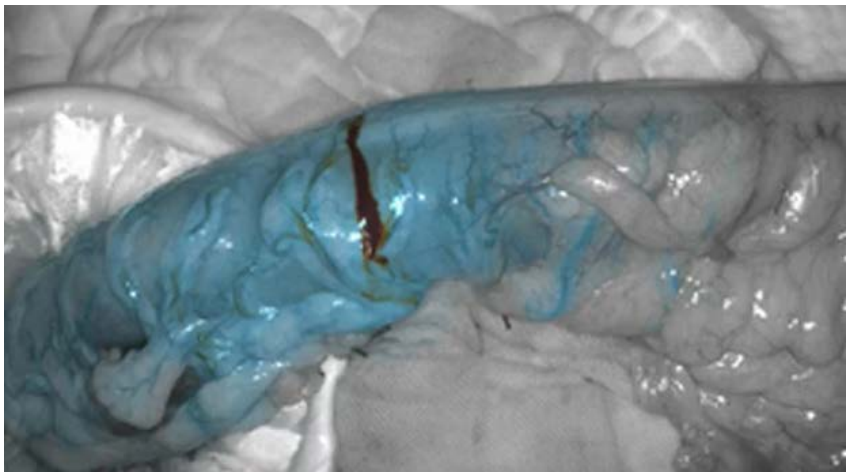


Figure 4. This mode is the purest florescent image that shows perfusion to the bowel wall, arterial flow, and flow though intestinal arcades. Fluorescence-guided surgery offers several benefits in various surgical procedures, including colorectal surgery

CST MODE (COLOR SEGMENT FLUORESCENCE)



*Stryker SPY-PH manual

Figure 5. In this mode, lymph node mapping, sentinel node mapping, and lymphatic distribution mapping are performed.

KEY ADVANTAGES OF FGS

Enhanced Visualization

Fluorescence imaging provides real-time visualization of structures that may not be easily visible under normal lighting conditions. By using fluorescent probes, surgeons can differentiate between healthy and diseased tissues, identify anatomical structures, and precisely locate specific areas of interest, such as tumors.

Improved Surgical Accuracy

The ability to accurately identify and localize targeted tissues during surgery helps improve surgical precision. Surgeons can more effectively remove tumors, lesions, or other abnormal tissues while minimizing damage to healthy surrounding structures. This can result in better clinical outcomes and reduced postoperative complications.

Minimized Damage to Healthy Tissues

Fluorescence-guided surgery enables surgeons to differentiate between healthy and diseased tissues in real-time. This distinction allows for more precise tissue resection, reducing the risk of unintentional damage to healthy structures and preserving important anatomical landmarks.

Increased Safety

The use of fluorescence imaging can enhance the safety of surgical procedures. Surgeons can better identify blood vessels, bile ducts, and other vital structures, reducing the risk of inadvertent injury during the operation. This can be particularly crucial in complex or minimally invasive surgeries.

Complete Tumor Resection

In oncologic surgeries, achieving complete tumor resection is critical for optimizing patient outcomes. Fluorescence-guided surgery helps surgeons identify and remove all cancerous tissues, including small or hard-to-detect lesions that may not be visible to the naked eye. This can lead to more effective cancer treatment and reduce the likelihood of tumor recurrence.

Shorter Operating Times

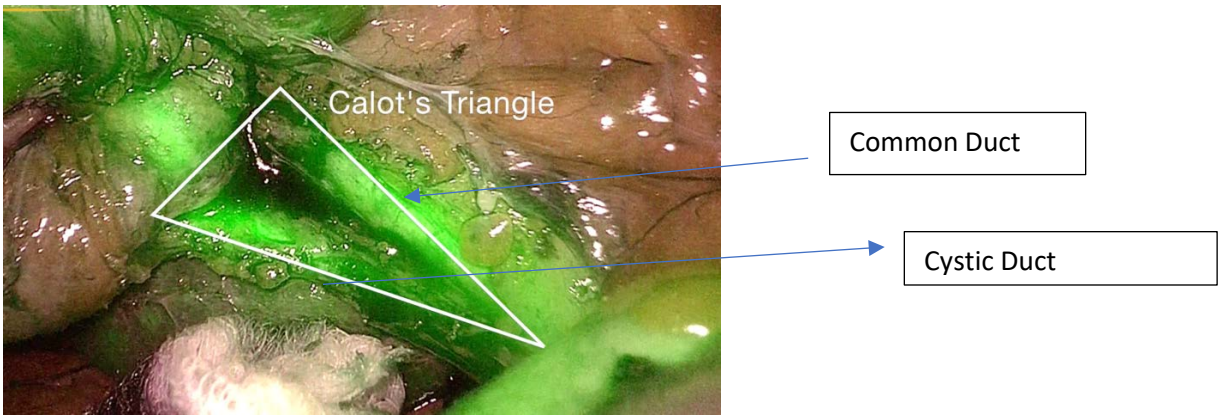
Improved visualization and accurate localization provided by fluorescence-guided surgery can potentially reduce operating times. Surgeons can work more efficiently and effectively, resulting in shorter procedures, reduced anesthesia exposure, and decreased overall surgical stress for the patient.

It's important to note that the specific benefits of fluorescence-guided surgery may vary depending on the surgical procedure and individual patient factors. Surgeons will assess the appropriateness and potential advantages of this technique on a case-by-case basis. Also, while ICG fluorescence imaging can provide valuable information in the intraoperative assessment of bowel perfusion, it is typically used as part of a comprehensive evaluation that includes clinical judgment, patient symptoms, physical examination findings, and other diagnostic tests. The decision to resect or revascularize ischemic bowel should be made by a skilled surgeon based on a thorough assessment of the individual patient's condition.

GALLBLADDER SURGERY

Laparoscopic cholecystectomy is one of the most common surgical specialties performed globally. Despite the prevalence of laparoscopic cholecystectomy, there is an unacceptably high risk of iatrogenic bile duct injury. Bile duct injury is multifactorial, combining a lack of technical skills and sustained perception error from the operating surgeon. Through the 1980s the incidence of bile duct injury during open cholecystectomy was estimated at approximately 0.1%. In 1989, the introduction of laparoscopic cholecystectomies yielded several advantages for patients. However, bile duct injury increased by fourfold. A study that was performed between 1992 and 1999 found an overall incidence of bile duct injuries laparoscopic cholecystectomy to be 0.5%. The introduction of intraoperative cholangiogram did not reduce the actual incidence of bile duct injury. The increase in bile duct injuries was thought to be the result of lack of tactile sensation and visual misinterpretations of the surrounding anatomy. Lack of clear biliary geography is also thought to contribute to bile duct injuries, because the common duct was misinterpreted for the cystic duct. This was not recognized until the contrast was injected into the common bile duct, with the injury already occurring. The addition of identifying the critical view of safety also has not decreased the incidence of common bile duct injuries during laparoscopic cholecystectomy.

Over the last several years, incisionless, near infrared fluorescent cholangiography using ICG as the contrast probe has been consistently shown to increase visualization and identification of extrahepatic biliary structures. NIFC consists of intraoperative, intravenous administration of ICG fluorescent dye and inoperative visualization with a fluorescence imaging system. Many laparoscopic systems have incorporated the use of fluorescent technology to identify ductal structures. Patients are given a 2.5 mg of ICG IV approximately 1-2 hours prior to the start of surgery with imaging performed during the cholecystectomy using white light and infrared light generated through the laparoscopic camera. This intraoperative imaging procedure requires no incision, is much less time consuming, and only a small fraction of the cost of an IOC. This eliminates the need to cannulate the biliary tree, which is one major source of bile duct injury. Up to 97% of bile duct injuries have been attributed to the inadequate visualization of variability structures, which is corrected by using NIFC.



Outcomes using NIFC with ICG have been promising. There have been a limited number of controlled randomized studies, and most of the data showing NIFC effectiveness comes from class two and class three studies. There have also been several meta-analysis and Delphi studies looking at the effectiveness of NIFC in gallbladder surgery. The overall incidence of bile duct injury was 0.12% in the NIFC group when compared to a rate of 1.31 in the non-NIFC group. The incidence of conversion to open surgery varied between 0-6.25% in the NIFC group and 0-24% in the non-ICG group. A retrospective study comparing NIFC with white light surgery showed reduced complications 2.3 to 2.6 fold. Using NIFC, anatomic visualization was also affected much less by obesity and surgical field inflammation. Conversion to open surgery was1/4 with ICG and as high as 1/17 with the white light group. Another group reported reduced rates of conversion open from 22%-2.6%. There were no differences with complications noted with laparoscopic or robotic surgery. The ICG group also significantly lowered operative time from 129 min. for the NIFC group vs. 150 min for the non-NIFC. There was also a lower probability of subtotal cholecystectomy. Also, NIFC when compared to IOC is faster, safer, and less expensive with decreased of laparoscopic cholecystectomy.

The other advantage of NIFC is that it's an incisionless study to evaluate the common bile duct. Ninety-seven percent of bile duct injuries have been attributed to inadequate visualization of biliary structures and direct injury of the duct during cannulation for IOC. Dip in 2019, was able to demonstrate that not only did NIFC identify and outline the CBD, but the study also accurately identified 7 accessory extra-biliary structures that cannot normally be visualized laparoscopically or during an open cholecystectomy. Damage to the structures can lead to significant complications. These structures included: the cystic duct, right hepatic, common hepatic duct, common bile duct, cystic duct, cystic common duct junction, cystic gallbladder junction, and accessory ducts. These can all be identified prior to dissection. There is reduction in the incidence of common bile duct injury and to these accessory ducts.

With these results in mind, the European Association for Endoscopic Surgery consensus on ICG has made a number of recommendations on the use of NIFC/ICG in gallbladder surgery: 1. NIFC during a laparoscopic cholecystectomy improves the identification of the extra-hepatic biliary anatomy before and after dissection of Calot's triad; 2. NIFC during laparoscopic cholecystectomy maybe reduce operative time and conversion rates, when compared to standard intraoperative imaging; 3.NIFC in obese patients improves identification of the extra-hepatic anatomy before and after the dissection of the Triangle of Calot compared with standard imaging; 4. NIFC during laparoscopic cholecystectomy in cases of acute cholecystitis may improve identification of the extrahepatic biliary anatomy before and after dissection of Triangle of Calot and identification of the Critical View of Safety. The final recommendation was fluorescent cholangiography during laparoscopic cholecystectomy should be used whenever available to improve the visualization of biliary structures and improve outcomes and improve outcomes.

COLON SURGERY

Approximately 600,000 colorectal surgeries are performed annually in the United States to treat various colorectal disorders, most commonly malignancy, inflammatory bowel disease, and diverticulitis. There are significant complications associated with colorectal surgery, including anastomotic leaks that are the most common catastrophic complications, significantly increasing patient morbidity and mortality, prolonging hospital stays, and resulting in reduced term quality of life and further complications. Anastomotic leaks increase morbidity and mortality. In patients with rectal cancer, local recurrences are increased with anastomotic leaks. Anastomotic leaks can be attributed to patient risk factors, technical factors, and blood supply at the distal approximal segments about. Also, assessment of the micro-perfusion at the time of the creation of an anastomosis may influence the rate of an anastomotic leak.

Imaging of colorectal perfusion with NIF fluorescence angiography (NIFA) can be performed in open, laparoscopic, or robotic surgery. An initial dose of 2.5 mg or 0.05 mg/kg is given IV, and imaging is performed in 2-3 minutes after the initial dose. Re-dosing can be performed to enhance structural visualization. Most laparoscopic units have a built-in imaging system that will use NFLIA seamlessly through a Pinpoint Endoscopic Florescent Imaging System. Hand-held imaging is accomplished using SPY technology. The units are connected to a high-resolution monitor for viewing. Systems allow for multiple images. NIR imaging can be accomplished with 2 modes: a pseudo-color green superimposed on a white light image; and SPY image, which is a black on white NIR florescent image. The latter gives the highest resolution and blood flow distribution. These images will a display qualitative image of blood flow to the colon and assessment of the integrity of the blood supply for anastomosis.

Imaging takes place during all aspects of the procedure. The initial FA image is observed after the dissection of the colon, with attention to blood supply and distal ends of the colon. If an ischemic segment of bowel is found, that segment can be resected back to a fully vascularized bowel and resected to optimize the blood flow at the anastomosis. This is most helpful in in evaluating the blood supply of the distal end in a low anterior resection. Also, the bowel arcades can be evaluated for integrity. At the completion of the anastomosis, the suture line, proximal bowel, and distal bowel can be inspected for perfusion and viability. If there are ischemic segments noted at the anastomosis, it should be revised. In the study below, after ICG was given 3 min before and evaluated with overlay green light after an anastomosis, there is a clear demarcation and no perfusion to the distal bowel. The bowel appeared perfused on white light illumination and the suture line revised after adequately perfused bowel was identified.

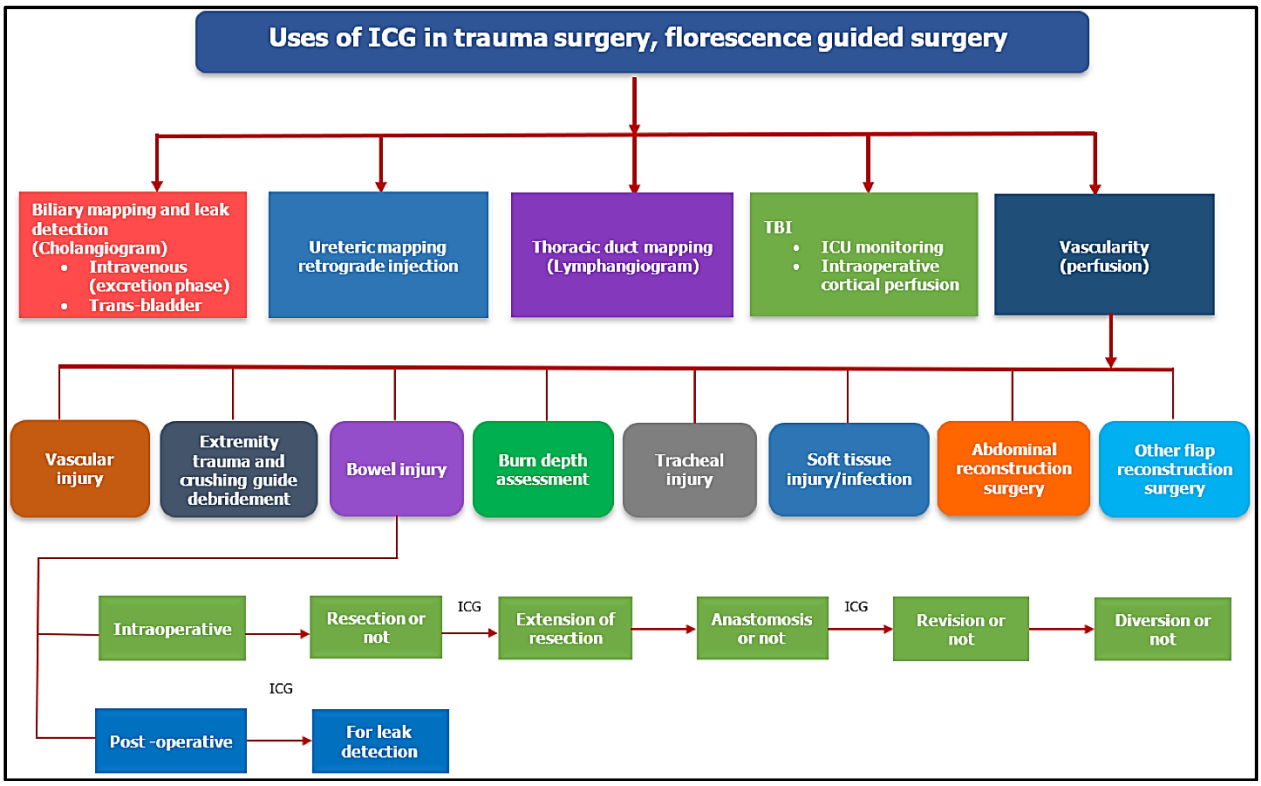
There is strong retrospective data to support the FA in colorectal surgery to reduce the risks of anastomotic leaks at the time of surgery. Anastomotic leak rates have been reduced significantly with FA angiography. Overall leak rates in some series were reduced from 8.6% to 3.7%. The PILLAR II study offered the strongest evidence for FA evaluation with left-sided colon surgery. This study reported leak rates of 1.4% with FA and about 6.5% with white light (due to unobserved ischemic changes).

Florescence has also been used in lymph node mapping in and sentinel node biopsy in colorectal surgery. The data is unclear as to effectiveness of florescence in lymph node mapping and sentinel node biopsy for cancer. The only area noted at present is for identification of parathyroids in surgery and mapping in lymph node thyroid surgery.

TRAUMA AND SOFT TISSUE INJURIES

Traumatically injured patients usually have complex, contaminated and revascularized wounds. This is compounded by comminuted compound fractures and large segments of avulsion of soft tissue. Recently, ICG angiography has become a useful adjunct in the evaluation and treatment of traumatic wounds. ICG has become effective in evaluation of areas of poor flow to tissues not observed by the naked eye.

The potential for NFI and FG an outlined in the following chart:



Husham, A. et al. World J Gastroint Surgery 15; 2023; 757-775

While there are no definitive studies in traumatic injuries, interest from the military has grown over the past years. Reports and ongoing experience have shown that florescent guided surgery has been effective in the management of soft tissue injuries, amputation levels, and skin flap viability. Early anecdotal reports suggest improved amputation care with decreased infections and reduction in amputation revisions. ICG has also been tried in evaluation of bowel viability and anastomotic evaluation. While the initial experience appears promising, many more studies will have to be performed to prove if this is an effective modality for combat injuries.

Florescence surgery (FS) continues to improve imagery with adoption in more procedures. Ongoing studies have shown improvements in outcomes with improved anatomical identification and identification of compromised blood flow. Improved outcomes in biliary and colorectal-bowel surgery been shown when fluorescence surgery has been used. The most important application will be in trauma surgery. This will result in more effective treatment of burn and extremity injuries, as well as improvements in the identification of necrotic tissue.

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PLASMA IN BURNS – WHAT'S OLD IS NEW AGAIN

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Burn Resuscitation Basics – What every doctor should know!

1. Do not be distracted by burn injuries! Burn wounds are rarely immediately life threatening; always look for other injuries.
2. Stop burning process and address bleeding and airway compromise.
3. Be aware of toxic chemicals in the environment and other risks to the patient and health care providers.
4. Prevent hypothermia. Burn patients are much more susceptible to hypothermia, which can exacerbate coagulopathy of trauma in polytrauma patients. Move patient to warm environment, control hypothermia.
5. Treatment Plan: a) Secure airways early; b) base resuscitation on the ISR Rule of 10s; c) avoid fluid creep, follow hourly urine output; d) early disposition.
6. Assess total body surface area (TBSA) of burn injury – under resuscitation is bad, over resuscitation is horrible; both can be deadly.
7. Formulas for burn resuscitation are a starting point – adjust resuscitation based on urine output.
8. The USAISR Rule of 10s is a simple way to remember the starting point for fluid resuscitation.
9. Crystalloid creep is real – fluid begets fluid. Careful not to over resuscitate. Excessive fluids are contraindicated in the hemodynamically stable burn patient. Excessive fluids contribute to total body edema and worsen outcomes.
10. The fluid deficit in burns is a result of a total body plasma deficit. Plasma resuscitation was used in WWII and is having a resurgence.

Burn injuries are a global concern, given they require large amounts of resources, and there is limited expertise in the management of complicated burn patients. Any type of multicausality incident involving burns creates a moderate amount of chaos, because the majority of health care providers are inexperienced in the care of burn patients. Burn care management and outcomes are inextricably linked to resuscitation. IV fluid resuscitation with crystalloid is the *sine qua non* of burn resuscitation; however, this practice – like all practices in medicine, should be carefully examined for alternatives that could potentially improve outcomes. Burn resuscitation, similar to resuscitation of trauma hemorrhage, has seen changes throughout the last century. And, similar to the resuscitation for bleeding, it is being more and more accepted that there is a morbidity from resuscitating with crystalloids.

Patients with significant thermal injury represent a unique population. Unlike other life-threatening conditions such as sepsis, hemorrhage, anaphylaxis, and traumatic injury--in which initial therapy results in reversal of physiologic abnormality and improvement in clinical status--burn resuscitation frequently results in ongoing physiologic derangement. Thermal injury leads to disruption of homeostasis secondary to local and systemic inflammatory responses, culminating in 'burn shock,' a unique combination of distributive and hypovolemic shock physiologies characterized by intravascular volume depletion, low pulmonary artery occlusion pressure, increased systemic vascular resistance, and depressed myocardial contractility. Fluid administration is the cornerstone of effective resuscitation, with the goal of restoring intravascular volume and perfusion. The type, quantity, duration, and endpoints of burn shock resuscitation have been debated over the last century; however, resuscitation without morbidity remains a significant challenge.

Burn Resuscitation

- Less < 20 TBSA → do not need IV fluid resuscitation.
- If hypotensive, rule out hemorrhage.
- >20% TBSA will need volume expansion.

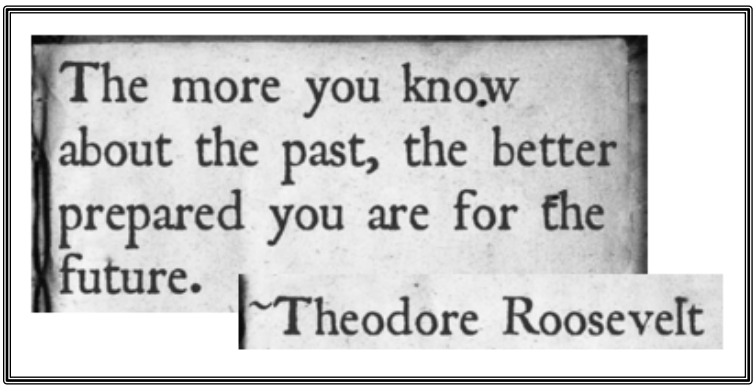
The resuscitation of patients with extensive burns (greater than 20% TBSA) is a significant challenge. Both over-resuscitation (too much fluid) and under-resuscitation (too little fluid) lead to potentially devastating complications ("resuscitation morbidity"), or even death. The pathophysiology of burn shock has been fairly well defined, but effective intervention strategies are mainly limited to various intravenous (IV) fluid regimens. The primary process that drives burn shock is a derangement of the Starling forces across the microvasculature. This can result in edema, leading to organ dysfunction or morbidity.

HISTORY OF BURN RESUSCITATION

Appropriate fluid management is critical to the survival of patients with burn injuries. Large burn wounds are fatal if not treated. Prior to the 1950's, hypovolemic shock or shock-induced renal failure was the lead cause of death after thermal injury. Burn injury results in massive fluid shifts and vascular changes. After the initiation of fluid resuscitation for thermal injury – early mortality decreased considerably.

The concepts of 'burn shock' and 'burn edema' were better understood after the Cocoanut Grove fire in 1942, and fluid resuscitation based on body weight was conceptualized. In 1952, Evans developed the first formula for burn resuscitation that took burn total body surface area (TBSA) and body weight into account. This formula became the first straightforward formula for computing the fluid replacement in a burn casualty.

Surgeons at the Brooke Army Medical Center in San Antonio Texas modified the original Evans Formula of: Normal Saline 1.0cc/kg/%TBSA + Albumin 1.0cc/kg/%TBSA to: Lactated Ringers 1.5cc/kg/%TBSA + Albumin 0.5cc/kg. Later, secondary to studies by Pruitt, the Modified Brooke Formula became 2.0cc/kg/%TBSA of Lactated Ringers. The Parkland Formula has been considered by many to be the 'Gold Standard' for burn shock resuscitation. It was developed by Dr. Charles Baxter at Parkland Hospital in the 1960 and remains one of the most commonly used formulas today. The Parkland Formula calls for Lactated Ringers to be administered at 4.0cc/kg/%TBSA, with one half of the volume administered within the first 8 hours. The modified Brooke Formula and the Parkland Formula are the most common resuscitation strategies used today; however, there is a large amount of heterogeneity, and the burn community lacks a prospective randomized clinical trial to inform the best resuscitation strategy for early and late outcomes.



Prior to WWII, the primary treatment for burns was topical, and the lethality of burn shock was very high. WWII was a turning point for burn resuscitation. While whole blood had been used as a resuscitation fluid for bleeding from traumatic injury during WWI and the Spanish Civil War, plasma was introduced in 1936 as a substitute for whole blood. Both liquid plasma and freeze-dried plasma were used early in WWII as part of the "Blood for Britain Campaign" in the United States, with over 14,000 units of blood donated and thousands of these processed into plasma units. Sterilization challenges and contamination of pooled plasma with hepatitis virus resulted in the cessation of this initiative in the early 1950s. Prior to WWII, in the anticipation of war, the United States made a national commitment to supporting medical research of military relevance, to include chemotherapeutics, surgical care, and resuscitation.

A prominent example of the use of plasma for burn shock resuscitation was provided following the mass casualty disaster at the Cocoanut Grove nightclub in November, 1942. In that instance, plasma, diluted half and half with normal saline was delivered by the blood bank at the Massachusetts General Hospital to the bedside. The assumption is that this was lyophilized plasma; however, the literature is not clear why is was diluted with normal saline. During WWII, widespread availability of plasma enabled it to play a prominent role in the resuscitation of combat casualties.

THE SHIFT TO CRYSTALLOIDS

> *That men do not learn very much from the lessons of history is the most important of all the lessons that history has to teach.*
>
> *Aldous Huxley*

During the 1960s and 1970s, a movement away from colloid for resuscitation was fueled by the concept that an extracellular sodium deficit drives the shock process in both hemorrhagic and burn shock, and that it should be corrected by vigorous administration of crystalloid fluids. The 1968 study that demonstrated the need for isotonic crystalloid solutions in the initial resuscitation of severe burns in order to resuscitate the extracellular fluid space included 11 thermally injured human patients as well as dog models, 12 in each study cohort. Much of the subsequent focus on crystalloid resuscitation can be attributed to theoretical basis, to include the initial 2-liter bolus prescribed by the Advanced Trauma Life Support program for mechanical trauma patients.

In the treatment of burn shock, a similar focus on crystalloid resuscitation resulted in the abandonment, for a time, of colloid during the first 24 hours postburn. The Parkland (or Baxter) formula called for 4 ml/kg/TBSA burned over the first 24 hours, all of it lactated Ringer's solution (LR). The modified Brooke formula called for 2 ml/kg/TBSA burned during the first 24 hours, again all of it LR. Colloid use, as 5% albumin at a dose of 0.3 to 0.5 ml/kg/TBSA, was postponed till hours 24-48 in these formulas. In order to begin volume resuscitation, the TBSA is required.

INITIAL BURN FLUID RESUSCITATION WITH CRYSTALLOID

Acute burn resuscitation is done with crystalloid, as mentioned above, and guided by TBSA, and response is measured initially by urine output. This has its pitfalls but is the most common and rudimentary way to guys initial resuscitation. Studies regarding the use of colloids or plasma for colloid for early resuscitation are ongoing. Currently, use of these fluids before the 24th postburn hour is recommended only when the resuscitation is complicated by continued hypotension; oliguria; or a predicted volume of >250 ml/kg during the first 24 hours.

After the TBSA (partial thickness and full thickness burn areas only) has been calculated, the US Army Institute of Surgical Research (USAISR) Rule of 10s can be used to determine the initial IV fluid rate for adults. The **Rule of 10s** was created at the USAISR to simplify the initial resuscitation of burn combat casualties during the recent conflicts in the Middle East.

US Army Institute of Surgical Research (USAISR)

RULE OF 10s

- Initial fluid rate = 10 ml/h x TBSA
- It is used for patients with burn wounds >20% TBSA
- The formula is a good estimate for patients between 40-80 kg
- For patients weighing more than 80 kg →100 ml/hour is added to the IV fluid rate for every 10 kg greater than 80 kg.

For children (those under 40 kg), the modified Brooke formula should be used, because patient weight must be taken into account. The volume of fluid projected for the first 24 h is 2 ml x weight (kg) x TBSA, with half of this to be given over the first 8 h. Thus, a 20 kg child with 50% burns would be programmed to receive 2 x 20 x 50 = 2000 ml. Half of this, or 1000 ml, would be given over the first 8 h. Thus, the initial rate would be 1000/8 = 125 ml/h. (Note that some references call for 3 ml x weight x TBSA for children.) In addition, children must receive a maintenance IV fluid of D5½NS or D5LR (at a rate predicted by e.g. the 4-2-1 rule). This fluid is maintenance, not resuscitation, and is not adjusted during burn shock.

Assessment/Interventions in First 24 hours

Complete full secondary trauma exam
Ensure thermoregulation; administer warmed fluids; cover with space blanket
Partial thickness (2nd degree): blanch, moist, blisters, sensate
Full thickness (3rd degree): leathery, white, non-blanching, dry, insensate, thrombosed vessels
Protect eyes with moisture shields if corneas exposed or blink reflex slow (NOT Fox shield)
Prompt intubation for facial burns, suspected inhalation injury, TBSA >40%

- anticipate induction-associated hypotension;
- secure with cloth tie, no tape;
- reassess ETT position at teeth Q1 hr
- Intubated patients require oro/naso-gastric tube for decompression
- IV administration of proton-pump inhibitor

Monitor bladder pressure at least Q4hrs for large burns or high volume resuscitations

- Abdominal compartment syndrome: decreased UOP, increased pulmonary pressures, difficulty ventilating, bladder pressure trending > 20 mmHg
- Avoid decompressive laparotomy; consider percutaneous peritoneal drainage with catheter
- Reduce crystalloid volume using colloid or vasopressors

Monitor pulses hourly: palmar arch, dorsalis pedis, posterior tibial with Doppler

- Consider escharotomy if signal diminished; refer to CPG for technique

Monitor extremity compartment pressures as clinically indicated

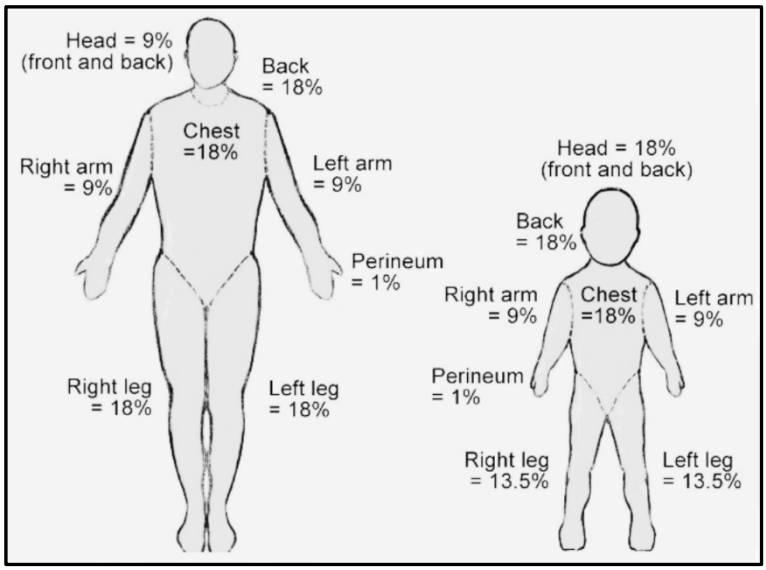
- Elevate burned extremities at all times
- Extremity compartment syndrome: pain, paresthesia, pallor, paralysis, pulselessness (late sign)
- Fasciotomy may be required

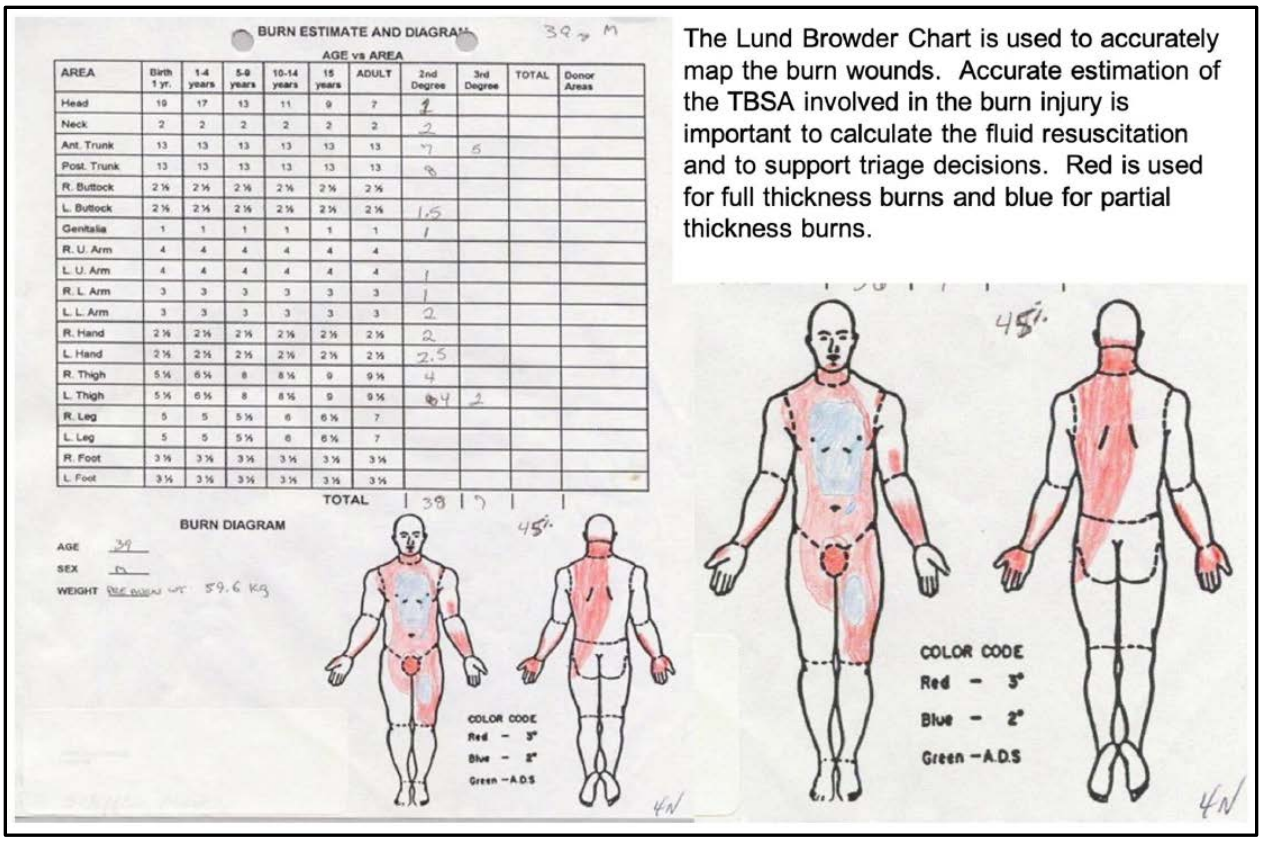
Wound care

- Thoroughly cleanse burn wounds, preferably in OR
- Select topical antimicrobial in consultation with Burn Surgeon
  - based on product availability, expected transport time, etc
- Acceptable to cover burns with dry sheets or clean dressings for first 24 hours

All definitive surgical burn interventions done at USAISR

It is imperative to keep track of resuscitation to prevent 'run away' resuscitation. Over resuscitation is associated with significant morbidity and mortality. Any formula-based calculation is only an initial estimate of fluid needs. It is imperative that this flowsheet be initiated at the first level of care and that it follow the patient through the continuum, with each role of care accurately documenting the IV fluids and UO. Calculating the appropriate TBSA is essential to determine appropriate resuscitation volumes. Over-resuscitation can be just as lethal as under-resuscitation.





UNDER RESUSCITATION SHOCK VS 'FLUID CREEP' AND OVER RESUSCITATION SHOCK – WHICH IS WORSE?

FLUID CREEP CAN BE DEADLY

Causes of Fluid Creep

- Lack of burn experience
- Inadequate attention to detail
- Patient has oliguria
- Patient factors may increase fluid requirements

The primary goal of resuscitation in burn patients is to maintain adequate end organ perfusion by using intravascular, sometimes large volume, fluid resuscitation. Prior to the understanding of the importance of fluid resuscitation in thermal injury, patients with moderate size burn wounds would survive the inciting event only to succumb to shock in the first 24 hours and approximately 30% of survivors developed renal failure. Under resuscitation results in a continued shock state, suboptimal tissue perfusion, and ischemic end-organ injury and renal failure. Volume resuscitation is recognized as crucial therapy, and the multiple formulas to guide fluid resuscitation indicate that there has not been a perfect resuscitation strategy. As mentioned above, over resuscitation results in 'fluid creep'.

'Fluid creep' is secondary to the extensive use of the crystalloid-only formulas and occurs when the volumes delivered greatly exceed the formula predictions. In a review of the use of the modified Brooke formula at the USAISR, patients actually received 4.9 ml/kg/TBSA. Similarly, patients started on the Parkland formula received 6.3 ml/kg/TBSA. Chung et. al. documented that combat casualties who were started on the modified Brooke formula, on average, received 3.8 ml/kg/TBSA; whereas those who were

started on the Parkland formula, on average, received 5.9 ml/kg/TBSA. These authors concluded that "fluid begets more fluid." A pathophysiologic explanation would be that early provision of large volumes (as in the Parkland formula) drives a higher edema formation rate, since the microvasculature is most sensitive to hydrostatic pressure during the immediate postburn period.

In an extremely thorough evaluation of the literature, Guilabert et al. performed a non-systematic review to help determine the current evidence and recommendations for the early resuscitation of burn patients. In their review, published in the British Journal of Anaesthesiology September 2016, they observed that many burn units based their resuscitation practices on formulas that were almost 50 years old, despite the advances in hemodynamic monitoring. The authors assessed 92 articles, 19 which were included in their review. Overall, there has been a paucity of high-quality prospective studies to determine the best resuscitation fluid in the early period after thermal injury.

EFFORTS TO CONTROL 'FLUID CREEP' AND OVER-RESUSCITATION

The most common rescue therapy for the runaway resuscitation is the institution of 5% albumin before the 24th postburn hour. Several algorithms have been proposed to determine when to do this. In the mid-1990s, Cancio and Pruitt recommended calculating the projected 24-hour fluid resuscitation volume at postburn hour 12. If this volume was predicted to exceed 6 ml/kg/TBSA, they called for institution of 5% albumin before hour 24 (at the dose usually used for the second day). At the University of Michigan, Park et al. described a similar protocol. This was associated with a decrease in vasopressors, ventilator days, and mortality, although a difference in fluid volumes was not significant.

In 2009 Greenhalgh published the results of an International Society for Burn Injuries (ISBI)/American Burn Association (ABA) survey of burn resuscitation practice which, while mentioning the Parkland formula as the preferred formula and LR as the preferred solution, also included the initiation of colloid during the first 24 hours by 49.5% of respondents. A prospective multicenter observational study of resuscitation, to include albumin use, is currently ongoing (Acute Burn Resuscitation Multicenter Prospective Observational Trial, or "ABRUPT", NCT03144427 at clinicaltrials.gov). A randomized controlled trial of albumin rescue has not been performed.

There is a fundamental shift in burn resuscitation toward earlier use of colloids has been underway for years, ever since the first description of 'fluid creep' and the complications which follow such over-resuscitation.

PLASMA IS RECOGNIZED AS A TREATMENT FOR THE ENDOTHELIOPATHY OF TRAUMA

A comprehensive reevaluation of fluid resuscitation strategy strategies (crystalloid, blood component products, whole blood, etc) in trauma patients has occurred over the last two decades, energized by experience with combat casualties from the wars in Iraq and Afghanistan. This effort began with "hemostatic resuscitation," which incorporated the early use of plasma, platelets, and red blood cells in 1:1:1 ratios into the initial management of seriously injured patients. Data has been published that supports there is an independent coagulopathy of trauma as well as an endotheliopathy of trauma (EOT) caused to due hypoperfusion and ischemic injury to the endothelium. A further development addressed the process whereby trauma patients become coagulopathic (coagulopathy of trauma), and the role of the endothelium in this process ("endotheliopathy of trauma", EOT). This supported the use of blood products to directly address the shock, coagulopathy, and endothelial injury that occurs with life-threatening hemorrhage. This has not only changed our approach to the initial care of the exsanguinating patient, but also has expanded our understanding of the role of the microvasculature in the response to other injuries such as burns.

Kozar et al. conducted studies of rats with hemorrhagic shock, then resuscitated with either LR or plasma. Shock caused degradation of glycocalyx by electron microscopy. The glycocalyx was partially restored by plasma, but not by LR. Plasma mitigated lung injury as well. Nelson and colleagues resuscitated rats bled 30% with FFP, albumin, or Ringer's acetate. Both FFP and albumin restored plasma volume, whereas Ringer's acetate did not. Overall, resuscitation with crystalloid solutions (LR or normal saline) evoked glycocalyx damage and increased permeability; resuscitation with fresh whole blood or plasma elicited protection, and albumin had an intermediate effect.

Restoration of the glycocalyx is increasingly being recognized as an important therapeutic goal. Holcomb and colleagues have demonstrated a decrease in mortality and improved outcomes in vitro and in vivo and clinically after trauma and hemorrhagic shock from plasma-based resuscitative strategies. These benefits appear to extend beyond the ability to correct trauma-induced coagulopathy and provide hemorrhage control and involve protective effects to a dysfunctional endothelium.

Early plasma-based resuscitation reverses the endotheliopathy of trauma by restoring the glycocalyx. In a multi-institutional analysis of bleeding patients requiring massive transfusion who were resuscitated with modern-day high plasma ratios, the increased use of crystalloids was associated with increased morbidity. There have been extensive studies in animal models and trauma patients that indicate the importance of the endothelial glycocalyx and the potential superiority of plasma to other fluids in protecting or restoring following trauma/hemorrhage.

> Using plasma as the primary volume expander rather than crystalloids has been associated with decreased morbidity and mortality in hemorrhagic shock patients.
>
> Cotton et al. Annals of Surgery 2011; 254(4)

Burn shock can be addressed with plasma-based resuscitation. Based on the aforementioned studies, there is an imperative to consider a paradigm shift for burn resuscitation and a move toward plasma-based resuscitation and away from the well accepted crystalloid-based resuscitation strategy.

ENDOTHELIOPATHY OF BURNS

A recent study in rats with 25% or 40% TBSA burns demonstrated increased syndecan-1 shedding proportional to burn size; and that endothelial injury, manifested by leakage of albumin (Evan's blue dye) into the lungs, can be mitigated by the use of FFP. In a prospective observational clinical study, and after adjusting for age, sex, TBSA, and inhalation injury, Osuka et al. found that syndecan-1 shedding was independently correlated with increased fluid requirements and the development of burn-induced compartment syndromes. The previously unrecognized associations of burn induced indices of systemic hyper-inflammation and hypermetabolism and endothelial dysfunction suggest that plasma has the potential to mitigate other parameters of burn injury beyond that of edema. While there is overall a paucity of data in this area, there exists an endotheliopathy of burns (EOB) that will be abrogated by a paradigm shift in burn resuscitation away from a crystalloid-based strategy to a plasma-based strategy.

A significant knowledge gap exists concerning the utility of plasma in burn resuscitation in the modern era, but accumulating data suggest that it may be a fluid of choice. Du et al. compared LR, FFP, and hypertonic saline (HTS) for burn resuscitation almost 30 years ago. The volume infused was a mean of 4.8 ml/kg/TBSA in the LR group, 3.16 in the HTS group and 2.68 in the FFP group. The median % weight gain

at the end of the first day of treatment was 10.7 in the LR group, 7.9 in the HTS group and 2.4 in the FFP group. Their formula, incorporating FFP for resuscitation, is called the Slater formula. O'Mara and colleagues from the same group conducted a single-center randomized controlled trial of FFP (plus 2000 ml of LR) vs. LR (at the Parkland dose) in 2004. The FFP group demonstrated lower volume needs than the LR group (0.21 vs. 0.26 ml/kg), and virtually eliminated intra-abdominal hypertension. Plasma has, in fact, become incorporated into burn resuscitation at some burn centers, despite there not being any high-quality prospective trials demonstrating improved outcomes. However, there is strong biologic plausibility that plasma we be a better resuscitation fluid than crystalloid for burn resuscitation. There is a growing acceptance in the burn community concerning the use of plasma for early burn shock resuscitation; however, future trials are needed to evaluate the different resuscitation modalities to determine best practices in the burn patient population.

SUMMARY

- Severe thermal injury results in a complex form of shock from an interplay of intravascular volume depletion combined with a severe inflammatory response, likely influenced by the endothelium.
- There is no universal consensus regarding the best fluid therapy and resuscitation strategy for severe burn injury, although most patients are resuscitated with crystalloids using rates according to widely accepted formulas based on burn size, patient weight, and time from injury.
- History matters! Pooled plasma was used for burn resuscitation during WWII and in civilian burn therapy as well. The shift away from plasma-based resuscitation was multifactorial and since the 1970's the primary resuscitation fluid for burn patients has been crystalloids.
- The risk of resuscitation morbidity in burn patients remains substantial with crystalloid-based resuscitation strategies.
- Resuscitation morbidity can lead to multiple complications, as well as increase mortality.
- Recent data supports the use of plasma-based resuscitation, and there is growing acceptance in the burn community for plasma as an alternative to crystalloid resuscitation.
- Plasma for resuscitation is predicated on its ability to serve as a volume expander while protecting the endothelial glycocalyx in a variety of shock models, to include burns.
- Early data indicates that plasma resuscitation decreases overall fluid volume needed.
- Long term outcomes are not available yet, but plasma-based resuscitation should be considered for all burn patients with large burns and burn shock, even mild shock.

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NEW AIRWAY TOOLS AND TECHNIQUES: PRE-HOSPITAL AND EMERGENCY DEPARTMENT

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WHY ARE PREHOSPITAL INTUBATION OUTCOMES SO BAD?

There is an extensive amount of literature reviewing prehospital intubations, with the vast majority demonstrating worse outcomes. The reasons behind this are multi-factorial and not just related to being able to successfully place an endotracheal tube. Access to appropriate training, clinical experience, difficult environmental conditions, access to appropriate medications, adjusting to the physical and physiological aspects of the patient, and appropriate post-intubation management all play a role.

WHAT MAKES A DIFFICULT AIRWAY?

What approaches can we make to minimize risk to the patient?

First, airway assessments, such as Mallampati or L.E.M.O.N. scores, typically cannot be performed in prehospital and emergency department due to emergent need for intervention. In addition, studies demonstrate pre-intubation airway assessments have poor reliability in predicting difficult endotracheal tube placement. Multiple factors increase the difficulty in successful intubations, including patients are not NPO, are intoxicated with full stomach, have head injuries, and other factors that may increase the risk of vomiting. Many patients are already physiologically compromised due to trauma, hypovolemia, or ingestions.

IMPORTANCE OF FIRST PASS SUCCESS

It is well demonstrated that patient adverse effects jump significantly the greater number of attempts it takes to intubate. These include hypoxia, aspiration, inadvertent esophageal intubation, among others. It is vital to focus on maximizing the potential of successful intubation on the first attempt.

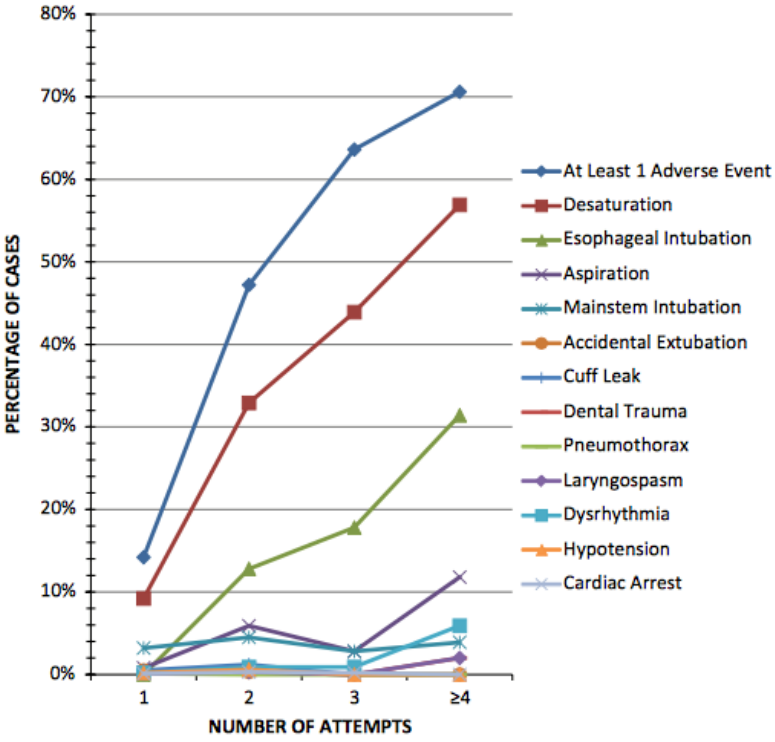


Figure 1. Incidence of one or more adverse events and incidence of specific adverse events versus number of attempts.

THREE COMPONENTS OF A DIFFICULT AIRWAY: "ABC'S"

- Anatomy
- Biochemistry
- Contamination

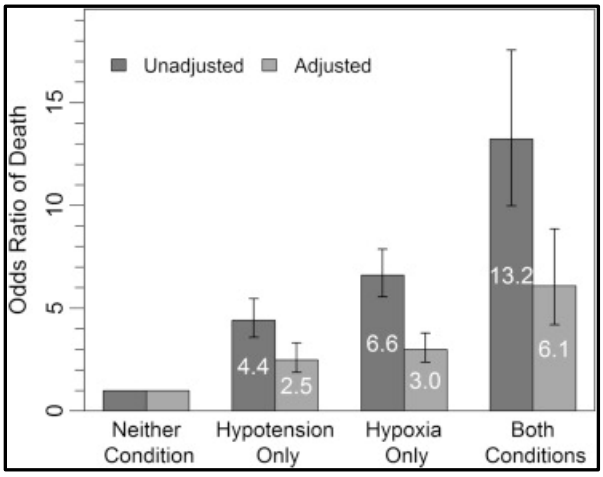
Anatomy

There are several anatomical challenges to emergent intubation, most we cannot control. However, trauma patients have additional characteristics that may increase the anatomical difficulty, including cervical spine immobilization, rigid supine position, and anatomical maxillofacial, head, or neck injuries, or burns. How do we overcome these challenges? Maximize the view through video laryngoscopy. Although they have been available for more than 15 years, there has been relatively slow adoption of the tool for a variety of reasons. There is now overwhelming evidence that they are superior in providing the best view with the highest success rates. This is probably best summarized by a Cochrane review involving 64 studies and 7044 patients, including 48 studies focused on a predicted difficult airway. The review summarized that video laryngoscopy *reduced rates of failed intubation, yielded higher rates of successful intubation on first attempt, improved glottic views, reduced rates of hypoxemic events, and reduced rates of esophageal intubation.* As video laryngoscopes become more affordable, and training and familiarity with the devices becomes more ubiquitous, it should become the primary modality for use in all emergent intubations.

Biochemistry

There are several physiological challenges in patients, creating increased complexity and risk to intubation. Both traumatically injured and critically ill patients may experience biochemical changes due to underlying injury or illness. Intubation is not a benign procedure, and there are certain physiological variables that increase the risk of peri-intubation cardiac arrest. The most common physiological conditions placing the patients at increased risk are referred to the ***three H's***: **hypoxia**, **hypotension**, and **H^+ anions** (acidosis). Both individually and in combination, these factors greatly increase the morbidity and mortality associated with intubation.

The best studied are hypotension + hypoxia in trauma patients. Considering the vast majority of intubations in trauma patients are secondary to traumatic brain injuries, these factors are vital to address in preventing secondary injury.



It is imperative to understand that the procedure itself is at risk of causing iatrogenic injury!

Intubation causes hypoxia and hypotension!!!

- Apnea
- Effect of medications
- Loss of vascular tone
- Changing to positive pressure ventilation
- Decreased venous return

How do we avoid hypoxia?

- Pre-oxygenate
- "Delayed-Sequence" intubation
- Passive / Apneic oxygenation

Delayed sequence intubation Procedure

- Ketamine 1.0 - 1.5 mg/kg IV
- Follow preoxygenation procedure
- BVM / NIPPV / temporary supraglottic airway
- Intubate after SpO2 > 94% for 3 minutes

Passive / Apneic Oxygenation

Continuous high-flow oxygenation via nasal cannulation (15 lpm) during the intubation procedure to passively assist in alveolar oxygenation and nitrogen washout

WHAT ABOUT HYPOTENSION?

Resuscitate prior to and during intubation attempt, based on underlying pathology (blood, IV fluids).

Peri-intubation cardiac arrest Risk Factors:

- Pre-intubation SBP < 90
- **Shock Index** (HR/SBP) - (Normally around 0.5)
- Pre-intubation Shock index > 0.9

Shock Index > 0.9 or **SBP <100?**

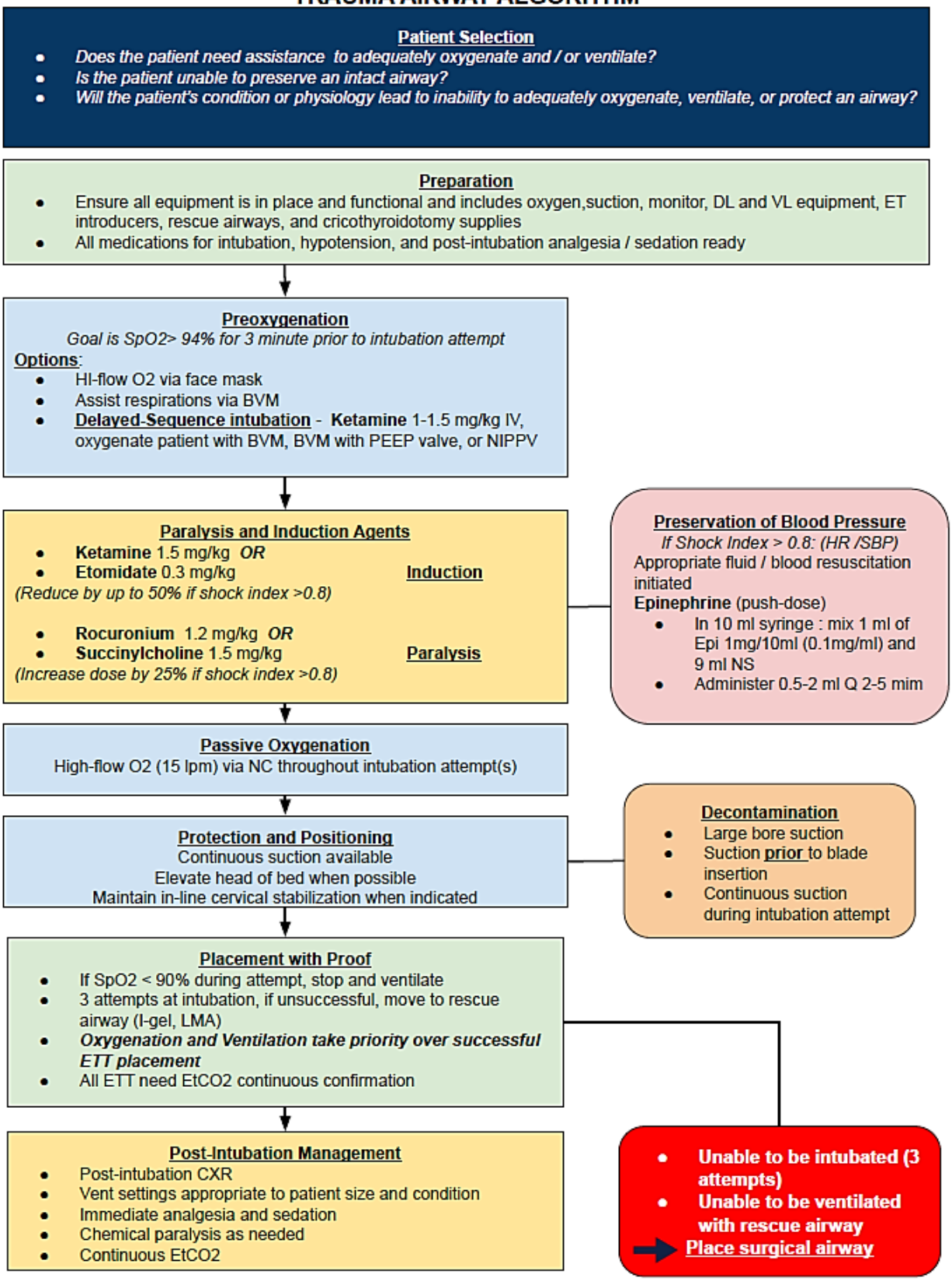
- Appropriate fluid resuscitation before / during intubation (blood, IVF)
- Consider lower dose Induction, higher dose paralytic (Ketamine / Rocuronium). Lower dosing of induction sedative may decrease the risk of medication-induced hypotension. Underlying hypotension may attenuate the effectiveness of paralytic necessitating a higher dose.
- Push-dose pressors (phenylephrine, epinephrine) pre / post intubation
- *Push-dose pressors are not treating the underlying cause of hypotension; rather, they are used to minimize the iatrogenic exacerbation of hypotension from induction medications and conversion to positive-pressure ventilation*.

Contamination

It is common for an airway to be contaminated with blood, vomit, or excessive saliva. Anesthesiologist James DuCanto promotes the **SALAD** technique "Suction assisted laryngosopy and decontamination." This starts with appropriate size suction catheter – use LARGE bore suction – these are less likely to become obstructed, rapid removal of contaminants.

Begin intubation procedure with suction and clear airway as much as possible ***prior*** to intubation. The catheter can continuously provide suction during intubation procedure by being left in the left side of the patient's mouth. An additional option is to "intubate" cords with suction catheter, disconnect from tubing, place endotracheal introducer ("bougie") through the catheter, remove suction catheter and place endotracheal tube over the bougie.

TRAUMA AIRWAY ALGORITHM



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CELL SALVAGE FOR DAMAGE CONTROL RESUSCITATION

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Damage control surgery and damage control resuscitation are predicated upon large volume transfusions with whole blood and components. The ability to resuscitate hemorrhaging patients who may require ultra-massive transfusion may be limited by availability of blood products. One way to supplement available blood products is to perform autotransfusion via blood salvage from the bleeding patient. Autotransfusion reduces the risk of transfusion reactions and transmission of transfusion transmitted diseases. Autotransfusion of shed blood can be performed either with washed and centrifuged red blood cell concentrate, as in the case of cell saver, or with unwashed whole blood, as in the case of chest tube blood that is anti-coagulated and returned to the patient unmodified. Autotransfusion was first described by Blundell in 1818 for the treatment of postpartum hemorrhage.[1] There have been numerous reports of blood collection and re-transfusion since that time. Original methods described included filtering the blood and re-transfusing it, and there are parts of the world where this technique of unwashed autotransfusion is still practiced.

The modern era of autotransfusion began in the mid-1970s, when cell saver technology was introduced. Cell-saver technology involves collection of shed blood from the patient using a dual lumen suction device and storage in a reservoir primed with anti-coagulant until there is an adequate quantity to produce a red blood cell unit consisting of 225ml, with a hematocrit of approximately 55%. The blood is centrifuged and washed with normal saline, producing a red blood cell concentrate similar to packed red blood cells. The centrifugation and washing process removes plasma proteins white blood cells, and platelets, which are discarded. (Figure 1) Depending on the device, either heparin or citrated solutions can be used as the anti-coagulant, and the entire process can be automated after adequate blood is collected. A cell-saver is typically operated by an anesthesia technician

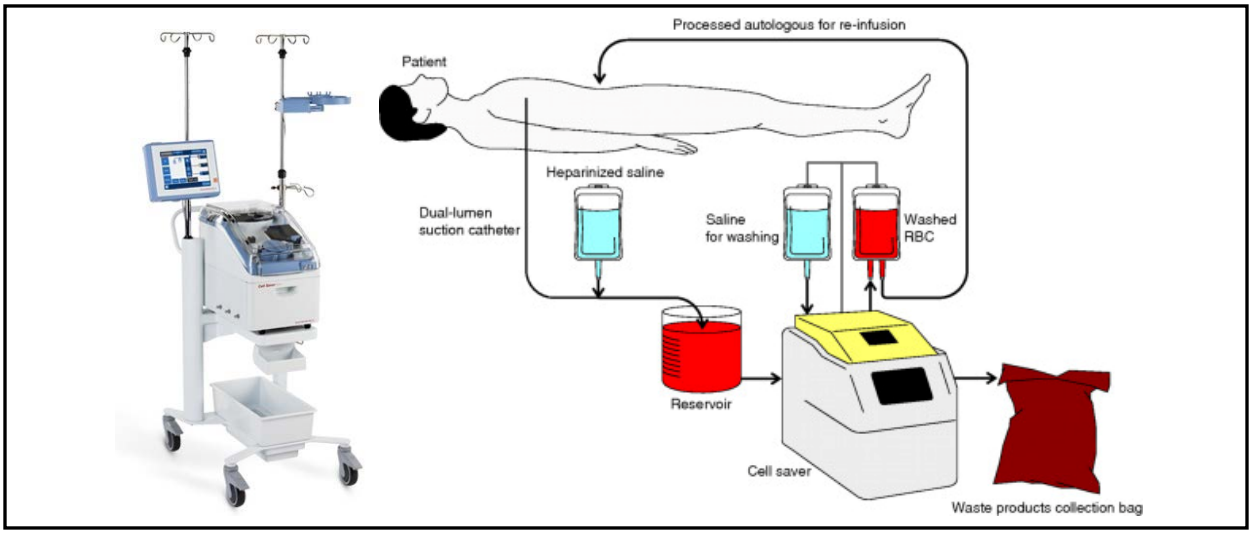

Figure 1. Modern Cell Saver Device and diagram outlining the cell saver process.

Cell-saver technology has been widely studied in elective surgery, including cardiothoracic surgery and spine surgery, as well as other surgeries known to have large blood loss. Results have been good, with significant reductions in allogeneic blood product utilization. Cell-saver has also been studied in trauma patients. Bowley et al. randomized 44 patients with penetrating abdominal trauma to a control group and a cell-saver group.[2] Patients were well-matched for demographics, and all underwent laparotomy. 74% of patients in the control group had enteric injury, as compared to 85% in the cell saver group. About 1/3 of patients in both groups survived, and the most common cause of death was exsanguination, followed by multiple organ failure, with no differences between groups. The mean volume of blood re-transfused in the cell-saver group was 1493ml. Patients in the cell saver group required about ½ the amount of allogeneic blood, compared to the control group. (Table I)

Table I. Comparisons of outcomes and blood transfusion requirements in control patients versus patients treated with cell-saver.

Patient outcomes by study treatment arm			
Parameter	Control	Cell save	*P* value
Bank blood transfusion in first 24 hours	11.17 (±SD 6.06)	6.47 (±SD 5.4)	0.008
Cause of death	EX: 10/15 MOF: 5/15	EX: 8/14 MOF: 6/14	0.71
Survival	8/23 (35%)	7/21 (33%)	1.0

SD: standard deviation; EX: exsanguination; MOF: multiple organ failure.

Transfusion of cell-saver blood in patients with enteric injury is an important issue. For patients with enteric injury, survival in the control group was 23.5%, and survival in the cell-saver group was 38.8%, which was not statistically different. Culture data from cell-saver blood and postoperative blood cultures are shown in Table II. All cultured samples from cell saver blood were positive except for one. Two of the patients who received this blood had positive postoperative blood cultures, and the cell-saver cultures and postoperative blood cultures did not match. (Table II)

Table II. Cultures from cell-saver blood prior to transfusion compared to blood cultures in patients who received the cell-saver blood.

Initial culture of salvaged blood and subsequent postoperative blood cultures in cell-saved patients		
Initial blood culture	Postoperative blood culture	Survival
Coagulase-negative *Staphylococci*	No	No
Coagulase-negative *Staphylococci*	Coagulase-negative *Staphylococci*, *Citrobacter diversus*, *Acinetobacter*, *Enterobacter*	No
Coagulase-negative *Staphylococci*	No	Yes
Coagulase-negative *Staphylococci*	No	Yes
Coagulase-negative *Staphylococci*	No	Yes
Escherichia coli	No	No
Escherichia coli, *Morganella morganii*, *Enterococcus faecium*, yeast	No	No
Escherichia coli, *Alcaligenes faecalis*, Clostridum species	Enterobacter, *Pseudomonas*, Coagulase-negative *Staphylococci*, *Klebsiella*	No
Escherichia coli, *Enterococcus faecium*, *Klebsiella*	No	No
Negative	No	No
Yeast	No	No
Yeast	No	No

Beeton et al. performed a systematic review of 9 studies comparing 1119 patients that received allogenic blood transfusions only (601) versus cell-saver plus allogeneic transfusions.[3] This large study showed no differences in mortality, infection, sepsis or ICU length of stay between the groups. The review revealed a reduction in allogeneic blood transfused in the cell-saver group and a reduction is cost in all but one study.

The other major source of autotransfusion in trauma patients is blood from the pleural cavity that has been collected in a specialized pleur-evac. This blood is evacuated from the pleural cavity, anti-coagulated, and re-transfused through a specialized system. (Figure 2) Rhee et al. performed a retrospective, propensity matched study comparing 136 trauma patients who received autotransfused chest tube blood to 136 patients who did not at 2 institutions.[4] This study showed no difference in in-hospital complications, mortality, or INR at 24 hours. Patients who received autotransfusion received less red blood cell transfusions and platelet transfusions. The authors concluded that whole blood from hemothorax is a safe and effective practice in trauma patients.

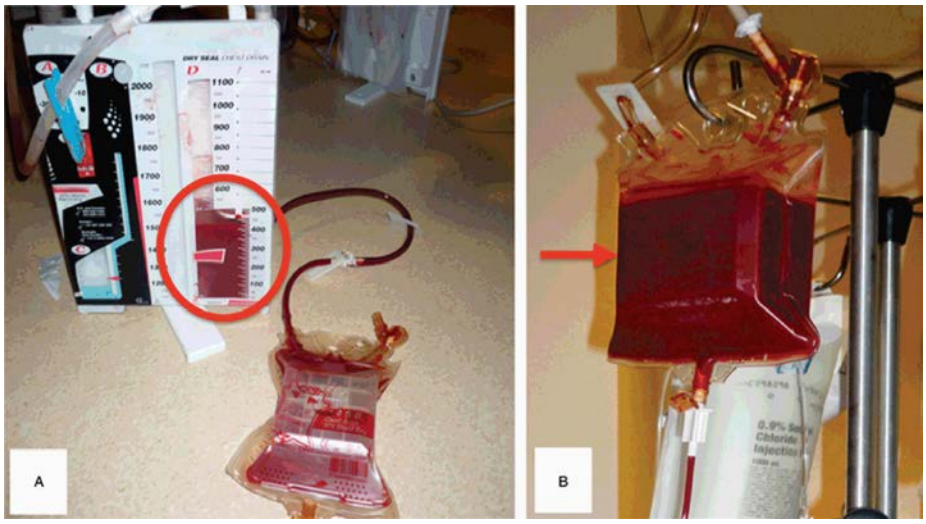

Figure 2. Chest tube blood collection system

While unwashed blood salvaged from hemothorax is whole blood, concerns about the quality of the blood persist. This blood has been studied extensively in the orthopedic and cardiac surgery literature and has been shown to have elevated inflammatory mediators, fibrin split products, and complement fractions. Febrile reactions have been noted in 4-12% of patients.[5] Salhanick et. al., compared coagulation factors, hematologic factors, and electrolytes in the pleural blood and venous blood in trauma patients with hemothorax.[6] These authors showed that hemoglobin, platelet count and WBC are significantly lower in chest tube blood, and INR, PTT and D-dimers are significantly higher. Tables III and IV. The data in this study suggest that chest tube blood could cause coagulopathy and/or disseminated intravascular coagulopathy. Mitchell et. al., found similarly concerning results, and they concluded that hemothorax blood causes coagulopathy due to increases in tissue factor and cell-derived microparticles.[7] The preponderance of existing data suggests that when hemothorax blood is utilized, careful monitoring of coagulation parameters is indicated, and the practice remains controversial.

Table III. Hematology profile of pleural blood compared to venous blood.

Parameter	Pleural blood (SD)	Venous blood (SD)	*P* value
Hematocrit (%)	26.4 (9.5)	33.9 (8.4)	.003*
Hemoglobin (g/dL)	9.2 (3.1)	11.7 (2.9)	.004*
Platelet (K/μL)	53.0 (40.9)	174.4 (81.7)	<.001*
WBC (K/μL)	9.8 (7.3)	11.0 (4.7)	.47*

SD = standard deviation.
*Signed rank test.

Table IV. Coagulation profile of pleural blood compared to venous blood.

Parameter	Pleural blood (median)	Venous blood (SD) (median)	*P* value
INR	>9	1.1	<.001*
aPTT (s)	>180	28.5	<.001*
Fibrinogen (mg/dL)	<50	288	<.001*
D-dimer (ng/mL)	>7,360†	—	—
Factor V (% of normal)	<5†	—	—
Factor VIII (% of normal)	64.7 (42.1)	—	—
Thrombin time	>120	—	—

SD = standard deviation.
*Wilcoxon Test.
†Twenty-one of 22 subjects had immeasurably high D-dimer, and the only subject with measurable D-dimer had a concentration of 3,584 ng/mL.

CONCLUSIONS

Massive transfusion is a key element of damage control resuscitation. Autotransfusion can substantially reduce the quantity of blood products required safely and effectively, especially when the products are washed. Unwashed whole blood from hemothorax has also been shown to reduce the need for allogeneic transfusion but may cause significant coagulopathy Cell saver transfusion should be considered in all trauma patients at risk for major hemorrhage.

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ARTIFICIAL INTELLIGENCE, MACHINE LEARNING, AND THE ACUTE CARE SURGEON

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Since the very beginning, machines have been changing the way we work. From the looms and steam engines of the Industrial Revolution to the computers and robots of today, technology has always forced us to adapt and learn new skills. Now, a new wave of change is upon us: Artificial Intelligence (AI). This powerful technology is already starting to impact many fields, and surgery is no different. AI can be described as the development of intelligent machines capable of performing tasks commonly associated with human intelligence. This includes tasks like problem-solving, learning, reasoning, and decision-making. AI algorithms can process and analyze vast amounts of data, allowing them to identify patterns, make predictions, and even learn to perform new tasks on their own.

Just like the machines that came before it, AI has the potential to significantly change the way we work in the operating room. But with any major change comes questions and concerns. How will AI affect the role of surgeons? What about patient safety? And will AI ultimately make surgery better or worse?

To answer these questions and understand how AI will shape the future of surgery, we need to look at the latest research and discussions happening right now. By exploring the potential benefits and risks of AI in surgery, we can start to prepare for the transformative changes that lie ahead.

WHAT IS AI?

Simply put, AI refers to the development of intelligent machines capable of performing tasks typically requiring human intelligence. This includes activities like learning, reasoning, problem-solving, decision-making, and even creative thinking. While the idea of intelligent machines has captivated our imaginations for centuries, advancements in computing power, data availability, and algorithms have finally made it a reality. AI encompasses a vast range of technologies and techniques, **Figure 1**, each with its own unique capabilities. Some of the most prominent subfields of AI include:

1. Machine Learning: This branch of AI focuses on training algorithms to learn from data without explicit programming. Machine learning algorithms are able to identify patterns, make predictions, and adapt their behavior based on new information.
2. Deep Learning: This subfield utilizes artificial neural networks, inspired by the structure and function of the human brain, to process information and learn from data. Deep learning algorithms have achieved remarkable results in areas like image recognition, natural language processing, and speech recognition.
3. Natural Language Processing (NLP): This technology aims to enable computers to understand and generate human language. NLP applications include machine translation, chatbots, sentiment analysis, and text summarization.

4. Robotics: More than just helpful machines, these are intelligent agents capable of learning, adapting, and working alongside us without direct human control.

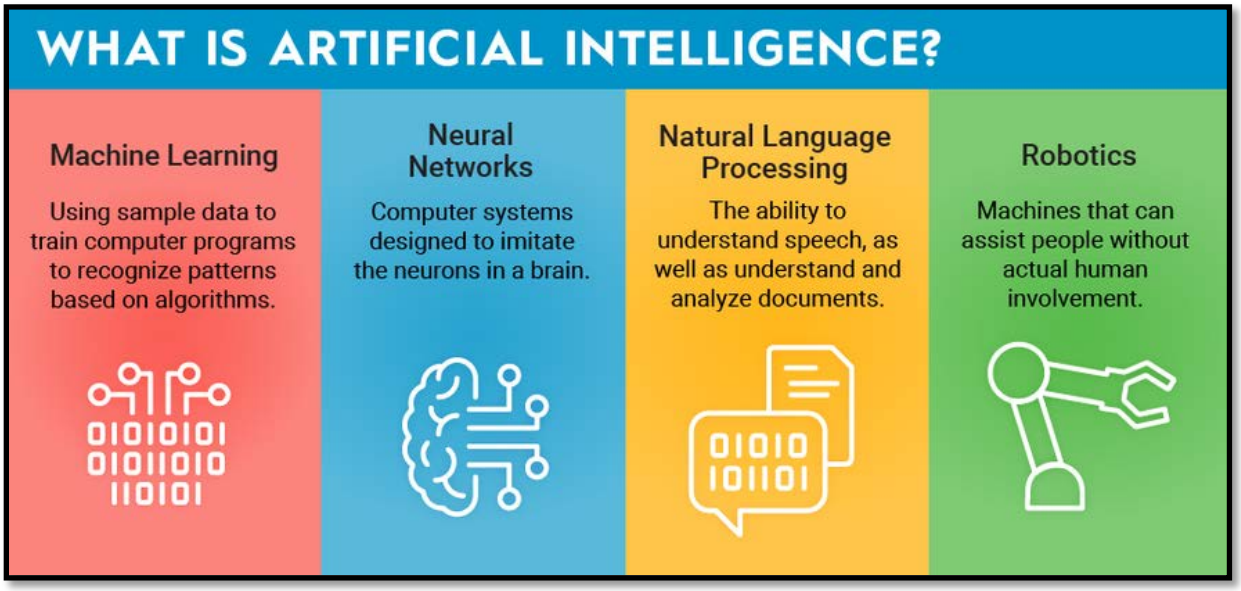

Figure 1. AI subtypes. Source: https://www.fool.com/terms/a/artificial-intelligence/

AI systems generally work by being trained on large amounts of data, learning from patterns within that data, and then using that knowledge to make decisions or predictions when presented with new, unseen data. The quality of the data, the algorithms used, and the computing power available are crucial factors in how well an AI system performs.

AI TO PREDICT COMPLICATIONS

While traditional surgical risk assessment tools like ACS-SRC, ASA score, and POSSUM have been valuable, they possess limitations that weaken their predictive power. These tools rely on statistical models that may overestimate or underestimate risks due to their focus on statistically significant variables, potentially neglecting subtle but important factors. Additionally, they often assume linear relationships between variables and outcomes, ignoring complex interactions, especially at variable range extremes. Furthermore, limitations like overfitting and multicollinearity in regression analyses restrict the examination of a large number of variables, leading to models that exclude potentially important modulators of outcomes. Therefore, current models are often limited in scope and may not capture the full picture of surgical risk. **Figure 2**. Linear vs nonlinear models. (A) Linear models assume that variables interact in a linear and additive manner and therefore over- or underestimate risks at the extreme ranges of variables. (B) Nonlinear models assume that the interaction of patient demographics, comorbidities, and surgical factors is far from linear and that certain variables gain or lose relevance as a function of the presence or absence of other variables, better representing the interaction of risk factors in real life.[1,2]

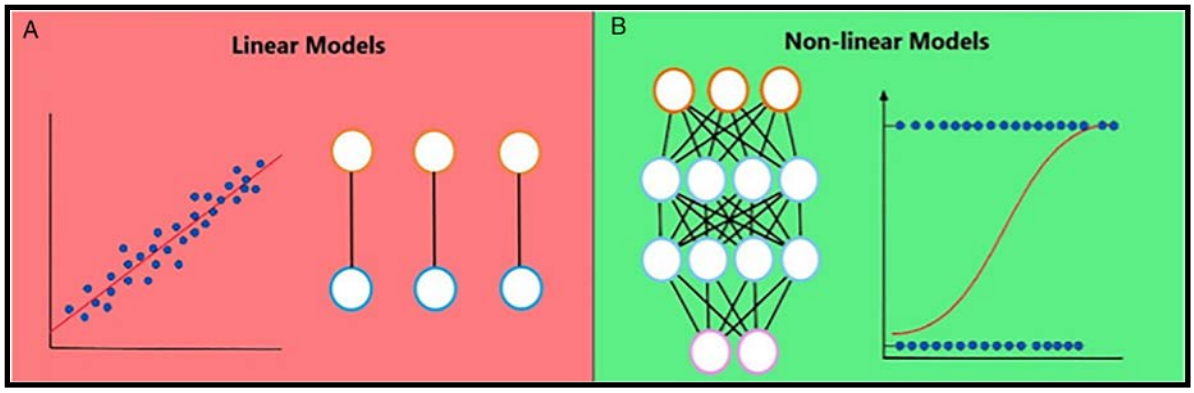

Figure 2. Linear vs Non-linear models of assessment. Source: *Hassan, Abbas M., et. al. "Artificial intelligence and machine learning in prediction of surgical complications: Current state, applications, and implications." The American Surgeon 89.1 (2023): 25-30.*

Merath et al. developed a machine learning model to predict complications in patients undergoing hepatic, pancreatic, and colorectal surgery. Utilizing the extensive National Surgical Quality Improvement Program (NSQIP) database, the model was trained on a large dataset of 15,657 patients. This robust training process resulted in impressive performance, with area under the curve (AUC) values ranging from 0.76 for predicting surgical site infections to a remarkable 0.98 for predicting stroke. Notably, the researchers demonstrated that their model significantly surpassed the predictive capabilities of traditional methods like the ASA and ACS-SRC scores, highlighting the potential of machine learning to revolutionize surgical risk assessment.[3]

In 2022, Hassan et al. leveraged machine learning to predict surgical complications in 725 patients. They developed an ensemble of nine supervised machine learning models that combined their predictions through a majority rule voting system to achieve superior accuracy. This model successfully predicted long-term complications like hernia recurrence (accuracy: 85%, AUC: 0.71) and short-term complications like surgical site occurrences and 30-day readmission (accuracy: 72-84%, AUC: 0.73-0.75) even after a long follow-up period (average 3 years). Notably, the model revealed previously hidden factors associated with poor outcomes, including surgical techniques, prior abdominal surgeries, and wound contamination levels, which traditional statistical approaches like logistic regression missed. Compared to logistic regression, which identified only five predictors of surgical site occurrences, the machine learning model identified 12, highlighting its superior ability to uncover subtle yet important risk factors. This enhanced understanding of risk factors can significantly improve surgical planning, preoperative optimization, and patient decision-making, ultimately leading to better surgical outcomes.[4]

Researchers have developed a machine learning model capable of predicting the risk of post-pancreatectomy pancreatic fistula (CR-POPF) based solely on pre-operative patient information. The model, developed by Ganjouei et al., was trained and validated using four different machine learning algorithms: logistic regression, neural network, random forest, and XGBoost. Of these, XGBoost emerged as the best performing, achieving an impressive area under the curve (AUC) of 0.72.[5] In addition to predicting CR-POPF risk, the model also demonstrated good performance for predicting 30-day mortality, discharge to a facility, and overall and significant complications, with AUC ranging from 0.62 to 0.78. This comprehensive functionality makes the model a valuable tool for clinicians in the pre-operative setting. By identifying patients at high risk for CR-POPF, the model can guide clinical decision-making, allowing surgeons to tailor their surgical approach and optimize peri-operative management. Additionally, the model can be used to provide patients with personalized risk estimates, facilitating informed decision-making and shared understanding of potential complications.

Dorken-Gallastegi et al. employed a novel artificial intelligence (AI) technique called optimal classification trees (OCTs) to transcend the limitations of traditional linear benchmarks and provide a more comprehensive assessment of emergency surgical care quality.[6] This approach moved beyond simply comparing observed and expected mortality rates, delving deeper to identify specific patient phenotypes associated with both superior and suboptimal outcomes. Utilizing a dataset of over 637,000 patients from the American College of Surgeons National Surgical Quality Improvement Program as a benchmark, the researchers initially compared the observed mortality rate in their hospital's emergency surgery to the AI-calculated risk-adjusted expected mortality rate. This initial comparison, revealing statistically comparable rates, served as a solid foundation for further exploration. The power of OCTs then came into play as the researchers interrogated the AI model to identify distinct patient subgroups (nodes) defined by pre-operative characteristics. This iterative process allowed for focused comparisons within these nodes, pinpointing specific areas where the hospital's care either excelled or fell below the national benchmark. This granular analysis yielded two distinct areas of excellence. Patients older than 75 with pre-operative respiratory failure and septic shock, a traditionally high-risk group, demonstrated lower-than-expected mortality rates when treated in the study hospital. Similarly, patients presenting with diagnoses like appendicitis and perforated ulcers achieved better-than-expected outcomes. However, the AI-powered approach also revealed four areas for improvement. Patients with pre-operative respiratory failure and thrombocytopenia, along with those with elevated international normalized ratios, exhibited higher-than-expected mortality rates. Additionally, specific combinations of diagnoses, beyond single pre-operative factors, were identified as areas requiring targeted interventions.

By applying this novel AI-powered methodology, Dorken-Gallastegi et al. were able to move beyond the limitations of traditional benchmarking and identify specific patient phenotypes associated with both exceptional and suboptimal outcomes. This granular approach, providing actionable insights for targeted interventions and quality improvement efforts, has the potential to significantly improve patient care in emergency surgical settings.

AI AND IMAGING

One of the first medical fields AI was introduced to was imaging. In a recent study by Levy et al., they used neural network architecture models to interpret focused assessment with sonography in trauma (FAST) examination of abdomen. With a total of almost 7000 images the models showed 89% accuracy, 83% sensitivity, and 94% specificity, and in positive only images the models' output improved to 98% accuracy, 90% sensitivity, and 100% specificity.[7]

Beyond enhancing image interpretation, AI's potential extends to streamlining healthcare workflows, further boosting efficiency. Jalal et al. studied the role of AI in enhancing the workflow of trauma radiology department by reviewing what is already happening what can be integrated into it.[8] When we look at **Figure 3**, step 1: order entry for imaging studies optimized by AI through checking if the order meets the indication and suggesting an order if missed by the physician. Step 2: image protocolling streamlined by AI which can save time and reduce error rates. Step 3: Image acquisition supported by AI. Research by Padole et al. revealed that certain algorithms have the potential to significantly improve the quality of CT images while reducing the needed radiation dose.[9] Step 4: AI-supported image post-processing, Emergency radiologists can utilize post-processing algorithms to create virtual non-contrast images from existing contrast-enhanced scans, expanding their diagnostic capabilities.[8] Step 5: decision support provided by AI; Radiologist would read imaging studies flagged by a diagnostic AI algorithm before reading other imaging studies, this may reduce the delay in diagnosing acute patients who need immediate attention.[8] Step 6: clinical decision support provided by AI integration; machine learning models have been developed that analyze data from multiple clinical monitors to trigger alarms more accurately. These models achieved impressive results, reducing false alarms by 80%.[10]

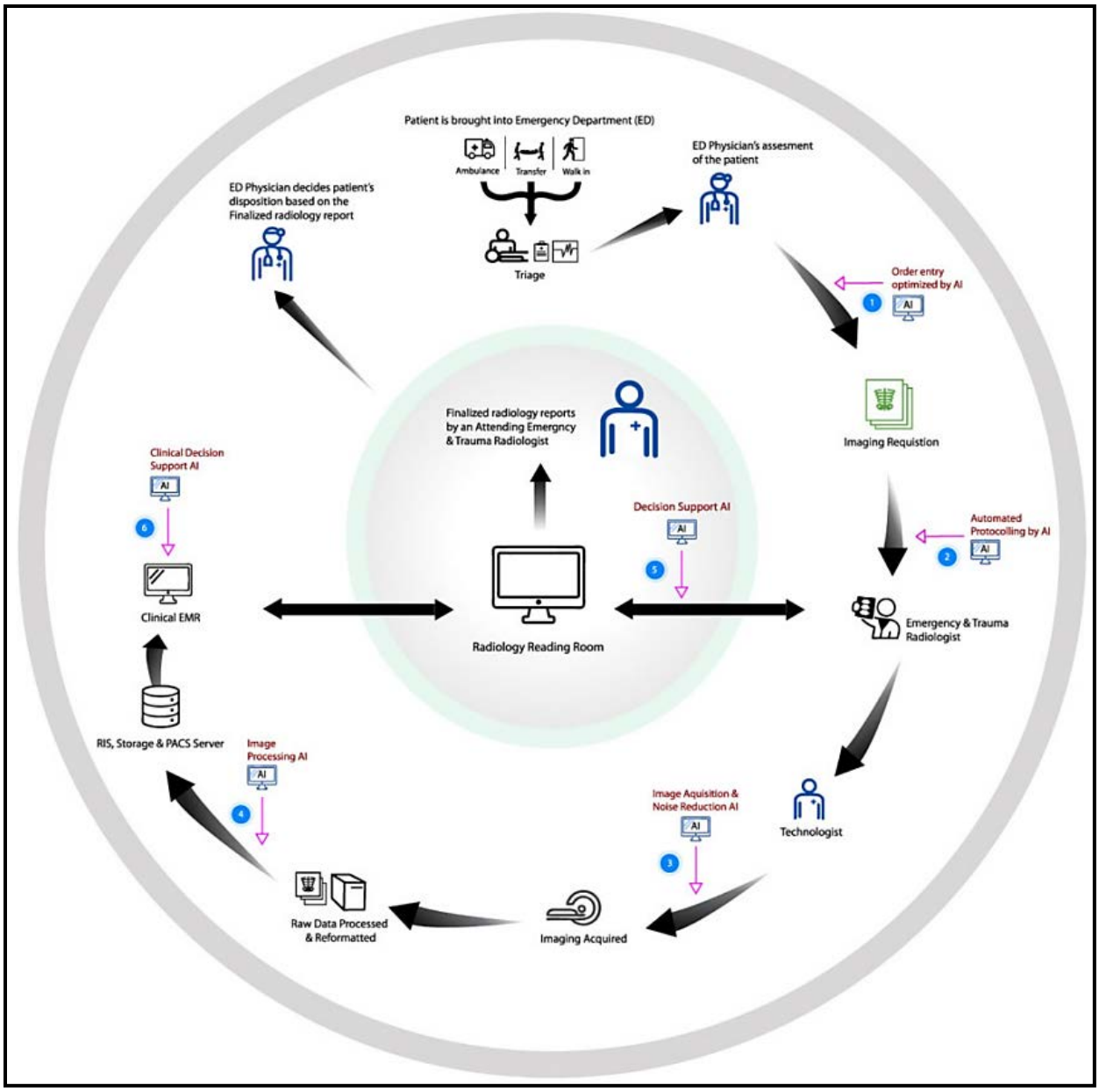

Figure 3. Showing the imaging pathway and the 6 stages AI can be integrated into.

EDUCATION

As surgical procedures become increasingly intricate, the need for high-quality education and training has become paramount. The emergence of AI is believed to revolutionize both the practice of surgery and surgical education. With the growing accessibility of this technology, educators and training programs are actively seeking ways to integrate AI into their curriculum to enhance the skills and preparedness of future surgeons. This will ultimately lead to a new generation of highly skilled surgeons equipped with the cutting-edge tools and knowledge to excel in the ever-evolving field of surgery.[11,12,13]

In a recent study, researchers led by Fard et al. explored the potential of AI-powered assessment in robotic surgery training. They monitored eight key movement features of surgeons performing two minimally invasive surgery tasks using the da Vinci robot. Analyzing kinematic data from both hands during knot tying and suturing, they classified surgeons into two skill levels: novice and expert. The researchers used quantitative metrics like turning angle, curvature, tortuosity, and task completion time to train three machine learning algorithms (k-nearest neighbor, logistic regression, and support vector machine) for classification. These algorithms then automatically predicted the skill level of surgeons with impressive accuracy: 82% for knot tying and 90% for suturing.[14]

The Virtual Operative Assistant (VOA) exemplifies how AI and machine learning are revolutionizing surgical training by offering automated educational feedback. In a study simulating a subpial brain tumor resection within the NeuroVR virtual reality platform, the VOA successfully classified participants into skilled and novice surgeons based on just four key metrics. The skilled group comprised experienced professionals, including staff neurosurgeons, fellows, and senior residents, while the novice group included junior residents and medical students. With an impressive accuracy of 92%, specificity of 82%, and perfect sensitivity of 100%, the VOA accurately assessed participants' skill levels. Thirty-one users received immediate, objective feedback on their performance across two stages. First, the machine learning algorithm classified them as "novice" or "skilled," followed by personalized feedback on specific metrics related to safety and instrument handling. This approach demonstrates the VOA's potential to provide valuable insights for trainees, allowing them to identify areas for improvement and accelerate their learning journey.[15]

Using AI and ML in training surgeons is not only more accurate due to the real-time feedback but also cost-effective. Researchers led by Lohre et al. conducted a randomized clinical trial comparing the effectiveness and cost-efficiency of two surgical training methods: immersive virtual reality (VR) simulations and traditional instructional videos. The study focused on training senior orthopedic residents (PGY 4 and 5) in performing reverse shoulder arthroplasty (RSA) on cadavers. The results were impressive: VR training not only significantly reduced learning time compared to videos but also led to superior surgical performance. Residents trained using VR achieved significant reduction in learning time by completing the training module up to 34 times faster than those using videos, demonstrating significantly faster acquisition of surgical skills. Also, they had higher Objective Structured Assessment of Technical Skills (OSATS) scores that indicates greater technical skill and proficiency in performing RSA.[16]

Although how lucrative AI in education sounds, it is not without limitations. One key obstacle is the limited experience and research on AI-powered training methods. A paucity of peer-reviewed randomized controlled studies exists, making it difficult to assess the effectiveness of AI compared to traditional approaches. This lack of robust evidence hinders widespread adoption and creates uncertainty regarding its true impact on surgical skill development. Furthermore, the current state of AI integration in surgical education tools suffers from a lack of standardization. With various platforms emerging and evolving independently, there is no established framework for ensuring consistency and quality across different systems. This inconsistency can lead to confusion and hinder the seamless integration of AI into existing training curricula.

AI IN THE OPERATING ROOM

Despite significant individual variations in skill, surgeons' technical abilities have a profound impact on patient outcomes.[17] However, technical errors are not the sole contributor to surgical complications. Diagnostic and judgment errors also play a crucial role, leading to a significant proportion of adverse events. Studies have identified lapses in judgment, memory failures, and visual illusions as common sources of error during surgery. Time pressure and uncertainty further exacerbate the issue, forcing surgeons to rely on cognitive shortcuts that can lead to poor decision-making.[18,19,20]

If we look at minimally invasive surgery (MIS) for example, AI has the potential to revolutionize MIS and improve patient safety by mitigating human errors. Firstly, MIS relies heavily on visual information for both the procedure itself and intraoperative decision-making. Advancements in AI-powered image recognition can significantly reduce the burden on surgeons by providing real-time guidance and assistance. Secondly, the vast amount of surgical video data available from MIS procedures can be utilized to train machine learning algorithms, enabling AI to learn from the experience of expert surgeons. Finally, AI-based image navigation can be invaluable for procedures requiring meticulous attention to fine anatomical structures, further enhancing surgical skill and precision. For instance, AI-based dynamic ultrasonography for training and education, demonstrating its broader potential. ScanNav in **Figure 4**, an AI technology incorporated into certain ultrasound machines by Intelligent Ultrasound (UK), utilizes color coding to guide users in identifying the appropriate anatomy for injection.[21] This could be the future of surgery, an AI system alerts the surgeon not to cut in this place as it identified a significant structure not noticed by the eye of human being.

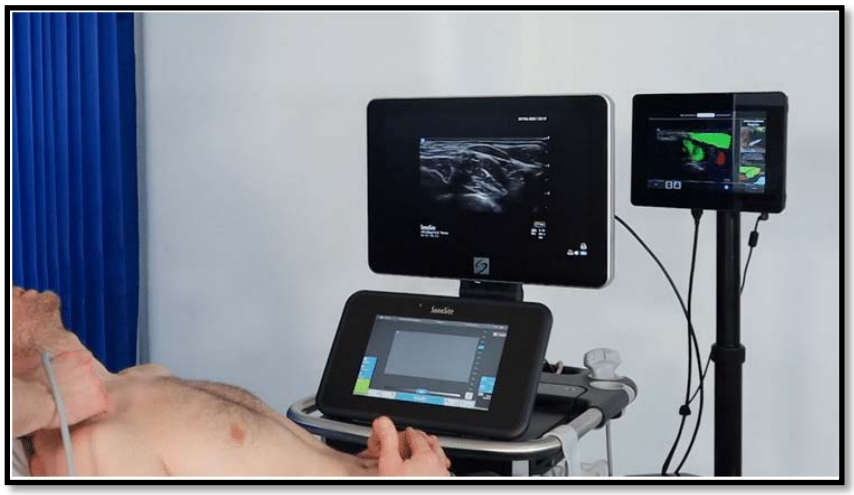

Figure 4. ScanNav. Source: https://www.intelligentultrasound.com/2021/05/04/scannav-anatomy-peripheral-nerve-block-uk-launch-event/

Another aspect of AI in the OR is knot tying. While knot tying is a fundamental and relatively quick skill in open surgery, it can take significantly longer in minimally invasive procedures. In laparoscopic surgery, completing a single knot can take up to three minutes. Recognizing this challenge, Mayer et al. developed a system utilizing recurrent neural networks (RNNs) to accelerate knot tying in robotic heart surgery.[22] Their approach involved presenting the network with a sequence of human-performed knot tying examples. An RNN with long-term memory capabilities then learned the task and applied its knowledge to autonomously complete the knot. Compared to a pre-programmed controller that finished the knot in 33.7 seconds, the RNN achieved a remarkable 25% speed improvement after learning from just 50 previous attempts, tying the knot in 25.8 seconds. This innovative application of AI demonstrates its potential to streamline minimally invasive surgery by automating repetitive tasks like knot tying, allowing surgeons to focus on more complex aspects of the procedure.

An exciting frontier for AI in the OR is endoscopic guidance. Weede et al. developed an autonomous endoscopic guidance system powered by machine learning.[23] This system analyzes recorded videos of surgical procedures to collect and process data on the movements of surgical instruments. Utilizing trajectory clustering, maximum likelihood classification, and hidden Markov models (HMMs), the system then predicts future instrument trajectories and uses this information to guide the endoscope in real-

time. This innovative approach demonstrated impressive accuracy, achieving a hit rate of over 89% in predicting instrument movement. This translated to a 29.2% reduction in camera movements, leading to improved visibility for the surgeon and potentially enhanced surgical precision. Such advancements showcase the potential of AI to revolutionize minimally invasive surgery by automating tedious tasks and providing valuable real-time guidance to surgeons, ultimately improving surgical efficiency and patient outcomes.

FUTURE OF SURGERY

Kitaguchi et al. looked at the recent advances and future perspectives in AL-Based surgery.[24] Looking at **Figure 5**, they mentioned that Similar to the evolution of autonomous driving technology in automobiles, the future of surgery is poised to move beyond image navigation and towards fully autonomous surgery. While AI-powered image recognition is undoubtedly a critical foundation for achieving autonomous surgery, it represents only the first step. In the automotive analogy, level 1 autonomy signifies that the driver is still in control, with assistive features like lane departure warning or adaptive cruise control being available. Similarly, current AI-based image navigation and robot-assisted surgery still fall under this basic level of autonomy. For surgery to reach the next level, AI must achieve real-time and robust accuracy in analyzing and interpreting surgical steps, anatomy, instruments, and other crucial aspects in every situation. This necessitates a significantly higher level of autonomy than what is currently available. Replacing the functions of the surgical assistant and scopist, who provide invaluable support during operations, is expected to be the next major challenge in the field of AI in surgery. This would represent a significant leap forward in surgical autonomy, paving the way for a future where AI plays a more central role in operating rooms.

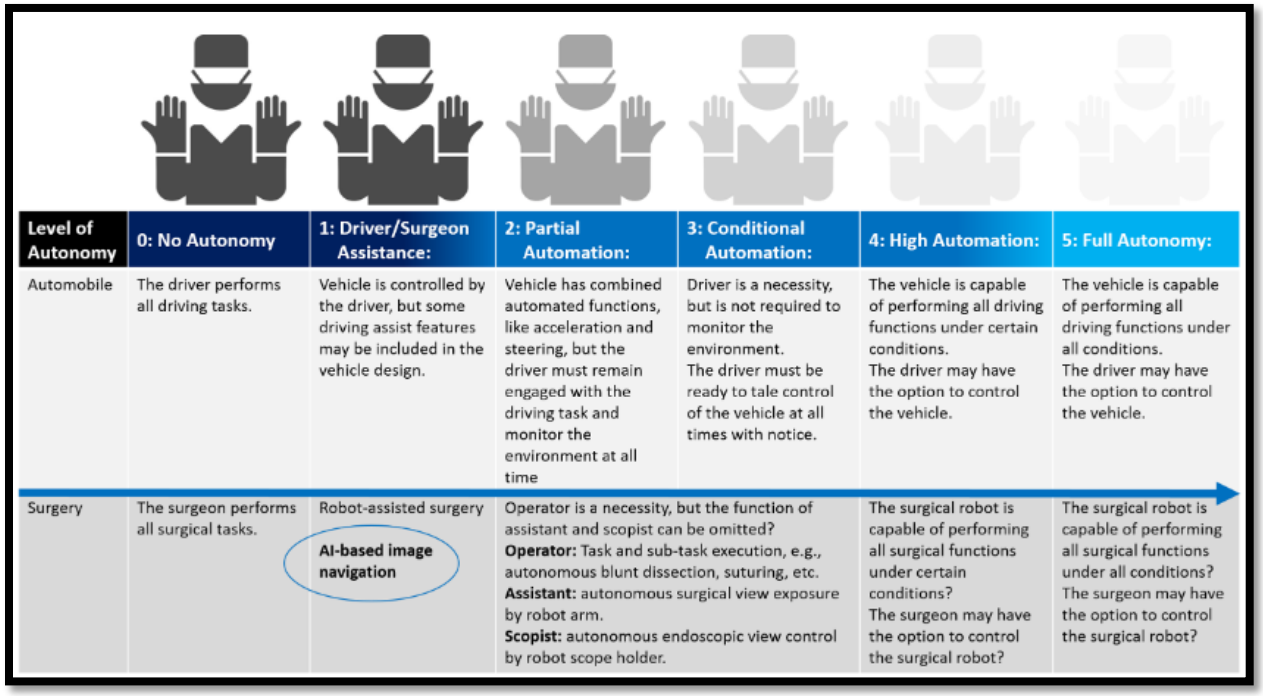

Figure 5. The way to AI full autonomy in surgery. Source: *Kitaguchi, Daichi, et al. "Artificial intelligence-based computer vision in surgery: Recent advances and future perspectives." Annals of gastroenterological surgery 6.1 (2022): 29-36.*

ETHICAL CONSIDERATIONS

There are dilemmas that surround using AI and ML in surgical care, and although it may seem that the patients are the main subjects at risk, there are also risks that threaten the providers. Currently, AI programs work to aid and augment provider's decisions.[25,26,27] However, in the future when programs provide real-time surgical decisions in the operating room, a crucial question arises, should the surgeon or the ML tool developer be held accountable? In case the surgeon decides to go against a recommendation made by an AI tool, how should a surgeon document their decision and rationale? This ambiguity concerning legal liability necessitates clear guidelines and regulations to ensure patient safety and establish accountability.

The foundation of a reliable and powerful AI tool lies in the quality of the data it's trained on. A comprehensive and high-quality dataset is crucial for the AI to learn and develop accurate predictions. If data collection practices aren't carefully designed and balanced, datasets can become biased on factors like race, gender, or socioeconomic status. This can perpetuate or even amplify existing inequalities, even if unintentional. Researchers and providers must constantly be on the lookout for biases creeping into their data. This means regularly reviewing and updating datasets to ensure they are diverse and representative of the population they serve.[28]

These considerations and more were discussed in the literature. Kohli et al. raised some ethical issues in AI use.[29] Integrating AI into healthcare should not come at the expense of the collaborative approach to decision-making essential for optimal patient care. Healthcare providers leveraging this technology must critically evaluate the potential biases inherent in its data sets to ensure they don't undermine the shared decision-making process with patients.

LIMITATIONS

While AI offers tremendous potential for revolutionizing surgery, it's crucial to acknowledge its limitations and potential disadvantages. Firstly, its dependence on human oversight and intervention. AI systems currently lack the critical thinking and decision-making capabilities necessary for fully autonomous surgery. They still require human oversight and intervention, making surgeons ultimately responsible for outcomes. Overreliance on AI could lead to complacency and decreased vigilance, potentially increasing the risk of errors. Also, cost and accessibility, implementing and maintaining advanced AI systems in the healthcare sector can be expensive, potentially limiting access to this technology for smaller hospitals and underserved communities. Ethical considerations arise regarding fair access to AI-driven surgical care, ensuring equitable distribution of benefits and minimizing potential disparities. Another aspect is cybersecurity and data privacy, AI systems reliant on vast amounts of patient data raise concerns about cybersecurity vulnerabilities and potential breaches of data privacy. Robust security measures and ethical data handling practices are essential and maintaining patient trust and transparency regarding data usage and control is crucial for ethical AI implementation in healthcare.

CONCLUSION

While AI holds immense potential for transforming surgery, it's important to acknowledge its limitations and potential drawbacks. Addressing these concerns through responsible development, ethical implementation, and ongoing research is crucial for ensuring that AI serves as a valuable tool to enhance surgical care and improve patient outcomes.

KEY TAKEAWAYS

- Enhanced prediction and risk assessment: AI models can analyze vast amounts of data to predict surgical complications and personalize care. Studies demonstrated impressive accuracy in predicting surgical site infections, stroke, and long-term mortality, surpassing traditional methods like ACS-SRC and ASA scores.
- Revolutionizing surgical workflow: AI-powered image interpretation streamlines imaging workflows, reduces errors, and enhances diagnosis. Applications include image acquisition optimization, trauma radiology support, and AI-assisted image post-processing.
- Transforming surgical training: AI-powered training tools like the Virtual Operative Assistant provide personalized feedback, accelerate skill acquisition, and reduce training costs. Studies show VR simulations significantly improve surgical skills compared to traditional video training.
- Augmenting surgical performance in the OR: AI assists surgeons in minimally invasive procedures by providing real-time guidance, mitigating human error, and automating repetitive tasks like knot tying. Endoscopic guidance systems powered by machine learning hold promise for improving visibility and surgical precision.

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SESSION 6

MEET THE MASTERS TCC & ACS – EXCITING OPPORTUNITIES

Moderator: Kenneth L. Mattox

Monday, April 15, 2024

5:30 – 6:30 PM
Palace Ballrooms 1-2
Palace Tower
Emperors Level – 4th Floor

- **Fellowship**
- **Practice Type: Community vs Academic**
- **Practice Models: Private vs Employment**
- **Boards: ACS vs Specialty**
- **GS + Specialty vs ACS + GS**
- **Audience Driven**

SESSION 7

CRITICAL TRAUMA / CRITICAL CARE TREATMENT

Moderator: Mark J. Kaplan

Tuesday, April 16, 2024

7:30 – 10:00 AM
Palace Ballrooms 1-2
Palace Tower
Emperors Level – 4th Floor

7:30 – 7:42	**Go BIG or Go Home: Implementing BIG Guidelines at Your Center** **Bellal A. Joseph, MD, FACS**
7:42 – 7:54	**Dry Land Drownings: Fluid Overuse in Sepsis Resuscitation** **Bryan A. Cotton, MD, MPH, FACS**
7:54 – 8:06	**Managing Severe Pulmonary Contusions** **Carlos V.R. Brown, MD, FACS**
8:06 – 8:18	**Trach or Wait? Early vs. Late Tracheostomy in the Trauma ICU** **Jayson Aydelotte, MD, FACS**
8:18 – 8:30	**Failing Kidneys: Renal Replacement Therapies in the ICU** **Purvi P. Patel, MD, FACS**
8:30 – 8:42	**Chill Out: Delirium & Sedation in the Critically Ill Acute Care Surgery Patient** **Andrew C. Bernard, MD, FACS**
8:42 – 8:54	**Updates in TBI Management: Brain Oxygenation, MMA Embolization, and New Protocols** **Tanya Egodage, MD, FACS**
8:54 – 9:06	**ICU Nutrition: Stuff Em' or Starve Em'!** **Andre' R. Campbell, MD, FACS**
9:06 – 9:18	**Ethical Challenges in the ICU** **Jay J. Doucet, MD, FACS**
9:18 – 9:30	**Double Jeopardy - BIlling for ICU Consults** **Jason W. Smith, MD, PhD, MBA, FACS**
9:30 – 10:00	**Panel Discussion**
10:00 – 10:30	**Break/Visit Exhibits** **Palace Ballroom 3, Palace Tower** **Emperors Level – 4th Floor**

GO BIG OR GO HOME: IMPLEMENTING BRAIN INJURY GUIDELINES AT YOUR CENTER

Bellal A. Joseph, MD, FACS

Martin Gluck Professor of Surgery
Chief of Trauma, Critical Care, Burns & Emergency Surgery
University of Arizona
Tucson, AZ

THE BURDEN OF TRAUMATIC BRAIN INJURY

Traumatic brain injury (TBI) is one of the leading causes of death and disability in the United States (US). According to recent statistics from the Centers for Disease Control and Prevention (CDC), there were approximately 214,110 TBI-related hospitalizations in 2020 and 70,208 TBI-related deaths in 2022 (**Figure 1)**. This corresponds to nearly 586 TBI-related hospitalizations and 192 TBI-related deaths per day.[1] These estimates do not include the many TBIs that are only treated in the emergency department, primary care, urgent care, or those that go untreated. It is important to note that over a third of TBI-related hospitalizations and deaths occur in older adults aged 75 and above. TBI is associated with a huge financial burden.[1] In a study using the IBM MarketScan Research Databases, Miller et al. reported that in 2016 alone, the total estimated annual healthcare spending attributable to nonfatal TBI among Medicaid, Medicare, and private insurance patients was more than $40.6 billion.[2] With TBI being a major public health burden, it is crucial to encourage efforts to reduce the unnecessary burden of interventions and healthcare expenditure both for patients and the healthcare system as a whole.

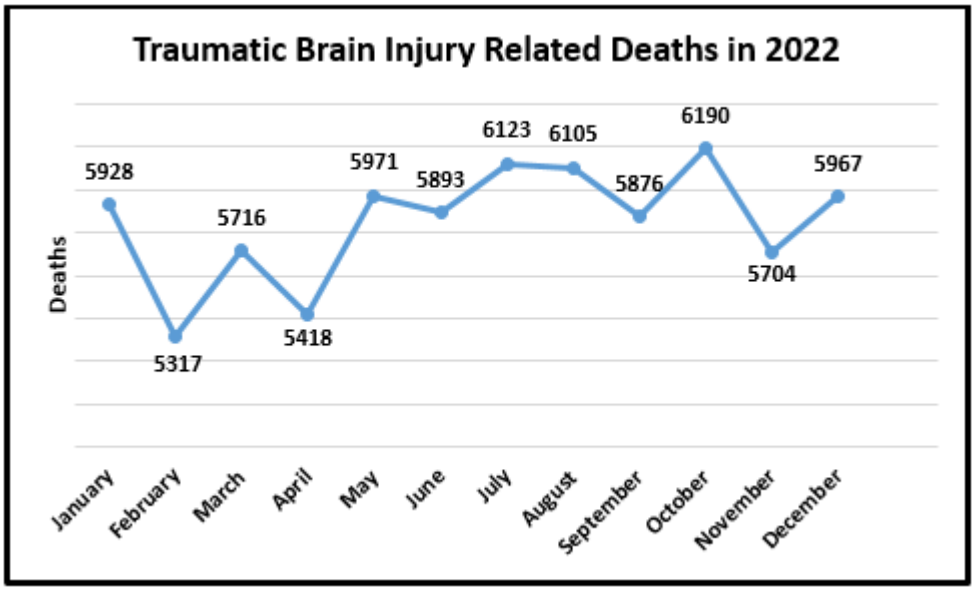

Figure 1. TBI related deaths in the US in 2022

THE NEED FOR EVIDENCE-BASED GUIDELINES

Not All ICH Need Neurosurgery

Traditionally, all traumatic brain injury patients with intracranial hemorrhage on initial head computed tomography (CT) scanning would undergo default neurosurgical consultation, repeat head CT, and transfer to a higher level of care. This resulted in reflex healthcare resource utilization, even for patients with mild traumatic brain injuries. However, not all traumatic brain injuries require neurosurgical intervention. Esposito et al. analyzed the National Trauma Data Bank (NTDB) for the years 1994 – 2003 and reported that 96.4% of the patients with TBI were managed non-operatively.[3] With most TBI patients being managed non-operatively, there remained a question of the need for routine neurosurgical consultation and repeat imaging.

Shortage of Neurosurgeons

Moreover, the availability of neurosurgeons is a huge limiting factor that affects the care of TBI patients. According to estimates from the American College of Surgeons, as of 2011, 25% of the US population was living in a county without a neurosurgeon, and 3,689 neurosurgeons are serving a population of 318 million; this contrasts with the high incidence of TBI, creating a scenario with high demand and limited resources. A 2021 study by Rahman et al. also demonstrated that there are significant socioeconomic and geographic disparities in access to neurosurgeons and that as of 2016, the median number of neurosurgeons per 100,000 population was 1.47.[4] Peterman et al. performed a geospatial analysis using the Medicare billing and demographic data, National Provider Identifier (NPI) registry data, and US census data to identify the average travel distance to reach a neurosurgeon. The authors identified that 2,160 counties in the US did not have a practicing neurosurgeon **(Figure 2)**.[5] Moreover, 60% of the neurosurgeons have been in practice for more than 20 years, thus retirement of these senior neurosurgeons will further impede the neurosurgery workforce. Farivar et al. identified actively practicing pediatric neurosurgeons by matching several registries and membership logs and reported that the average person in a surgeon desert and cluster was found to be 189.2 miles and 39.7 miles away from the nearest pediatric neurosurgeon, respectively.[6]

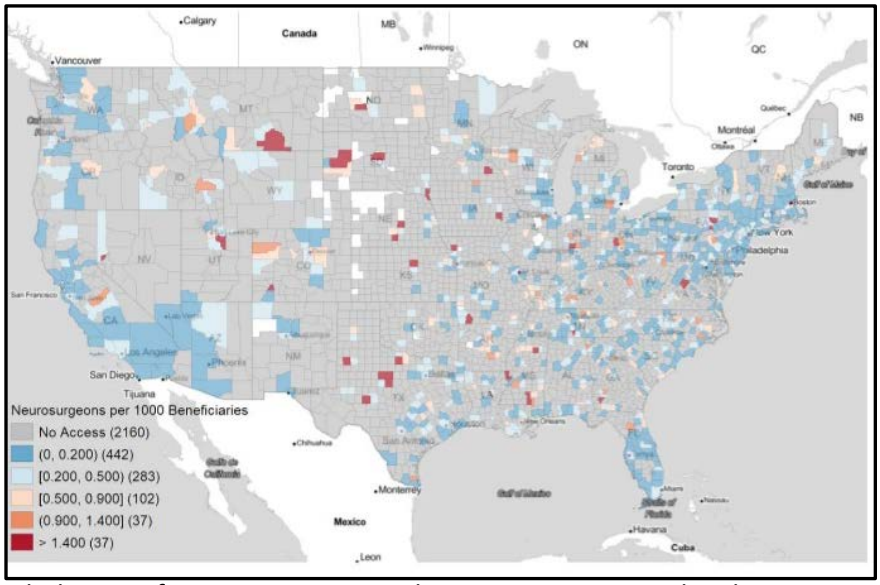

Figure 2. Choropleth map of neurosurgeon prevalence. Neurosurgeon distribution is represented by the number of neurosurgeons per 1000 Medicare beneficiaries, calculated at the county level for 3061 counties. Gray denotes counties without neurosurgeons and white denotes counties without sufficient information. (Peterman et al., 2022).

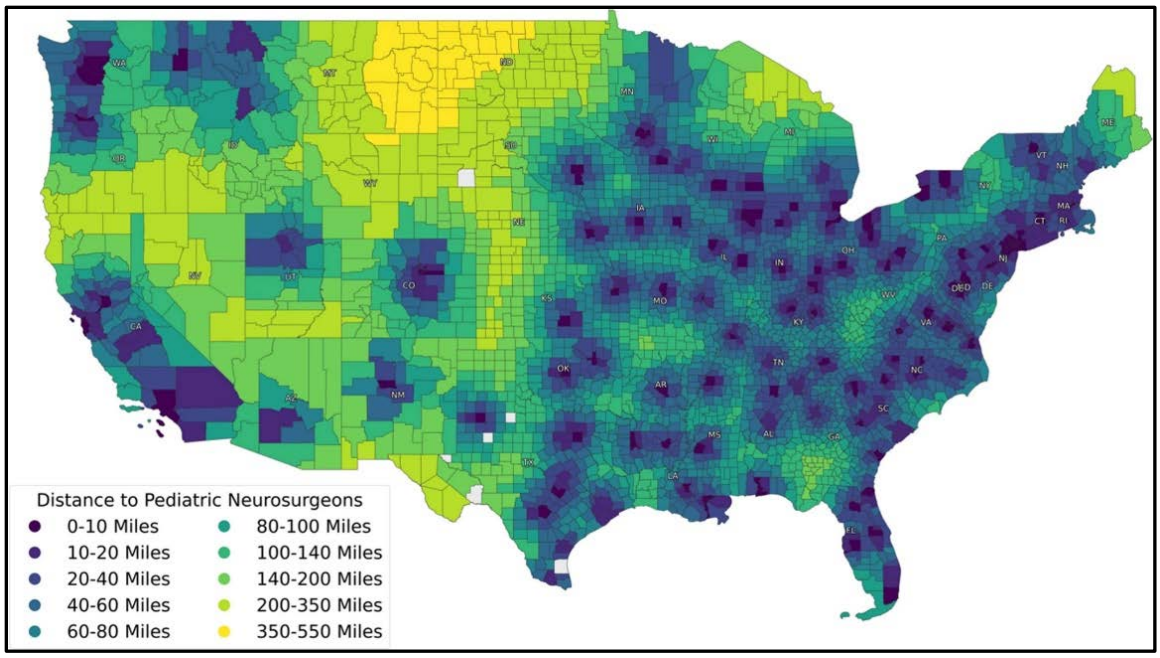

Figure 3. The average distance in miles from any point in a county to the nearest pediatric neurosurgeon displayed on a by-county level. (Fariar et al. 2023).

The Role of Acute Care Surgeons

With the advancements in the quality of care of the trauma patient, the non-operative management of the injured patient emerged as a safe possibility. Ditty et al. performed a retrospective review of 500 patients with mild TBI and subarachnoid hemorrhage (SAH) and/or intraparenchymal hemorrhage (IPH) admitted to a level I trauma center in Alabama between May 2003 and May 2013, and concluded that patients with SAH and/or IPH and mild TBI do not require neurosurgical consultation, and that solely these criteria were not enough to justify transfer to tertiary referral centers.[7] Zhao et al. performed a retrospective review of patients with isolated nonoperative mild head injuries with Glasgow Coma Scale score of 13 – 15 admitted on a weekly rotational basis to trauma surgery, neurosurgery, and neurology, and found that patients managed by the trauma team had significantly lower rates of repeat CT imaging compared to those managed by neurosurgeons and neurologists.[8]

Multiple studies have revealed that there is no difference in outcomes of non-operatively managed TBI patients managed by trauma surgeons compared to those managed by neurosurgeons. Hewitt et al. analyzed 14 retrospective observational studies, with a total of 1,988 reported interventions from hospitals located in Australia, the USA, and other countries, and observed that the most common surgeries performed by the general surgeons for TBI patients were decompressive surgery with burr holes or craniectomy for head trauma, and insertion of intracranial pressure monitors. In addition, the most common setting was rural hospitals, with very heterogeneous mortality rates ranging from 5% for evacuation of chronic subdural hematoma in Kenya to 81% in head injuries in a Hong Kong study. The results from the review from Hewitt et al. show the heterogenous scenario for the treatment of TBI patients in a worldwide context[9], however, data from studies showing low mortality rates among patients treated by a general surgeon for a neurosurgical emergency give a glimpse of the feasibility of emergency neurosurgical procedures being carried out by non-specialists.

THE CONCEPTION OF BRAIN INJURY GUIDELINES

As the current standard of practice for the management of nonoperative TBI is variable and has not adapted to the new defined role of acute care surgeons, we developed guidelines for the management of TBI based on patient history, and clinical and radiologic findings.[10] The brain injury guidelines (BIG) consisted of three categories as follows: BIG 1, BIG 2, and BIG 3 (**Figure 3**). We reviewed 3,803 patient charts and then categorized each patient meeting inclusion criteria into one of the three BIG categories based on the patient's history (antiplatelet/ anticoagulation therapy, loss of consciousness, intoxication), physical examination (focal neurologic examination, pupillary examination, and GCS on admission), and CT scan findings (size and location of ICH and type of skull fracture). It is important to note that patients had to meet all the criteria for categorization into one of the three BIG categories. Failure to meet even one criterion (in BIG 1 or BIG 2) upgraded the patient to the BIG 3 category and altered the therapeutic management plan of the patient based on the BIG 3 category.

We defined a definitive therapeutic management plan for each category based on the requirements of hospitalization, the need for RHCT scan, and the need for NSC. The therapeutic plan for each category was developed after consensus among acute care surgeons and neurosurgeons at our institution based on the published literature defining the management of TBI. The proposed management for BIG 1 is a 6-hour period of observation in the emergency department, without the need for neurosurgical consultation or an RHCT scan. For BIG 2, the plan consisted in hospitalization of the injured patient, and for BIG 3, hospitalization, RHCT, and NSC were suggested.

Brain Injury Guidelines			
Variables	**BIG 1**	**BIG 2**	**BIG 3**
LOC	Yes/No	Yes/No	Yes/No
Neurologic examination	Normal	Normal	Abnormal
Intoxication	No	No/Yes	No/Yes
CAMP	No	No	Yes
Skull Fracture	No	Non-displaced	Displaced
SDH	$\leq$ 4mm	5 - 7 mm	$\geq$ 8 mm
EDH	$\leq$ 4mm	5 - 7 mm	$\geq$ 8 mm
IPH	$\leq$ 4mm, 1 location	3 – 7 mm, 2 locations	$\geq$ 8 mm, multiple locations
SAH	Trace	Localized	Scattered
IVH	No	No	Yes
THERAPEUTIC PLAN			
Hospitalization	No Observation (6hrs)	Yes	Yes
RHCT	No	No	Yes
NSC	No	No	Yes

BIG, brain injury guidelines; CAMP, Coumadin, Aspirin, Plavix; EDH, epidural hemorrhage; IVH, intraventricular hemorrhage; IPH, intraparenchymal hemorrhage; LOC, loss of consciousness; NSC, neurosurgical consultation; RHCT, repeat head computed tomography; SAH, subarachnoid hemorrhage; SDH, subdural hemorrhage

Figure 4. Brain Injury Guidelines

Of the 1,232 patients with positive head CT scan findings included in the initial study, 121 patients were classified as BIG 1, 313 under BIG 2, and 798 patients in the BIG 3 category. All patients categorized as BIG 1 and BIG 3 were consistent with the BIG. Nine patients categorized as BIG 2 were not in concordance with the established BIG 2. Out of these, 7 patients had no change in neurologic examination and failed because of progression on RHCT, whereas, the remaining two patients had worsening findings on clinical examination, resulting in an upgrade of the patient to BIG 3 classification. However, none of these 9 patients required neurosurgical interventions. We found an excellent agreement between the assigned BIG therapeutic plan and the actual therapeutic plan of the patients (κ = 0.98; 95% confidence interval, 0.97 – 0.99) (**Figure 5).**

	Verified Therapeutic Plan		
Guideline Therapeutic Plan	**BIG 1**	**BIG 2**	**BIG 3**
BIG 1	121	0	0
BIG 2	0	304	9
BIG 3	0	0	798
κ = 0.97; 95% confidence interval, 0.97 to 0.99			

Figure 5. Agreement between guideline and therapeutic plan

PROSPECTIVE VALIDATION OF BRAIN INJURY GUIDELINES

Since the BIG were developed by performing a retrospective chart review, prospective validation was necessary before widespread implementation. We implemented BIG in March 2012 at our level I trauma center.[11] On comparing BIG-1 patients managed without NSC compared to propensity matched patients who were managed with NSC before implementation of BIG, we found significant reduction in the rates of repeat head CTs, ICU and hospital admissions wth no difference in terms of progression on repeat head CT, neurosurgical interventions, and 30-day readmissions. Moreover, the simplicity of BIG made us achieve 100% compliance within 7 months of implementation (**Figure 6)**.

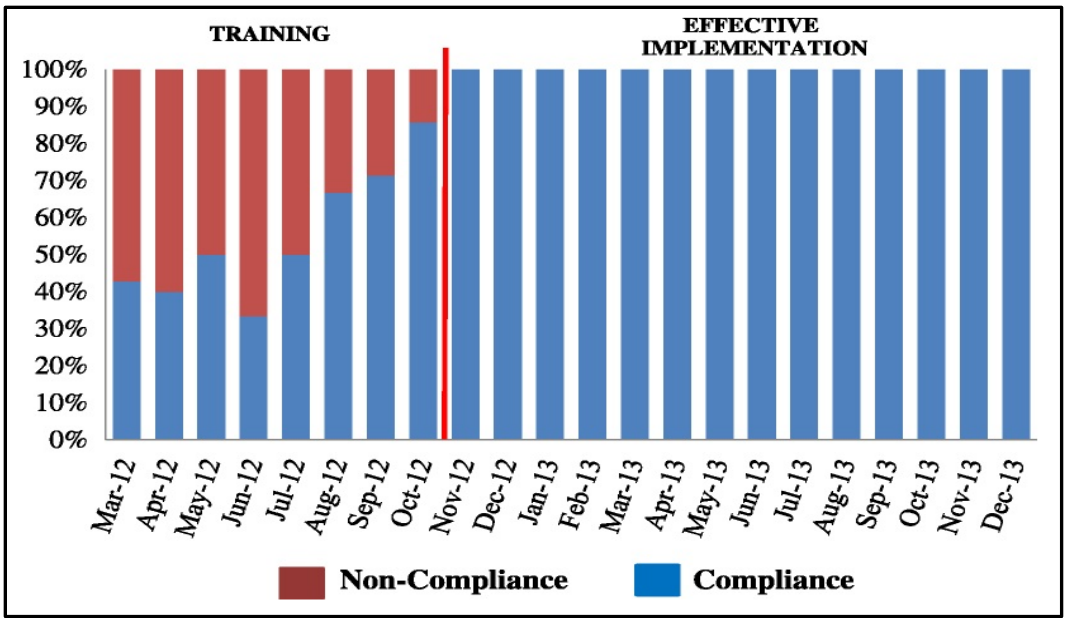

Figure 6. Compliance with BIG

WHY SHOULD YOU IMPLEMENT BIG?

Improving Hospital Quality and Costs

Using the BIG, acute care surgeons can manage patients with TBI safely and in a cost-effective manner, resulting in more effective use of resources. We performed a 5-year study (2009 – 2014) on all patients with TBI (skull fracture/intracranial hemorrhage on head computed tomography) presenting to our level I trauma center. We assessed the change in outcomes over the years to see the effect of implementation of BIG. We found significant reduction in the use of repeat head CT (91% in 2009 to 54% in 2014) (**Figure 7a)**, neurosurgical consultations (93% in 2009 to 60% in 2014) (**Figure 7b)**, and average hospital costs per patient ($19,062 in 2009 to $10,611 in 2014), with no significant differences in terms of neurosurgical interventions, discharge disposition, and mortality.[12]

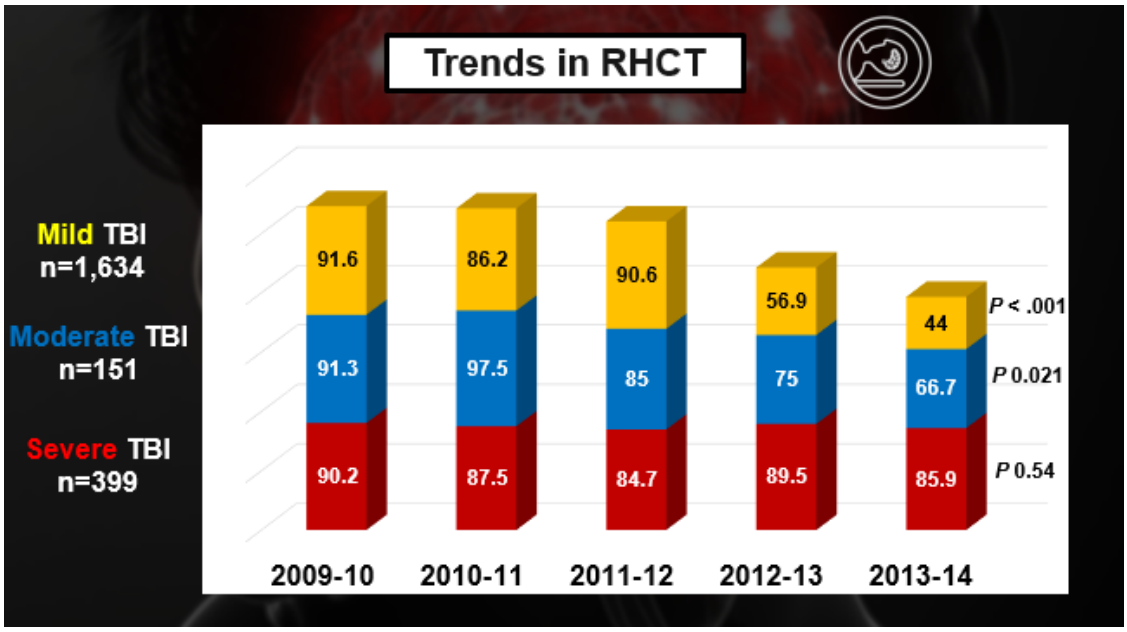

Figure 7a. Trends in the use of repeat head CT scans

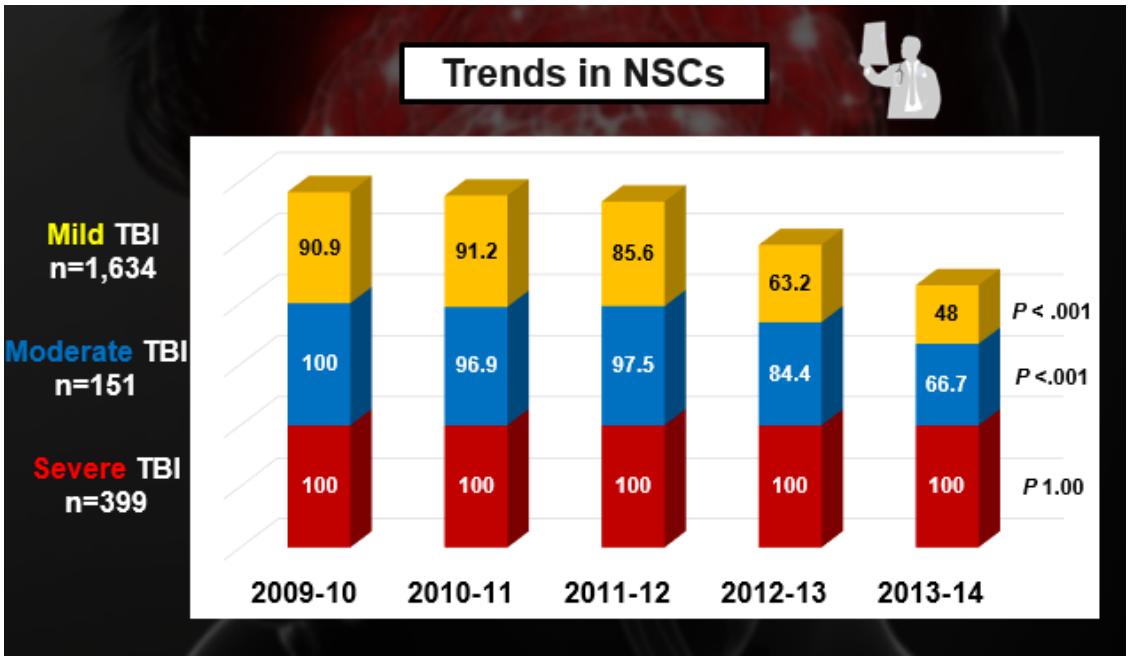

Figure 7b. Trends in neurosurgical consultations

BIG Is Not Just For Level I Trauma Centers

Level I trauma centers have the required facilities including advanced ICU facilities to emergency neurosurgical capabilities. Hence many have concerns about the utility and safety of BIG at lower-level trauma centers. Gribbell et al. successfully implemented the BIG at level III trauma centers, none of the BIG 1 and BIG 2 patients were transferred to higher levels of care with no complications, readmissions or unexpected transfers.[13] Grace et al. assessed the BIG at the University of Cincinatti Health System which includes a level I university trauma center and a suburban level III trauma center.[14] Of the 115 BIG-1, 25 BIG-2, and 192 BIG-2 patients, only 9 patients each from the BIG-1 and BIG-2 groups, and 87 patients from the BIG-3 group were transferred to the level I trauma center. All the BIG-1 and BIG-2 patients including those transferred to level I trauma centers survived to discharge without the need for neurosurgical intervention. In addition to the above-mentioned studies, Salvino et al. also implemented BIG at their level III trauma center. During the two years of pre-BIG implementation, they transferred 36 BIG-1 and 23 BIG-2 patients to higher level of care, whereas after BIG implementation, none of the BIG-1 or BIG-2 (n = 52) patients were transferred. The authors reported an estimated helicopter transport savings of $1.9M based on an average charge of nearly $50K per flight.[15]

BIG Is Not Just For Adults

Even though BIG were originally developed for adult trauma patients, we subsequently validated them in pediatric TBI patients.[16] We compared 80 pediatric TBI patients classified as BIG-1 who were managed without neurosurgical consultation to propensity matched group of 80 patients who were managed with neurosurgical consultation before the BIG implementation period. We found significant reduction in the use of repeat head CT (pre-BIG 41% vs post-BIG 6%, p = 0.001) with no significant difference in terms of neurosurgical interventions and mortality. Schwartz et al. also retrospectively reviewed the pediatric registry at their level I trauma center and reported that none of 28 patients identified as BIG-1 required neurosurgical interventions.[17]

EXTERNAL VALIDATION

Single Center Studies

BIG have been externally validated in various single center studies conducted outside the University of Arizona. Ross et al. retrospectively evaluated BIG in 590 patients and then prospectively implemented the guidelines. None of the BIG-1 (n = 88) and BIG-2 (n = 107) patients in the retrospective cohort, and the prospectively enrolled cohort (BIG-1 – n = 105, BIG-2 – n = 48) required neurosurgical interventions.[18] Vitale et al. implemented the BIG at a Department of Defense (DoD) Level 1 trauma center, and reported a significant decrease in neurosurgical consultations (98.4% pre- to 77.0% post-implementation, $p < 0.001$) and ICU admissions (84.1% pre-, 74.5% post-implementation, $p = 0.025$) with no difference in mortality.[19]

American Association for the Surgery of Trauma (AAST) BIG Multiinstitutional Trial

To confirm the external validity of BIG, we conducted a prospective multi-institutional trial sponsored by the AAST multiinstitutional trials committee.[20] We aimed to validate the guidelines at multiple institutions, with the hypothesis that BIG would reliably predict requirement of neurosurgical intervention, neurological examination worsening, progression on repeat head CT, post-discharge ED visits, and 30-days readmissions among patients presenting with TBI to one of ten participating level I and level II trauma centers.

After including all the TBI patients with positive head CT scan findings who met the inclusion criteria and stratifying them according to the BIG categories, we found no BIG 1 or BIG 2 patients requiring neurosurgical interventions, and only seven BIG 2 patients requiring upgrade to the BIG 3 category. If the BIG had been implemented in our study cohort, 425 RHCT, 401 prolonged hospitalizations, and 511 neurosurgical consultations would have been avoided in a study cohort of about two thousand patients. With the data provided by the multi-institutional validation of BIG, we can conclude that the guidelines establish a clear therapeutic plan for the management of TBI patients while avoiding unnecessary utilization of healthcare resources. The BIG are safe and effectively define the management of TBI by trauma and acute care surgeons and also appropriately predict when neurosurgical services should be involved.

POTENTIAL CONCERNS

Even though BIG are being adopted by various centers, uniform implementation of these guidelines has been limited due to certain reasons. Firstly, since most initial studies were performed at a single level I trauma center, questions have been raised about the generalizability. However, various single-center studies from other institutions have confirmed the safety of BIG. More recently, we have validated the BIG in AAST sponsored multi-institutional trial including 10 trauma centers across the US. Moreover, the progression of hemorrhage seen on repeat head CT scans has been reported in a minor subset of BIG-1 and BIG-2 patients. Hence, reluctance towards BIG implementation is secondary to the fear of patient deterioration due to these cases. However, it is important to note that even though the progression of hemorrhage has been reported among a minority of BIG-1 and BIG-2 patients in various series (including our studies), none of these BIG-1 and BIG-2 patients eventually required neurosurgical interventions or were readmitted due to TBI related causes. Hence, BIG can be safely implemented in all trauma centers. Center specific modifications based on the available resources are encouraged.

STEPS TO IMPLEMENT BIG AT YOUR INSTITUTION

Implementing new guidelines at a center for the management of TBI is associated with various issues, including fear of patient deterioration. However, BIG are safe and have been incorporated into TBI management protocols by various institutions. We suggest the following implementation pathway to introduce BIG at your centers.

a) Identify the Current TBI Management Practices at Your Institution

Identify the current TBI management protocols at your institution. Perform a review of all patients with radiographic evidence of TBI at your institution for a defined period. Assess the rates of routine repeat head CT scans performed, ICU admissions, and neurosurgical consultations. Identify the reasons for deviations from your institutional protocol.

b) Retrospectively Validate BIG at Your Center

Retrospectively implement the BIG at your center. Assign BIG score to all the patients identified in the review in the previous phase. Observe the actual management of the patient and compare it with the management proposed by the guidelines. Assess the impact BIG would have made if it was implemented.

c) Clinical Implementation

Prospectively implement BIG criteria. Training the staff with new guidelines and polices can be challenging. However, BIG are simple and easy to follow. At our center, we achieved a compliance of 100% within 6 months of implementing our BIG guidelines. Assess the compliance with the guidelines and take necessary measures to improve the compliance in case of repeated deviations. Actively follow-up the patients during the initial months. Calculate the difference in outcomes pre- vs post-BIG implementation.

d) Qualiy Control

Create a BIG quality control team that will track every TBI patients for review of appropriate application of BIG criteria. This team must also call for discharges of BIG 1 patients. Assess the outcomes including unplanned ICU admissions, unplanned visit to operating room, and unexpected readmission due to TBI related causes. Assess the rates of overuse of radiology resources, and the average time spent in the ED for BIG 1 patients.

e) Institutional Modifications

Perform necessary modifications according to the available resources. For instance, Gribbell et al. successfully implemented the BIG at level III trauma centers, however, they replaced neurosurgical consultation with transfer to level I trauma center due to the lack of availability of neurosurgeons.[13] In a rural trauma center in Arizona, the authors finalized BIG scores after pharmacologic reversal of anticoagulant.[21] Similarly, necessary modifications according to the locally available resources may be performed.

f) Integrate Other Specialities and Administration

Invite trauma, neurosurgery, radiology, emergency medicine, nursing, and administritative colleagues to develop TBI registry, robust peer review process, criteria for escalation of care, developing faster ways to read the imaging, training the nursing staff regards to neurotrauma. Support from the administration is mandatory for large scale expansion of the BIG project.

g) Frequent Meetings With the Neurotrauma Team

Monitor the progress of trauma registry and compliance with BIG criteria. Understanding the roadblocks from each division is necessary to address the ssues related to compliance. Frequent assessments and training related to BIG protocols may be necessary.

h) The Role of Technology

Modern technology may be used to further enhance the TBI management strategies at institutions. BIG protocol may be integrated to the EMR systems that can automatically assign the BIG criteria to the patients. Standardizing the reads of CT scans is necessary in terms of reporting hemorrhage patterns.

i) Identify the Areas of Improvement

Repeated quality improvement studies, feedback, and tracking the outcomes are necessary to identify the potential areas of improvement.

CONCLUSIONS

Brain injury guidelines are evidence-based guidelines that define the triage and management of TBI by trauma surgeons. BIG has been validated in various single institutional studies and recently concluded AAST multicenter study. The management of minor TBI by trauma and acute care surgeons is safe, while also being effective, and less resource-intensive as compared to management by the already-dwindling neurosurgical workforce. BIG can be used at trauma centers with varying resources to to guide triage and management of mild TBI patients by acute care surgeons. BIG can be retrospectively validated at centers followed by prospective real time implementation. Even though a minor subset of BIG-1 and BIG-2 patients might have progression of intracranial hemorrhage on susbsequent imaging, they do not typically need neurosurgical interventions. Hence, BIG can be safely implemented across trauma centers.

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DRY LAND DROWNINGS: FLUID OVERUSE IN SEPSIS RESUSCITATION

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In 2017, there were 11 million global deaths due to sepsis. In fact, almost 20% of global deaths were due to sepsis. In the United States, sepsis results in more than 270,000 deaths per year, with a cost of 62 billion dollars.[1] Despite improvements in sepsis outcomes since the initial Rivers and colleagues' paper on early-goal directed therapy (EGDT) in 2001, much of the guidelines have been ignored, misinterpreted, or abused.[2] In an effort to "right the ship" in care of the septic patient, the International Guidelines for Management of Sepsis and Septic Shock were updated and published in 2021.[3] Significant changes were implemented and emphasis was placed on a few simple guidelines: (1) balanced fluids are preferred to normal saline, (2) still unsure of optimal fluid strategy, and (3) three hours to get antibiotics in from presentation.

Until the recent 2021 guidelines, there were no clear directions or solid recommendations for what product should be used. With respect to crystalloids over colloids (albumin, hydroxyethyl starch) what drove this recommendation for crystalloids is that hetastarches have increased rates of acute kidney injury (AKI), as well as coagulopathy and need for transfusions.[3] Albumin is more expensive and, while recommended in those with cirrhosis and high risk for volume overload, it provides no survival benefit. While it was argued that crystalloids were preferred over colloids, there was no distinct choice between normal saline or balanced solutions (lactated Ringer's, Isolyte, Plasmalyte). However, increasing evidence has noted that balanced solutions are the preferred solution for early bolus and, if needed, maintenance fluids.[4] The SMART trial found that 30-day mortality was decreased from 30% to 26% in patients receiving balanced crystalloid resuscitation compared to saline, along with a reduction in adverse renal events from 40% to 35%.[5]

Characteristics of the fluids used in sepsis resuscitation

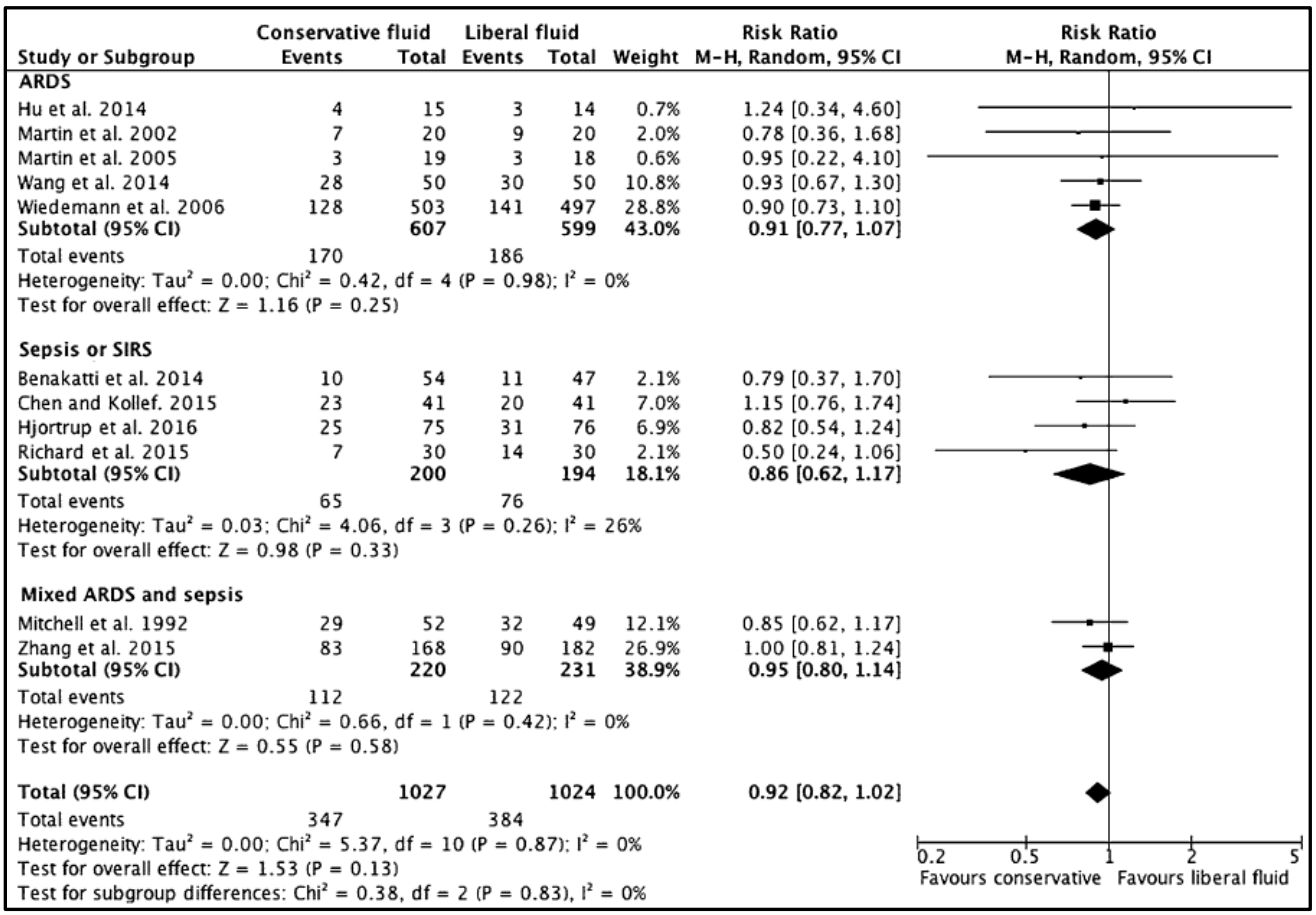
Components	Plasma	Balanced crystalloid	Saline	Albumin (Iso-/ Hyperoncotic)	L-HES
Osmolarity (mOsm/ kg)	291	Hypotonic (254–273)	Isotonic (286)	Hypotonic (4%, 260; 5%, 250; 20%, 200; 25%, 250)	Isotonic to Hyper-tonic (283–304)
Na/Cl (mmol/l)	140/103	130–140/98–111	154/154	130–160/128–130	137–154/110–154
K/Ca (mmol/l)	40/4	4–5/2–2.7	0/0	< 2/0	0–4/0–2.5
Sepsis Outcomes	Less fluid required Lowest transfusion volume	Lowest mortality Lowest acute kidney injury More fluid volume required Fluid of choice for sepsis	Higher mortality More fluid volume required Not favored for sepsis	Lower mortality (Iso-oncotic) Least fluid volume required Iso-oncotic albumin for sepsis patients with risk of fluid overload	Highest mortality More acute kidney injury More transfusion volume Not favored for sepsis

The most critical tenets of EGDT were that early recognition of sepsis AND early administration of antibiotics were crucial. Large volume, aggressive resuscitations are of no benefit and are actually harmful, without early antibiotics and source control. If sepsis is suspected in a patient presenting in shock, antibiotics should be administered within ONE HOUR.[3] In those with suspected sepsis WITHOUT shock, antibiotics are still recommended within one hour of presentation, but within three hours meets guidelines. Antibiotics alone have shown to be the most crucial part of the protocol-based care of sepsis and septic shock, with mortality rates unaffected (or worsened) with large volume resuscitation.[3,4] The antibiotics chosen should be broad-spectrum and guided with cultures and should include an anti-fungal in those with any suspicion for fungal component (recent ICU stay, recent/current antibiotic use, TPN, recent intra-abdominal infection/surgery).[3] These antibiotics should be augmented with early invasive monitoring and early use of vasopressors, specifically norepinephrine. Steroids should be added with poor vasopressor response (after addition of vasopressin @ 0.04 u/min).

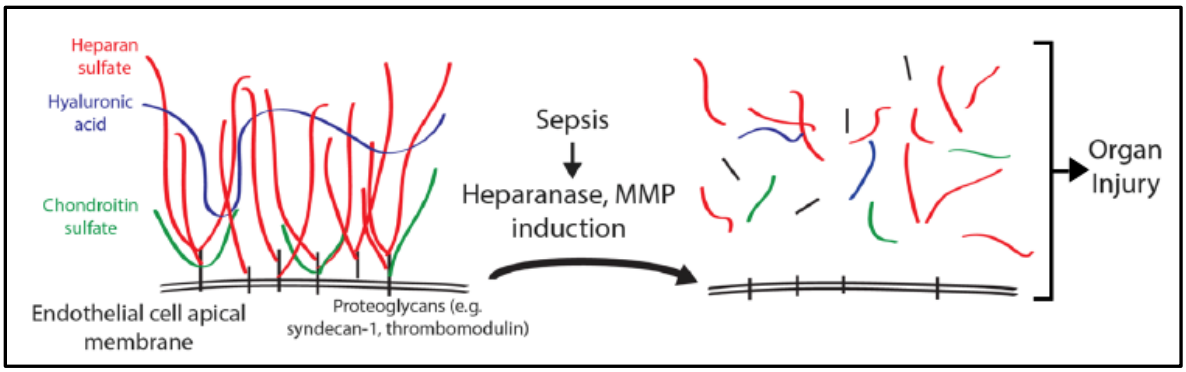
With early sepsis identification, antibiotic administration within 1-3 hours of arrival, and early initiation of vasopressors, fluid requirements should be far lower than previous recommendations. The current recommendation is 30 mL/kg in the first three hours of arrival and identification.[3,4] Using this early bolus recommendation, followed by judicious crystalloid administration over the first few days, the evolving sepsis literature shows no difference in survival compared to more aggressive resuscitation protocols (with the exception of potentially worse outcomes). The ProCESS investigators compared *early goal directed therapy* proposed by Rivers et al (prompt placement of a central venous catheter to monitor pressure and Scvo2 and to administer intravenous fluids, vasopressors, dobutamine, or packed red-cell transfusions,as directed), to *protocol-based care* (less aggressive endpoints, start with peripheral access, fluids and vasoactive agents to reach goals for systolic blood pressure and shock index, RBC transfusion only if the hemoglobin <7.5 g/dL), to *usual care* (bedside providers directed all care) (5). Despite having lower 6-hour fluid resuscitation volumes (2.3L vs 2.8L vs 3.3; p<0.001), the usual care had lower cardiac, pulmonary, and renal adverse events, with similar mortality at 60 and 90-days. Consistent with this, the ARISE trial of 1600 septic patients randomized to EGDT versus usual care found 90-day mortality rates were no different between groups, with similar early resuscitation volumes (2.5L in both groups).[6] The third of three large, multicenter, randomized trials evaluated EDGT to usual care, again finding no difference in mortality, this time measured at 28-day and discharge.[7] The EGDT group did, however, have greater ICU length of stay and greater need for cardiovascular support.

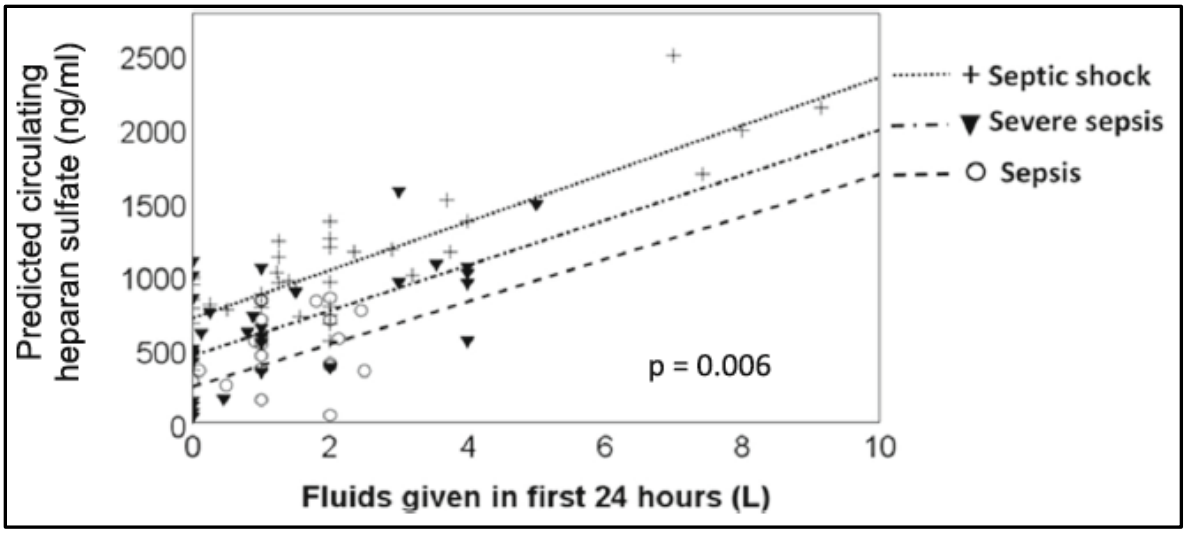
While the most recent three studies were performed in large centers in first world settings, aggressive fluid management in sepsis fairs even worse in other less advanced settings. The Fluid Expansion as Supportive Therapy (FEAST) study randomized African children with sepsis-related hypoperfusion to a bolus of 5% albumin, a bolus of saline, or no intravenous fluid bolus.[8] Mortality in both the albumin (10%) and saline (10%) groups was significantly higher than in the group not treated with a fluid bolus (7%). Similar findings were noted in the Simplified Severe Sepsis Protocol (SSSP) and Simplified Severe Sepsis Protocol-2 (SSSP-2) trials examining early fluid management for adults with sepsis in a limited-resource setting, without the routine availability of intensive care unit (ICU) beds or mechanical ventilation.[9,10] The SSSP trial was stopped early by the data and safety monitoring board out of concern that patients with hypoxemic respiratory distress at baseline experienced higher mortality with protocolized care (100 vs 70%; P = 0.09).[9] The SSSP-2 trial attempted to mitigate this risk by excluding patients at high risk for respiratory failure and stopping fluids if there were signs of worsening respiratory function.[10] However, patients treated with the sepsis protocol experienced a higher rate of respiratory decline (36 vs 22%) and in-hospital mortality (48 vs 33%) compared to usual care. Taken together, Together, these three latter 2 trials demonstrate the harm of aggressive fluid resuscitation, likely minimized or at least masked in the former three studies by those studies having access to mechanical ventilation and other advanced ICU support in their settings.

Given these results, investigators have argued for even more restrictive strategies following the initial "30 mL/kg in three hours." Given increased capillary permeability, sodium and water retention, and AKI associated with sepsis, the accumulation of large volumes of fluid in the interstitium is a frequent occurrence and may impair oxygen delivery at the cellular Level.[11] A recent meta-anlysis demonstrated an association between fluid overload and mortality and it has been suggested that strategies aimed at prevention or treatment of fluid overload may be beneficial in reducing ICU length of stay, as well as ventilator days. Their summary Forest plot for mortality demonstrates conservative or de-resuscitative fluid strategy was favored to liberal fluid strategy.



So, through what pathway or mechanism do these aggressive resuscitation volumes cause harm? Several studies suggest that intravenous crystalloids promote degradation of the endothelial glycocalyx, composed of transmembrane or membrane-anchored proteoglycans (such as syndecan-1) and sulfated glycosaminoglycans (predominantly heparan sulfates). In addition to being essential to microvascular homeostasis, the glycocalyx contributes to the endothelial barrier, mediates shear-induced vasorelaxation, and opposes leukocyte-endothelial adhesion.[12] During sepsis, tumor necrosis factor-α and angiopoietin-2 induce degradation of the glycocalyx heparan sulfate, inducing endothelial dysfunction and consequent organ injury. Using samples from the ProCESS trial, investigators evaluated the relationship of fluids on the endothelium during sepsis. Hippensteel and colleagues found that while glycocalyx degradation occurs in sepsis and is associated with in-hospital mortality, it is the volume of intravenous fluids administered during sepsis resuscitation that is independently associated with the degree of glycocalyx degradation.





These findings suggest a potential mechanism by which intravenous fluid resuscitation strategies may induce iatrogenic endothelial injury and suggest several possible recommendations for the early resuscitation of sepsis. First, lower volumes of resuscitation are likely of benefit. While the 30 ml/kg is recommended in the first few hours after identification, stretching this out over initial time frame with 20 mL/kg followed by an infusion of the remaining 10 mL/kg has been suggested. Second, guiding subsequent fluid resuscitation wisely with small volume replacement guided by point-of-care volume assessment such as IVC collapsibility by U/S, and then, only in the face of low urine output or worsening lactate. As well, using low-dose vasopressors earlier could provide enough vascular tone to avoid over-resuscitation. Finally, the use of plasma has been suggested in the face of further hypovolemia given its performance in restoration of the glycocalyx in hemorrhagic shock. Resuscitation with plasma as the primary volume expander in trauma patients has been associated with a reduction in serum biomarkers of endotheliopathy, improved survival and decreased morbidity associated with inflammatory and edema-related complications.[13] Resuscitation of patients with sepsis using plasma may improve outcomes by modulating shock-induced glycocalyx damage and endothelial injury.

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MANAGING SEVERE PULMONARY CONTUSIONS

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A pulmonary contusion is essentially a bruise of the lung that can occur after blunt and penetrating trauma or blast injury. This monograph will review the history, pathophysiology, epidemiology, diagnosis, management, and outcomes for trauma patients presenting with a pulmonary contusion.

The Italian anatomist, Giovanni Morgagni, was first credited in 1761 with identifying lung injury that was not associated with the chest wall overlying it. However, it was not until the 1800's that French military surgeon, Guillaume Dupuytren, coined the term pulmonary contusion. Moving into the 20th century, pulmonary contusion was better understood as a clinical entity during combat, as blast injuries in World War I, and World War II led to the identification of blast injury patients with pulmonary dysfunction and bleeding, without external signs of injury to the chest wall. The Vietnam War led to more widespread use of chest x-ray and a better understanding of pulmonary contusions after blast injury.

Pulmonary contusion results from damage to the lung tissue as the result of an external force from either direct blunt or penetrating trauma to the lung or indirect trauma to the lung from blast injury. Regardless of mechanism, the pathophysiology is similar, with bleeding and inflammation occurring within the lung parenchyma leading to ventilation-perfusion mismatch. Three mechanisms are thought to contribute to the lung parenchyma damage, including intertial effect, spalling, and implosion. Inertial effect leads to alveolar damage, as the lighter parenchymal tissues and heavier hilar structures accelerate and decelerate at different velocities. Spalling is a shearing or bursting effect that occurs at the interface between gas and liquid. When air-containing organs such as the lung are exposed to such forces, the spalling effect may result in the disruption of the alveolus at the point of its initial contact with the shock wave. Finally, implosion occurs after an increase in pressure followed by a rebound over-expansion that can lead to alveolar damage.

As most pulmonary contusions are mild, the clinical presentation may by quite subtle and often asymptomatic. However, in more severe cases, the patient with a pulmonary contusion may present tachypneic, hypoxic, or in respiratory failure. In these patients, more common causes of hypoxia after trauma, such as pneumothorax and hemothorax, must be identified and treated. The first indication of a pulmonary contusion is often seen on imaging, including the initial chest x-ray as well as more detailed information obtained during CT scanning. In general, pulmonary contusions will worsen over the first few days, at least radiographically, though this may or may not manifest clinically. As a real-world external example, when you get punched in the arm it is initially a little red and converts to a bruise over several days. The same occurs with a pulmonary contusion, as the initial trauma leads to mild inflammation of the lung that worsens, particularly on radiographic imaging, over the next several days.

Pulmonary contusions may be graded according to the AAST Lung Injury Scale:

Lung Injury Scale

Grade*	Injury Type	Description of Injury	ICD-9	AIS-90
I	Contusion	Unilateral, <1 lobe	861.12	3
			861.31	
II	Contusion	Unilateral, single lobe	861.20	3
			861.30	
	Laceration	Simple pneumothorax	860.0/1	3
III	Contusion	Unilateral, > 1 lobe	861.20	3
			861.30	
	Laceration	Persistent (> 72 hrs) air leak from distal airway	860.0/1	3-4
			860.4/5	
			862.0	
	Hematoma	Nonexpanding intraparenchymal	861.30	
IV	Laceration	Major (segmental or lobar) air leak	862.21	4-5
			861.31	
	Hematoma	Expanding intraparenchymal		
	Vascular	Primary branch intrapulmonary vessel disruption	901.40	3-5
V	Vascular	Hilar vessel disruption	901.41	4
			901.42	
VI	Vascular	Total uncontained transection of pulmonary hilum	901.41	4
			901.42	

The AAST lung injury grading system categorizes pulmonary contusions as either grade I, II, or III injuries depending on the number of lobes involved. Though chest x-ray may give some indication of involvement, a CT scan is needed for more detailed information to be obtained. Another severity scoring system that may be used if the blunt pulmonary contusion or BPC-18 score. This scoring system ranges from 0-18 and assigns 0-3 points for contusions involving portions of each lung, left upper, middle, lower and right upper, middle, lower.

Treatment for patients with pulmonary contusions is the same as any other trauma patient, starting with the primary survey. The treatment for pulmonary contusion is largely supportive, aimed and treating the hypoxia and respiratory failure associated with severe injury. Patients with severe pulmonary contusions seen on imaging should be admitted to the ICU. Patients who are hypoxic should receive supplemental oxygen and those in respiratory failure, or on the verge of failure, should be intubated and mechanically ventilated. Chest tubes are not needed in patients with a pulmonary contusion but may be required as hemo- and pneumothorax are common in these patients. Treatment for any patient with pulmonary contusion should be driven by clinical status rather than severity of contusion seen on imaging.

Once admitted to the ICU, and after initial resuscitation for associated injuries, patients with pulmonary contusions require ongoing supportive care ensuring adequate oxygenation, ventilation, pulmonary hygiene, and pain control if there are rib fractures present. Fluid overload should be avoided, as this may worsen pulmonary contusions. In addition, gentle diuresis may be considered after several days, as long as the patient is completely resuscitated and there is no concern for ongoing hemorrhage. There should be a high index of suspicion for complications that may arise as a result of pulmonary contusion, particularly pneumonia and ARDS.

As rib fractures are commonly associated with pulmonary contusions, some patients may be considered candidates for rib fracture fixation. Though pulmonary contusion was initially thought to be a contraindication to rib fracture fixation, several recent studies have found rib fracture fixation to be safe and effective in patients with severe pulmonary contusions. (Van Wijck, Jiang, Lagazzi).

Though mortality is rarely due directly to the pulmonary contusion, patients who present with a pulmonary contusion have a mortality reported to be as high as 20-40%. This is most often the result of associated thoracic and more commonly extra-thoracic injuries.

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EARLY VS. LATE TRACHEOSTOMY

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Patients involved in longterm intubation in the ICU present a specific set of problems: most notably, their discomfort, prolonged hospital/ICU length of stay, ventilator associated pneumonia, and mortality. For anyone who rounds regularly in the ICU, there is always the question: Can we liberate this person from the ventilator in a reasonable amount of time, or should we just change their ET tube for a tracheostomy tube?

It's best to look at the research that's been done on the topic to help sort out this decision. Multiple retrospective and prospective randomized trials have been done to address this issue. Each individual complication/clinical goal should be addressed specifically to help make this difficult decision. Several huge metanalyses have been done to try and address early vs. late tracheostomy: 1) Chorath, et al. JAMA 2021. 2) Bice, et al. Seminars in Respiratory Critical Care Medicine 2015 and 3) Andriolo Chochrane Database Systematic Review 2015. Let's look at each indicator/outcome and how they stack up via each study:

Outcome Measure	**Chorath 2021**	**Bice 2015**	**Andriolo 2015**
Pneumonia	Favors Early	Wash	*Maybe* favors early
Mortality	Wash	Wash	*Maybe* favors early
Vent Days	Wash	Maybe a decrease	*Maybe* favors early
ICU LOS	xxxx	Wash	Early

The ultimate conclusions in most of these data sets are that early tracheostomy is probably favored. But, like most things in medicine, especially critical care medicine, each individual provider and group needs to take the best evidence available and execute a reasonable plan in their community. For most of the ICU's in the modern world, it appears that early (around 1 week) tracheostomy is safe, reasonable, and might reduce some common hospital complications/issues such as pneumonia and ICU length of stay. However, one of the forgotten elements of tracheostomy is discomfort, both for the intubated patient and the family at their bedside. A tracheostomy facilitates removal of the oral endotracheal tube, which can reduce/remove all the sedatives commonly used in the ICU, as well as get the patient looking like their uninjured self. Both these things are huge steps forward for the patients and family. Whereas tracheostomy is usually viewed by the lay person as the "end of the line" in medical care, most seasoned ICU physicians and nurses see tracheostomy as the beginning of recovery. We studied this in our

institution where we asked families what they thought about their loved one's new tracheostomy, and several interesting findings were statistically significant:

1) They felt their family member looked generally more comfortable
2) They felt their family member appeared to be progressing forward
3) They felt their family member was more able to see and interact with them

Each physician and group needs to look at their own ICU and their own patient population and come up with a plan for tracheostomy that addresses each patient, the family, and the community's needs. More than likely, the best solution is to edge towards and earlier tracheostomy plan than later.

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FAILING KIDNEYS: RENAL REPLACEMENT THERAPIES IN THE ICU

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Acute kidney injury (AKI) impacts between a third to a half of all ICU patients, with approximately 20% of patients requiring renal replacement therapy (RRT).[1] It is one of the most common organ dysfunctions experienced by critically ill or injured surgical patients. The incidence is greatly impacted by the type of injury, with AKI occurring in up to 25% of ICU patients after blunt trauma and 40% of burn patients.[2] A recent cohort study of patients presenting to a level 1 trauma center demonstrated an AKI incidence of 45%. 69% of this group (31% of all patients) presented with AKI on admission, but the majority recovered renal function within 2 days.[3] The incidence of AKI after surgery ranges from 5% after major abdominal surgeries to nearly 50% after orthotopic liver transplantation.[2] The presence of AKI increases overall hospital mortality. A recent TQIP analysis of patients with severe AKI demonstrated a mortality rate of 28%.[4] The risk of death increases to 50% among all ICU patients with AKI requiring RRT within the first week of ICU admission.[1]

DIAGNOSIS & CLASSIFICATION OF AKI

There have been varying definitions for diagnosis and classification of acute kidney injury. Three of the most used systems include RIFLE, AKIN, and KDIGO. They all incorporate some combination of timing of renal dysfunction onset, glomerular filtration rate (GFR), serum creatinine, and urine output into their assessment strategy. The Risk, Injury, Failure, Loss of Kidney Function, and End-stage Kidney Disease (RIFLE) classification system was first introduced in 2004 by the Acute Dialysis Quality Initiative group. This system defined AKI as a rise of serum creatine by greater than 50% over 7 days and focused on levels of decreased GFR and urine output (UOP) along with rising creatine to define the stages of AKI – Risk, Injury and Failure. The Acute Kidney Injury Network (AKIN) modified RIFLE in 2007. Key elements included shortening the initial time of symptoms to 48 hours, decreasing the initial rise of serum creatinine to 0.3, and excluding GFR. More recently, there has been a push towards adoption of The Kidney Disease: Improving Global Outcomes (KDIGO) Acute Kidney Injury Group classification system, which aims to blend the RIFLE and AKIN criteria into a single unified definition of AKI. **Table I** highlights the commonalities and differences between these systems. Comparison studies in critically ill patients have noted that application of KDIGO leads to an increased diagnosis of AKI and is more predictive of in-hospital mortality.[5]

Recently, biomarkers are being incorporated along with the functional metrics of urine output and serum creatinine to identify patients at high risk for AKI. An elevated urinary [TIMP2]·[IGFBP7] – a marker for cell-cycle arrest, predicts AKI after cardiac and non-cardiac surgery.[6] Specific biomarkers for kidney tubular injury – neutrophil gelatinase-associated lipocalin (NGAL), kidney injury molecule 1 (KIM-1),and α- and π-glutathione s-transferase (GST) can be detected prior to changes in serum creatinine and can predict AKI progression and severity.[6] NGAL is available as a point of care test allowing for rapid identification of AKI. This early detection can allow for prompt interventions to treat the AKI and allow for measures to prevent

additional injury. Ongoing trials are looking at how specific biomarkers can identify AKI causes and lead to targeted therapies.

RIFLE		Urine Output	AKIN		KDIGO	
↑SCr ≥ 50% w/in 7 days		*same across all criteria	↑SCr ≥ 0.3 mg/dL or ↑SCr 50% w/in 48 hours		↑SCr ≥ 0.3 mg/dL w/in 48h or ↑SCr ≥ 50% w/in 7days	
Risk	↑SCr x 1.5 or GFR ↓ >25%	<0.5 mL/kg/h for >6h	I	↑SCr ≥ 0.3 mg/dL or ↑SCr to 1.5 to 2-fold from baseline	1	↑SCr ≥ 0.3 mg/dL w/in 48h or ↑SCr 1.5 to 1.9 fold from baseline
Injury	↑SCr x 2 or GFR ↓ >50%	<0.5 mL/kg/h for >12h	II	↑SCr > 2 to 3-fold from baseline	2	↑SCr 2 to 2.99-fold from baseline
Failure	↑SCr x 3 or SCr > 4 with an acute ↑ >0.5 or GFR ↓ >75%	<0.3 mL/kg/h for >24h or anuria for 12h	III	↑SCr ≥ 3-fold from baseline or SCr > 4 with an acute ↑ >0.5 or initiation of RRT	3	↑SCr ≥ 3-fold from baseline or SCr > 4 or initiation of RRT
Loss	Persistent ARF > 4 weeks					
ESKD	Persistent > 3 months					

Table I. Diagnosis and Classification Systems for AKI

WHEN TO INITIATE RENAL REPLACEMENT THERAPY?

There are several commonly accepted triggers to initiate RRT. These include severe acidosis defined by a pH <7.2 or serum bicarbonate <12 mmol/L, serum potassium > 6.0 mmol/L and fluid overload state marked by respiratory dysfunction with a PaO2/FiO2 <200.

The question arises when to initiate RRT in critically ill patients with AKI without these severe complications. The hypothesized advantage to early RRT prior to major complications is to restore a balanced physiologic state, avoid exposure to metabolic toxicities, and mitigate the negative consequences of positive fluid balance. The major point advocating for delayed RRT is that many patients may recover renal function if given an appropriate period of supportive care, thus completely avoiding RRT and its accompanying risks. Several randomized controlled trials – ELAIN[7], AKIKI[8], IDEAL-ICU[9], STARRT-AKI[10], AKIKI 2[11] - have been completed over the past 10 years to examine what other factors should direct the ideal timing of RRT initiation in this group. **Table II** summarizes key aspects and findings of each study.

The most recent studies are STARRT-AKI and AKIKI 2. START-AKI included 3019 patients across 168 hospitals in 15 countries that were randomized to early versus late RRT initiation.[10] Patients qualified for RRT if meeting KDIGO stage 2 or 3 AKI criteria. The early group received therapy at a median of 6.1 hours versus the delayed group at a median of 31.1 hours. Key findings in this study include **NO** advantage to early initiation of RRT. There was **NO** decrease in 90-day mortality between groups. There was **NO** difference in ventilator-free days, vasoactive-free days, or ICU-free days at 28-days. Also notable, there were less adverse events in the delayed group and over 35% of patients in the delayed group **never** received RRT due to renal recovery or death.

Noting that the longer RRT was delayed resulted in more patients avoiding therapy, AKIKI 2 pushed the delay to RRT initiation even further. This study included 278 patients across 39 ICUs in France.[11] Patients with KDIGO stage 3 AKI were eligible and randomized to delayed versus more delayed RRT once they met

one of the following criteria: oliguria or anuria for more than 72h or BUN between 112 to 140. This was the same criteria for RRT initiation in the delayed group of the initial AKIKI trial. The delayed group received RRT at a median time of 44 hours from meeting KDIGO stage 3 AKI criteria and 3 hours from randomization. The more delayed group trigger for RRT were the standard criteria including severe acidosis or pulmonary dysfunction due to edema or BUN > 140. This group received RRT at a median of 94 hours from meeting KDIGO stage 3 AKI criteria and 33 hours from randomization. Key findings demonstrated an **INCREASE** in adjusted in 60-day mortality in the **MORE-delayed** strategy group.

These two studies demonstrated that while early RRT does not afford improved outcomes, a more-delayed strategy may be associated with potential harm. **KDIGO stage 3 AKI does not mandate immediate RRT; however, if no renal recovery is noted after 48-72 hours, initiation of RRT will likely benefit the patient.**

	ELAIN[7]	AKIKI[8]	IDEAL-ICU[9]	STARRT-AKI[10]	AKIKI 2[11]
Year published	2016	2016	2018	2020	2021
# patients	231	620	488	3019	278
Setting	Single center in Germany	31 centers in France	24 centers in France	168 centers in 15 countries	39 ICUs in France
Population	Mainly postop patients (47% cardiac sx)	80% medical patients	Septic shock patients	67% medical patients	55% septic shock; 35% ARDS
Key Inclusion criteria	KDIGO stage 2 AKI, sepsis, vasopressors, overload state	KDIGO stage 3 plus mech vent and/or vasopressors	RIFLE failure, AKI w/in 48h of vasopressor start; septic shock	KDIGO stage 2-3 AKI	KDIGO stage 3
Window for early RRT	w/in 8h of stage 2 AKI	w/in 6h of stage 3 AKI	w/in 12h of RIFLE failure	w/in 12h of full eligibility	plus oliguria/ anuria ≥72h or BUN 112 to 140
Time to Early RRT	6h following full eligibility	2h post-randomization; 4h from stage 3 AKI	8h from early stage AKI dx	6h following full eligibility	44h from KDIGO stage 3 AKI / 3h post-assignment
Trigger for Delay RRT	w/in 12h of stage 3 AKI or BUN>100, K^+>6, diuretic resistant edema	BUN>112, K^+>6, pH<7.1, oliguria >72h, acute pulmonary edema	48h after inclusion, or earlier if K^+>6, pH<7.1, fluid overload	K^+>6, pH<7.2 with HCO3 ≤12, pulm edema w/ PaO2/FiO2 <200, or AKI≥ 72h	K^+>6, pH<7.2 with HCO3 ≤12, pulm edema w/ PaO2/FiO2 <200, Or BUN ≥ 140
Time to Delay RRT	26h post-randomization	57h post-randomization	51h from early stage AKI dx	31h following full eligibility	94h from KDIGO stage 3 AKI / 33h post-assignment
% Delay pts received RRT	91%	51%	62%	62%	79%
Initial RRT mode	CCRT (CVVHDF)	Mixed (CRRT 45%)	Mixed (CRRT 56%)	Mixed (CRRT 70%)	Mixed (CRRT 40%)
Mortality outcome (early vs delayed)	90-day 39% vs 54% (p=0.03)	60-day 49% vs 50% (p=0.79)	90-day 58% vs 54% (p=0.38)	90-day 44% vs 44% (p=0.92)	60-day 44% vs 55% (p=0.07)

Table II. Summary of recent RCT examining RRT initiation

Adapted from Table 1 in Wald R et al. Delivering optimal renal replacement therapy to critically ill patients with acute kidney injury. Intensive Care Med. 2022;48(10):1368-1381.[12]

WHAT IS THE BEST ACCESS?

Once deciding a patient requires RRT, the next step is choosing the best access. The goal is to maximize blood flow rates and minimize complications such as infection and line thrombosis. The KDIGO guidelines recommend preferential placement in the right internal jugular vein, followed by either femoral vein, and lastly the left internal jugular vein. When placing a jugular catheter, the tip of the catheter should ideally be placed in the right atrium, while a femoral catheter should terminate in the inferior vena cava. Subclavian access is discouraged due to the risk of vein stenosis, potentially limiting long-term fistula options if needed. While femoral catheters have been associated with increased infection in the past, recent studies have shown similar rates of catheter infection regardless of site, except in morbidly obese patients. It is critical to use sterile techniques and maximal protective barriers when placing these catheters.

Two major types of catheters are available for renal replacement therapies distinguished by the presence of a cuff, if they require tunneling during placement, and optimal duration of use. Most commonly used for RRT initiation is a non-tunneled, non-cuffed dialysis catheter. These are easily placed at the beside under ultrasound guidance by an intensivist. These are considered temporary and should be removed prior to hospital discharge. The alternative, tunneled, cuffed dialysis catheters are placed under fluoroscopic guidance usually by an interventional radiologist or surgeon. Tunneled, cuffed dialysis catheters are associated with decreased risk of infection, greater dialysis efficiency, less treatment interruptions, and overall, less complications. If it is believed that the patient will require dialysis for greater than 1 week, has no active blood stream infections, and no significant coagulopathy, one may consider initial placement of a tunneled catheter.

WHICH MODALITY IS BEST?

RRT manages fluid balance and solute clearance in the setting of AKI through ultrafiltration, convection, and diffusion. Ultrafiltration refers to the movement and removal of plasma water. Convection (hemofiltration) is a form of solute clearance that relies on the movement of water and its dissolved solutes through the semi-permeable membrane dragging solutes along. Diffusion (dialysis) relies on the concentration gradient between the blood and the dialysate to remove solute. In diffusion, clearance is inversely proportional to the size of the molecule. Convection more effectively removes medium to large sized molecules from the blood compared to diffusion.

There are several modes in which RRT can be delivered to critically ill patients. Most often used are intermittent hemodialysis (IHD), continuous renal replacement therapy (CRRT) and prolonged intermittent renal replacement therapy (PIRRT). Peritoneal dialysis (PD) has also been used in the ICU population but is mainly utilized in limited resource centers or in the pediatric population. The ideal modality should be based on patient parameters including hemodynamics and volume status, metabolic derangements, overall goals of RRT, and local expertise and resources.

CRRT has become the predominant mode within ICUs in the US. The main rationale for this is CRRT occurs at a lower rate and reduces osmotic shifts decreasing the risk of hemodynamic instability and intradialytic hypotension in critically ill patients. One major disadvantage of CRRT is that the patient remains connected to the circuit for a prolonged period of time. There are several modes of CRRT including continuous venovenous hemofiltration (CVVH) using convection, continuous venovenous hemodialysis (CVVHD) using diffusion, and continuous venovenous hemodiafiltration (CVVHDF) using both diffuse and convective modes. These are further described in **Table III**.

Characteristic	Comparisons of CRRT modalities			
	Slow continuous ultrafiltration (SCUF)	**Continuous venovenous hemofiltration (CVVH)**	**Continuous venovenous hemodialysis (CVVHD)**	**Continuous venovenous hemodiafiltration (CVVHDF)**
Mechanism	Ultrafiltration	Convection	Diffusion	Diffusion & Convection
Treatment duration (h)	Continuous	Continuous	Continuous	Continuous
Removes:	Remove plasma water	Remove solutes based on membrane porosity & large volume fluid	Remove small solutes based on concentration gradient (**NO** fluid removal)	Remove solutes based on membrane porosity & large volume fluid
Ideal patient issue	**Fluid overload** withOUT electrolyte / acid-base disturbances	Fluid overload, electrolyte/ acid-base disturbances	**Electrolyte / acid-base disturbances**	Fluid overload, electrolyte/ acid-base disturbances
Blood flow (mL/min)	100	50-300	50-300	50-300
Dialysate flow (mL/min)	None	None	500-4000 Counter-current flow	500-4000
Replacement fluid	None	500-4000	None	500-4000
Anticoagulation	Heparin, citrate, none	Heparin, citrate, none	Heparin, citrate, none	Heparin, citrate, none

Table III. Comparisons of Continuous Renal Replacement Therapies (CRRT)

Adapted from Table 1 in Alvarez G et al. Renal replacement therapy: a practical update. Can J Anaesth. 2019;66(5):593-604.[13]

Clinical situations requiring rapid correction of metabolic abnormalities such as severe hyperkalemia and intoxications are better served by IHD. Use of IHD in a hemodynamically unstable patient may be optimized by increasing treatment time, increasing the bath sodium concentration, and decreasing the bath temperature.[1] Many patients will transition between modes based on their clinical state. PIRRT finds a balance between the two more commonly used modes. Lower rates mimicking CRRT decrease intradialytic hypotension while providing the patient periods of time free from RRT allowing for procedures, imaging, and increased mobility. **Table IV** compares the characteristics of the different RRT modalities.

Characteristic	Comparisons of RRT modalities			
	Intermittent Hemodialysis (IHD)	**Prolonged Intermittent Renal Replacement Therapy (PIRRT)**	**Continuous Renal Replacement Therapy (CRRT)**	**Peritoneal Dialysis (PD)**
Treatment duration (h)	3 – 6	6 – 18	24	4 – 6
Frequency	3+ / week	3+ / week	Continuous	Daily
Solute transport	Diffusion/ convection/ both	Diffusion/ convection/ both	Diffusion/ convection/ both	Diffusion
Blood flow (mL/min)	200 – 400	100 – 300	100 – 250	N/A
Dialysate flow (mL/min)	300 – 800	100 – 300	0 – 50	N/A
Filter size (m^2)	1.7 – 2	0.4 – 1.7	0.6 – 1.5	N/A
Urea clearance (mL/min)	150 – 180	90 – 140	20 – 45	15 – 35
Anticoagulation	+ / -	+ / -	Usually required	No
Advantages	● Rapid solute clearance ●Allows mobility ●Min RN needs	● > Hemodynamic stability vs IHD ●Allows mobility ●Less RN needs	● Hemodynamic stability ●Volume management ●Min effect on intracranial pressures	● Hemodynamic stability ●Allows mobility ●Min RN needs

Table IV. Comparisons of Renal Replacement Therapy Modalities

Several studies have been undertaken to identify advantages between these options. Currently, there is limited evidence to select one modality over another. Secondary analysis of the STARRT-AKI trial did demonstrate those with initial CCRT had a lower rate of dialysis dependence and greater ICU and hospital-free days at 90-days; however, these patients also had better kidney function at baseline limiting the impact of these results.[14] Alternatively, pooled analysis of patients undergoing initial CCRT in the AKIKI and IDEAL-ICU trials was associated with higher mortality at 60-days and no difference in dialysis dependence.[15]

Once the optimal modality is determined for the patient, a RRT dose must be prescribed. For dialysis, this is conveyed by the function Kt/V, where K is dialyzer clearance, t is duration time of dialysis treatment, and V is volume of distribution of urea.[2] The dose of CRRT is conveyed as the effluent dose adjusted for body weight expressed as mL/kg/hr. Due to common treatment interruptions encountered during CRRT, the delivered dose can be up to 20% less than the prescribed dose. The VA/NIH acute renal failure trail network (ARFTN) MCT and the RENAL trial both demonstrated no benefit to higher dose therapies. Based on these findings, KDIGO group created recommendations regarding optimal dosing of RRT. Each dose should be individualized for the patient to meet specific goals regarding electrolyte management, acid-base status, solute clearance, and fluid balance. This should be reassessed before each session. The recommended dose for IHD or PIRRT is a Kt/V of 3.9 per week, while for CRRT the recommended effluent volume is 20–25 ml/kg/h, which usually requires a higher prescribed volume.[16] Medications and nutrition need to be monitored and adjusted based on RRT modality and dosing.

SPECIAL CONSIDERATIONS IN SURGICAL ICU PATIENTS:

1. **INTRACRANIAL HYPERTENSION**: For patients after traumatic brain injury, stroke, subdural hematoma (SDH), liver failure patients, and those with cerebral edema, management of fluid shifts and sodium levels is critical. **In this cohort, CRRT is recommended as the RRT of choice.** Use of IHD results in greater osmolar shifts which may cause spikes of intracranial pressure (ICP) and worsen cerebral edema. CRRT decreases the risk of intradialytic hypotension and provides improved ICP stability. A recent study comparing RRT modalities in ESRD patients with SDH demonstrated significantly increased risk of hematoma expansion affecting neurological function (29.7% after IHD vs 12% after

CVVHD).[17] There was also a significant increase in in-hospital mortality or discharge to hospice in the IHD group (35%) versus CVVHD (5%).

2. **RHABDOMYOLYSIS**: While rhabdomyolysis is frequently seen after traumatic injury, only approximately 10% of these patients develop AKI with 5% requiring RRT. The biochemical diagnosis commonly referenced is CK values > 5 times the upper limit of normal or > 1000 IU/L. Resuscitation with crystalloid fluids at a starting rate of 400 mL/h is recommended and then should be titrated to urine output of 1-3 mL/kg/hr.[18] There is no role for RRT to prevent AKI in these patients and it should be used only if patients meet the accepted triggers for RRT initiation. The McMahon Score (Table 5) uses 8 variables to prognosticate risk of RRT or in-hospital mortality. A score ≥ 6 is 86% sensitive and 68% specific in identifying patients that will require RRT. In the study, 61.2% of the group with a risk score of >10 required RRT or died.[19]

Table 5: McMahon Score

Variable	Score
Age, years	
• >50 to ≤ 70	**1.5**
• >70 to ≤ 80	**2.5**
• > 80	**3**
Female	**1**
Initial creatinine, mg/dL	
• 1.4 – 2.2	**1.5**
• > 2.2	**3**
Initial calcium < 7.5 mg/dL	**2**
Initial CPK (creatinine phosphokinase) > 40,000 U/L	**2**
Origin NOT seizure, syncope, exercise, statins, or myositis	**3**
Initial phosphate, mg/dL	
• 4.0 – 5.4	**1.5**
• > 5.4	**3**
Initial bicarbonate < 19 mEq/L	**2**

*Adapted from Table 3 in McMahon GM et al. (2013). A risk prediction score for kidney failure or mortality in rhabdomyolysis. *JAMA internal medicine*, *173*(19), 1821–1828.

3. **ANTICOAGULATION:** Patients after surgery and trauma have an increased risk of bleeding compared to other ICU patients. While IHD can often be completed without any anticoagulation, CRRT often requires some form of anticoagulation to optimize dose, minimize downtime, and decrease complications as exposure of blood to the extracorporeal circuit promotes clotting. Systemic heparin infusion with a goal PTT 1.5-2 time normal can be used if the risk of bleeding is minimal. An alternative is Regional Citrate Anticoagulation (RCA). RCA works by chelating calcium and dropping iCa < 0.45 mmol/L within the circuit to prevent critical steps of the coagulation cascade. While RCA decreases risk of bleeding, there is a higher risk of hypocalcemia and it should be used with caution in patients with impaired citrate metabolism due to liver failure.[2] Anticoagulation selection should be individualized based on the patient's risk of bleeding, the consequences of bleeding and RRT modality required.

4. **CONTRAST IMAGING:** While controversy has existed in the past regarding the impact of IV contrast on renal dysfunction, there has been a recent push to demonstrate IV contrast has minimal risks even in patients with AKI. A consensus statement has been made by the American College of Radiology and the National Kidney Foundation regarding the use of IV iodinated contrast media in patients with kidney disease.[20] They note the risk of contrast induced AKI to be near 0% if eGFR ≥ 45, 0-2% if eGFR is 30 – 44, and 0-17% if eGFR < 30. They recommend prophylaxis for contrast induced AKI with normal saline in patients with a reduced eGFR. A recent cohort study including 14,449 patient encounters looking at the impact on IV contrast media administration in patients with AKI demonstrated no association with either persistent AKI at hospital discharge or initiation of RRT within 180 days.[21] The use of contrast is essential in identifying bleeding and enhancing imaging in surgical and trauma patients and should not be avoided if needed in patients with AKI.

WHEN TO STOP RENAL REPLACEMENT THERAPY?

There is limited guidance on when and how to stop RRT in ICU patients. Assessment to stop RRT should occur when there are signs of renal recovery and resolution of the acute illness. The KDIGO group recommends "RRT should be discontinued when it is no longer required, because intrinsic kidney function has recovered to the point that it is adequate to meet the patient's needs."[16] Clinically this is often interpreted using variable application of the measures 1) adequate UOP > 1000 mL/day or UOP > 2000 mL/day in setting of diuretics 2) spontaneous decrease in serum creatinine 3) absence of any AKI KDIGO

stages and 4) not requiring RRT in the past 7 days.[22] ICU patients on CRRT and PIRRT should be transitioned to IHD if they continue to require RRT.

HIGHLIGHTS:

1. There is a high incidence of AKI in surgical and trauma patients with resulting ↑ morbidity & mortality.
2. KDIGO is the preferred definition and classification system for AKI.
3. Biomarkers - [TIMP2]·[IGFBP7], NGAL), KIM-1, GST can be used for AKI diagnosis and guide therapies.
4. There is NO benefit to early RRT if accepted triggers are not present.
5. KDIGO stage 3 AKI does not mandate immediate RRT however if no renal recovery is noted after 48 to 72 hours, initiation of RRT will benefit the patient.
6. Many patients with AKI will be spared RRT using the delayed strategy for RRT initiation.
7. Use the Right Internal Jugular Vein for vascular access. Catheter tip should be in the right atrium.
8. There is limited data to support CRRT versus IHD as first mode of RRT, even in unstable patients.
9. Patients with intracranial hypertension - TBI, liver failure, stroke, cerebral edema benefit from CRRT.
10. Regional anticoagulation with RCA is ideal for surgical and trauma patients on CRRT
11. IV contrast is safe in patients with AKI. Provide adequate IV hydration during peri-contrast period.

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CHILL OUT: DELIRIUM & SEDATION IN THE CRITICALLY ILL ACUTE CARE SURGERY PATIENT

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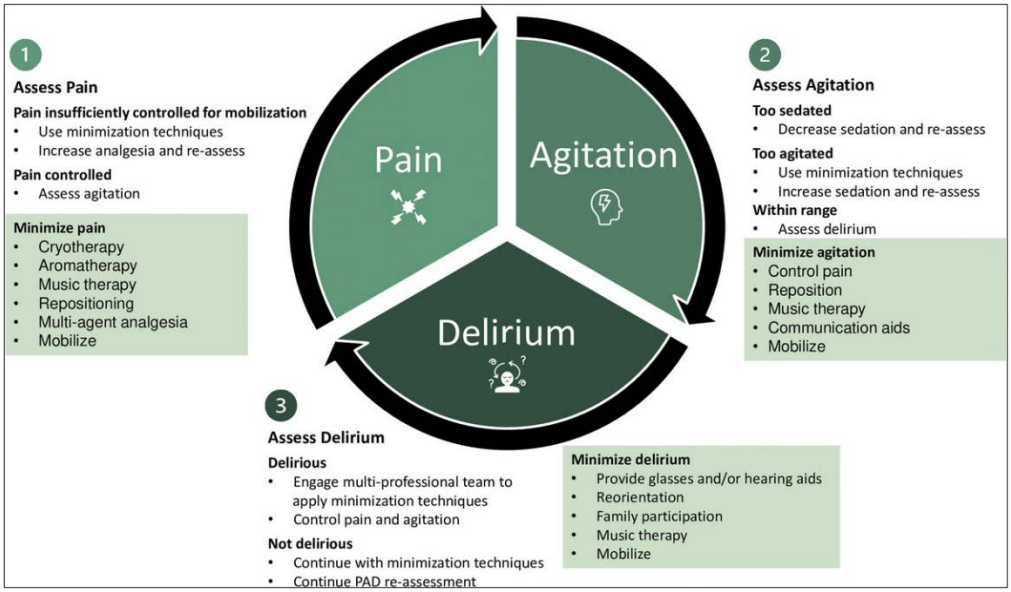
OPTIMAL APPROACH TO DELIRIUM AND SEDATION (EVANS JTACS 2023)

a) have a protocol
b) use objective assessment
c) assessment-guided diagnosis and management
d) prevention supersedes therapy
e) begin with nonpharmacologic prevention and management techniques
f) analgesia first/no sedation approach
g) engage a multiprofessional team
h) incorporate patient experience

HAVE A CONSISTENT, COMPREHENSIVE PLAN – 1, 2, 3



Evans. JTACS 2023

ASSESSMENT: BE OBJECTIVE. YOU HAVE TO HAVE THE RIGHT TOOLS

- Pain: Critical Care Pain Observation Tool (CPOT) or Behavioral Pain Scale (BPS)
- Sedation: Richmond Agitation and Sedation Scale (RASS) or Riker
- Delirium: Intensive Care Delirium Screen (ICDS) Checklist or Confusion Assessment Method for the ICU (CAM-ICU)

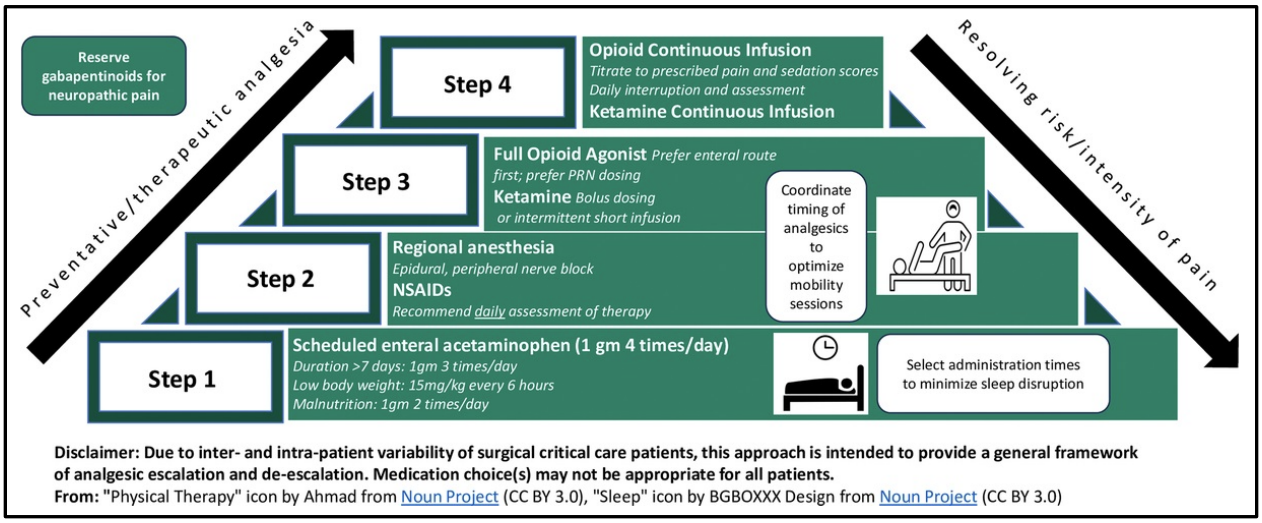
USE MULTI-PROFESSIONAL TEAMS

Pharmacy, physical therapy, nutrition, and, of course, nurses and providers must all work together to prevent and manage delirium.

STEP 1: ANALGESIA FIRST

Sedation is not essential in ICU care, even with mechanical ventilation. Start with analgesia. You may avoid the need for sedation altogether.

Building Your Analgesia Regimen-Start Small and Step Up.



Evans. JTACS 2023.

STEP 2: IF NEEDED, CHOOSE FROM SEDATION OPTIONS

Table I. Sedative Characteristics and Pearls

Sedative	Onset	Titration Frequency	Usual Dose Range	Deep Sedation
Propofol (first line)	1-2 min	Every 5 min	5-50 $\mu g \cdot kg^{-1} \cdot min^{-1}$	Yes
Dexmedetomidine (first line)	5-10 min	Every 30 min	0.2-1.5 $\mu g \cdot kg^{-1} \cdot h^{-1}$	No Do not use for patients requiring chemical paralysis
Benzodiazepines (reserved for select indications only)	Clinical Pearls			
Midazolam	• Lipophilicity results in rapid onset of action and is effective for managing acute agitation. • Short-acting agent; however, erratic pharmacokinetics and accumulation are expected with longer-term use.			
Lorazepam	• Hydrophilicity results in longer onset of action in comparison to midazolam; therefore, clinicians must be cognizant of dose-stacking and accumulation with repeated dosing. • Intermediate-acting, a characteristic that makes titration difficult and is a predisposing factor for accumulation since steady-state concentrations from a given titration can take days.			

STEP 3: ASSESS, PREVENT AND MANAGE DELIRIUM

Delirium Facts

- Definition: Acute confusion
- Common (>75% in ICU)
- Worsens outcome (short- and long-term)
- Risk is measurable
- Assessment Method: CAM
- Treatment: Reverse the cause, eliminate contributing factors

Delirium is the most common surgical complication in older patients

Risk factors for development of delirium in the ICU	**Nonpharmacologic approaches to limit agitation/delirium**
Advanced age	Lights on during the day
Dementia	Out of bed during day/progressive increases in mobility
Prior coma	Maintaining normal sleep/wake cycle
Pre-ICU emergency surgery/trauma	Eyeglasses
Higher APACHE Score	Music
Benzodiazepine use	Familiar faces and activities
Blood transfusion	

Prevention (of Delirium) is the Best Medicine (Evans JTACS 2023)

DOES MOBILITY REALLY HELP?

It doesn't hurt.

IS THERE A DRUG FOR DELIRIUM?

Table V. **Pharmacologic Therapy of Agitated Delirium.***

Agent	Drug Class	Dosing†	Routes	Degree of Sedation	Risk of EPS	Adverse Effects	Comments
Haloperidol	Typical antipsychotic	Initial: 0.25–0.5 mg Maximum: 3 mg	Oral, IM, or IV	Low	High	Risk of EPS increases if daily dose exceeds 3 mg	Longest track record in delirium; several large trials are ongoing
Risperidone	Atypical antipsychotic	Initial: 0.25–0.5 mg Maximum: 3 mg	Oral or IM	Low	High	Slightly less risk of EPS than with haloperidol at low doses	Small trials; considered to be very similar to haloperidol
Olanzapine	Atypical antipsychotic	Initial: 2.5–5 mg Maximum: 20 mg	Oral, sublingual, or IM	Moderate	Moderate	More sedating than haloperidol	Small trials; oral route is less effective than other routes for management of acute symptoms
Quetiapine	Atypical antipsychotic	Initial: 12.5–25 mg Maximum: 50 mg	Oral	High	Low	Much more sedating than haloperidol; risk of hypotension	Small trials; can be used, with caution, in patients who have parkinsonism
Ziprasidone	Atypical antipsychotic	Initial: 5–10 mg Maximum: 40 mg	Oral or IM	Moderate	Moderate	More sedating than haloperidol; risk of cardiac arrhythmia, heart failure, and agranulocytosis	Owing to risks, used primarily in ICU; large trial is ongoing
Lorazepam	Benzodiazepine	Initial: 0.25–0.5 mg Maximum: 2 mg	Oral, IM, or IV	Very high	None	More paradoxical excitation and respiratory depression than with haloperidol	Second-line agent; use in sedative and alcohol withdrawal or if patient has a history of the neuroleptic malignant syndrome

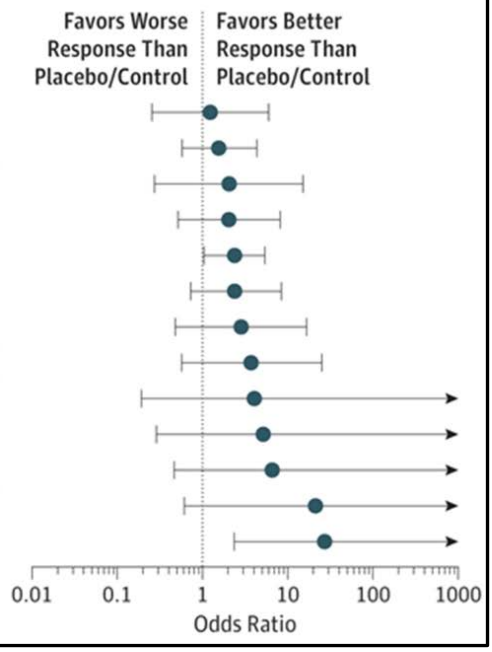
* Use of all these drugs for delirium is off-label in the United States. Atypical antipsychotic agents have been tested primarily in small noninferiority trials with haloperidol and recently in small placebo-controlled trials in the intensive care unit (ICU). The Food and Drug Administration (FDA) requires a "black box" warning for all atypical antipsychotics because of increased risks of cerebrovascular events (e.g., stroke) and death among patients with dementia. Typical antipsychotic agents have an FDA "black box" warning because of an increased risk of death among patients with dementia. EPS denotes extrapyramidal symptoms, IM intramuscular, and IV intravenous.

† The doses recommended in this table are for older adults. "Initial" represents the initial dose for an acutely agitated older patient; the dose may need to be repeated. "Maximum" represents the maximum recommended cumulative daily dose — that is, the sum of all as-needed and scheduled doses over a period of 24 hours. Somewhat higher doses may be used in younger patients if the side-effect profile is acceptable.

Marcantonio. NEJM 2017.

C Treatment response

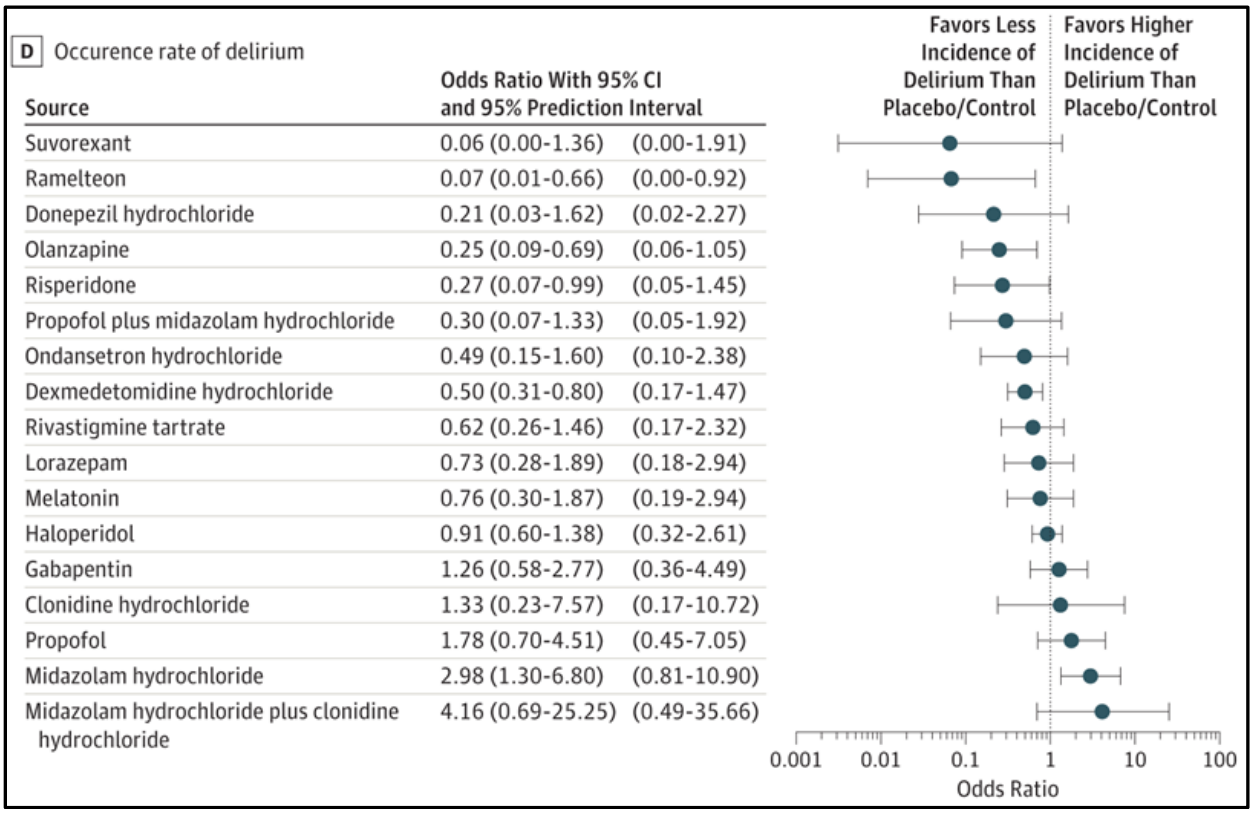
Source	Odds Ratio With 95% CI and 95% Prediction Interval	
Ondansetron hydrochloride	1.23 (0.24-6.22)	(0.03-53.71)
Risperidone	1.57 (0.56-4.38)	(0.07-37.78)
Haloperidol plus rivastigmine tartrate	2.06 (0.27-15.71)	(0.03-147.19)
Dexmedetomidine hydrochloride	2.06 (0.51-8.34)	(0.06-70.60)
Haloperidol	2.37 (1.04-5.43)	(0.12-48.80)
Olanzapine	2.46 (0.71-8.57)	(0.08-72.49)
Ziprasidone hydrochloride	2.89 (0.48-17.29)	(0.05-153.40)
Quetiapine fumarate	3.78 (0.55-25.84)	(0.06-235.65)
Amisulpride	4.10 (0.18-91.61)	(0.01-1256.98)
Lorazepam	5.34 (0.28-101.95)	(0.02-1308.79)
Chlorpromazine hydrochloride	6.68 (0.47-95.24)	(0.04-1089.82)
Rivastigmine tartrate	21.87 (0.61-790.15)	(0.04-13477.64)
Haloperidol plus lorazepam	28.13 (2.38-333.08)	(0.22-3563.80)



Wu. JAMA Psychiatry 2019.

IS THERE A DRUG TO PREVENT DELIRIUM (WU. JAMA PSYCHIATRY 2019)?

1. Dexmedetomidine
2. Ramelteon
3. Olanzepine (Zyprexa)
4. Melatonin?
5. Risperdone



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UPDATES IN TBI MANAGEMENT: BRAIN OXYGENATION, MMA EMBOLIZATION, AND NEW PROTOCOLS

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Traumatic brain injury (TBI) confers a significant healthcare burden reported to result in 190 deaths per day in the United States (US), disabling far more, and accruing billions of dollars in healthcare expenditures per year.[1] Trauma surgeons treat patients with TBI and its sequelae, daily. Understanding the pathophysiology, current research, and recommendations is vital to improving care to this vast population of patients.

Brain injury includes both primary and secondary injury. Whereas primary injury denotes the initial insult that occurs, secondary injury evolves in the subsequent hours to days and occurs as a result of altered cerebral metabolism, cerebral blood flow, and arterial oxygen content, which worsens cerebral ischemia.[2] Optimizing outcomes for those with TBI requires maneuvers to improve cerebral blood flow and oxygenation, traditionally accomplished by improving hemodynamics and decreasing intracranial pressure or volume. Preventing both hypotension and hypertension by use of vasoactive agents, and evaluation of intracranial pressure (ICP) with subsequent external ventricular drainage or surgical intervention have been standard of care for TBI. However, ICP measurement in patients with moderate to severe TBI may be a late indicator of deterioration.[3] Authors continue to investigate methods to enhance oxygen delivery, decrease secondary injury, and optimize outcomes for patients with TBI. In this manuscript, we review the updates in TBI, including brain oxygenation, middle meningeal artery embolization, and new protocols.

BRAIN OXYGENATION

Hypoxia is known to be independently associated with mortality in patients with TBI, in some studies demonstrating a dose-dependent increase in mortality with worsening hypoxia.[4-6] Several mechanisms have been proposed to increase oxygen delivery, including the use of transfusions and vasoactive agents, jugular venous oxygen measurement, and brain tissue oxygen measurement.

Given the known correlation between hypoxic events and mortality in TBI, researchers have proposed direct measurement of partial pressure of oxygen in brain tissue ($pBtO_2$) as a means to improve outcomes.[5-8] Direct brain oxygen measurements are conducted via intracranial probes capable of oxygen detection placed via craniotomy. Prior reports note that unfavorable outcomes are seen with $pBtO_2 < 15$ mmHg in the setting of ICP > 20 mmHg.[5,9,10] Observational trials including patients with TBI demonstrate that a majority of patients fall below 20 mmHg during their intensive care unit (ICU) course.[7] Chang et al. further elicited that hypoxia is common in patients with severe TBI and is independent of intracranial pressure (ICP) elevation.[7,10] Whether $pBtO_2$ measurement is a better predictor of TBI-related ischemia remains to be determined.

In attempts to evaluate the effects of brain oxygen measurement and treatment, researchers commenced the Brain Oxygen Optimization in Severe Traumatic Brain Injury Phase-II trial (BOOST-II).[8] Patients with a Glasgow Coma Score (GCS) of 8 or less, or those with a greater GCS who rapidly declined were selected for enrollment. Patients were stratified into two tiers of severe TBI: the first with a GCS 3-5 (motor GCS 1-2 if intubated); the second with a GCS of 6-7 (motor GCS 3-5 if intubated). Patients were subsequently randomized into those receiving only intracranial pressure monitors (ICP), and those receiving ICP monitoring in conjunction with brain tissue oxygen measurements. All patients received both ICP and $pBtO_2$ probes, and no adverse events were attributed to the probe placement. Patients in the ICP only group were treated when ICP measured ≥ 20 mmHg, in a stepwise fashion. Those randomized to the $pBtO_2$ arm were treated with either an ICP ≥ 20 mmHg, or a $pBtO_2$ < 20mmHg. Tiered approaches to treatment were utilized (Table I, from Okonkwo et al.), with ICP monitoring conducted for 2-5 days.[8]

Isolated ICP increase	Isolated $PbtO_2$ drop	ICP increase + $PbtO_2$ drop
TIER 1 • Adjust head of the bed to lower ICP • Ensure Temperature < 38°C. • Titrate pharmacologic analgesia or sedation • Optimize CPP to a max of 70 mm Hg with fluid bolus or vasopressors • CSF drainage (if EVD available) • Low dose Mannitol (0.25 – 0.5 g/kg), to be administered as bolus infusion. • Low dose Hypertonic saline (1.5 – 3%). Titrate to ICP control and avoid serum Na+ above 160. • Initiate or titrate anti-seizure medications (AEDs) • Adjust ventilator for a target PaCO2 of 35 - 40 mm Hg and target pH of 7.35 - 7.45	**TIER 1** • Adjust head of the bed to improve Pbt02 • Ensure Temperature < 38°C. • Optimize CPP to a max of 70 mm Hg with fluid bolus or vasopressors. • Optimize hemodynamics by: 1) Treating hypovolemia; 2) Avoid hypervolemia • Adjust PaO2 by: 1) increasing FiO2 up to 60%; 2) adjusting PEEP; 3) Pulmonary toileting (suctioning) • Adjust ventilator for a target PaCO2 of 38-42 mm Hg and target pH of 7.35 - 7.45 • Initiate or titrate anti-seizure medications (AEDs)	**TIER 1** • Adjust head of the bed to lower ICP • Ensure Temperature < 38°C. • Pharmacologic analgesia and sedation • CSF drainage (if EVD available). • Increase CPP to a maximum >70 mm Hg with fluid bolus. • Low dose Mannitol, (0.25 – 0.5 mg/kg) or Hypertonic saline (1.5 – 3%) • Optimize hemodynamics by: 1) Treating hypovolemia; 2) Avoid hypervolemia; • Increase PaO2 by: 1) increasing FiO2 up to 60%; 2) adjusting PEEP; 3) Pulmonary toileting (suctioning) • Adjust ventilator for a target PaCO2 of 38-42 mm Hg and target pH of 7.35 - 7.45 • Initiate or titrate anti-seizure medications (AEDs).
TIER 2 • Adjust ventilatory rate for target PaCO2 of 33 – 38 mm Hg and target pH of 7.30-7.45 • High dose Mannitol 1-1.5 g/kg or higher frequency of standard dose mannitol • High dose Hypertonic saline bolus (i.e., 7.5%, 30 ml of 23.4%). • Increase CPP above 70 mmHg with fluids or vasopressors. • Treat surgically remediable lesions according to guidelines • Adjust temperature to 35 – 36°C, using active cooling measures. • Neuromuscular blockade with short acting agents, use a bolus dose to determine effect	**TIER 2** • Adjust ventilatory rate to increase PaCO2 to 40 – 45 mm Hg and target pH of 7.35-7.45 • Increase PaO2 by: 1) increasing FiO2 up to 100%; 2) adjusting PEEP; 3) bronchoscopy • Increase CPP above 70 mmHg with fluids or vasopressors. • Neuromuscular blockade with short acting agents, use a bolus dose to determine effect • Transfuse pRBCs. • Decrease ICP to < 15 mm Hg. • CSF drainage. • Increased sedation	**TIER 2.** • High dose Mannitol 1-1.5 g/kg, or frequent boluses standard dose Mannitol • High dose Hypertonic saline bolus (i.e., 30 ml of 23.4%) • Increase CPP above 70 mm Hg with vasopressors. • Increase PaO2 by: 1) increasing FiO2 to 100%; 2) adjusting PEEP; 3) bronchoscopy • Transfuse pRBCs • Treat surgically remediable lesions according to guidelines • Adjust temperature to 35 - 36°C, using active cooling measures. • Neuromuscular paralysis blockade with short acting agents, use a bolus dose to determine effect

TIER 3 (Tier 3 therapies are optional). • Pentobarbital coma, according to local protocol. • Decompressive craniectomy. • Adjust temperature to 32-35°C, using active cooling measures. • Adjust ventilatory rate for target PaCO2 of 30 – 35 mm Hg and target pH of less than 7.50 • Other salvage therapy per local protocol and practice patterns	**TIER 3 (Tier 3 therapies are optional).** • Adjust ventilatory rate to increase PaCO2 to > 45 mm Hg if ICP is < 22 mm Hg and maintain a target ph of 7.30 – 7.45 • Increase cardiac output with inotropes (milrinone, dobutamine) • Assess for vasospasm, if present augment CPP • Consider hyperventilation for reverse Robin-Hood syndrome • Other salvage therapy per local protocol and practice patterns • Consider other causes: PE, CSDs, CST	**TIER 3. (Tier 3 therapies are optional).** • Pentobarbital coma: • Decompressive craniectomy. • Induced hypothermia. hypothermia to 32-35° C. • Increase cardiac output with inotropes (milrinone, dobutamine) • Assess for vasospasm, if present augment CPP • Consider hyperventilation for reverse Robin-Hood syndrome • Other salvage therapy per local protocol and practice patterns • Consider other causes: PE, CSDs, CST

Table I

A total of 119 patients were enrolled, and 106 followed up at six months. The primary outcome, efficacy of $PbtO_2$ treatment, demonstrated that patients in whom a lower $PbtO_2$ was utilized as a threshold for treatment suffered reduced total duration and depth of cerebral hypoxia. These results are delineated in Table II. ICP remained similar between the two groups, validating that cerebral hypoxia is independent of ICP.[8]

$PbtO_2$ metric	**ICP Only (n = 58)**	**$PbtO_2$ + ICP (n = 55)**	**p-value**
Proportion of time below 20 mmHg	0.44 (0.31)	0.15 (0.21)	0.0000147
Average depth (mmHg)	3.6 (3.9)	1.0 (2.0)	0.0000005
Area over the curve (mmHg x hrs)	255 (291)	58 (97)	0.0000002

Table II

The secondary outcomes of safety and feasibility demonstrated that $PbtO_2$ measurement and titration were safe, without any difference in serious adverse events between the two groups. Glasgow Outcome Scale–Extended (GOS-E) and Disability Rating Scale (DRS) were evaluated as long-term outcomes at 6 months and were similar between groups, although there was a trend toward improved outcomes and lower mortality amongst the $PbtO_2$ group. Figures 1 and 2 demonstrate these results.[8] This phase II trial was terminated early given positive results.

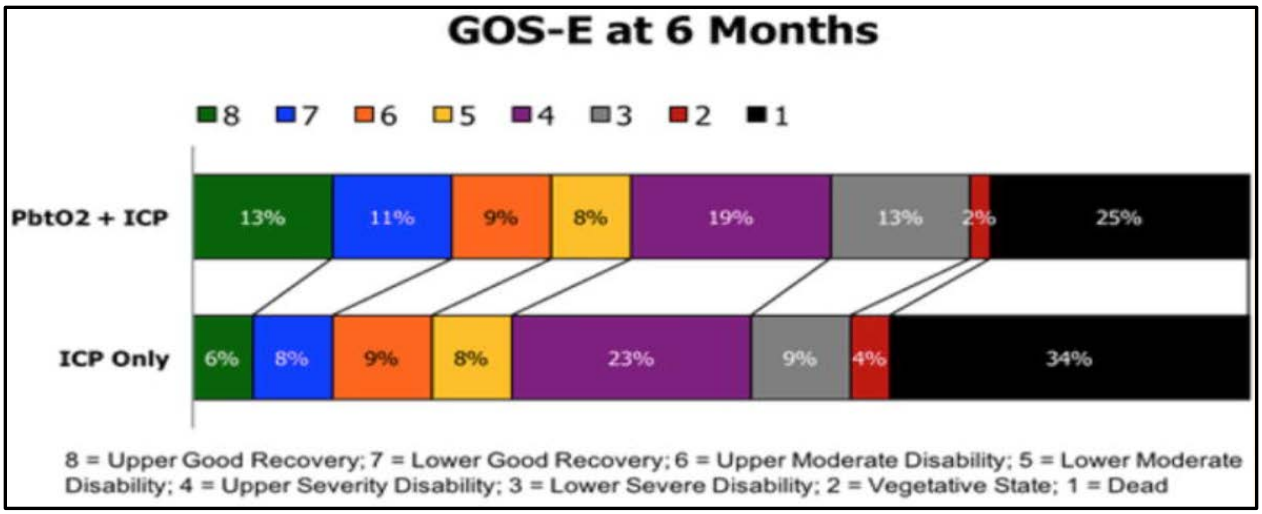

Figure 1

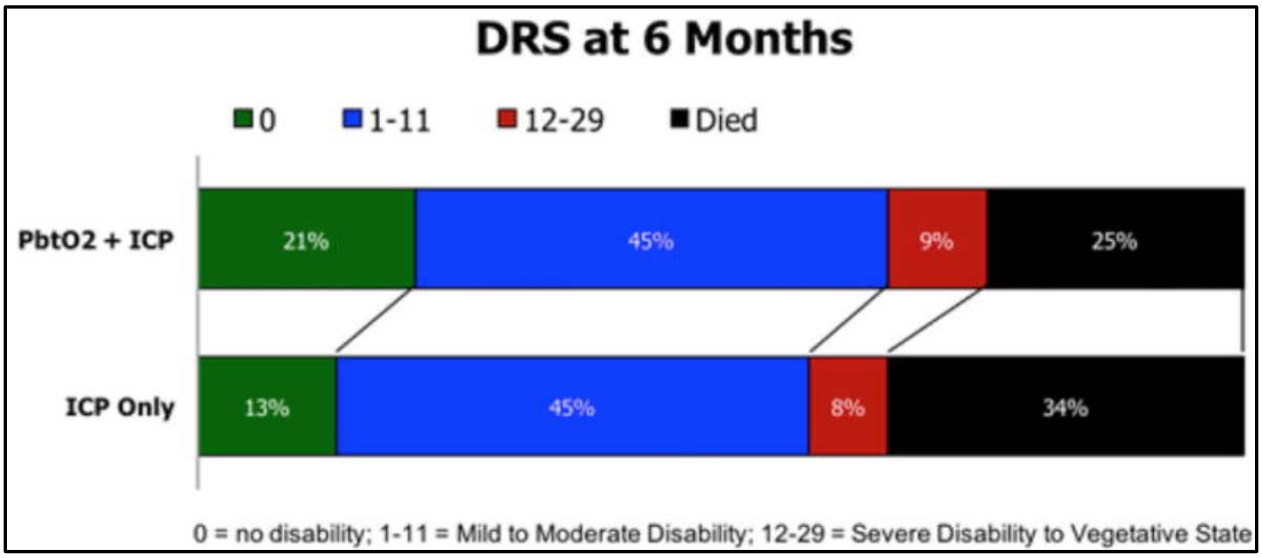

Figure 2

Whereas BOOST-II evaluated the feasibility and efficacy of their treatment protocol, several phase 3 trials are ongoing and recently completed. One of those was the Intracranial Pressure Monitoring with and without Brain Tissue Oxygen Pressure Monitoring for Severe Traumatic Brain Injury in France (OXY-TC). This trial studied the superiority of ICP with $pBtO_2$ measurement over ICP monitoring alone. Patients aged 18 - 75 years old with severe blunt TBI were assigned to either ICP only or ICP + $pBtO_2$ arms. Over a five-year period, 318 patients were included. The primary outcome was GOSE at 6 months, with similar ICP and $pBtO_2$ parameters to BOOST-II. Researchers determined that ICP + $pBtO_2$ did not improve GOSE, as compared to ICP alone. There was a significantly increased incidence of intracerebral hematoma with the $pBtO_2$ group and no difference in mortality at 12 months.[11]

Two additional ongoing trials attempt to corroborate or refute these findings. One of those, the Brain Oxygen Optimization in Severe Traumatic Brain Injury Phase 3 (BOOST-3) trial, is an ongoing trial to investigate functional outcomes for patients with severe blunt TBI with ICP only or ICP + $pBtO_2$. This trial will evaluate survival at discharge, degree of brain hypoxia, and additional functional outcomes and is currently enrolling at several centers in the United States and Canada. Inclusion criteria are patients ≥ 14 years of age, having sustained a blunt traumatic brain injury confirmed on computed tomography (CT) scan, with a GCS of 3-8 without paralysis, or <6 if requiring mechanical ventilation. The exclusion criteria include the ability to follow commands, non-survivable injuries, absent pupillary responses, and resistant hypoxia or hypotension. All patients receive both ICP and $pBtO_2$ catheters. Physicians select treatment from a tiered algorithm, and functional outcomes will be assessed via the GOSE at 6 months. Secondary outcomes include additional functional and behavioral outcomes at 6 months.

Finally, the Brain Oxygen Neuromonitoring in Australia and New Zealand – Global Trial (BONANZA) is being conducted in a similar fashion to BOOST-3. Here, patients ≥ 17 years old, with blunt severe TBI and a GCS < 9 will be stratified into ICP monitoring only, or ICP + $pBtO_2$. Similar to both BOOST-3 and OXY-TC, the primary outcome is GOSE at 6 months. Given the similarities between study design of the three aforementioned trials, future meta-analysis is anticipated. Results from BOOST-3 and BONANZA are pending and will surely assist in guiding therapy for patients with severe TBI in the future.[12]

As we await results from these ongoing trials, current guidelines per the Brain Trauma Foundation state that $pBtO_2$ measurements should be utilized to monitor oxygen delivery only if hyperventilation is used.[13] However, at the 2022 meeting of the The Seattle International Severe Traumatic Brain Injury Consensus Conference (SIBICC), international experts developed an algorithm to integrate ICP and $pBtO_2$ measurement in treatment.[14] This algorithm is described below in the "New Protocols" section of this manuscript.

Additional measures, including arterio-jugular venous oxygen (AVDO2) measurements, cerebral microdialysis, and transcranial doppler examination, are areas of ongoing research in patients with TBI.

MMA EMBOLIZATION

The middle meningeal artery (MMA) has long been implicated as an associated vessel in patients who sustain epidural hematomas. However, as it perfuses the dura, it has been associated with the development and progression of chronic subdural hematomas (cSDH). Given the shortcomings of surgical treatment of cSDH, middle meningeal artery embolization (MMAE) has emerged as an alternate technique for treatment of this insidious and somewhat pervasive problem.

Although the exact mechanism remains unclear, cSDH is thought to develop with chronic inflammation following a SDH. Recurrence of a SDH is reported in up to 37% of patients, even after surgical intervention.[15] Studies have demonstrated that there is small vessel communication between the MMA, through the dura, to vessels on the outer membrane of the cSDH. As such, MMAE has been proposed as a technique for treatment of cSDH.

MMAE was initially employed by Mandai et al. in conjunction with burr hole craniotomy for a patient with cSDH.[16] The patient had improvement of neurologic function and no permanent deficits thereafter. Given the positive results of this case report, it became increasingly studied. Okuma et al. evaluated patients receiving MMAE for refractory cSDH. In a series of 17 patients, none demonstrated recurrence or complications following embolization. This early report demonstrated the efficacy of this therapy.[17]

Several additional trials have evaluated the efficacy of MMAE in cSDH as a primary treatment strategy and following recurrence after other interventions. Several series utilizing MMAE as a primary therapy for cSDH demonstrated between 50-88% reduction in cSDH on repeat imaging, with none of the treated patients demonstrating recurrence on 6 month follow-up and low complication rate.[18-21] Shotar et al., found that patients who received MMAE for risk of cSDH recurrence had significantly fewer recurrences.[22] Ng et al., found that patients receiving surgery with MMAE for cSDH had greater hematoma resolution as compared to surgery alone. No endovascular-related complications were noted.[23] There is additional evidence to demonstrate that MMAE is superior to conventional surgery as well.[24]

Di Cristofori conducted a systematic review of the published literature evaluating risks and benefits of MMAE, and found that the procedure is safe with few documented complications and a low failure and can be used as an adjunct to surgery or as an isolated treatment.[25] An additional study found that patients treated with MMAE has no difference in mortality, outcomes, or the need for surgical rescue, as opposed to primary surgery, and may be an optimal option in patients with high Charlson comorbidity indices.[26] Given this breadth of literature, MMAE has now become a standard therapy for adult patients with cSDH. Pediatric patients have a lesser incidence of cSDH, given its etiology; however, studies demonstrate the efficacy of MMAE in this population as well.[27] Further literature is required to validate this finding.

NEW PROTOCOLS

Several new protocols have been established in the management of TBI. First, pre-hospital guidelines from the Brain Trauma Foundation have been amended to include specific parameters of blood pressure and blood pressure cuff size for pediatric and adult patients with TBI. There is a focus on ventilation monitoring and measures, with additional weak recommendations regarding temperature monitoring and management. Finally, acknowledgement of resource limitations and recommendations for oxygenation, blood pressure, ventilation, and temperature monitoring in these settings was newly added.[28]

Given ongoing data surrounding $pBtO_2$ evaluation, the SIBICC developed protocols to guide therapy. In this report, conducted similar to a Delphi-method consensus, a tiered approach is recommended to optimize ICP and cerebral perfusion and oxygenation. Tier 0 treatment involves a neuroprotective strategy to prevent further decline, regardless of ICP measurement. Tiers 1-4 involve optimization of sedation and analgesics, ventilator compliance, temperature management to avoid fevers, and maintaining CPP > 60 mmHg, depending on a patient's $pBtO_2$ and ICP measurements. Treatment options are a summary of treatments from the BOOST-II trial, and depicted by Meyfroidt et al. in Figure 3.[29]

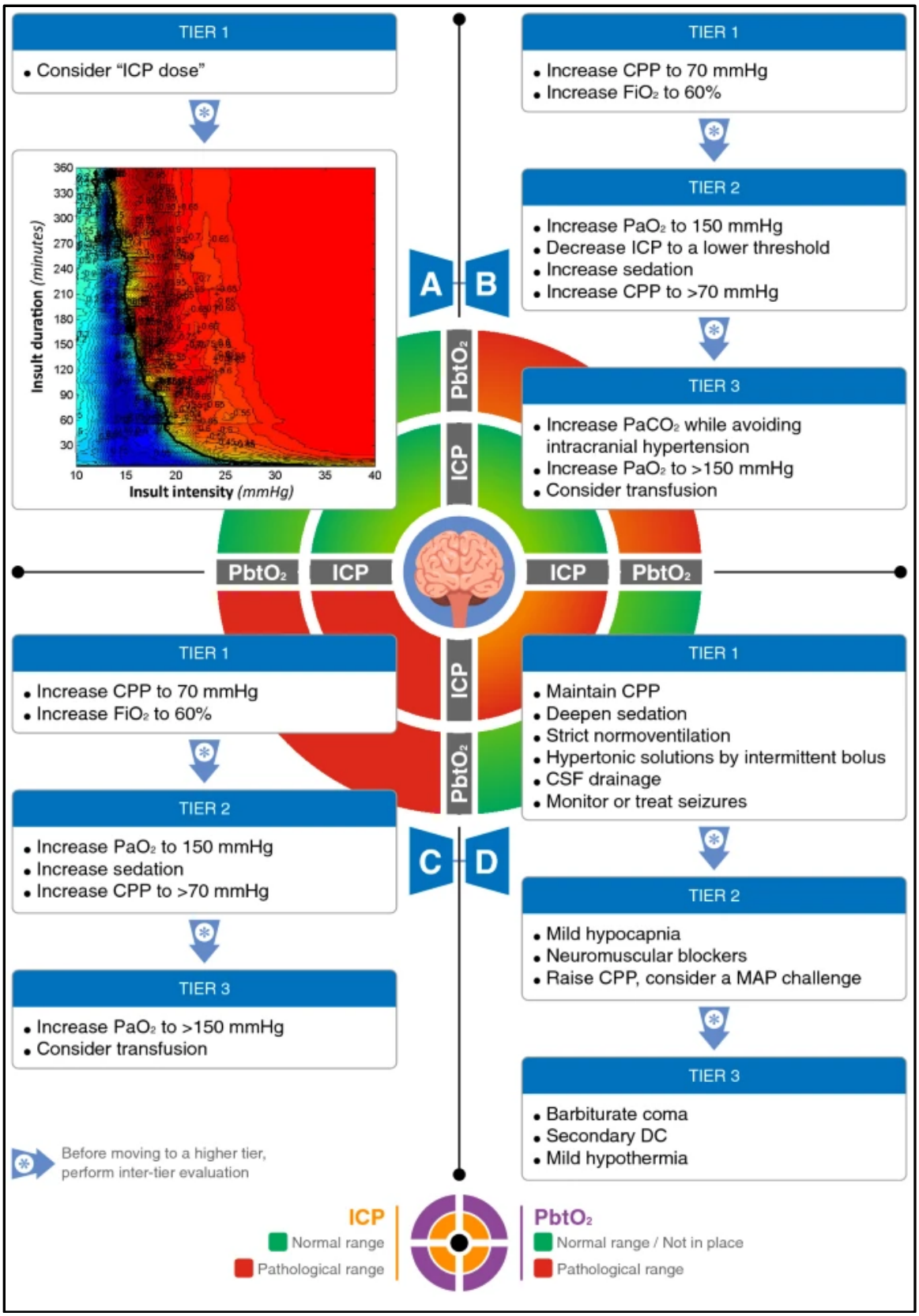
TIER 1
• Consider "ICP dose"
Insult duration (minutes)
Insult intensity (mmHg)
TIER 1
• Increase CPP to 70 mmHg
• Increase FiO₂ to 60%
TIER 2
• Increase PaO₂ to 150 mmHg
• Decrease ICP to a lower threshold
• Increase sedation
• Increase CPP to >70 mmHg
TIER 3
• Increase PaCO₂ while avoiding intracranial hypertension
• Increase PaO₂ to >150 mmHg
• Consider transfusion
A
B
C
D
PbtO₂
ICP
TIER 1
• Increase CPP to 70 mmHg
• Increase FiO₂ to 60%
TIER 2
• Increase PaO₂ to 150 mmHg
• Increase sedation
• Increase CPP to >70 mmHg
TIER 3
• Increase PaO₂ to >150 mmHg
• Consider transfusion
TIER 1
• Maintain CPP
• Deepen sedation
• Strict normoventilation
• Hypertonic solutions by intermittent bolus
• CSF drainage
• Monitor or treat seizures
TIER 2
• Mild hypocapnia
• Neuromuscular blockers
• Raise CPP, consider a MAP challenge
TIER 3
• Barbiturate coma
• Secondary DC
• Mild hypothermia
Before moving to a higher tier, perform inter-tier evaluation
ICP
Normal range
Pathological range
PbtO₂
Normal range / Not in place
Pathological range

Figure 3

THE MANTLE

Godoy and colleagues developed a bundle to be used in the intensive care unit (ICU) for management of patients with TBI. This bundle includes optimization of metabolic parameters, arterial blood pressure, nutrition and glucose, oxygenation, lung protective ventilation, control of edema and ICP, temperature, hemoglobin, and electrolytes.[2] Whether this protocol improves outcomes globally will require further investigation, but it may increase the ability for multidisciplinary teams to communicate and streamline care for this patient population.

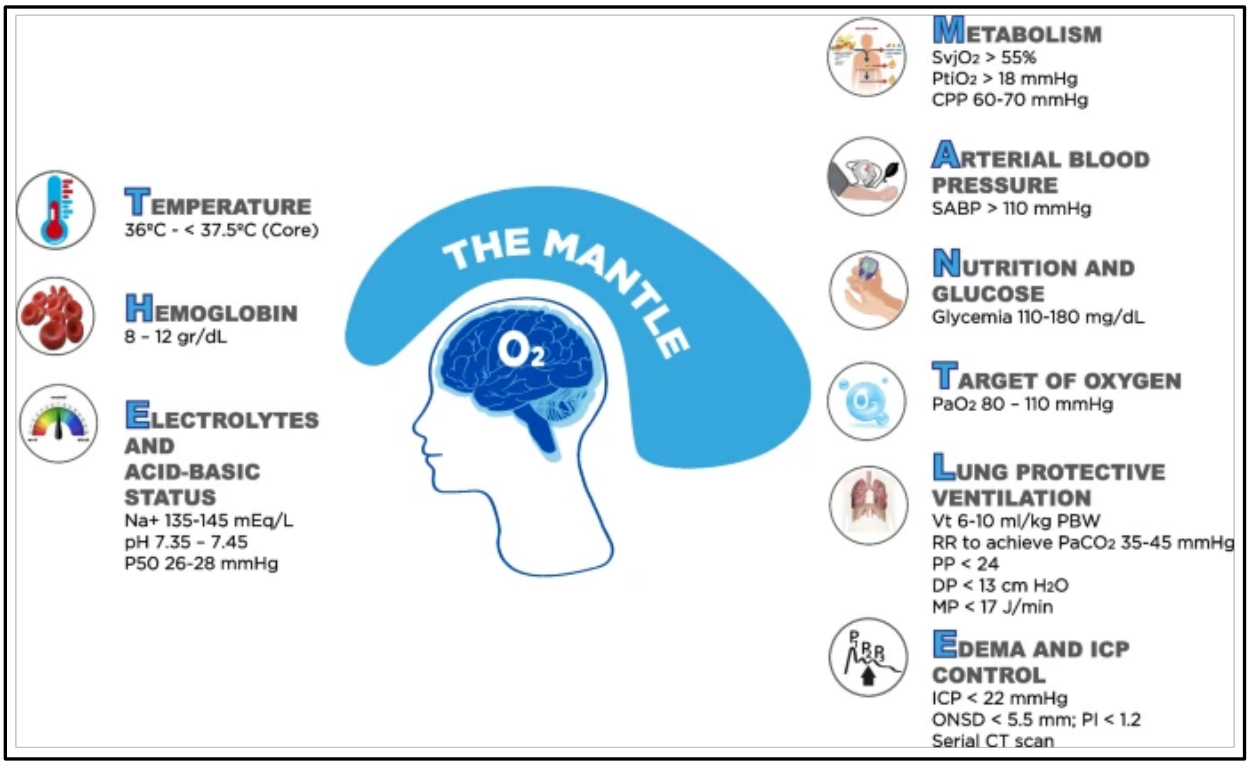

Figure 4

CONCLUSIONS

The management of TBI continues to evolve, with the promise of integrating brain tissue oxygen measurement into the management of those with severe TBI. Middle meningeal artery embolization is now a more standard therapy for chronic subdural hematomas, and several new treatment algorithms have been proposed to optimize the care of patients with TBI. Trauma surgeons should continue to investigate mechanisms to improve both short term and long-term functional outcomes for this considerable patient population.

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ICU NUTRITION: STUFF EM OR STARVE EM!

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Nutrition in the ICU is a complicated issue that surgical patients confront in our everyday practice of surgery and trauma. Whether it is after acute care surgery problem or after major trauma, each patient must be assessed for nutritional management. There is much debate in surgical literature as to the best way to nourish postop patients. Historically, prior to the ICU movement in the 1960's, surgical patients were treated in postop recovery rooms or on a regular floor. Even in these early days, the importance of nutrition in post surgery patients was recognized. In fact, during ancient times in Egypt and Greece, enteral feeds were given through the rectum. As you can imagine, this method was not effective, since the colon is only used by the body for storage and water absorption. After President Garfield was shot in the abdomen, he was treated by physicians who decided to give him nutrition by the rectum, he was administered a mixture of whiskey, egg yolk, bouillon, milk and opium, per rectum. After 80 days, he had lost a significant amount of weight and subsequently died. Feeding through the upper GI tract was started in the late 18th century and became the predominant way to feed patients. Jejunal feeds were introduced the 20th century.

Surgeons caring for injured patients recognized there were a number of issues related to nutrition requirements and intestinal failure in various groups of patients. Pediatric patients with necrotizing enterocolitis, gastroschisis and other pediatric abnormalities, had intestinal failure. Patients with intestinal fistulas also had major problems with enteral nutrition. Additionally, patients who sustained head injuries and other types of major trauma became difficult to nourish. Many post injury patients had higher metabolic demands, as did patients who sustained burns and major injury.

Each patient is admitted to the ICU should have a nutritional assessment done. Without question, Appropriately timed and delivered nutritional support improves outcomes following surgical illness and injury. The first step is evaluation of nutritional status, best done by a dietitian with the goal of identifying nutritional risks and any nutrition related diagnosis. The scoring systems allow for assessment of nutritional risk through evaluation of variables such as age, APACHE II and SOFA scores, co-morbidities, days in the hospital, dietary intake, gastrointestinal symptoms, functional status, etc. The scoring outcome guides the nutritional support strategy in the critically ill and injured patient.

There are simple methods as well as more complicated ways of assessment. One simple bedside test commonly used by nutritionists is done in the ICU. The subjective global assessment tool, SGA, first described by Detsky, is a basic and quick way to assess the nutritional needs of the patient. The Canadian Nutric Score is another system, the goal of which is to identify which patients are most likely to benefit from aggressive nutritional therapy. This system incorporates age, APACHE 2 and SOFA scores, and comorbidities prehospital, ICU length of stay, and Interleukin-6 levels. Many other screening tools have been used, but there is no one tool that is recognized and the perfect option. Nutritional assessment and support must be individualized.

Indirect Calorimetry is the gold standard - the only true means to obtain caloric requirements and set an accurate goal for nutrition therapy. Measurements taken include REE, RQ, VO2, and VCO2 when the patient is not being suctioned, turned, or stressed in any way. A patient's FI02 greater than .80 FI02 invalidates the measurement of the RME. The indirect calorimeter machine uses the Haldane transformation equation to measure RME and allows the clinician to give the proper amount of nutrition and not over-feed. Unfortunately, this technology is not available in many hospitals/centers and some clinical conditions limit its practical and accurate use (evolving lung injury, pneumothorax with air leak, etc.), standardized formulas provide the most widely available tool for assessment of energy need.

One of the more common ways to assess the patient's metabolic rate or resting metabolic expenditures is the Harris Benedict Equation, which resulted from a study by James Arthur Harris and Francis Daniel Benedict published in 1919. In 1984, the study was validated and updated for accuracy. The rate was calculated for both men and women:

Men

BMR (Basil Metabolic Rate)

BMR= 66.4749 + 13.7516 x weight in kg + 5.0033 x height in cm – 6.7550 x age in years

Women

BMR (Basil Metabolic Rate)

BMR= 655.0955 + 9.5634 x weight in kg + 1.8496 x height in cm – 4.6756 x age in years.

This method has been used for years to assess patient metabolic needs when indirect calorimetry is not available. These equation are most used is an estimate of the caloric needs of the ICU patients. A multiplier corrects for the needs of patients' increasing stress, which affects metabolic needs. It is estimated that 40% of hospitalized patients are malnourished, particularly cancer patients, chronically ill with COPD, ESRD, elderly, polysubstance abuse patients, as well as the unhoused patients who may not have access to food. In general, ICU patients will require 25-30 Kcal/Kg each day.

Other states that can increase metabolic needs include:

Trauma 0.3 x RME

Elective Surgery: 0.1 x RME

Sepsis up to 0.5 x RME

Severe sepsis: up to 0.6 x RME

Massive Burnr: 1x RME

Nutritional therapy in the ICU it should be monitored on a regular basis to assure the proper nutritional support has been chosen and is being supplied as planned and prescribed. Assessment of estimated energy and protein requirements is an ongoing requirement for each patient, as is evaluation of how the patient is tolerating feeding. Finally, the goal of monitoring is to detect specific micronutrient deficiencies in patients at risk for special losses (e.g., drains, renal replacement therapy, or pathology, like burns).

When exposed to the stress of an infection or trauma, for example, the patient will experience an "ebb phase," which is associated with decreased cardiac output and metabolic rated. The ebb phase usually occurs after the first hours of injury (24-48 hrs.). The body tries to maintain normal homeostasis during this phase. There is a decrease in total body energy and urinary nitrogen excretion, with early increase in catecholamines and cortisol. These patients are typically in shock during this phase of injury.

The flow phase typically occurs in the 2-to-7-day period after injury. During this phase, adipose tissue and skin can be damaged. During the initial period of catabolism, it is critical the patients receive adequate nutrition, as the metabolic response is related to supply of energy and protein substrate to protect against tissue damage and preserve organ function. Catecholamines mediate the response to this phase. The transition from catabolic to anabolic phase depends on severity of insult. For elective surgery, it may be 3 to 8 days, but for severe injuries, the catabolic phase can persist, and the process can take weeks after severe injury or sepsis. This period is known as the cortical withdrawal phase, and there is net negative nitrogen excretion and appropriate potassium nitrogen balance is needed. When the patient begins to diurese and oral intake picks up, the anabolic phase will begin. This may take weeks to months in severely injured patient. When the patient has positive nitrogen balance, weight gain and increased protein will be seen. If the patient has maximum positive nitrogen balance of 4 g/day, it will result in approximately 25 g/day of body mass gain of 100g/dy.

Under- and Overfeeding

It is important to assure adequate caloric nutrition throughout postoperative recovery. Daily assessment is key. Underfeeding may be a problem, even after ICU discharge, so correctly managing nutrition throughout the hospital stay is important. This is more of a concern with enteral feeds than when a patient is on TPN.

Overfeeding in the ICU occurs when the patient receives more that 100% of the calories they require and can occur with both enteral and parenteral feeds, but the incidence is higher with parenteral feeds. If the patient is receiving both at the same time, the risk of overfeeding is even higher. The concept of catch-up feeds is not a valid concept and is associated with complications over the long term, including alterations in liver function and hyperglycemia. If this is used only over a period of hours, then complications are not a major issue. Symptoms of overfeeding include cardiac dysfunction, e.g., heart failure or ventilatory compromise may mean that nutrition is being given to fast to a patient. Care must be taken with nutrition in patients who are at risk for refeeding syndrome and hypophosphatemia in that they may be at risk for cardiovascular issues.

Types of Nutrition

Measuring of the typical serum levels of proteins may not be a reliable determinant of the amount protein a patient may need. Albumin and prealbumin blood levels may be affected by critical illness. Amino acid levels are also not readily available in most centers. The loss of protein is a way to help determine nitrogen store in patients, which is a helpful guide to nutrition therapy. The typical nitrogen loss over a 24-hour period is 100-500 mg/kg/day from urine. A multiplication factor of 6.25 is used to help calculate the corresponding amount of protein. The recommended amount of protein to be given is 1.2-1.3 g/kg for most ICU patients. Some have more recently proposed an even higher amount of 2.5g/kg. Using this range helps to ensure that critically ill patients get adequate protein early in their hospitalization. Too much protein can have an adverse effect on patients, particularly if they have renal impairment.

Administration of carbohydrates is another important part of nutrition, but each guideline is slightly different. ASPEN and ESPEN have different recommendations. The ASPEN guidelines do not have strict numbers but recommend keeping blood sugar 140-180mg/dl. ESPEN recommends > 2g/kg/day and keeping blood sugar below 180mg/dL. The key element is making sure patients do not become hyperglycemic due to their feeds.

Lipid intake should be part of nutrition in patients. If the patient is on propofol, that these calories are considered. ASPEN does not suggest for lipid other that avoiding soy base lipids in the first week. However, ESPEN recommends giving 0.7-1.5 g/kg/day. How often this is given depends on whether and how often nutrition is given parenterally or enterally.

Parenteral versus Enteral Feeds

Feeding in the ICU has been controversial for many years. Two large multicenter randomized trials did not show any difference in mortality for both routes, but enteral feeds had more GI complications. A large study by Harvey et. al., of 2400 patients showed no difference in 30-day mortality or infectious complications. In this study, they found less hypoglycemia and less vomiting in the parenterally fed patients. The NUTRIKEA-2 study recruited 2410 patient and found no difference in 28-day mortality and infection rates but found more GI complications in the enteral feeding group.

Even with the above noted evidence, nutritional guidelines uniformly recommend enteral feeding if the patient can receive feeds by the GI tract, the goal being to make sure clinicians use the gut or it will not function as well. There is a worldwide consensus that an attempt should be made to give trophic feeds as soon as possible in patients in the ICU, starting as early as 24 to 48 hours after admission. Enteral feeds can be given in the stomach or jejunum, as needed. An individualized approach is recommended. The European Society of Intensive Care Medicine recommends against enteral feeds for patients who are unstable or on high dose pressors and increasing lactate. Combinations of parenteral and enteral feeds can be used, when needed, if the patient is not tolerating tube feeds at goal and is in the acute phase of illness.

In conclusion, nutrition in the critically ill is an important issue for trauma surgeons and ICU physicians to consider. When the patient arrives in the ICU, a nutrition assessment should be done to determine their current and goal nutritional state. Currently, enteral feeding is the preferred route of treatment for the patients in the ICU, though many studies show equal risks for both parenteral and enteral feeding.

Figure 1 - ASPEN and ESPEN ICU nutritional recommendations

Subject	ASPEN recommendation	ESPEN recommendation
Energy intake	>80% (25–30 kcal · kg^{-1} · d^{-1}) of energy requirements in EN or hypocaloric PN dosing (≤20 kcal · kg^{-1} · d^{-1} or 80% of estimated energy needs) with adequate protein doses (≥1.2 g · kg^{-1} · d^{-1}) in severely malnourished patients or patients at high nutritional risk during the first week of hospitalization (2)	≤25 kcal · kg actual BW^{-1} · d^{-1} during the acute phase (48 h after ICU admission), and ≤30 kcal · kg actual BW^{-1} · d^{-1} during the postacute phase (≥4 d postadmission) (48)
Protein intake	1.2–2.0 g · kg actual BW^{-1} · d^{-1} for patients with BMI (in kg/m^2) <30 and 2.0–2.5 g · kg ideal BW^{-1} · d^{-1} for patients with BMI >30 (2)	1.3–1.5 g · kg ideal BW^{-1} · d^{-1} (17)
Carbohydrate intake	Not defined Maintenance of blood glucose concentrations of 140–180 mg/dL (2)	≥2 g · kg^{-1} · d^{-1} (17) Maintenance of blood glucose concentrations <180 mg/dL (17)
Lipid intake	Doses not defined Avoid soy-based lipids in the first week of hospitalization (2)	0.7–1.5 g · kg^{-1} · d^{-1} (17)

SPECIAL PATIENT POPULATION GUIDELINES

Pediatric Patients

Estimating Pediatric Energy Needs in Critical Illness			
Age (years)	Gender	Resting Energy Expenditure (REE) or Basal Metabolic Rate (BMR) Equations (Kcal/day)	
		WHO	Schofield
0-3	Male	(60.9 x Wt) – 54	(0.167 x Wt) + (15.174 x Ht) – 617.6
	Female	(61 x Wt) – 51	(16.252 x Wt) + (10.232 x Ht) – 413.5
3-10	Male	(22.7 x Wt) + 495	(19.59 x Wt) + (1.303 x Ht) + 414.9
	Female	(22.5 x Wt) + 499	(16.97 x Wt) + (1.618 x Ht) + 371.2
10-18	Male	(17.5 x Wt) + 651	(16.25 x Wt) + (1.372 x Ht) + 515.5
	Female	(12.2 x Wt) + 746	(8.365 x Wt) + (4.65 x Ht) + 200

Wt = weight in kg; Ht = height in cm

Source: Adapted from Pocket Guide to Pediatric Nutrition Assessment (Leonberg, 2013).

Adult Patients

For mechanically ventilated patients, the Ireton-Jones and Penn State equations are the most widely utilized and most accurate in estimating energy needs, though Indirect Calorimetry remains the gold standard. They include factors for not only height, weight, and age, but also intensive care status, minute ventilation, Tmax for past 24 hours, and factors for trauma and burn. Per current guidelines (ASPEN 2016 and 2021), the use of 25-30 kcal/kg may also be used for adults of non-obese weight status.

Ireton-Jones	
RMR = 1784 – (11 x A) + (5 x W) + (244 x sex) + (239 x T) + (804 x B)	
RMR = Resting Metabolic Rate	W = weight in kg
A = age in years	T = Trauma Present = 1 ; Absent = 0
Sex Male = 1 ; Female = 0	B = Burn Present = 1 ; Absent = 0

Penn State	
RMR = (Mifflin-St. Jeor x 0.96) + (V_E x 32) + T_{max} x 167) – 6212	
V_E = minute ventilation (L/min)	T_{max} = maximum body temp previous 24 hr (C)
Mifflin-St Jeor	
Men = 5 + (10 x W) + (6.25 x H) – (5 – A)	Women = -161 + (10 x W) + (6.25 x H) – (5 x A)
W = weight (kg)	W = weight (kg)
H = height (cm)	H = height (cm)
A = age (yr)	A = age (yr)

Geriatric Patients

The geriatric population has a high variability in needs and predictive equations are not as accurate as in non-geriatric adults. If indirect calorimetry is unavailable, there has been no significant difference found between the different equations and measured resting energy expenditure with any statistically significance. The Penn State and Ireton-Jones equations for elderly patients with trauma to account for age, ventilation status, and injury severity are recommended.

Morbidly Obese Patients

The use of weight- based or predictive equations to determine energy requirements are utilized including the practice of underfeeding in obesity with the provision of increased protein to induce lipolysis for additional caloric provision to prevent overfeeding in the critically ill obese patient.16

Current energy recommendations for obesity are dependent upon the patient's body mass index.

- BMI 30-50: 11-14 kcal/kg using patient actual body weight
- BMI >50: 22-25 kcal/kg ideal body weight

These parameters must be used with higher protein recommendations to ensure adequate provision to prevent lean body mass catabolism

- BMI 30-40: 2gm/kg protein using ideal body weight
- BMI >40: 2.5gm/kg protein using ideal body weight

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ETHICAL ISSUES IN THE ICU

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OBJECTIVES

- Learn the four ethical principles that guide medical ethics in the ICU
- Recognize the definition of futility/non-beneficial care
- Understand indications for palliative care in the ICU
- Describe characteristics for a successful family patient discussion

ETHICAL PRINCIPLES

There are four main principles of medical ethics: autonomy, beneficence, justice, and non-maleficence.[1]

- **Autonomy**: Each patient has the right to make their own decisions based on their own beliefs and values.
- **Beneficence**: We have a duty to refrain from maltreatment, minimize harm, and promote good towards patients.
- **Justice**: All patients have a right to be treated fairly and equally by others.
- **Non-maleficence**: Patients have a right to no harm.

ETHICAL VALUES AND RULES

These are extensions of prior principles above as expressed in guidelines, policies or procedures. Examples of ethical values include confidentiality, human dignity, and quality of life. Examples of Ethical Rules include DNR orders, withdrawal of life-support, and brain death criteria.

ETHICAL DILEMMAS IN CRITICAL CARE

These typically include the following factors, and multiple factors are common:

- Use of technology
- Limits on treatment
- Admission/discharge triage needs
- Resource limitations
- Physician-patient/family relations
- Personal beliefs of healthcare provider
- Cultural differences between family and providers
- Concepts of futility and death

FUTILITY

The term, “futility”, or, perhaps, better called “non-beneficial care” is often clinically invoked when a seriously ill patient has a low likelihood of a meaningful recovery. What defines recovery and what the goals of care are vary from patient to patient. The dictionary definition of the term “futile” is “incapable of producing any result; ineffective; useless; not successful”. Doctors cannot ‘force’ patients to follow their advice, but equally, doctors can refuse to give treatment that they think is not in the patient’s best interest. Care that will not improve symptoms or restore health may be non-beneficial. There is no obligation to “do everything” if that will not restore the patient’s health or reduce symptoms. Hospitals may have futility or non-beneficial care protocols when patients have reached a stage where aggressive care is thought futile or non-beneficial by their physician. If the patient and/or family does not want to adopt a palliative approach to care, these protocols will require palliative and ethics consultations and possibly legal action prior to adoption of comfort-based care only.

INTERFACE OF ETHICS AND END OF LIFE CARE

There is overlap between ethical issues for end-of-life ICU care and when palliative care may be appropriate. Ethics and palliative care consultants can be helpful in cases where there is lack of clarity regarding goals of care or the best way to achieve symptom control. Using early triggers for palliative care consultation is associated with greater transition to do-not-resuscitate/do-not-intubate and to hospice care, as well as decreased ICU and post-ICU healthcare resource utilization. In some studies, early palliative care ICU consultation was actually associated with improved mortality.[2]

WHAT IS PALLIATIVE CARE?

Palliative care (from the Latin word *palliare*, “to cloak”) in its simplest definition focuses on the prevention and relief of suffering. Palliative care medicine uses an interdisciplinary team approach (including physicians, mid-level providers, nurses, social workers, pharmacists, chaplains, and other allied health professionals) to focus on patients with life-limiting medical conditions with symptom burden. The palliative care approach is a holistic one that focuses on the patient’s experience. Surgeons are eligible for palliative care subspecialty fellowship training and board certification.

WHY PALLIATIVE CARE IN THE ICU AND HOW CAN IT RELATE TO CARE IN THE ICU?

Providing palliative care to patients requiring ICU-level care is a timely topic that has engaged the interest of both the medical profession and the lay public. Recent data suggest that more than 20% of Americans who die each year (approximately 500,000 people annually) die in, or shortly after, ICU care. In addition, there are approximately 100,000 ICU survivors each year who suffer chronic and severe symptoms. The role of palliative care in the ICU is not only to provide symptom management at life’s end, but also to help align the patient’s goals and values with the clinical realties and to provide guidance and support for both patients and families. Most would agree that patients and families often desire both active treatment and concurrent relief of symptoms.[3,4]

STRUCTURING PALLIATIVE CARE IN THE ICU

Palliative care teams have begun to participate as integrated team members or in consultative roles in the ICU. Both the integrated and consultative functions have advantages and disadvantages, and should not be considered mutually exclusive. The consultative role provided by a palliative care consulting service can provide expert skills using an interdisciplinary team, and provide continuity and transitions during and after ICU discharge. This type of model, however, may require increases in staffing. Integrated models assign the palliative care role to members of the critical care team, which may require fewer staff, although some additional training may be desirable.

BARRIERS TO PALLIATIVE CARE IN THE ICU

One of the most significant barriers to providing palliative care in the ICU is the lack of understanding among patients, families, and clinicians as to the role of palliative care in the ICU. Too often, the perception of palliative care is a narrow one that views the role of palliative care as synonymous with hospice care or "giving up." When palliative care is seen as only providing end-of-life care and comfort care for patients, opportunities are missed to improve communication, clarify goals of care and improve symptoms and quality of life. An important ICU protocol is to document ICU patient's "Goals of Care" or "Advanced Care Planning" note if a stay of more than one day is anticipated. This is a reimbursable activity under Medicare and so there is no reasonable reason while this cannot be accomplished for any significant ICU patient stay. Careful review and documentation of any Advanced Directives or Practitioner Order for Life-Sustaining Treatment (POLST) is done.

Communication issues in the ICU

Effective communication with patients, their families, and care providers is an essential component of ethical and palliative care in the ICU, and is the foundation on which optimal care is provided in this setting. The ICU can be a very scary place for patients and families. Many families have never experienced a critically ill family member, and the initial interaction with their serious ill and injured family member who appears entangled in tubes, catheters and machines can be unsettling. Communication is a key critical care skill, some advice is given at Table I.

UC San Diego Guide for Talking with SICU Families

1. Communicate regularly, using family meetings prophylactically. Beware of family members who are non-participants. Involve the staff, especially the nurse.
2. Listen, listen, listen - for family understanding, affect, and how they make decisions. Establish trust. Acknowledge emotions. Avoid jargon. Lecture less and let the family guide you to further topics.
3. Provide psychosocial and spiritual support. Offer hope, not false hope. Bad news is a shock. Use support from the team. Culture & religion play key roles.
4. Inform family regularly about goals of care and how we know if goals are met.
5. Convey uncertainty; avoid false certainty.
6. Describe treatment as a "therapeutic time trial' aimed at specific short-term goals.
7. "Care" always continues, but treatments may be withdrawn or withheld. (We never "withdraw care", we stop non-beneficial treatments.)
8. Don't ask the family to decide about each diagnostic or treatment option; ask them what the patient would want and allow them to concur with a plan consistent with patient values.

Adopted from Mass. General Hospital Palliative Care Service

Table I. UC San Diego Guide for Talking with SICU Families

SPIRITUAL AND EMOTIONAL SUPPORT OF PATIENTS AND FAMILIES

A critical illness not only affects patients' clinical and physiologic status, but it may also affect the emotional, social, and spiritual needs of patients and their families. Social and spiritual support should be offered to patients and families and is part of the Care and Communication bundle previously mentioned. Bereavement is a normal process, and it is imperative for clinicians to recognize that adoption of comfort care measures by the patient and family may take some time, with all of the Kubler Ross stages of grief needing to be processed. Chaplains and community spiritual leaders can help the patient and family come to terms with their grief.

Indications for Palliative Care consult in UC San Diego SICU:

1. Family request.
2. Futility considered or declared by SICU team.
3. Family disagreement with team, advance directive, or each other lasting >7 days.
4. Death expected during same SICU stay.
5. SICU stay >1month.
6. A diagnosis with median survival <6 mos, or patient with metastatic malignancy.
7. >3 SICU admissions during same hospitalization.
8. Glasgow Coma Score <8 for >1wk in a patient >75 yrs old.
9. Glasgow Outcome Score <3 (i.e., persistent vegetative state)
10. Multisystem organ failure >3 systems

Table II. Indications for Palliative Care consult in UC San Diego SICU[5,6]

PALLIATIVE SEDATION

Palliative sedation is defined as the "use of a sedative medication to reduce patient awareness of distressing and intractable symptoms that are insufficiently controlled by symptom-specific therapies." Though controversial within some circles when confused with physician aid in dying or euthanasia, the American Academy of Hospice and Palliative Medicine has a position paper on palliative sedation supporting its use in terminal patients, as do many critical care organizations.[7] The concept of allowable "double action" may exist, where sedation is needed to provide symptom control, even though it may accelerate dying.

DNR ORDERS/WITHDRAWAL OF LIFE-SUSTAINING TREATMENTS

Despite the arsenal of advanced, life-prolonging therapies commonly available in the ICU, patients or their surrogate decision makers may decide that such therapies are no longer concordant with their goals of care. Patients have the right to request to refuse therapy or request that it be discontinued, and that neither of these is akin to physician aid in dying or euthanasia. However, how patients live and die with or without such interventions can vary, and this point must be discussed. It should be pointed out that the ultimate goal of a patient and family conference is not only to establish a do-not-resuscitate status or to obtain a withdrawal of aggressive care, although this may well be an important part of the conversation. It is often most important to define the patient's values and goals and align this in a shared mental model with the care team.

BRAIN DEATH

Although death by neurologic criteria has been accepted as death medically for over 40 years, legal variance exists throughout the states, especially regarding religious accommodations and in pregnancy. The need to obtain informed consent from surrogate decision makers prior to brain death testing remain uncertain, and there is no guideline regarding obtaining ancillary testing despite recent efforts. Not all

religions and cultures accept brain death, which was largely developed as a concept to allow organ donation of the liver and other organs. A recent survey of adult and pediatric neurologists found that at least half have requests from family members to extend medical care to those who have met criteria for the diagnosis of brain death. In states such as California, the patient's body becomes the property of the next-of-kin at brain death, and hospitals must continue life support measures for a period of "reasonable accommodation" for the family. New Jersey is the only state that allows declaration of death solely on cardiorespiratory criteria if personal religious beliefs do not recognize brain death. There, a patient may not be declared dead legally even while meeting brain death criteria medically. These differences in state law are well illustrated in the 2013 Jahi McMath case, a patient who was ruled to be legally dead in California but was treated as living under New Jersey law and was kept on life support measures there for years. Since the McMath case, lawsuits have arisen where families have sued to have the brain-dead patient moved to New Jersey or other countries, such as Guatemala, where brain death criteria are not as strictly observed.[8]

RATIONING CARE/ETHICAL DECISION MAKING IN RATIONING OF CARE/DISASTERS

The recent SARS-COV-2 pandemic severely stressed critical care units in many parts of the world and led to concerns that ventilators may need to be rationed given resource limitations. Many jurisdictions and systems developed protocols for the fair distribution of limited ventilator resources.[9] However, actual withdrawal of ventilator support in otherwise salvageable patients appears to have been rare in the US pandemic. Rationing of medical care in the situation of widespread shortage in resource limitations is using the principle of Justice on a broader scale than the individual patient. Physicians should not make hasty justice-based determinations at the bedside unless a system-wide protocol has been adopted and medical and public health authorities have determined that such rationing is necessary to maintain a population-based standard of care.

FAMILY DISCUSSIONS

Ethics determines the principles by which a decision about ICU care in the best interest of the patient can be made, but the mechanism by which this actually is done is via family-patient discussion. These are not a "doorknob discussion", team preparation is needed. Some advice regarding these discussions can be seen at Table III.

UC San Diego Guide to SICU Family Meetings

1. Prepare agenda and setting. Assure team consensus on facts. Decide who comes to the meeting and who leads the discussion. SICU nurse and SICU team MD should be there.
2. Introduce participants.
3. Assess family understanding and what they want to know.
4. Summarize the patient's medical condition & key clinical decisions.
5. Describe what is it like for the patient now?
6. What was the patient like before illness? What would the patient want in such circumstances? (a.k.a.: "substituted judgment").
7. Explore and address family fears and concerns.
8. Frame recommendations.
9. Plan for follow-up.
10. Document meeting and communicate content to team.

Adopted from Mass. General Hospital Palliative Care Service

Table III. UC San Diego Guide to SICU Family Meetings

MEDICAL AID IN DYING (MAID)

In some US states (Figure 1) and Canada, physicians and other providers are permitted to prescribe a lethal dose of medication as MAiD to patients if their suffering cannot be relieved under conditions that they consider acceptable. Informed consent requires that the person requesting MAiD has received all the information needed to make their decision; that is, medical diagnosis and prognosis, and available treatments including palliative care. However how to evaluate suffering in social, mental and physical domains is unclear, and clear guidelines on the medical determination of suffering are lacking.[10] Many hospitals, intensivists and palliative care physicians have refused to offer or participate in MAiD for ICU patients due to this uncertainty. Most MAiD procedures occur at the patient's home and not in ICU or hospital settings.

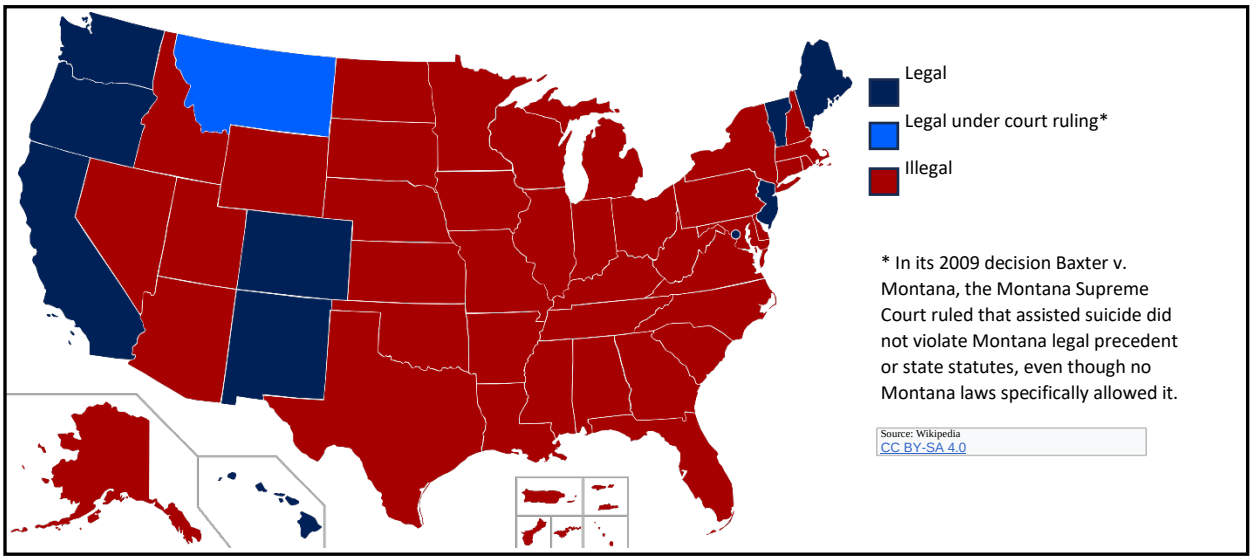

Figure 1. State laws regarding Medical Aid in Dying (MAiD) in the United States

ETHICAL ICU RESEARCH AND CONSENT

The Nuremberg Military Tribunal's decision post World War II in the case of the United States vs. Karl Brandt et al. includes what is now called the **Nuremberg Code**, a ten-point statement delimiting permissible medical experimentation on human subjects.[11] According to this statement, humane experimentation is justified only if its results benefit society, and it is carried out in accord with basic principles that "satisfy moral, ethical, and legal concepts." The World Medical Association (WMA) has developed the **Declaration of Helsinki** as a statement of ethical principles for medical research involving human subjects, including research on identifiable human material and data. These principles of ethical clinical research must be satisfied in the eyes of the institutional research board to comply with Title 45 of the Code of Federal Regulations, Part 46, and Title 21, CFR 50 and 56. ICU patients are typically unable to provide consent, and family members are trying to do everything to help their loved one. Care must be taken so that they are not susceptible to being unduly influenced into providing a research consent to obtain a hopeful therapy that may not actually benefit the patient.[12]

CONCLUSION

The intensive care unit is a dynamic, intense medical setting where patients get lifesaving, complex care. However, even with the best medical efforts, situations will arise when ethical decisions, including painful end-of-life care decisions must be made. High complexity critical care and its providers must include provisions to deal with these ethical challenges and adopt effective palliative care as required.

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DOUBLE JEOPARDY - BILLING FOR ICU CONSULTS

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OVERVIEW

CMS recently revised its critical care billing rules, which will be effective January 1, 2023. The most significant requirements include:

- Split/Shared Services are now allowed and billed using a new F.S. modifier.
    - Only one practitioner per specialty can submit a bill for critical care services (unchanged from prior years).
    - The billing practitioner on a split/shared claim must be the practitioner who provided the **substantive portion** of the care, which is greater than 50% of the total time reported.
- 99292 may only be coded when a full 30 additional minutes are claimed.
- Physicians and NPPs (Non-Physician Practitioners) of the same specialty can combine times to meet all 30-minute thresholds (99291 and 99292). Care provided before midnight and continued **uninterrupted** into the next day is billed on the date the service **originates**. Services that are not continuous are billed on their respective dates.

INTRODUCTION

Critical care is defined by the CPT as "a critically sick or wounded patient whose condition is at risk of imminent or life-threatening deterioration due to acute impairment of one or more important organ systems." Medicare's standards have been updated to reflect this definition. Moreover, critical care necessitates the implementation of intricate decision-making processes to address the failure of single or multiple key organ systems or to avert the patient's state from deteriorating further, which might be fatal.

Physicians and non-physician practitioners (NPPs), such as certified nurse specialists (CNSs), certified nurse midwives (CNPs), and nurse practitioners (NPs), are capable of delivering critical care services. Unlike the situation preceding January 1, 2022, Medicare now permits P.A.s to bill and be compensated directly for their personal and professional services using their NPI. Ensure that each professional visiting patient is accredited to conduct services in the hospital.

These are the critical care codes:

99291 Initial thirty to seventy-four minutes of critical care, assessment, and treatment of the severely sick or wounded patient

99292 for each further thirty minutes (list separately in addition to code for primary service)

Critical care services are often provided in a designated area, such as an intensive care unit or emergency department, and may be rendered on numerous days. Critical care necessitates the undivided attention

of the attending Physician or NPP; hence, the practitioner cannot attend to other patients during the same time that critical care services are being administered.

The total time spent on a given date may be paid for using these codes, regardless of whether that time is continuous. If continuous services continue until midnight, the Physician or NPP should consistently produce a report of the total units of time rendered. Nevertheless, every service interruption generates a fresh beginning to the service.

When a patient receives an additional evaluation and management (E/M) visit concurrently with critical care services on the same calendar date, both visits may be billed (irrespective of practitioner specialty or group affiliation) provided that the documentation in the medical record substantiates the following:

1. The other E/M visit was offered before the critical care services at a time when the patient did not require critical care,
2. The services were medically necessary, and
3. The services were separate and distinct, with no duplicative elements from the critical care services provided later in the day.

Modifier 25 should be appended to the hospital E/M code in these situations.

Physicians or NPPs within the same group and specialization may administer concurrent follow-up treatment, such as a critical care visit after the critical care visit of another practitioner. When an individual practitioner provides the complete initial critical care service and submits CPT code 99291, any additional practitioners from the same specialty and the same group who are simultaneously providing care for the same patient on the same date must also submit their time using the code for subsequent time intervals (CPT code 99292).

When a practitioner initiates critical care but fails to fulfill the reporting deadline for CPT code 99291, another practitioner within the same specialty and group can proceed with critical care for the same patient on the same day.

CPT code 99291 must be reported once the cumulative required critical care service time has been fulfilled. However, code 99292 can only be billed by a practitioner in the same specialty and group if they have provided an additional 30 minutes of critical care services to the same patient on the same date (74 minutes plus 30 minutes equals 104 total minutes).

For example, in the scenario where Practitioner A dedicates 15 minutes to critical care, they are not eligible to charge 99291. However, if Practitioner B dedicates 30 minutes to critical care, they can bill 99291 for a total of 45 minutes as a single claim.

- When many physicians provide more extensive services than consultation services, this is referred to as concurrent care. Each physician's services providing contemporaneous care are covered if they actively participate in the patient's treatment. Within critical care services, a patient in critical condition may be afflicted with multiple medical conditions that necessitate a wide range of specialized medical interventions and the active participation of various practitioners, each with their own area of expertise in the patient's treatment. Each supplier is obligated to provide medically essential services, qualify as critical care, and do not constitute duplication of efforts with other providers.

Interpretation of cardiac output measurements, chest X-rays, pulse oximetry, blood gases, and collection and interpretation of physiologic data (e.g., ECGs, blood pressures, hematologic data) are bundled services included by CPT in critical care services and are therefore not separately payable. Gastric

intubation, temporary transcutaneous pacing, ventilator management, and vascular access procedures are included in this category.

Critical care time should not be accumulated with time spent conducting procedures or services that are separately reportable; such time should be reported separately.

Critical Care Changes Comparison Between 2021 and 2022 Guidelines		
Guideline/Year	**2021 (eff. 1/1/22)**	**2022 (eff. 1/1/23)**
Split/Shared Service	Not Allowed	Allowed (F.S. modifier required)
Times combined for same group practice Physician/NPP – Includes 30-minute threshold.	Not Allowed	Allowed
NPP Specialty for Critical Care Services	Their own specialty	No longer own specialty for CC services. Now, the specialty of the physician with whom they work
Continuous Critical Care Services over a midnight bill date	Poorly defined	Date continuous services began
Unchanged Critical Care Billing Practices		
E/M is billed on the same day as CC (includes E.D.).	Allowed if E/M occurred before complication or comorbidity (CC) (25 modifier req. on CC)	Allowed if E/M occurred before CC (25 modifier req. on CC)
Same patient, same day – more than one CC billed by practitioners from different specialties	Allowed	Allowed
E/M Code bundling with Anesthesia CPTs	Bundled and cannot be unbundled	Bundled and cannot be unbundled

Table I. Critical Care Changes Comparison Between 2021 and 2022 Guidelines

SPLIT/SHARED CRITICAL CARE SERVICES

Critical care must have been performed substantially by the provider accountable for recording the treatment to qualify as a split/shared visit. This segment is classified as exceeding 50% of the time devoted to the medical practitioner and NPP. To bill for a split/shared critical care service, the billing practitioner must use Modifier F.S. (to identify a split/shared E/M visit) to the critical care code on the claim. Furthermore, it is crucial to specify that time spent in a critical care setting conversing or meeting with the patient jointly by two or more physicians can only be tallied once.

Physicians and NPPs from the same group who provide Critical Care services for the same patient on the same day can now submit invoices for these services as split/shared services. Critical care times of the aggregation of practitioners determine the payment eligibility of any 99291s. Before January 1, 2023, aggregated timeframes for fulfilling the 30-minute requirements of 99291 or 99292 were not deemed acceptable.

Any time devoted to critical care must remain distinct from any time spent in conjunction with other practitioners. Time spent in collaboration with another practitioner is restricted to a single practitioner for reporting purposes, irrespective of whether they are of the same or different types.

The entity or individual listed as billing practitioner 99291/9 is responsible for providing the majority of the care. The billing practitioner is identified based on which practitioner accumulated more than fifty percent of the total time recorded (e.g., practitioner A will bill if practitioner B reports fifteen minutes and practitioner A reports sixteen minutes). In cases where more than two practitioners document critical care time, the billing practitioner for a given patient on a given day is the practitioner who demonstrates the highest volume of time. With the introduction of the F.S. modifier, the duration of combined critical care services will be shown.

By implementing this billing process, businesses can meet the 30-minute threshold for a 99291 more regularly. Nevertheless, billing for a 99292/992 requires an additional 30 minutes of care in addition to the initial 74 minutes (i.e., 104 minutes of critical care services must be furnished to bill 99291 and one 99292).

When multiple practitioners of the same kind (e.g., NPP/NPP) deliver critical care services (e.g., MD/MD), their times are combined for billing purposes. The billing practitioner is responsible for providing a significant proportion of the services on a particular day. If practitioners independently document an adequate amount of time to satisfy both a 99291 and 99292 requirement, they are each eligible to file a claim for the proportionate portion of the claim. Despite this, each group is limited to one 99291 billing each day, regardless of the amount of time each practitioner spends on the procedure (e.g., if Physician A documents at least 74 minutes and physician B reports at least 30 minutes, Physician A would bill the 99291, and physician B would bill the 99292).

NPPS ARE NO LONGER THEIR OWN SPECIALTY FOR CRITICAL CARE SERVICES

Please note that while CMS typically considers NPPs to be their own specialty, this classification will change in 2022 for NPPs providing critical care services. They are considered practicing in the same specialty as the attending physician. Documentation of treatment rendered by an NPP should, therefore, attribute the service to the specialty of the billing physician with whom the NPP is affiliated.

CRITICAL CARE SERVICES BY DIFFERENT GROUP PRACTICES

The times of practitioners with distinct group practices are not aggregated. For a particular date, each group bills its 99291s and 99292s. This remains constant compared to previous years. ***In contrast, it is now the responsibility of each group to aggregate their times to ascertain who is responsible for billing and what is billed.***

CRITICAL CARE SERVICES THAT CARRY INTO THE NEXT CALENDAR DATE

CMS has clarified that when critical care commences on one calendar date and continues into another, the billing for the whole duration of critical care services will occur on the date the services started. It is vital to record whether or not the service was uninterrupted meticulously. When documentation demonstrates that services were not continuous, the total critical care time provided on each calendar

date must also be documented for billing purposes. The paperwork in these situations should specify that the time has ceased on the first calendar date and resumed on the subsequent calendar date.

ENCOUNTERS E&M AND RESIDENTS/FELLOWS

The attending must be physically present during the critical portions of the services rendered by the resident or fellow during an E&M encounter. It must document their participation in the patient's management. Like attestation of an APP's E&M service, the attending may record the following: "On this date, I observed and assessed this patient. Consensus was reached with the resident/fellow over the findings and plan recorded in the resident/note." However, this would require the resident or fellow to record the attending's activities with extreme precision. It is in the attending's best interest to incorporate one of the three fundamental elements into their evidence.

Although charging critical care patients has never been contingent on including such extra medical records, several health organizations have imposed internal policies that demand doctors to complete all fields, leading to clinicians' discontent. In addition, split-share billing for advanced practice nurses (APPs) was introduced in 2022: the APP was responsible for critical care time alone, the attending and APP shared critical care time concurrently, or the attending alone provided critical care time. This action generated considerable resentment and a multitude of inquiries. In 2023, CMS and CPT issued clarifications as a consequence.

Two significant points of clarification about the time thresholds for charging the add-on code 99292 for CMS patients as opposed to non-CMS patients went into effect on January 1, 2023. CMS holds a contrasting viewpoint to the CPT Committee's, stipulating that 99292 can only be billed upon completing a 30-minute time increment, as illustrated in Table II. Furthermore, CMS posits that 99292 can be billed upon fulfilling the requisite time threshold, irrespective of whether the time is contributed by a single individual or through a split-share visit. Furthermore, CMS does not mandate that the initial provider furnish a minimum of 30 minutes.

ADDITIONAL CONSIDERATIONS

- When bedside procedures are performed with consultation, ICU consultation time should exclude procedure time. When these services occur, thoughtful documentation should be included to delineate between these independent services.
- Consultations performed by NPPs should include proper modifiers, and the total billed ICU consultation time should not exceed twenty-four hours or whole shift time unless a continuous service is provided that spans two calendar days.[2]
- Private-payer ICU billing rules may differ from Medicare rules. Always check for your specific contracted terms.

Scenario	Group	Practitioner Type	Reported time	Biller	Codes billed
The same Group Physician and NPP report enough time for a 99291, and the physician reports a substantive portion.	Same	Physician 1	25	Physician 1	99291
		NPP 1	10		
The same Group Physician and NPP report enough time for a 99291, and the NPP reports a substantive portion.	Same	Physician 1	10	NPP 1	99291
		NPP 1	25		
2 Same Group Physicians who report enough time to bill a 99291 and 99292 separately.	Same	Physician 1	74	Physician 1	99291
		Physician 2	30	Physician 2	99292
2 Same Group Physicians who do not report enough time to bill a 99291 and 99292 separately.	Same	Physician 1	95	Physician 1	99291
		Physician 2	9		99292
2 Same Group NPPs who report enough time to bill a 99291 and 99292 separately.	Same	NPP 1	74	NPP 1	99291
		NPP 2	30	NPP 2	99292
The same Group Physician and 2 NPPs report enough time for 99291 and 99292, and the NPP notes the substantive portion.	Same	NPP 1	60	NPP 1	99291 99292
		NPP 2	25		
		Physician 1	30		
Same Group 2 Physicians and 1 NPP who report enough time for a 99291 and NPP reports substantive portion despite the greater total physician time.	Same	NPP 1	35	NPP 1	99291
		Physician 1	15		
		Physician 2	25		
Practitioners with *different group practices, cardiology (card) and anesthesia (anesthesia). It could be physicians or NPPs.*	Same	Surgery	35	Card	99291
		Anes	40	Anes	99291

Table II. Here are examples of billing scenarios that may apply to a practice

Critical Care that Crosses over a Midnight	
Critical care begins at 2330 on day 1 and is continuously provided until 0045 the next calendar day (day 2).	99291 billed on day 1 (75 minutes)
Critical care begins at 2245 pm and continues to 2330 pm on day 1. Critical care resumed at 0230 on day 2 until 0335.	99291 billed day 1 (45 minutes) 99291 billed day 2 (65 minutes)
Critical care begins at 10:45 pm and continues to 11:30 pm on day 1. Critical care resumed at 2:30 am on day 2 until 3:35 am.	99291 billed day 1 (45 minutes) 99291 billed day 2 (65 minutes)
Critical care begins at 2345 pm on day 1 and continues until 0005 on day 2. Critical care resumed at 0230 on day 2 until 0335.	No bill day 1 (20 minutes) 99291 billed day 2 (65 minutes)

Table III. Critical Care that Crosses over a Midnight

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1. Medicare NCCI 2023 Coding Policy Manual – Chapter 2, Section B, #6 (https://www.cms.gov/files/document/medicare-ncci-policy-manual-2023-chapter-2.pdf)
2. van der Wilden GM, Schmidt U, Chang Y, Bittner EA, Cobb JP, Velmahos GC, Alam HB, de Moya MA, King DR. Implementation of 24/7 intensivist presence in the SICU: effect on processes of care. J Trauma Acute Care Surg. 2013 Feb;74(2):563-7.
3. https://www.cms.gov/files/document/mm12543-internet-only-manual-updates-iom-critical-care-split-shared-evaluation-and-management-visits.pdf

SESSION 8

HOUDINI SESSION

Moderator: Bellal A. Joseph

Tuesday, April 16, 2024

10:30 – 12:30 PM
Palace Ballrooms 1-2
Palace Tower
Emperors Level – 4th Floor

10:30 – 10:45	**Plugging the Perf: Managing the Complicated Peptic Ulcer Perforation** **Carlos V.R. Brown, MD, FACS**
10:45 – 11:10	**Ventral Hernia and the Hostile Abdomen: Robotic eTEP to the Rescue!** **Matthew J. Martin, MD, FACS , FASMBS**
11:10 – 11:15	**When To Call IR** **Rakesh Navuluri, MD, FSIR**
11:15 – 11:30	**Cut to the Core: Pulmonary Hilar Injuries** **Matthew J. Wall, Jr., MD, FACS, MAMSE**
11:30 – 11:45	**Junctional Vascular Injury: External Iliac to Common Femoral Artery** **Kenji Inaba, MD, FRCSC, FACS**
11:45 – 12:00	**Biliary Obstruction: Surgical Options When ERCP Fails** **Mark J. Kaplan, MD, FACS**
12:00 – 12:15	**Backed Into a Corner: Damage Control Surgery in the Rural or Austere Setting** **Jason L. Turner, MD, FACS**
12:15 – 12:30	**Panel Discussion**

PLUGGING THE PERF: MANAGING THE COMPLICATED PEPTIC ULCER PERFORATION

Carlos V.R. Brown, MD, FACS

Professor of Surgery
Chief, Division of Acute Care Surgery
Dell Medical School
University of Texas at Austin
Austin, TX

Peptic ulcer disease affects up to 5% of the US population and is largely managed medically, using both antacid medications and *H. pylori* eradication. These treatments have essentially replaced elective surgery for the treatment of peptic ulcers. However, emergent surgery for complications of peptic ulcer disease (bleeding, perforation, and obstruction) remains a part of general surgery practice. While bleeding is largely managed endoscopically, perforated peptic ulcer disease usually requires urgent surgical intervention. This manuscript will review the causes, diagnosis, and management of perforated peptic ulcer disease.

Perforated peptic ulcers may occur in the stomach or duodenum. The most common risk factors for peptic ulcers include tobacco, alcohol, NSAID use, *H.* pylori infection, and acid hypersecretion. While all duodenal ulcers are associated with excess acid secretion, only some gastric ulcers are acid-related, depending on the type of gastric ulcers. Gastric ulcers come in five types, I-V, and types II and III are acid-dependent. Type I ulcers are the most common and occur on the lesser curve of the stomach. Type II gastric ulcers occur on the body of the stomach and have a concomitant duodenal ulcer. Type III gastric ulcers are pre-pyloric. Type IV gastric ulcers occur high on the lesser curve. Type IV gastric ulcers can occur anywhere in the stomach and are associated with NSAID use.

Patients with a perforated peptic ulcer most often present with the acute onset of severe midepigastric abdominal pain and may even be able to pinpoint exactly when the pain began. Most patients will present relatively ill, and some may even present in extremis, especially if they have been sitting at home for hours or days. On physical exam, some patients will be febrile, and all will have abdominal tenderness, with either localized or diffuse peritonitis. Labs will show an elevated white count. Plain imaging may reveal pneumoperitoneum, but CT scan with IV contrast (oral contrast is not necessary) will provide much more detailed information including fluid, inflammation, and pneumoperitoneum. The diagnosis may be made at the time of laparotomy for a patients taken to the OR with diffuse peritonitis or free air seen on plain films. Otherwise, diagnosis is made with CT scan prior to the OR. Treatment begins, as with any other critically ill patients, and includes crystalloid resuscitation and broad-spectrum antibiotics prior to surgery.

A perforated peptic ulcer may be surgically managed using an open or minimally invasive approach. Regardless of approach, the surgical principles are the same. Upon entry into the abdomen, all contamination should be suctioned out and attention turned to the upper abdomen. The perforation may not be readily visualized due to omental adhesions or inflammatory rind. Once the ulcer has been visualized, treatment depends on the location and size of the ulcer.

Perforated duodenal ulcers most often occur on the anterior surface of the first portion of the duodenum. Prior to repair, the duodenum should be widely mobilized with a generous Kocher maneuver. If the ulcer is small (< 1cm) and there is healthy tissue around the ulcer, it may be primarily repaired using interrupted suture. Following repair, a pedicled omental buttress can be sutured in place to reinforce the repair. If the ulcer is too large to come together without tension, or the tissue is too friable to hold suture, several other options exist. A pedicled omental flap (Graham's patch) may be sutured in place without closing the defect. Similarly, a pedicled omental flap may be used to plug the defect. This is performed by sliding the NG tube out of the perforation and suturing the NG to the omental flap using non-absorbable suture. Once the omentum is secured, the NG is backed out until the omentum completely plugs the ulcer opening. Other options include a serosal patch of the ulcer using jejunum in either a loop or Roux-en-Y configuration. After repair, the ulcer bed should be widely drained, and an NG tube should be left in place for decompression.

Routine use of procedures to "protect" the repair (tube duodenostomy, pyloric exclusion, triple tube therapy, or duodenal diverticularization) should not be performed as they do not provide any benefit and may cause more harm. Furthermore, a definitive acid-reducing operation, such as a highly selective vagotomy, vagotomy and pyloroplasty, or vagotomy and antrectomy, should be avoided, as these procedures bring significantly higher morbidity and mortality, and excellent acid reduction can be achieved with postoperative medical management. In addition to acid-suppression therapy, patients with a perforated peptic ulcer should be treated postoperatively for *H. pylori* infection.

The management of perforated gastric ulcers also depends on the location and size. However, there are some nuances to perforated gastric ulcers that are different than duodenal ulcers. First, perforated gastric ulcers may be the initial presentation of a gastric cancer. For this reason, a gastric ulcer should be biopsied at the time of the initial procedure. In addition, as gastric cancer is in the differential for a perforated gastric ulcer, a resection of the ulcer can be considered at the initial operation. This resection may be in the form of a wedge resection or anatomic resection such as an antrectomy, distal gastrectomy, or subtotal gastrectomy, depending on the location of the ulcer. If a perforated gastric ulcer is not resected, it can be managed in the same manner as a perforated duodenal ulcer, described above. However, unlike a duodenal ulcer, a gastric ulcer managed with primary repair or omental pedicle requires a delayed EGD with biopsy to ensure ulcer healing and rule out malignancy. Medical management for acid suppression (for type II and III ulcers) and *H. pylori* eradication for all gastric ulcers is also required.

Though open surgery has been the mainstay for management of perforated peptic ulcer, laparoscopic repair has become more common in the last two decades. A meta-analysis published by Cirocchi et al., in JTACS in 2019, reviewed eight randomized controlled trials comparing laparoscopic vs. open management of perforated peptic ulcers. Despite significant heterogenicity and bias in the studies, they found that the laparoscopic approach was associated with less postoperative pain and fewer wound infections. Though robotic repairs have been reported, there is not significant literature published.

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1. Cirocchi R, Soreide K, Di Saverio D, et al. Meta-analysis of perioperative outcomes of acute laparoscopic versus open repair of perforated gastroduodenal ulcers. J Trauma Acute Care Surg. 2018 Aug;85(2):417-425.
2. Ferzoco FJ, Ashley S. Surgical management of peptic ulcer disease. In UpToDate. Soybel DI, Feldman M (Eds), Wolters Kluwer. (Accessed on October 20, 2023)
3. Furay E, Fielder WD. Gastroduodenal perforations. In: Emergency General Surgery: A practical approach. Brown C, Martin M, Inaba K, Salim A (Eds), Springer 2019.

VENTRAL HERNIA AND THE HOSTILE ABDOMEN: ROBOTIC eTEP TO THE RESCUE!

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"Robots don't perform the surgeries, but they are tools that give the surgeon more dexterity. They let you get into confined spaces. You can eliminate hand tremor, and you can be very precise and delicate. It's as if the tips of the instruments become your fingertips"

- William Peine, PhD

BLUF (BOTTOM LINE UP FRONT)

1. Robotic-assisted surgery results in CLEAR benefit to the patient when used appropriately and expertly: Adopt and develop these skills now!
2. The actual patient benefit from using a robotic approach may range from none to significant, but it can facilitate extension of minimally invasive options rather than an open approach.
3. Robotics CAN be integrated into your Trauma/ACS practice but requires an initial dedication to training and then continued use early in the learning curve. Cholecystectomy is often the initial ACS entry case into robotics & can be used to hone your initial basic skills.
4. Ventral hernia repair represents the fastest growing area of robotic utilization in general surgery, and offers multiple advantages and potential benefits vs laparoscopic ventral hernia repair techniques.
5. The main technical advantages of the robotic platform in these cases are improved instrument ergonomics and range of motion, 3D high def visualization, enhanced ability to suture the anterior abdominal wall, elimination of painful trans-fascial sutures or tacks, and ability to perform complete posterior component separation if needed.
6. Advantages to the patient include a shorter length of stay, decreased wound complications, enhanced recovery, reduced postoperative pain, and superior cosmetic results.
7. The robotic eTEP (extended-view totally extraperitoneal) repair technique is an excellent option for many ventral/incisional hernias and can be performed with little or no violation of the peritoneal cavity. This can be particularly attractive in patients with a suspected hostile abdomen.
8. Robotic eTEP is typically a three-stage procedure: 1) dissection of unilateral retrorectus space, 2) dividing medial posterior sheath and dissecting the preperitoneal space including hernia reduction, and 3) dividing the contralateral medial posterior sheath (“crossover”) and dissecting the contralateral retrorectus space.

9. Repair is then completed with suture closure of any defects in the posterior sheath/peritoneum, suture reapproximation of the anterior sheath, and retrorectus mesh placement.
10. Larger defects may require addition of a unilateral or bilateral transversus abdominal release (TAR)

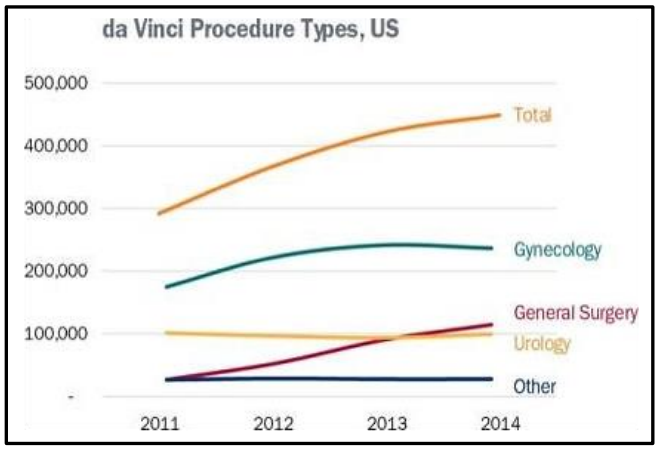
CAN ROBOTIC SURGERY HAVE A ROLE IN TRAUMA/ACS PRACTICE?

The short answer is: absolutely YES!

The long answer is obviously more complicated and is a fundamentally different question than with laparoscopy.

Laparoscopy was REVOLUTIONARY, as it presented an entirely different and less invasive approach compared to open surgery. The benefits to the patient were immediate, obvious, and applied across all types of procedures and specialties. Robotics is an evolutionary change from laparoscopy, which for most procedures may not result in a clear benefit to the patient and has several downsides that must be considered. These include the obvious learning curve, increased operative times, increased costs, and limitations of the current technology. However, we must also recognize that the robotic technology is advancing at a far more rapid pace versus other areas of MIS and is increasingly addressing areas where it can become superior to laparoscopy. I believe that if we again lag behind in robotics, as we did in advanced laparoscopy, we will be poorly prepared and positioned when the inevitable jump to the next revolutionary change in robotic techniques and technology occurs.

- Robotics is rapidly growing in the U.S.
- Sharpest increase is in general surgery (figure)
- Expensive, but majority of expense is the initial outlay for purchase and costs are decreasing
- Most large hospitals have already made this initial investment: the robot is already there!
- Robot OR time under-utilized at most centers, so often amenable to ACS service starting to utilize for select cases



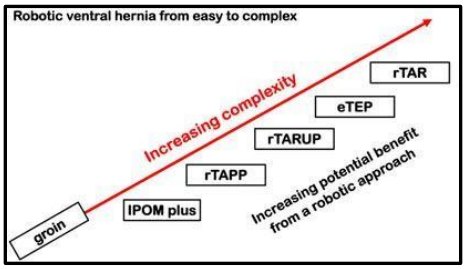
WHY ROBOTIC VENTRAL HERNIA REPAIR VS LAP OR OPEN?

- Ventral hernia repair represents the fastest growing area of utilization of robotics in general surgery
- Ideally suited for the acute care surgeon who frequently is called to manage complicated hernias
- Laparoscopic repairs limited by poor angles and ergonomics to work on the anterior abdominal wall, particularly for significant dissection and suturing
- Fascial defect commonly left open in laparoscopic repair (bridging mesh) and results in less abdominal wall stabilization and higher recurrence rates

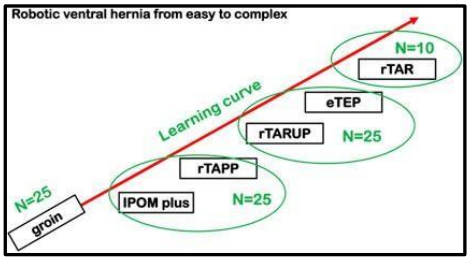
- Mesh typically secured with trans-fascial sutures and/or tacks which result in significant pain and limited mesh fixation in the intraperitoneal position. Also need to use a coated mesh product
- Open repairs provide excellent ability to dissect planes and to achieve midline closure with reinforcing mesh, but require a large incision and tissue dissection, increased risks of wound complications and infection
- Robotic approach allows for similar extensive tissue dissection/component separation as open approach but with markedly decreased wound complication rates and enhanced recovery
- Robotic approach allows for much easier suture closure of defect and suture fixation of the mesh, compared to the laparoscopic approach

SO YOU WANT TO DO ROBOTIC HERNIA SURGERY: TIPS

- Don't start your robotic experience by doing ventral hernias. Start with simpler cases including cholecystectomy, simple inguinal hernias, even appendectomies.
- Jumping from open hernias directly to robotic hernias is difficult, while moving from laparoscopic to robotic is less difficult.
- Observe and even scrub in with someone who does robotic ventral hernias if available at your institution.
- Watch as many videos of these procedures as you can…but beware! Most of the online videos are highly edited and taken from selective cases featuring perfect anatomy. Don't expect your first cases to look like that or go as smoothly.
- Have a robotic proctor for your first several ventral hernias if possible. Having the robotic vendor rep there also can be very helpful until you get fully comfortable.
- Start with smaller and simpler ventral hernias like primary umbilical or epigastric defects, and then progress to larger and more complex defects as your skills develop.
- Stick to primarily midline or paramedian defects initially, and save atypical hernia locations (suprapubic, flank, subxiphoid) for later in your experience.
- Use a logical progression from simpler to more challenging types of hernia repairs as shown in the Figure to the right. IPOM plus (IPOM plus primary midline fascial closure) and robotic TAPP should be your initial approaches to learn and develop. Save the more complex eTEP and robotic TAR techniques for later in your learning curve

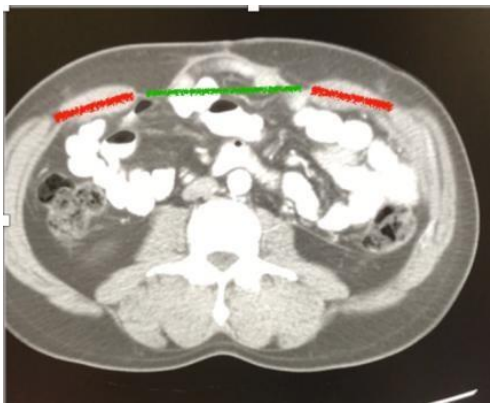


- Understand and respect the typical learning curve for robotic ventral hernia repairs. As shown on the Figure to the right, the average inflection point for progressing from simpler to more complex repair types is approximately 25 cases for eTEP and 50 cases for TAR

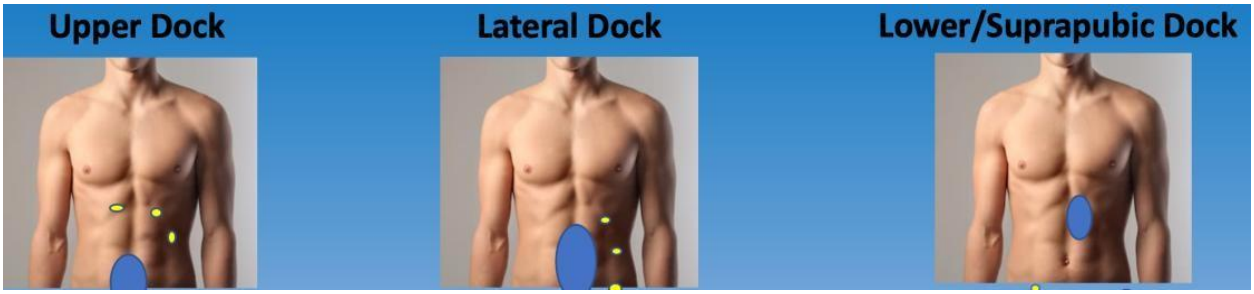


PATIENT SELECTION, PREP, AND POSITIONING FOR ROBOTIC eTEP [1,2]

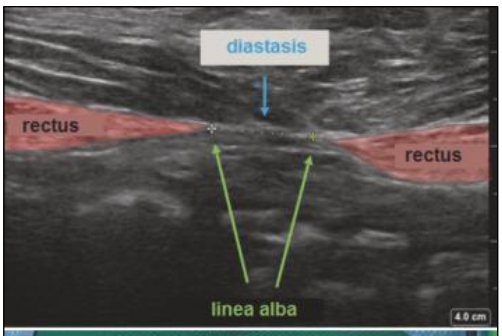
- Review of CT scan is critical. Measure the rectus abdominus width (red line) – typically at least 6cm width is required for eTEP. Also measure the fascial defect (green line). The ratio of the sum of the rectus widths/defect width can give a good estimation of whether eTEP alone will suffice (ratio<1) or whether the addition of a transversus abdominus release will be required (ratio>1)



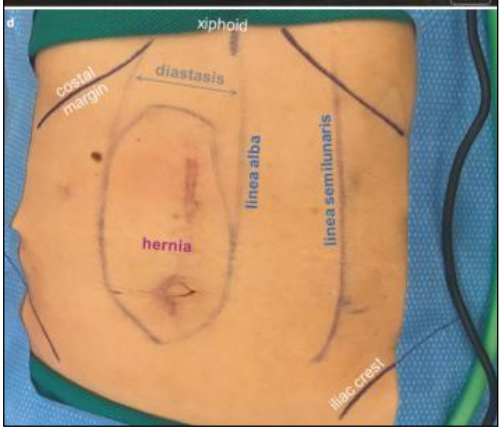
- Several options for docking the robot are shown below. Lateral dock is used most commonly, although some surgeons utilize an upper dock with early crossover and then approaching the defect from top down. Lower dock is typically reserved only for localized upper abdominal/subxiphoid hernias.



- Marking the key anatomy and landmarks prior to prepping is critical (Figures, right). Ultrasound can be utilized to identify the rectus muscles, the anterior and posterior sheath, the linear semilunaris, and to identify the presence of width of any rectus diastsis (top panel)

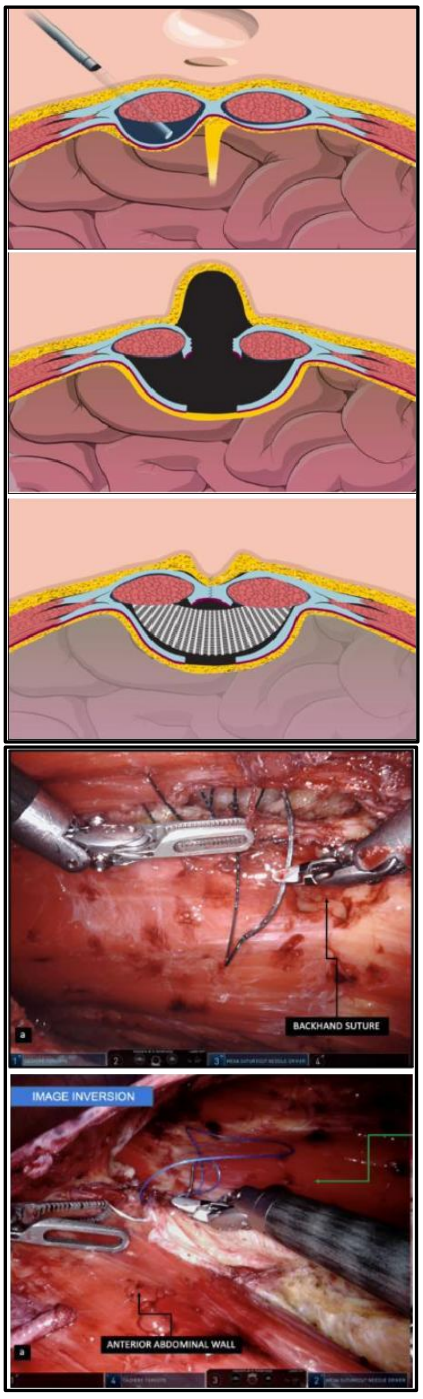


- The skin is then marked to identify these key landmarks as well as the margins of the hernia defect if easily palpable (bottom panel). Of particular importance is the linea semilunaris on the side where initial trocar entry is planned, and the contralateral medial rectus border which is where the crossover maneuver will be performed. The bedside assistant can also palpate these areas or pass a needle at these sites for intraoperative guidance.



KEY TECHNICAL STEPS FOR ROBOTIC ETEP VENTRAL HERNIA REPAIR

1. Robotic eTEP allows for repair of even complex hernias without entering the peritoneal cavity. This is shown in the Figures to the right and starts with retrorectus camera placement and dissection (top panel).
2. Division of the unilateral posterior sheath, dissection of the preperitoneal midline space, and then division of the contralateral posterior rectus sheath (aka “crossover”) for contralateral retrorectus dissection (middle panel). This completes creation of the large retrorectus space for fascial closure and mesh placement.
3. Any posterior peritoneal defects are closed, and the anterior rectus sheath is closed with a running barbed suture. A large mesh (non-coated) is placed in the retrorectus space, and no fixation is required (bottom panel).
4. Closure of anterior fascial defect can be difficult, as view is looking upward and usually requires backhand suturing (suturing “on the ceiling”). This can be particularly difficult laparoscopically, compared to robotically
5. Using the image inversion feature and reassigning control of the robotic arms, the anterior fascial defect now appears to be facing down, and the defect can be sutured forehand (suturing “on the floor”).
6. If posterior or anterior closure is still not possible, then a transversus abdominus release can be performed on one or both sides. Retrorectus drains are at the surgeon’s discretion, but should always be utilized if a TAR was performed



KEY REFERENCES FOR ROBOTIC eTEP TECHNIQUES AND PROCEDURAL GUIDE

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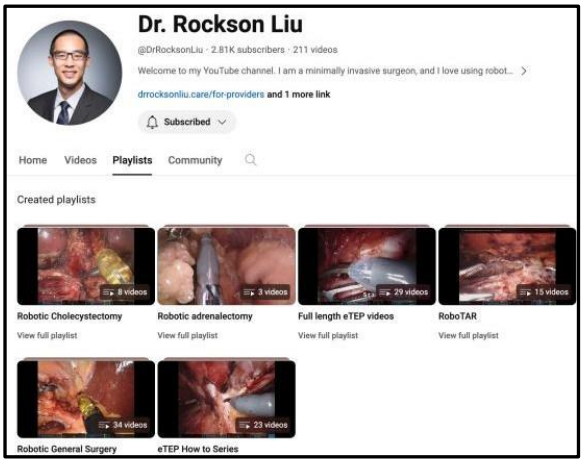
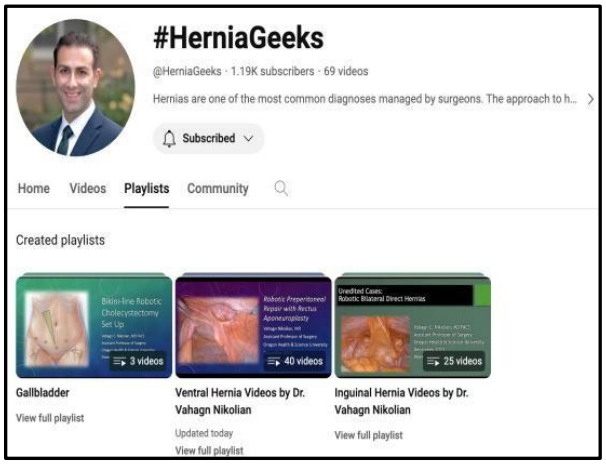
Two Youtube.com channels I strongly recommend for great videos and tutorials on robotic eTEP, TAR, and other robotic ventral hernia repair techniques:





ADDITIONAL ONLINE RESOURCES

Collaborative Facebook Groups: Facebook groups for surgeons where colleagues discuss cases, post photos and videos, and ask for advice on challenging cases or scenarios (must request to join from admin):

Fantastic website with high-quality intraoperative MIS videos organized by body system and organ or pathology. Also has extensive "how-to" technical videos, and interviews with MIS experts. Free registration for full access to all videos.

New website devoted to high quality surgical videos, fully searchable and well organized. Includes both open and MIS procedures. Less overall content currently than websurg, but rapidly increasing. Free registration for physicians.

Official website for surgeons using the DaVinci robotic platform. Free registration for surgeons, contains operative videos, procedure-specific case cards for positioning & port placement, plus all of the training and familiarization videos required to become certified to use any of the DaVinci robotic platforms, or to upgrade from one platform to another.

WHEN TO CALL IR

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The role of interventional radiology (IR) in trauma care has evolved over the years with advancements in diagnostic radiology and the availability of interventional radiology resources at hospitals. The effectiveness of endovascular treatment is supported by a growing body of literature and has been validated by the inclusion of IR in the American College of Surgeons (ACS) guidelines, which necessitates 24/7 availability of IR at all level 1 and level 2 trauma centers.[1]

The management algorithm relies on determining the mechanism of injury (blunt versus penetrating), hemodynamically status (stable versus unstable), as well as grade of injury (low grade versus high grade). In brief, nonoperative management (NOM) is commonly used for low grade injuries, with operative management reserved for high grade injuries. Interventional radiology fills a gap between these two ends of the treatment spectrum and can also be an effective adjunct following surgery.

The operating room is typically reserved for hemodynamically unstable patients – those unresponsive to initial resuscitative efforts in the emergency department trauma bay. In contrast, patients who respond to resuscitation undergo cross-sectional imaging with CT and may be managed by interventional radiology if vascular injury is identified. If there is suspected hollow-viscera injury, the operating room is the first-line, even in the setting of vascular injury. On the other hand, patients with complex pelvic fractures may benefit from primary IR intervention because surgical access to the pelvis can be difficult, opening of the pelvic can release the tamponade effect, and surgical ligation can be less effective due to the rich collateral network. Thus, CT imaging is a prerequisite in determining if a patient is a candidate for endovascular therapy by IR.

Trauma CT protocol should always be performed with IV contrast. The routine use of oral or rectal contrast is of questionable benefit and not utilized at the author's institution. Multi-phase CTA, which includes unenhanced, arterial-phase, and portal-venous phase imaging, is recommended in patients with a positive Focused Assessment with Sonography for Trauma (FAST) when there is clinical concern for vascular injury. CT findings of solid organ injury include lacerations and hematomas within or adjacent to the injured organ. The size of the laceration and involvement of major central vessels forms the basis of the American Association for the Surgery of Trauma (AAST) injury scoring scales. Active arterial bleeding presents as contrast extravasation on arterial phase imaging that pools on delayed (venous) imaging.

Vascular injury can also be indicated by free fluid with attenuation values between 30 to 70 HU. Other findings potentially amenable to endovascular therapy include arteriovenous fistula, pseudoaneurysm, dissection, thrombosis, and abrupt vessel occlusion. Findings specific for hollow visceral injury include discontinuity of bowel or extraluminal leakage of oral contrast, though these are relatively rare. More commonly, focal bowel wall thickening reflecting a hematoma or a projectile tract adjacent to a segment of bowel is seen.[2]

Endovascular treatment primarily involves embolization of injured arteries to control hemorrhage. Preprocedural localization of bleeding helps in limiting radiation and iodinated contrast administration and also allows the interventionalist to map out their approach to the site of interest – particularly in cases with anomalous or surgically altered anatomy. Selective coil embolization is ideal, though nonselective embolization with gelatin sponge can be used in cases of multifocal bleeding or unstable patients with extensive pelvic injuries. In some cases, placement of a stent-graft may resolve a vascular injury while preserving perfusion.

Complications of endovascular treatment include post-embolization syndrome, abscess formation, ischemia, and target organ dysfunction.

Concurrent open surgical and endovascular intervention can also be performed, though this requires a hybrid OR with an expansive collection of both surgical and IR supplies, as well as a more challenging coordination of expertise between surgeons and interventional radiologists.

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CUT TO THE CORE: PULMONARY HILAR INJURIES

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Pulmonary hilar injuries often present unstable and can be extremely challenging to manage. There are few series - primarily case reports. Cardiac injuries, lung injuries, and aortic injuries have been extensively reported. Injuries to the bronchus, pulmonary arteries, and pulmonary veins, individually, have been reported. While anatomically it is a small area, there is a high concentration of critical structures in the pulmonary hilum that can lead to clinical instability and mortality greater than 30%.

Transition zones are always problematic. For example, there are often algorithms for thoracic trauma and abdominal trauma, but at the diaphragm, where they meet, these are difficult to integrate. Thoracic outlet injuries can be some of the most challenging to address, because, again, surgeons are experienced in dealing with intrathoracic great vessel injuries and cervical injuries, but in the transition zone, the algorithms can become problematic. Hilar injuries are in the transition from the pericardium to the pleural cavity. Because of hemodynamic instability, injuries to the pulmonary hilar often require a damage control approach.

ANATOMY

The lung is a pedicled organ supplied by the pulmonary artery and drained by two pulmonary veins. There is a systemic arterial supply that courses along the bronchus. The bronchus is a secondary system as a distal part of the airway. The hilum, if injured, can immediately compromise all aspects of the primary survey of airway breathing and circulation in a rapid manner. While the pulmonary circuit is typically a lower pressure system, this is balanced against the relative thinness of the pulmonary vessels. Pulmonary arterial injuries can be some of the most daunting of all vascular injuries to manage, as they have very little substance and are subject to tear. The anatomy of the pulmonary hilum is complex and variable and is different from right to left. In a way, the lung is analogous to the liver in that it has two arterial supplies, a venous drainage, and a secondary conduit. Like the liver, the anatomy of the hilum is highly variable. Elective lung resections require knowledge of the multiple anatomic variations and often require dissection of the entire pulmonary artery prior to resecting branches. There are also ascending branches and vessels with origins away from the operating area that may not be obvious during resection. Thus, formal anatomic resections can be daunting in the trauma patient.

MECHANISM AND CONTROL

Injury to the hilum can be blunt or penetrating. There have been isolated reports of avulsion of the pulmonary hilum from high energy transfer. These are often lethal and seen in autopsy studies. Alternatively, there have been case reports where pseudoaneurysms have been noted, and the lower pressure of the pulmonary circulation made these survivable. Penetrating injuries to the pulmonary hilum can result in devastating disruption of multiple vessels and loss of anatomy. There have been reports of pulmonary hilar injuries that require prehospital thoracotomy for survival. It has been noted through these experiences that with the lower pressure of the pulmonary circulation if the blood pressure is not artificially raised, a clot may form temporarily quell hemorrhage.

Initial management is determined by whether the airway, vascular structures, or both are injured. Bronchial disruptions from either a blunt or penetrating mechanism can manifest by pneumothorax, tension pneumothorax and inability to ventilate. Tube thoracostomy is often performed urgently and results in a large air leak. This is highly suggestive of a bronchial injury, and placing the chest tube to water seal can be live saving. This allows time to transport the patient to the operating room for flexible bronchoscopy to confirm the diagnosis. Patients in extremis may require immediate thoracotomy either in the operating room or the emergency center and control of the hilum so the opposite lung can be ventilated.

Penetrating injuries to the hilum are often found during empiric exploration in an unstable patient. For through-and-through injuries to the lung, tractotomy can be a diagnostic maneuver in that by unroofing the pulmonary parenchyma, a distal hilar injury may be exposed. More often what's noted is a large hematoma in the area of the hilum with significant distortion of the anatomy.

One of the advantages of a pedicled organ is that proximal and distal vascular control can be obtained with a single maneuver. Pulmonary hilar control can be a lifesaving procedure in these patients, and there are many techniques. Often, the hilum can be grasped by the operator and a large aortic or partial occluding/angled vascular clamp placed across the hilum. This is sometimes made easier by sweeping the inferior pulmonary ligament to mobilize the lower lobe. Of note, there is often a very small vein approximately one centimeter below the pulmonary vein, so when this is encountered, the maneuver is almost complete. The lung can then be grasped in the operator's hand, and a selected vascular clamp can be placed across the hilum. At times, suitable clamps may get in the way, and encircling the hilum with a Rumel tourniquet has been described, compressing vascular structures around the bronchus. Sometimes, even intra-pericardial injuries can be temporarily controlled by retracting the hilum and placing the clamp as proximately as possible.

One technique that can be used for expediency in the EC during EC thoracotomy is the pulmonary hilar twist. It was noted that if the inferior pulmonary ligament is taken down and the lung is rotated 180° degrees, it twists the pulmonary vascular structures around the much more rigid bronchus and buys time until appropriate instruments can be obtained for hilar control. Pulmonary hilar control is also extremely helpful in the massively injured lung, as these patients are often on positive pressure ventilation, which can result in air passing from the alveoli to the pulmonary venous circulation, causing air embolis and cardiac arrest. Pulmonary hilar control is probably, thus, underutilized, and an important tool. Intrapericardial injuries to the hilum can be extremely difficult to manage. Fortunately, they are extremely rare. Simply opening the pericardium to get control is often suggested. When the operator does this, he/she realizes quickly that there are multiple pericardial reflections surrounding the pulmonary vessels that the surgeon needs to be aware of. Reviewing the anatomy of the pericardial folds and openings can be extremely helpful when one anticipates being in this situation.

MANAGEMENT

After hilar clamping, the hilum can be examined. More limited injuries to the pulmonary artery, pulmonary vein, or bronchus can be accessed and repaired primarily. The pulmonary artery is repaired with a fine polypropylene suture and careful technique, as it does not have much substance. If repair sacrifices small branch vessels, this, at worst, may result in a wedge-shaped pulmonary infarct, which is often well tolerated. Concern for injury to major lobar branches may require lobectomy. Pulmonary venous injuries can be repaired in a similar manner. Loss of the main vein draining the lobe usually requires lobectomy.

Proximal bronchial injuries in a stable patient may be visualized after mobilization of the hilum. An airway has often been obtained by fiberoptic intubation or direct intubation beyond the injury. As the bronchus passes more distally, it becomes surrounded by the pulmonary arterial and venous structures requiring

careful mobilization. This is why distal bronchial injuries are, perhaps, better managed in the critical patient with lobar resection. In a stable patient with a limited bronchial injury, repair is done primarily with interrupted absorbable sutures. At the completion of the procedure, the repair is tested under water and can be reinforced with an intercostal flap.

While many advocate emergent formal lung resections for these injuries, it can be extremely daunting due to the large hematoma displacing the often-abberrent anatomy. To do a truly anatomic resection requires the dissection of the sub-lobar branches and understanding them. This is similar to the challenge of the hilum of the liver. Even those who frequently do elective lung resections find this to be an extremely challenging task.

As many of these patients are hemodynamically unstable, the surgeon is looking for a lifesaving solution; thus, a damage control approach is often required. If the hilar injury can be isolated to an individual lobe of the lung, an en-masse stapled lobectomy can be performed. This sometimes may require developing one of the fissures and may need to be done in a rapid non-anatomic fashion. The staples are placed across the hilum of the lobe, and the lobe resected. Have a partial including clamp and vascular suture available, as there is sometimes residual bleeding from the staple line. There have been considerations for the development of arteriovenous fistulae; however, these, have not been borne out by experience. For destruction of the pulmonary hilum with a large hematoma, an en-masse pneumonectomy may be required. This can carry mortality up to 75%; however when done earlier in the procedure, the mortality may be closer to 50%. Again, a stapler is placed across the hilum and the lung removed. Having a partial occluding clamp available for any residual bleeding can be extremely helpful as well as appropriate polypropylene sutures. Occasionally, prior to pneumonectomy, the hilum is grasped with a vascular clamp and pulled up, and, then, a clamp is placed behind that working back for more room. Some have also advocated placing a clamp and leaving it before firing the stapler, but there may not always be enough room in the area to permit that. En masse pneumonectomy and the damage control technique carry mortality between 50 and 75%. It acutely causes significant strain on the right ventricle, which may already be stressed by the traumatic event. After resection, the bronchial closure is tested underwater, and reinforcing the bronchus intercostal flap may be considered, perhaps at a second operation.

Patients that require pneumonectomy for trauma and have injury to the opposite lung have an extremely low survival. Even with elective cases, pneumonia of the opposite lung carries a massive mortality, and injury/contusion/blood aspiration to the remaining lung is extremely common in the injured patient. Strategies to protect that lung postoperatively are often required. Aggressive therapeutic bronchoscopy and lung protective ventilator strategies post-operatively can be helpful. In extreme cases, where the pulmonary injury is the primary issue, extracorporeal membrane oxygenation has been reported to be efficacious. If the issue is primarily oxygenation, venovenous ECMO may be a bridge to support the patient to allow the opposite lung to recover. There have been case reports of its use. In cases where RV strain is a contributing factor or the patient is hemodynamical unstable, venoarterial ECMO may need to be considered.

Pulmonary hilar injuries can be devastating. Knowledge of anatomy and initial control maneuvers may be lifesaving, allowing time to consider treatment options. ECMO may be increasingly used in these cases.

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JUNCTIONAL EXTREMITY TRAUMA

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Extremity trauma is common and can be both limb, and life threatening. In this session, a practical diagnostic approach to the injured extremity will be provided, with a focus on junctional injuries to the groin. The transition segment between the external iliac artery and the common femoral artery is challenging, as it spans two body cavities, making access difficult. A general approach to penetrating injuries to this area, starting with hemorrhage control, diagnostic evaluation and treatment will be covered.

HEMORRHAGE CONTROL

For injuries to the groin, in general, as for all penetrating injuries that are bleeding, the initial step is application of pressure. Because of the high location of injuries to this region, a traditional tourniquet will not be effective. Junctional tourniquets are available on the commercial market and can be effective, in general, for most pre-hospital and in-hospital applications, but because of the cost and low expected usage, this is not a practical, universally available option. If pressure cannot be maintained, the use of a large foley catheter balloon filled with water or saline can be effective for stopping the bleeding. Alternatively, there are FDA approved commercially available devices such as X-Stat which can be used to temporarily control bleeding. These are small foam devices that expand upon contact with liquid, and the expansion provides temporary internal pressure within the wound cavity, much like the balloon previously described. The newest generation of these devices are housed within a mesh bag, which allows for easier removal.

DIAGNOSTICS

While these junctional injuries to the transition zone from external iliac to common femoral artery are often worked up as an extremity injury, the same principles apply to patients who present with a lower abdominal gunshot wound, undergo laparotomy, and are found to have a distal external iliac artery injury.

As for all patients that sustain an injury to the extremity, the skeletal framework, soft tissue mass, neurologic and vascular status requires detailed examination. Plain films should be used to document any bony fractures. This is critical, even if the patient is found to have a vascular injury and will be proceeding directly to the operating room for exploration. If there is a bony injury in concert with a vascular injury, this allows for the pre-operative coordination of care with orthopedic surgery and the possible use of intravascular shunting prior to bony fixation to optimize the operative outcomes. In addition to x-ray evaluation, a complete neurologic examination should be performed, and any neurologic deficits clearly documented. This is especially true for any patients about to undergo operative intervention. This allows for the documentation of any injury related neurologic abnormalities.

The most time sensitive structure to be evaluated is, then, the vasculature. The vascular examination should be utilized to categorize the patient into those that have hard signs requiring operative intervention, soft signs requiring imaging, and no signs allowing safe discharge home. Hard signs include

shock attributed to the extremity injury, arterial bleeding, an expanding or pulsatile hematoma, pulselessness, and a bruit or thrill. These patients should proceed directly to the operating room. Exceptions to this are stable patients with multi-level injuries or shotgun injuries, where pre-operative angiography may help with pre-operative planning and determining the most proximal injury. For patients with no signs of injury, discharge home is a safe treatment option. For patients with soft signs of injury, several options exist. While duplex can be used for very specific cases, such as a knee dislocation for evaluation of the popliteal structures, for any groin injuries, especially if a junctional transition injury is possible, CT Angiography is the modality of choice. Catheter based angiography remains an option and allows for not only diagnosis, but also in specific cases, facilitates therapeutic interventions to be performed. However, it does require the use of specialized equipment and teams that may not be available 24/7 and requires a central arterial puncture. CT Angiography is available wherever there is CT, using standard power injectors and pre-existing hardware and software, 24/7, without the need for a specialized team. Using peripherally injected contrast, clinician friendly 3-D images are produced with a sensitivity of 100% and specificity approaching the same. In most scenarios, the accuracy of this imaging test will allow it to be both the screening as well as definitive diagnostic test.

ACCESS

For injuries to the transition zone from external iliac artery to common femoral artery, gaining adequate access is key. As soon as the determination is made that this is the injury location, rapid evaluation of the potential for fully exposing and reconstructing the injury through the existing incision should be made. For borderline cases, good retraction will allow for adequate visualization. However, one should not hesitate to extend the incision as required to open up access to the area. The physical barrier that will need to be cleared for these injuries is the inguinal ligament. If coming from below, the incision is carried up through the inguinal ligament, curving towards the anticipated lower pole of an exploratory laparotomy. In most cases, even for a truly destructive injury, the laparotomy will not be necessary, and adequate exposure will be gained through dividing the inguinal ligament alone. These cases can be challenging, often associated with significant blood loss, even with aggressive exposure of the injury, even in experienced hands. If the patient physiology and remaining injury burden will allow a definitive reconstruction, this should be performed. Invariably, however, you should be prepared to temporize with a temporary intravascular shunt. If a definitive reconstruction is undertaken and there is a segmental loss of tissue in this region, a size matched ringed PTFE graft will provide a suitable replacement conduit. Reconstruction of the inguinal ligament is best done early if the patient is able to tolerate the vascular repair. If, however, the injury directly impacts the inguinal ligament, and a complex reconstruction is required to ensure optimal functional recreation of the inguinal ligament, initial damage control, with temporary coverage of the area, with reconstruction by an experienced team is also an acceptable option. Prior to leaving the operating room, as for any extremity vascular injury, compartment syndrome must be ruled out.

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BILIARY OBSTRUCTION: SURGICAL OPTIONS WHEN ERCP FAILS

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Gallstones are a common problem in developed countries. Most patients with gallstones remain asymptomatic throughout their lifetime, but approximately 10 to 25% may develop biliary pain, acute cholecystitis, or other complications. A complication of gallbladder disease is related to the migration of stones into the common bile duct. Prevalence of common bile duct stones (CBDS) detected during intraoperative cholangiography can be as high as 11.6%. The natural history of common bile duct stones is not well understood, but patients with symptomatic cholelithiasis have a 5-15% incidence overall of CBDS. Asymptomatic common duct stones have an incidence of less than 5%. If common bile duct stones are found, they should be removed to reduce the risk of complications over time. Extraction of biliary stones is an essential component of managing biliary tract stones.

Endoscopic retrograde cholangiopancreatography (ERCP) prior to laparoscopic cholecystectomy should be performed to remove CBDS. ERCP is the first-line procedure for the treatment of common duct stones. It combines endoscopy and fluoroscopy to visualize and access the bile ducts, allowing for stone removal and treatment of possible ductal strictures. ERCP allows for the evaluation and extraction of common duct stones before the removal of the gallbladder.

Twenty-three percent of patients with common duct stones will develop complications that include pancreatitis and cholangitis. Patients who had undergone common bile duct stone removal have a lower complication rate of about 12%. Current data supports a strategy of extracting common bile duct stones, regardless of the size. Patients that are admitted with acute cholecystitis have a risk of occult common bile duct stones. Liver function tests and abdominal ultrasound are the initial diagnostic steps for suspected common stones. A risk predictor for biliary stones has been established by SAGES and European Society of Gastrointestinal Endoscopy. Moderate risks for CBDS are a bilirubin of 1.8-4 mg/dL, dilated CBD on ultrasound or CT scan, and older than 55 years old. This group of patients should have a MRCP or intraoperative cholangiogram to evaluate the common duct. High risk patients that have a bilirubin >4 mg/dl, CBS on US, common duct dilated duct > 6mm, and clinical features of cholangitis need biliary clearance prior to cholecystectomy. An ERCP is performed prior to a laparoscopic cholecystectomy, if possible.

Performing an ERCP before laparoscopic cholecystectomy is preferred in cases of known CBDS. Stone clearance via ERCP can effectively remove common duct stones, relieve biliary obstruction, and reduces the risk of complications during or after cholecystectomy. ERCP can identify stone characteristics and provides information about the size, location, and composition of the common duct stone, which can guide the surgical approach during cholecystectomy. An ERCP can minimize the risk of bile duct injury by preoperative assessment of bile duct anatomy, identification of any associated abnormalities, and reducing the risk of inadvertent injury to the bile ducts during surgery. Some institutions have had success

with a one-stage procedure, combining ERCP and cholecystectomy in a single hospital admission, so patients can avoid potential delays and the need for multiple procedures. However, there may be situations where immediate ERCP is not feasible or necessary. This can include cases where the common duct stone is small and asymptomatic, or where there are contraindications to ERCP. In such instances, the decision should be made on a case-by-case basis, taking into consideration the patient's symptoms, clinical findings, and surgeon's expertise. Ultimately, the management plan should be determined in consultation with an experienced gastroenterologist and surgeon, considering the specific circumstances and individual patient factors.

While ERCP is a widely used procedure for diagnosing and treating common duct stones, there are cases where ERCP fails to successfully retrieve a common duct stone. ERCP failure rate is between 5 to 15%. Successful cannulation of the common bile duct should happen greater than 85% of the time. If an ERCP fails in retrieving common duct stones, significant morbidity and mortality can result if left untreated. Reasons for ERCP failure may be due to multiple factors, including anatomical variations or distortions, stones that are too large or firmly impacted in the common duct, posing challenges for extraction, poor visualization, inadequate instrumentation, or limited expertise.

Unsuccessful biliary cannulation is defined as the inability to gain deep and free access to the CBD. The criteria for difficult biliary cannulation is more than 5 minutes of calculation time to gain access within the five instances of meaningful ampullary contact, or more than one instance of unintentional pancreatic duct canulation. There is a direct correlation of success associated with expertise, endoscopic training, and practice setting. The reasons for failed ERCP can vary and may include technical, anatomical, or patient specific factors. Anatomic challenges with variations and distortions in the biliary and pancreatic ductal system are the first challenge, making it difficult to access the duct or visualize any underlying pathology. Dysfunction of the Sphincter of Odie may lead to difficulties in cannulating the pancreatic ducts. Previous surgery or altered anatomy in the upper GI tract may pose challenges, including patients who had upper GI cancers, or gastric by-pass Roux-en-Y surgery. This is because the ductal papilla is approached, either from the opposite direction or using a forward viewing endoscope that lacks the advantage of elevating the ampullary duct off the duodenal mucosa for access. Also, stones that are large, impacted, or adherent at the biliary or pancreatic ducts can make successful retrieval difficult. Patient factors, such as obesity, altered gastrointestinal anatomy, or complex medical history may also contribute to the difficulty in achieving a successful ERCP. Many times, reasons for failed ERCP can be multifactorial, and individual patient cases may present with unique challenges. Therefore, alternative methods and a multidisciplinary approach involving radiologists and surgeons may be necessary to determine the most appropriate course of action.

If ERCP fails, there are several surgical options that can be considered. In event of a failed ERCP cannulation, studies indicate that 50 to 60% of patients will need further therapeutic procedures, either radiologic or surgical. Data suggests that when there is a failure to cannulate the CBD or a complex stone removal, prior to any surgical intervention, referral to experienced, high volume center for a second attempt at ERCP results in superior procedural and patient outcomes and increases the probability of success. Rescue options to consider include: 1. **Percutaneous transhepatic cholangiography** (PTC). PTC involves the insertion of a percutaneous catheter through the liver into the bile ducts, with canulation of the common duct to inject contrast dye for imaging, extraction of common duct stones, and stenting of the common duct and ampulla. 2. **Surgical exploration:** In cases where ERCP fails, surgical exploration of the bile ducts may be necessary. This can involve open surgery during a cholecystectomy to remove common duct stones. Laparoscopic common bile duct exploration (LCBDE) is a minimally invasive surgical procedure that uses small incisions and a camera to access and remove stones or perform other interventions in the bile ducts. This can be performed with laparoscopic instruments or robotically.

3. **Endoscopic ultrasound-guided interventions:** In certain cases, when ERCP fails, endoscopic ultrasound-guided interventions may be considered. This involves using an endoscope with an ultrasound probe to guide interventions, such as drainage or stone removal, directly in to the bile ducts. The choice of surgical options will depend on various factors, including the underlying anatomic condition, the expertise of the medical team, and the patient's overall health. It is important to consult with a healthcare professional for a proper evaluation and to determine the most appropriate surgical option in each individual case.

For patients that have had previous gastric by-pass surgery, cannulation of the distal gastric stomach and then a side ERCP scope is not recommended. Advances in laparoscopic/robotic surgery have progressed to replace this procedure, where a standard common duct exploration can be performed more efficiently with less time and reduction in complications.

PERCUTANEOUS TRANSHEPATIC CHOLANGIOGRAPHY (PTC)

PTC is useful when ERCP fails or is not feasible due to anatomical abnormalities or prior surgical alterations. PTC involves the percutaneous insertion of a needle into the liver to access the bile ducts for stone removal and is most successful when there is a dilated common duct from obstruction. Under fluoroscopic or ultrasound imaging guidance, a radiologist advances a needle through the liver into the bile ducts, where contrast material is injected to visualize the common bile duct and biliary stones. PTC offers direct visualization of the biliary tree and ampulla and the ability to perform interventions such as stone removal, biliary dilatation for strictures, or stent placement. Biliary decompression is accomplished with a biliary catheter and is very effective, especially in patients who are septic and hemodynamically unstable from cholangitis when ERCP was not successful. Biliary stones are extracted with cages and balloons designed to clear the common bile duct. This percutaneous approach has the ability to access the biliary tree, especially in patients with difficult or altered anatomy, such as pre-ampullary diverticulum, Billroth-2 gastrectomy, Roux-en-Y gastrojejunostomy for cancer or gastric by-pass. A PTC can also be used to assist obtaining access to the biliary tree via endoscopy using a rendezvous procedure by passing a wire into the biliary tree from above and snaring it with the endoscope and guiding a wire into the common duct for stone extraction. In a small retrospective study, 100% of those who had failed ERCP to clear the stone were able to have complete stone removal. Also, lithotripsy either using ultrasound or laser technology, can be used to remove the stones. PTC carries a risk of bleeding, infection, and injury to surrounding structures.

SURGICAL EXPLORATION OF COMMON BILE DUCT

Surgical exploration for the retrieval of CBS can be considered when endoscopic or percutaneous methods fail. It allows for comprehensive evaluation and treatment of the bile ducts with retained stones. Common duct exploration should be performed during a cholecystectomy after a failed ERCP. While an open common exploration was a widely used technique, it was replaced with the adoption of an ERCP to extract biliary stones. In 1988, 40% of patients with choledocholithiasis had some form of CBD exploration. This had decreased to 9% by 2013. There was a parallel increase of 95% using ERCP as the primary method for common duct stone extraction.

Common duct exploration for stone retrieval traditionally involved open surgical procedures, but advancements in minimally invasive techniques have led to the emergence of robotic exploration of the common duct. Traditional open surgical exploration carries significant morbidity and prolonged recovery. Laparoscopic stone extraction can be performed with laparoscopic instruments or robotic exploration. Common duct exploration can be accomplished through the cystic duct or via a choledochotomy. Trans-cystic exploration can be accomplished after an intra-operative cholangiogram defines the anatomy. If the cystic duct is small (<4mm), or stones are large (>6mm), cystic duct exploration cannot be performed, so procced to a common duct exploration. Studies have shown that the trans-cystic approach, when possible,

is associated with lower morbidity, shorter hospital stay, decrease in bile duct leak rates, mean operating time, and morbidity.

Robotic exploration of the common duct presents an alternative minimally invasive approach that combines the advantages of laparoscopic surgery with enhanced dexterity and visualization. Robotic systems assist surgeons in performing procedures with enhanced precision and control. A typical robotic surgical system consists of a console, robotic arms, and specialized instruments controlled by the surgeon. Robotic surgery offers improved dexterity, 3D visualization, tremor elimination, and wristed instrument motion. Robotic exploration of the common duct involves the use of robotic instruments to access and explore the common bile duct for stone retrieval or other interventions. A choledochoscope is used to explore and clear the duct. Trocar placement is the same for robotic cholecystectomy, providing access for robotic instruments and camera in the same orientation for a laparoscopic gallbladder procedure. The gallbladder is left in to facilitate exposure of the cystic duct. Robotic exploration offers the advantages of minimally invasive surgery, including smaller incisions, reduced blood loss, and shorter hospital stay.

The closure of the common bile duct after exploration has been somewhat controversial. This involves primary closure with or without a T-tube. T-tubes were historically used to minimize bile leaks and provides easy access for the common bile duct postoperatively. However, T-tubes cause morbidity, such as possible dislodgement, erosion, and pain in the surrounding skin. A Cochrane database review of both laparoscopic and open common bile duct explorations concluded that routine T-tube drainage is associated with longer operating time and hospital length of stay, with no differences in morbidity or mortality. Another meta-analysis demonstrated that primary closure was superior to the T-tube drainage after laparoscopic common bile duct exploration. Robotic exploration of the common duct has demonstrated comparable stone clearance rates, reduced blood loss, and seen shorter hospital stays, and lower conversion rates to open surgical traditional approaches. Surgeons require specific training to gain proficiency in robotic exploration techniques, robotic surgery may involve higher costs, compared to traditional surgery, including initial setup, maintenance, and instrument expenses. Robotic exploration of the common duct represents an innovative and minimally invasive approach for stone retrieval. As with any surgical technique, appropriate patient selection, and surgeon expertise, and comparative evaluation between robotic and traditional approaches are essential. Further research and long-term studies are needed to establish the broader role of robotic exploration in the management of common duct stones.

Some patients will require advanced approaches to clear common duct stones. This class of patients includes those with multiple large calculi, recurrent stones, associated strictures, and those at high risk for recurrent biliary stones. These patients will require an advanced procedure to decrease the recurrence of CBDS. Also, there are a small percentage of patients who have stones impacted in their CBD, usually at the ampulla, that cannot be removed either with an ERCP or common duct exploration. Drainage procedures of the common bile duct include choledochoduodenostomy or a Roux-en-Y choledochojeunostomy. A Laparoscopic choledochoduodenostomy has been shown to be a reliable rescue procedure for complicated bile duct stones that cannot be extracted either by ERCP or surgical exploration of the bile duct. The procedure is performed by creating a longitudinal incision on the common duct just above the duodenum and before the cystic duct. The standard laparoscopic approach is performed by milking the stones out of the duct. A transverse incision is made on the duodenum just below the common duct. An anastomosis is performed between the common bile duct and the incised duodenum using interrupted absorbable sutures. A T-tube is not used in the closure. Outcomes have been reported successful in about 80 to 95% of the cases.

Another approach for retained stones after failed ERCP is an intraoperative rendezvous approach. During laparoscopic cholecystectomy, a wire is placed through the common duct and exits into the duodenum. An endoscopist with a choledochoscope will grab the wire and retract it through the ampulla, perform a

sphincterotomy, and cannulate the duct. Common duct stones are removed, and if needed a stent is placed. This technique has a lower incidence of pancreatitis and inadvertent pancreatic duct cannulation. A study performed in 2020 concluded that laparoscopic rendezvous is equal to a two-stage procedure in terms of biliary clearance and conversion, and it is associated with less pancreatitis and a shorter hospital stay. Limitations on this procedure are endoscopists with expertise to perform this procedure.

ENDOSCOPIC ULTRASOUND

Endoscopic ultrasound-guided interventions allow for imaging to directly access the CBD and perform interventions, such as stone retrieval, drainage, or stent placement. EGU can be considered when ERCP fails, and there is a need for precise targeting. The procedure combines endoscopic and ultrasound guidance, allowing for accurate interventions. The procedure will access the duct with direct canulation. Dilators and wires can then be passed to dilate the duct or to remove the stones with a basket. Stents can also be placed.

Surgical options when ERCP fails depends on various factors, including the underlying condition, anatomical considerations, patient's comorbidities, and the expertise and resources available at the medical center. Multidisciplinary discussions among gastroenterologists, surgeons, and interventional radiologists are crucial in determining the most appropriate surgical approach for each patient. While ERCP is the preferred procedure for common duct stone retrieval, it can be challenging in certain cases. When ERCP fails, several surgical options, including PTC, surgical exploration, laparoscopic surgery, and endoscopic ultrasound-guided interventions can be considered. A thorough evaluation and a multidisciplinary approach are essential for successful stone removal and optimal patient outcomes.

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BACKED INTO A CORNER: DAMAGE CONTROL SURGERY IN THE RURAL OR AUSTERE SETTING

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Damage control surgery is typically defined as an intervention to correct the "lethal triad" in critically ill patients. The goals are to control bleeding, gain source control, and ultimately stop acidosis, coagulopathy and hypothermia.[1] This strategy is employed across many environments; from Level 1 Trauma Centers, to the rural community hospital, to the front lines of the battle field. The focus here is on Damage Control Surgery in a Rural Community Setting (ACS Level 3/4 trauma centers).

Numerous studies in the 1970's and 1980's show benefit in source control of bleeding and infection in an augmented fashion. In the early 1980's, liver packing was found to be successful to control liver hemorrhage in 90% of patients.[2] Shortly thereafter, the lethal triad was further understood. In 1993, Dr. Rotondo et al. published the first paper coining the term Damage Control Surgery.[3]

The initial articles and current perception of damage control surgery usually imply the open abdomen after abdominal trauma/sepsis. This concept has been extended to a wide range of other applications, specifically at community hospitals: intraabdominal sepsis, intraabdominal hemorrhage, pelvic hemorrhage, necrotizing fasciitis, ED thoracotomy, vascular shunts and intrathoracic trauma.

Most community and critical access hospitals lack 24/7 vascular surgery, thoracic surgery, dedicated intensivist, dedicated trauma/acute care surgery operating room's, interventional radiology, neurosurgery, plastic surgery, or orthopedic trauma. The blood bank is typically limited to 4-6 units of PRBC/FFP and 1 unit of platelets. One of the greatest limitations at a Level 3 center is blood availability. Obtaining additional blood from neighboring hospitals takes a minimum of 2 hours to transport prior to crossmatch. OR call teams are typically a 30 min call-back response, depending on their ACS trauma designation. Usually, there is a surgeon on call, which is where the predicament starts. The general surgeon is present to intervene, but the ancillary support is absent.

Obvious situations arise that prevent patient transport to a higher level of care and require surgical intervention at the initial receiving hospital. These situations may force the surgeon to perform a damage control surgery or potentially, a definitive surgery. In some cases, the patient may be appropriate for transfer to a higher level of care; however, EMS availability has become a limiting factor in many rural settings. Weather also plays a significant role in transport options based on patient's status.

Other cases (for example, necrotizing fasciitis) may be discussed with the surgeon on call, and recommendations for transfer are made prior to source control or surgical intervention. This leads to a delay in care and ultimately increases morbidity/mortality, depending on the length of transport and delay to OR.

SPECIFIC SITUATIONS

Necrotizing Fasciitis

General surgeons can gain source control in most situations prior to transfer. A 9-fold increase in mortality occurs if delay is greater than 24 hours.[4,5,6] The absence of the following: ICU care (or surgical critical care), OR availability for serial debridement, specialized wound care nursing, plastic surgeon for reconstruction, or 72-hour bed wait once admitted, with no available transport are all reasons for surgeon hesitation in the community setting. However, there is a role for damage control debridement with plans for immediate postop transfer to avoid excessive delays in source control. These system issues should not be a reason to delay early intervention.

Pelvic Hemorrhage

Ongoing pelvic bleeding and hemodynamic instability in a hospital setting without IR, ortho trauma, vascular, or adequate blood supply are a nightmare for any general surgeon. Most general surgeons in these settings are not equipped or adequately familiar with REBOA, so while REBOA is an option, pre-peritoneal pelvic packing is something general surgeons are familiar with. The procedure can be completed in 15 minutes and may be the bridge needed for expeditious transfer to a level 1 center. Surgeons at Level 3 and 4 centers may need to refresh on this technique. As mentioned below, the ACS ASSET course is an excellent opportunity for this.

Vascular Injury Requiring Shunt

After reading this, call your OR materials' management and ensure appropriate quantity and availability of shunts. Numerous shunts are available, but the important thing is that you are familiar with what is available at your facility. Many facilities stock Argyle and Javid shunts. If you cannot find a true vascular shunt when it is needed, a small-bore chest tube, gastric tube, or similar single lumen device will suffice. For extremity vascular injuries, obtain proximal and distal control, thrombectomy, shunt, secure shunt and splint. Pack the wound and plan for transport. Consider fasciotomies when extended transport is expected. Though prophylactic fasciotomy has fallen out of favor at many centers due to the acuity of intervention, it is important to consider the time to definitive care in these cases. This skill is also covered in the ACS ASSET course.

ED Thoracotomy

Most importantly, have an evidence-based algorithm that fits your situation and location based on available resources, injury pattern, and patient age. If ROSC is obtained after ED Thoracotomy in a community hospital, resource utilization is already at its maximum. In these situations, many factors will play into the definitive plan: blood availability, transport time, helicopter availability, and FAST exam of abdomen. Regardless of the injury, with a 30-minute call back for the OR and absence of a dedicated trauma room, the ER becomes the OR. This necessitates having a readily available "trauma cart," as discussed below.

The studies on damage control surgery were multicenter trials at level 1 centers. To date, there are no studies comparing outcomes at level 1 vs Level 4 centers. However, in the post-COVID era of bed unavailability and transport limitations, not all patients will arrive to the desired level of care within the ideal timeframe. Smaller level 3 and 4 centers can provide similar temporizing measures with less available resources- IF systems and plans are in place for ongoing care following the index procedure.

Recommendations for the Level 3/4 general surgeon for damage control preparedness

1. Have a working relationship with receiving facility
    a. Invite trauma surgeons from your receiving facility to visit your hospital and explain what resources you have available. Make the relationship personal.
    b. Make arrangements for OR-OR transfer when necessary. If the receiving hospital does not have available beds, direct transfer to the OR is always an option.
    c. "Safe Haven Bed"- WVU's Level 1 Trauma Center has 3 beds that are not counted in the daily house census that are staffed 24/7 for emergent transfers (ICU level care). These beds are for patients/situations that cannot wait for bed availability.
2. Have a transport plan
    a. When commercial transport is not available, have a backup plan. Make an arrangement with local volunteer/paid Fire and EMS personnel to provide an ambulance for transport when the commercial company is not available. A nurse or respiratory therapist from your facility may need to go with the team, if necessary, based on patient condition and personnel training.
    b. Have a flight crew on standby postop for immediate transport to the accepting facility to avoid delay in critical care.
3. Have the necessary supplies and instruments on hand
    a. Create a "trauma cart" with inventory that you need. The ER staff, OR staff, nursing supervisor and surgeon on call should know where the cart is located and what it contains.
    b. The cart should be inventoried and stock rotated on a regular basis.
    c. Items to consider: vascular suture, vascular shunts, GIA vascular/GI Staplers, Combat Gauze, thoracotomy tray, abdominal tray, vascular tray, Fogarty balloons, vessel loops, multiple packs of lap pads, chest tubes, pleura-vac, abdominal vac dressing, and vessel sealing energy device of your choice. The inventory list should include any item that you may need at 3 am and the travelling nurse will be unable to locate in the OR Core.
4. Continuing Education
    a. ATLS and ASSET are ESSENTIAL!
        i. Know the key exposures and review them frequently
    b. Familiarize yourself with the vascular shunts at your facility
    c. Watch videos. If you haven't done preperitoneal pelvic packing or a thoracotomy in a while, don't get caught off guard.

Figure 1. Trauma Cart – stocked and stored in the OR. Available for transport to any location, as needed

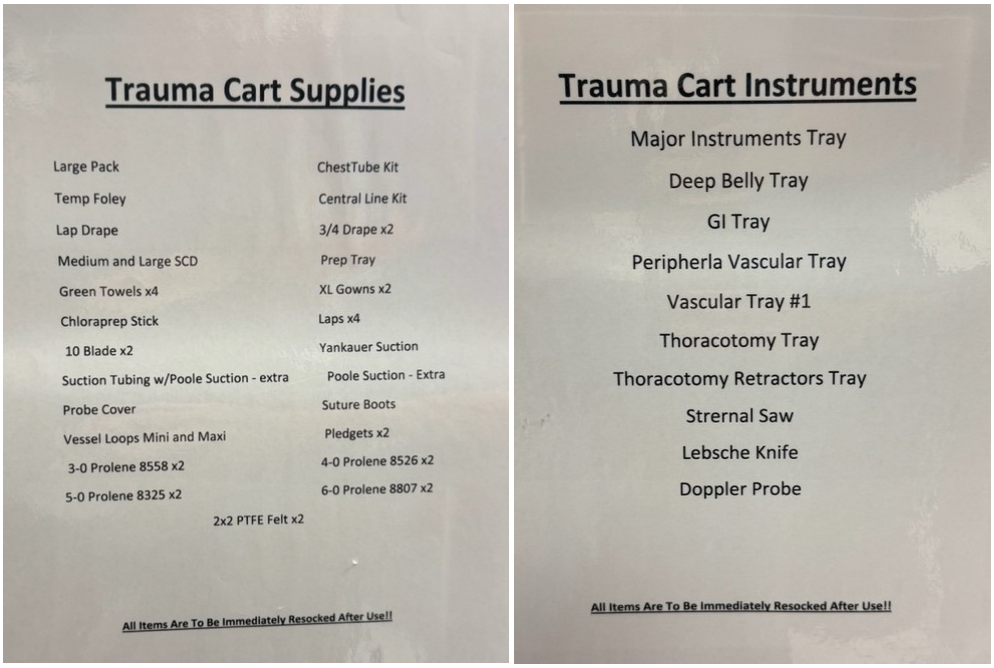

Figure 2. Supply list – checked weekly and items exchanged to avoid expiration. For completion, would recommend addition of vascular shunt and Fogarty balloon.

SUMMARY

There is a role for damage control surgery in both general surgery and trauma patients at level 3 centers. The successful implementation and completion of damage control surgery requires thorough planning and a full understanding of resource limitation. Additional training or practice for infrequently performed procedures may be necessary. A systems-based approach with postoperative transfer to a higher level of care is acceptable and expected.

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SESSION 9

CAPSULE COMMENTARIES – BECAUSE YOU ASKED

Moderator: Purvi P. Patel

Tuesday, April 16, 2024
2:00 – 2:56 PM
Palace Ballrooms 1-2
Palace Tower
Emperors Level – 4th Floor

2:00 – 2:08	**Are Pigtails All They Promised?** **Meghan R. Lewis, MD, FACS**
2:08 – 2:16	**TXA: Is the Story Complete?** **Sydney J. Vail, MD, FACS**
2:16 – 2:24	**Stop the Clot: VTE Prophylaxis Update** **Elliott R. Haut, MD, PhD, FACS**
2:24 – 2:32	**"Incisional Wound Vacs: Do They Live Up to the Hype?"** **Marc A. de Moya, MD, FACS**
2:32 – 2:40	**Perianal Emergencies for the Acute Care Surgeon** **Chris Cribari, MD, FACS**
2:40 – 2:48	**Implementing a Robotic Program in a Community Hospital** **Jason L. Turner, MD, FACS**
2:48 – 2:56	**Getting to the Heart of the Matter: Pericardial Exploration** **Patrick Georgoff, MD, FACS**
2:56 – 3:25	**Break/Visit Exhibits** **Palace Ballroom 3** **Palace Tower** **Emperors Level – 4th Floor**

ARE PIGTAILS ALL THEY PROMISED?

Meghan R. Lewis, MD, FACS

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Thoracostomy tubes have been described as early as the 5th century BC. Traditional teaching has advocated for placement of a large (36-40 Fr) tube after trauma to ensure optimal chest drainage. However, in 2012, Inaba et al. challenged this dogma, demonstrating that smaller chest tubes (28-32 Fr) were equally effective.[1] Since that time, smaller chest tubes have been increasingly utilized after trauma.

Standard tube thoracostomies are placed by surgical cutdown with finger thoracostomy to allow for rapid release of a tension pneumothorax and to ensure correct placement in the chest cavity. Use of pigtail catheters for drainage of the pleural cavity, without cutdown, was first described in the 1980s.[2,3] This alternative procedure for chest drainage was initially used for simple effusions in stable patients. Rivera et al. first described use of pigtails for primary management of chest trauma; however, placement was with image guidance in the Interventional Radiology Suite.[4] Several studies have reported a learning curve before surgeons can demonstrate proficiency with the procedure at bedside, with many converting to traditional chest tube during their first few attempts.[5] Also, many surgeons have been initially hesitant to use these drains for traumatic hemothorax, due to concern that blood may not adequately drain through such a small diameter tube. Despite these concerns, pigtail catheters have become increasingly popular over the past 2 decades, due to their less invasive nature, as well as the ability to use image guidance for precise placement.

The driving factor to replace traditional thoracostomy tubes with pigtail catheters is the less invasive nature. A percutaneous dilational approach is theoretically associated with less tissue trauma and less pain for the patient.[6] Less pain may also lead to better pulmonary hygiene and fewer pneumonias. However, the procedure is technically more nuanced than an open cut down. There are more steps, and the procedure takes longer. For this reason, pigtails have initially been used for non-emergent chest drainage in stable patients.

TECHNIQUE

Multiple techniques exist for placement of pigtail catheters. The most common is the Seldinger technique:

1. aspirate air or fluid from the chest cavity into a hollow needle
2. place a wire through the needle
3. dilate the tract
4. Place the catheter using a straight hollow trocar over the wire
5. Remove the trocar and wire to allow curling of the catheter

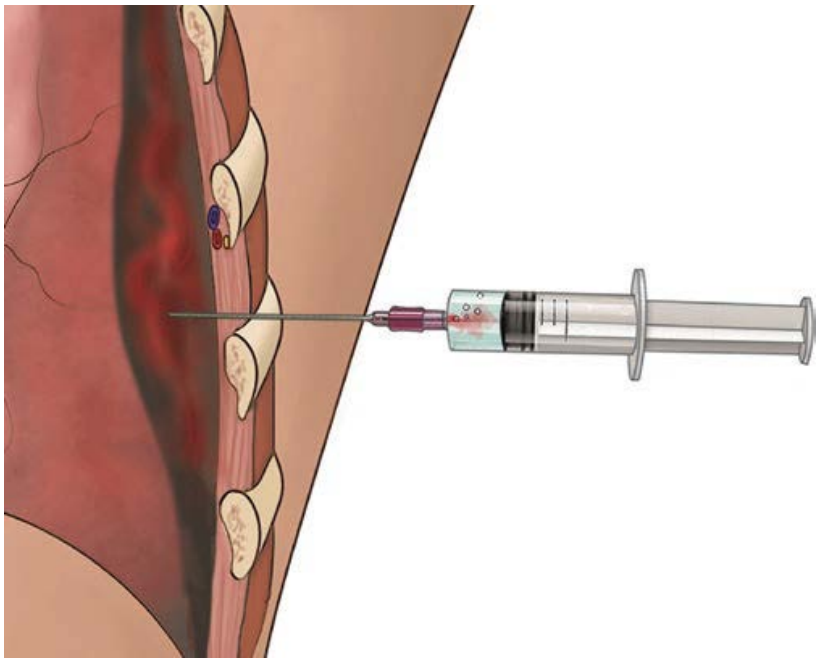

Figure 1a. Aspirate air or fluid from the chest cavity into a hollow needle

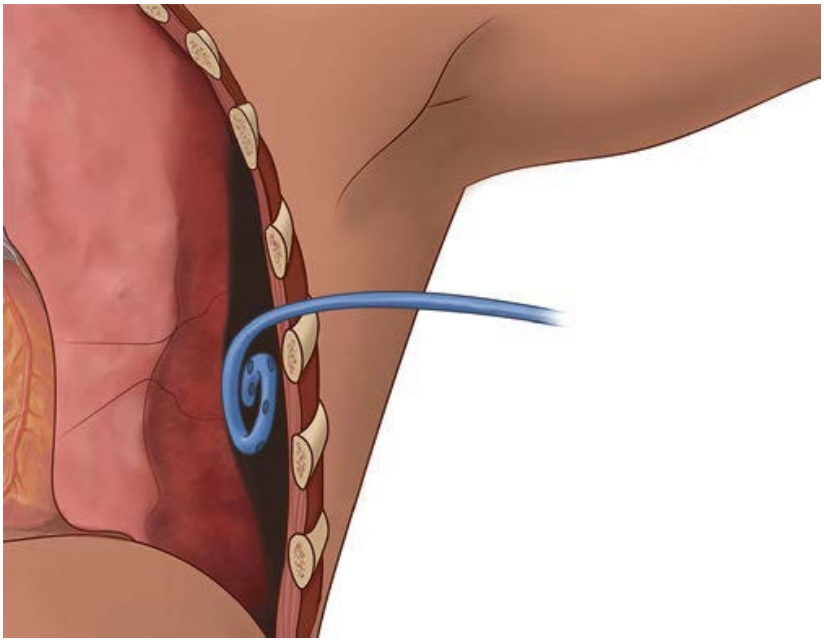

Figure 1b. Removal of the trocar and wire to allow curling of the catheter
From *Atlas of Critical Care Procedures,* Demetriades, et al.[7]

Placement of pigtail catheters has been described in 2 locations[8]:

1. at the second or third intercostal space anteriorly
2. in the fourth or fifth intercostal space laterally

The fourth or fifth intercostal space laterally is the more popular location.[8]

COMPLICATIONS

Complications secondary to pigtail catheters have been well described and are similar in nature to those of traditional tube thoracostomies.[9,10] Although a less-invasive intervention, some studies have demonstrated that small-caliber tubes have a high complication rate, including infection (cellulitis 3%, empyema 3%), catheter dislodgment (2%), catheter malfunction (4%), pneumothorax (6%), and, more rarely, bleeding and injury to adjacent organs.[9]

Early complications of pigtail catheters involve organ injury (e.g., spleen, liver, lung, diaphragm, heart, major blood vessels, esophagus, stomach, bowel) during placement, equipment malfunction (e.g., kinking of the wire during placement), re-expansion pulmonary edema, and bleeding. This can include major bleeding, requiring surgical control, due to an injury of an intercostal vessel, coronary vessel, pulmonary artery branch, or the heart or lung. Errors in placement technique can also occur (e.g., subcutaneous placement or retained obturator).[11,12]

Late complications encompass infection (e.g., cellulitis or empyema), pneumothorax, bronchopleural fistula, nonfunctioning tube, premature removal or dislodgement, nerve irritation, arteriovenous fistula, and cardiac arrhythmias.[12]

Ultrasound can be used at the bedside for guidance and has the advantage of decreased complications and increased first attempt success rates.[13]

TRAUMATIC PNEUMOTHORAX

In 2011, Kulvatunyou et al. retrospectively described the introduction of bedside pigtail catheters placed after trauma at their institution.[14] They compared patients who had pigtails or chest tubes inserted solely for non-emergent traumatic pneumothorax and reported no statistical differences in tube days, need for mechanical ventilation, or insertion-related complications. The tube failure rate, defined as requirement for an additional tube or by a pneumothorax recurrence that required intervention, was higher in the pigtail group but was not statistically significant.

In 2014, the same group published a randomized clinical trial of 40 patients, comparing bedside pigtail catheter placement to tube thoracostomy for non-emergent traumatic pneumothorax.[7] Primary outcome measures were pain at the tube site and the daily intravenous pain medication usage. Pigtail catheters were associated with a greater than 50% reduction in tube-site pain, compared with 28-Fr chest tubes, both on day of insertion and for the following 2 days; however, there was no significant difference in pain medication usage. Secondary outcomes included success rate (defined as no requirement for a second tube insertion) and tube insertion-related complications, which were similar between the two groups. The authors concluded that pigtail catheters for treatment of non-emergent traumatic pneumothorax were associated with less pain but no other important differences.

ACUTE HEMO- OR HEMOPNEUMOTHORAX

Kulvatunyou et al. also studied bedside drainage of traumatic hemothorax by pigtail catheters.[15] In 2012, they published 30 months of prospective pigtail data from their center, comparing it to their retrospective chest tube data from the same time period (36 pigtails, 191 chest tubes). The primary outcome was the initial drainage output. Contrary to concerns about the ability of small tubes to adequately drain blood, initial output was higher in the pigtail catheter group (560 mL versus 426 mL in the chest tube group, p=0.13); however, this was not statistically significant. Also, in the pigtail group, the time from trauma to tube insertion was longer than the chest tube group. This longer time period could have allowed for accumulation of a larger hemothorax. Secondary outcomes in the study were tube duration, insertion-related complications, and failure rate, which were all similar.

Bauman et al. published a prospective series of 496 patients from the same center from 2008 to 2014 comparing bedside pigtail catheters to chest tubes in traumatic hemo- or hemopneumothorax.[5] Some of this data overlapped with the aforementioned hemothorax study. The primary outcomes included initial drainage output, tube insertion-related complications, and failure rate. The initial output was, again, higher after placement of a pigtail catheter, suggesting efficacy of the pigtails for drainage of hemothorax. However, pigtails were again placed at a later time, also in older patients, and after blunt trauma. These risk factors may have increased the overall volume of hemothorax at the time of drainage. In addition, insertion-related complications were higher in the pigtail catheter group, though this was not statistically significant. Failure rate, defined as an incompletely drained or retained hemothorax that required a second intervention, was higher in the chest tube group, but this also was not significant. The use of pigtail catheters increased over the study period, and the conversion rate to traditional tube thoracostomy decreased, demonstrating increasing provider comfort with the procedure over time. The authors also did a sub-analysis of the 226 patients who had chest drainage emergently, which was defined as placement in the trauma bay shortly after arrival. On sub-analysis, output was again higher in the pigtail group. Insertion-related complications were also higher in the pigtail group, though still not statistically significant.

In 2021, Bauman et al. published a randomized controlled trial comparing 14 Fr pigtail catheters placed at the bedside to large-caliber (28-32 Fr) chest tubes in non-emergent traumatic hemo- or hemopneumothorax in 43 patients.[16] The primary outcome was failure rate, defined as the need for an additional drainage intervention, which was found to be similar between the 2 groups. Initial and daily outputs were also similar between the groups, suggesting no difference in efficacy for draining the chest. There was also no difference in tube days between the 2 groups; however, insertion perception experience (IPE), rated by the patient, favored the pigtail catheter over the traditional chest tube. Interestingly, there were no insertion-related complications.

Finally, in 2021, Kulvatunyou et al. published a multicenter randomized controlled trial comparing 56 patients with 14-Fr pigtails placed at bedside to 63 patients with 28- to 32-Fr chest tubes for traumatic hemothorax from 2015 through 2020.[17] They again excluded patients in extremis who required emergent tube placement. The primary outcome was failure rate, which was defined as a retained hemothorax requiring a second intervention. Secondary outcomes included daily drainage output, tube days, intensive care unit and hospital length of stay, and IPE score on a scale of 1 to 5 (1, tolerable experience; 5, worst experience). Failure rate was similar (11% pigtails vs. 13% chest tubes, $p = 0.74$), and all other secondary outcomes were similar. However, pigtail catheter patients reported lower IPE scores (median, 1) than chest tube patients (median, 3; $p < 0.001$). The authors concluded that small caliber pigtails are equally as effective as standard chest tubes with no difference in complications and better patient IPE scores.

DELAYED HEMOTHORAX

In 2020, Orlando, et al. published a retrospective multicenter trial of patients with “delayed hemothorax” treated with either large-bore chest tubes (>14 Fr) or small-bore pigtail catheters (</=14 Fr).[18] Patients were included if their initial drainage tube was placed for hemothorax at 36 hours or greater after hospital arrival. The primary outcome was at least one tube complication (including need for a second chest tube, tube dislodgement, clogging of tube, pneumonia, empyema, or retained hemothorax requiring intervention). This occurred in 17% of tubes, with no difference between groups. With regard to specific complications, large-bore chest tubes had a higher rate of need for subsequent video-assisted thoracoscopic surgery (VATS), and small-bore chest tubes were associated with a higher rate of pneumonia. Due to the retrospective nature of the study, these findings may be attributable to a number of factors. The decision to place an additional tube, attempt thrombolytic therapy, or proceed with VATS varies with center and provider. In this study, all of the pigtail catheters were placed at the same center,

while the other 5 centers preferentially placed chest tubes. Practice patterns at the centers, therefore, likely impacted the VATS numbers. Also, number of rib fractures and number of ventilator days were not evaluated, which would have impacted pneumonia rate. There was no difference between groups in time each chest tube was in place or volume of initial output; however, large-bore tubes drained at a rate 4 times faster than small-bore tubes. The drainage rates, however, may not be accurate, because they were based on a subset of the total study population, and they were calculated dependent on timing of output recording.

AGGREGATE DATA

Beeton et al. performed a meta-analysis of the previously published literature comparing bedside pigtail catheters to traditional chest tubes after traumatic injury.[19] A total of 7 studies (2 randomized controlled trials, 3 prospective studies, and 2 retrospective studies) met inclusion criteria, 6 of which came from the same institution. The study aimed to compare failure rate (requirement of an additional intervention), initial drainage output (within 30 minutes), ICU length-of-stay (LOS), hospital LOS, ventilator days, and tube duration in adult trauma patients with thoracic injuries who received either a pigtail catheter (≤14Fr) or chest tube (>16Fr). Failure rates were compared between 750 patients (6 studies) with chest tubes and 393 patients with pigtail catheters. The relative risk of failure rate of chest tubes compared to pigtail catheters was found to be 1.13 [95% CI: (.85-1.51)]. Patients in the chest tube group had a higher risk of requiring VATS vs the pigtail group (sub-analysis of 5 studies), with a relative risk of 2.77 [95% CI (1.50, 5.11)]. However, as previously mentioned, VATS is not always the first or only intervention for failure of chest drainage. It is possible that patients in the pigtail group received placement of a larger chest tube or thrombolysis for failure. Out of 5 studies, the pigtail group (461 patients) had higher initial output volumes compared to the chest tube group (644 patients), with a mean difference of 114.7 mL [95% CI (70.6 mL, 158.8 mL)]. Tube duration was also compared in all 7 studies and was found to be significantly lower in the pigtail group, but by a difference of only 0.8 days. ICU length of stay, hospital length of stay, and ventilator days were no different between the groups.

COMMENTARY

Taken in aggregate, the aforementioned studies have established the pigtail catheter as an acceptable alternative to standard chest tubes for traumatic pneumo- and hemothorax. However, there have been important criticisms of the existing literature. Pigtails have been associated with decreased pain at the tube site. However, pain scores after trauma are subjective, and it is difficult to isolate the pain associated with thoracic soft tissue, lung, or bone injury from that due to the tube itself. Pigtails have also been associated with a significantly improved insertion perception experience, as rated by patients. It should be noted that the scale used has not been previously validated in the literature.[16]

Regarding the safety of bedside percutaneous pigtail placement in comparison to traditional cutdown for chest tube placement, the most important limitation is that emergency placements have almost always been excluded from these studies. Though one sub-analysis evaluated “emergency” drainage tubes, this was defined by placement in the trauma bay on the day of presentation, not by hemodynamic or respiratory instability.[5] The majority of complications from drainage tubes occur during emergency placement. If pigtail catheters were to be adopted for emergency placement, further comparison of complications would be appropriate. In addition, there are different techniques and different locations for placement of pigtails, with variable complications. Most of the studies have evaluated lateral pigtails placed by Seldinger technique, so the complication rates cannot necessarily be extrapolated to other techniques. Also not addressed in the studies was bedside placement of pigtail catheters using ultrasound guidance. This practice likely improves the safety of the procedure, though also requires additional training/expertise, equipment, and time for placement.

Regarding the efficacy of pigtails for chest drainage after trauma, the existing studies come largely from the same center, and with some overlapping data. Though the results have demonstrated that pigtail catheters drain traumatic pneumo- and hemothorax as effectively as standard chest tubes, this is at a center where the practice has been adopted and providers have progressed through the learning curve.

GUIDELINES

Recent guidelines (2020) by the Eastern Association for the Surgery of Trauma (EAST) *conditionally* recommend the use of pigtail catheters in patients that are hemodynamically stable over a standard large-bore chest tube to decrease the rate of retained hemothorax and the need for additional intervention.[20] Western Trauma Association Guidelines recommend pigtail catheters or small-bore chest tubes for traumatic pneumothorax, chest tubes for emergent hemothorax, and either for non-emergent hemothorax.[21,22]

CONCLUSION

Placement of a pigtail catheter at bedside is a less invasive management option for thoracic trauma compared to traditional tube thoracostomy. The procedure requires a learning curve for safety and success. Based on current data, in the hands of experienced users, the safety and efficacy appear comparable to that of a traditional chest tube for non-emergent pneumo-, hemo-, or hemopneumothorax. Pigtails are associated with improved pain at the tube site and improved insertion perception experience, as rated by the patient. There may also be a difference in tube duration of less than 1 day in favor of pigtail catheters, though this is based on low-quality evidence. Providers still appear hesitant to use pigtail catheters for hemodynamically or respiratory unstable trauma patients, and professional guidelines do not currently support the practice in hemodynamically unstable patients with hemothorax.

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TXA: IS THE STORY COMPLETE?

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"TXA: 'It will help everyone so give it to everyone.' 'Good for all types of bleeding, has no bad side effects, and it's not expensive…' " I overheard this being said at a conference I attended by a speaker discussing their presentation on TXA with some audience members.

…….or Everything, or Some Things??!!

This presentation could have been titled "TXA: The In-Complete Story." The number, breadth, and types of studies with both trends and statistically significant varied outcomes and recommendations can numb your mind. I hope to provide some sanity (and clarity) on this issue; the story is NOT complete!

GOOGLE, search term: "tranexamic acid in trauma patient" - About 675,000 results (0.46 seconds); I wish all of us good fortune in reading, analyzing, and summarizing all these publications.

We will begin with well-known trials that did give us some useful information/indications for use.

CRASH-2[1] made headlines around the world:

> The CRASH-2 trial: a randomized controlled trial and economic evaluation of the effects of tranexamic acid on death, vascular occlusive events, and transfusion requirements in bleeding trauma patients
>
> ***Tranexamic acid, administered within 3 hours after injury was shown to reduce 28-day mortality among patients with suspected bleeding!!***

Napolitano, et al., in the June 2013 issue of the Journal of Trauma, analyzed the CRASH-2 data carefully and found the study to have major problems, including:

- Only approximately 5% of patients had bleeding as a cause of death
- The CRASH-2 approach to randomization. The CRASH-2 wording is: "Doctor is reasonably certain that antifibrinolytic agents are indicated or contraindicated – Do not randomize"
- Concern regarding selection bias
- No data regarding injury severity of the patient cohort
- No data regarding shock in the patient cohort (i.e. lactate and base deficit), and there was the inability to determine if the cohorts were similar
- Small sample size of hypotensive (SBP < 90 mm Hg) (31.5%) and tachycardic (HR>107) (48%) patients, which were the target populations
- No data regarding fibrinolysis on admission and no coagulation testing. The rate of fibrinolysis at admission in North American trauma centers is approximately 5%
- The most common cause of death was traumatic brain injury (TBI)
- TXA did not reduce blood transfusions. Only 50% of study cohort received blood transfusions
- No adverse events were regarded as serious, unexpected, or suspected to be related to the study treatment
- Concern about possible inadequate reporting
- Patient follow-up reported as 100%, which is difficult to believe
- Effect size was small. This effect was statistically significant but not a clinically meaningful finding. The study determined a 0.8% absolute reduction in "death caused by bleeding"

CONCLUSION: CRASH-2 does not adequately show a clinically significant outcome: no transfusion reduction, no clinically relevant mortality benefit (i.e. 0.8% absolute reduction in 'death caused by bleeding').

So why are so many physicians that deal with injured patients using it? Are they using other data to support their use?

In OB/GYN, it started with a Japanese wife and husband team in Tokyo in the 1950s. At that time, postpartum hemorrhage was a leading cause of maternal death in Japan, and Utako and Shosuke Okamoto set out to identify a drug that could reduce the number of mothers dying during childbirth. In 1962, they published in the Keio Journal of Medicine about a drug called tranexamic acid (TXA), which they discovered to be 27 times more powerful than a previous lysine-based drug.

The WOMAN trial (World Maternal Antifibrinolytic Trial)[3] focused specifically on pregnant women and found that TXA significantly reduced death due to postpartum hemorrhage. Utako passed away shortly after recruiting for the WOMAN study reached its goal of 20,000 participants, but she said she already knew the results. ***"I am absolutely sure that it's going to be effective - I don't need the research to know this."*** This statement seems to be pervasive in today's medical environment of use of resource(s) without definitive scientific validation; TXA and REBOA, just to name two recent ones.

The idea that TXA is saving lives today is not unique to any one specialty. Since its discovery in 1962, its uses and indications became widespread, despite limited data. TXA has found its way into our practices

based on many studies with limited statistical outcomes, many issues related to quantifiable results, and limitations in data interpretation that make us ask…….ARE WE DOING THE RIGHT THING by administering this medication to so many patients?? Over treat to find the 1-7 patients per 100 that will benefit; do you agree or disagree?

A useful study is the Military Application of Tranexamic Acid for Trauma Emergency Resuscitation study (MATTERs),[4] which evaluated the patients who clearly needed an anti-fibrinolytic. In this study, those military trauma patients who needed at least a unit of blood were divided into TXA or no TXA arms. The MATTERs results were significant: a relative reduction in mortality of 6.7%, and those who received TXA received less blood products. This is data we can base decisions on! Complications also were significant in this trial and were not seen or appreciated in CRASH-2. MATTERs study showed that rates of PE and DVT among patients who received TXA were, respectively, 9 and 12 times the rates among those who did not get TXA.

Most recently, the PATCH trial was published (Prehospital Tranexamic Acid for Severe Trauma. July 13, 2023. N Engl J Med 2023; 389:127-136) that looked at both survival and functional outcomes at 6 months post treatment. (This article was published on June 14, 2023, at NEJM.org.)

THE PATCH-TRAUMA INVESTIGATORS AND THE ANZICS CLINICAL TRIALS GROUP

Abstract

Background

Whether prehospital administration of tranexamic acid increases the likelihood of survival with a favorable functional outcome among patients with major trauma and suspected trauma-induced coagulopathy who are being treated in advanced trauma systems is uncertain.

Methods

We randomly assigned adults with major trauma who were at risk for trauma-induced coagulopathy to receive tranexamic acid (administered intravenously as a bolus dose of 1 g before hospital admission, followed by a 1-g infusion over a period of 8 hours after arrival at the hospital) or matched placebo. The primary outcome was survival, with a favorable functional outcome at 6 months after injury, as assessed with the use of the Glasgow Outcome Scale–Extended (GOS-E). Levels on the GOS-E range from 1 (death) to 8 ("upper good recovery" [no injury-related problems]). We defined survival with a favorable functional outcome as a GOS-E level of 5 ("lower moderate disability") or higher. Secondary outcomes included death from any cause within 28 days and within 6 months after injury.

Results

A total of 1310 patients were recruited by 15 emergency medical services in Australia, New Zealand, and Germany. Of these patients, 661 were assigned to receive tranexamic acid, and 646 were assigned to receive placebo; the trial-group assignment was unknown for 3 patients. Survival with a favorable functional outcome at 6 months occurred in 307 of 572 patients (53.7%) in the tranexamic acid group and in 299 of 559 (53.5%) in the placebo group (risk ratio, 1.00; 95% confidence interval [CI], 0.90 to 1.12; P=0.95). At 28 days after injury, 113 of 653 patients (17.3%) in the tranexamic acid group and 139 of 637 (21.8%) in the placebo group had died (risk ratio, 0.79; 95% CI, 0.63 to 0.99). By 6 months, 123 of 648 patients (19.0%) in the tranexamic acid group and 144 of 629 (22.9%) in the placebo group had died (risk ratio, 0.83; 95% CI, 0.67 to 1.03). The number of serious adverse events, including vascular occlusive events, did not differ meaningfully between the groups.

Conclusions

Among adults with major trauma and suspected trauma-induced coagulopathy who were being treated in advanced trauma systems, prehospital administration of tranexamic acid followed by an infusion over 8 hours *did not result in a greater number of patients surviving with a more favorable functional outcome at 6 months than did the placebo group*. (Funded by the Australian National Health and Medical Research Council and others; PATCH-Trauma ClinicalTrials.gov number, NCT02187120.)

If you read one of the many published comments about this article, you begin to understand that there are limitations to this and every study and that "THE" answer has yet to be published on who, what, why, and to whom TXA should be administered to have a scientifically validated/reproducible positive impact, (which subset(s) of patients, every time?).

https://www.annemergmed.com/article/S0196-0644(23)01229-5/fulltext

"*The PATCH-Trauma trial failed to show a clinically important difference in the trial's primary outcome. Furthermore, these results do not support the routine administration of out-of-hospital TXA to improve survival with favorable functional outcomes at 6 months. From a treatment safety standpoint, there was no increase in serious adverse events in the group that received TXA."* [5]

https://www.east.org/education-resources/east-monthly-literature-reviews/december-2023-surgical-critical-care

"In summary, favorable functional outcome at 6 months was not altered with the administration of TXA in severely injured trauma patients, suggesting a need for further research to identify which trauma patients have meaningful clinical benefit from TXA administration."

Conclusion to be made from the PATCH trial:

1. The PATCH trial supports the findings of CRASH-2 in that prehospital TXA reduces early death due to hemorrhage in major trauma patients (small but real reduction)
2. The primary outcome focused on mortality AND functional outcome
3. There are more survivors with poor neurological outcome in the TXA group.
4. There is inadequate statistical power to interpret the subgroup findings due to small numbers, i.e., penetrating trauma

Another trial, The Study of Tranexamic Acid During Air and Ground Medical Prehospital Transport (STAAMP) [6] was a phase III, multicenter RCT of TXA versus placebo, given within an 'estimated' 2 hours of injury in the pre- hospital setting to patients with hypotension or tachycardia. There was *no significant difference in the primary outcome of 30-day mortality.; but, in a pre- determined subgroup analysis, patients with severe shock (systolic blood pressure <70 mmHg) who received TXA within 1 hour of injury had a significant reduction in 30- day mortality.* So, another study with a limited patient population demonstrated clinical benefits.

If you look through literature as recently as last month, you appreciate that there remain more questions than answers, which should alert you to the fact that we are not at the point of definitive focused clinical criteria per patient injury type or severity and that clinical acumen still trumps the varied recommendations presented to us. If we had the answers, they would be published not as guidelines but as 'THE GOSPEL' or 'THE VALIDATED RECOMMENDATION(S)' for universal use; we DO NOT have them yet. Each trial will have flaws and faults, but each time we attempt to answer the question, we seem to move closer to a better-defined patient injury type that will ultimately benefit.

EAST.org proposed *guidelines under development* [7] Tranexamic Acid Administration in Patients with Traumatic Injury: A Practice Management Guideline from the Eastern Association for the Surgery of Trauma ***2020***

Type: New Practice Management Guideline (PMG)

Category: Surgical Critical Care. Committee Liaison: Rachel S. Morris, MD, FACS; Team leader(s) Matthew J. Martin, MD, FACS, FASMBS.

"We propose a robust PMG with four PICO questions:

PICO Question 1: In adult trauma patients at risk for hemorrhage (P), should Tranexamic Acid (TXA) in the hospital setting (I) versus no TXA (C) be used to decrease mortality or total blood products used (O)?

PICO Question 2: In adult trauma patients at risk for hemorrhage (P), should prehospital TXA (I) versus no prehospital TXA (C) be used to decrease mortality or total blood products used (O)?

PICO Question 3: In adult trauma patients at risk for hemorrhage (P), should a high-dose prescription (2-3g) of TXA (I) versus a low-dose prescription (1g) of TXA (C) be administered to decrease mortality or total blood products used? Does TXA dose impact rates of arterial and venous thromboembolic events (O)?

PICO Question 4: In adult trauma patients (P), should TXA be reserved for severely injured patients in severe shock (I) versus administered to all adult trauma patients at risk for hemorrhagic shock (C) to decrease mortality and total blood products used? Does the use of TXA increase rates of venous and arterial thromboembolic events (O)?"

This medication has been available for decades, yet we remain without answers to appropriately administer it under definitive clinical circumstances; the elusive diagnosis. Reviewing the types/levels of recommendations:

Level I: recommendation is justifiable based on the available scientific evidence alone; recommendation is based on class I or a preponderance of class II evidence.

Level II: recommendation is reasonably justifiable based on the available scientific evidence and supported by expert opinion; recommendation is supported by class II evidence or a preponderance of class III evidence.

Level III: recommendation is supported by available data, but inadequate scientific data is available; recommendation is supported by class III evidence.

The strength of the recommendation for each PICO: ***Strong (should be the new standard of care)*** *vs Conditional (intervention should be employed in the majority of applicable cases). To decide on strength, consider: The quality of the evidence; The risk-to-benefit ratio of implementing the recommendation and potential side effects that may arise; Patients' values / wishes; Cost and resources needed to implement the recommendation; Acceptability among physicians and patients; Feasibility……*

We are not at a strong level of evidence yet for all aspects of administration!

As we wait for the EAST practice management guideline, there is still generalized use, both pre-hospital and in-hospital, that is tied to a patient having 'bleeding,' sometimes without regard to degree of blood loss, source of blood loss, hemodynamic status or other institutional/person determined clinical or physiologic indication. There remains variability in how much TXA to administer (within 3 hours from incident), in the field, or hospital, bolus 1-2 gms vs bolus and drip, based on suspected injury types. AT least, from CRASH-3, we agree that a 2-gram bolus was superior to bolus and longer-term drip. There are many unknown factors, including internal bleeding (CNS, truncal/abdominal) that can't be visualized by pre-hospital personnel or the physician teams until CT scans or other diagnostic modalities are utilized.

We lose time and are not sure of a correct indication. Have all of the pre-hospital operational Medical Directors and state agencies consulted with their regional trauma centers to update their field guidelines for TXA use? Is the present literature 'good enough' to overuse TXA in the 1-7/100 patients that may benefit with reduced transfusions or mortality?

The EAST guideline could become, based on present references to other EAST PMGs, the leading reference on appropriate use of TXA **when it becomes available**. Keep an eye on EAST.org for its future publication. Remember, CRASH-2 started an avalanche of TXA use for many trauma patients without regards to injury patterns, hemodynamics, site of injury, or types of injuries and prompted prehospital protocols and in hospital CMGs to better direct its use……where's the benefit? Show me your data!

CRASH-3 trial demonstrated that among patients in the TXA group with mild-to-moderate traumatic brain injury (GCS 9-15) there was a significantly reduced death rates (5.8% vs 7.5%)[8] ; I believe we all agree with this indication.

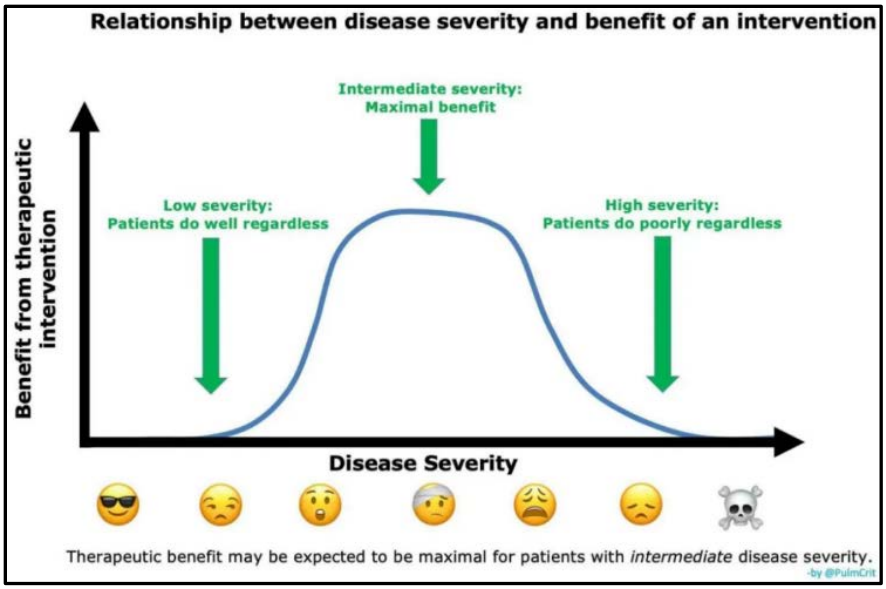
CRASH-4 is presently enrolling EU patients***: 'Intramuscular tranexamic acid for the treatment of symptomatic mild traumatic brain injury in older adults: a randomized, double-blind, placebo-controlled trial.***[9]

AIM: The CRASH-4 trial aims to provide reliable evidence about the effects of early intramuscular TXA on intracranial hemorrhage, disability, death, and dementia in older adults with symptomatic mild head injury. **(NOTE: TXA given without CT head being performed**)

OBJECTIVES: To assess the effectiveness and safety of early intramuscular TXA administration in older adults with mild head injury. Outcomes include the proportion of patients discharged from the emergency department within 24 hours of arrival, intracranial bleeding on CT scan, neurosurgery, death due to intracranial bleeding, and the risk of dementia at 1 year.

They presently have 1347 patients randomized, 39 hospitals and 4 ambulance services participating.

So how do we best determine the 'sweet spot' where patients will achieve benefit (mortality and/or reduced transfusion)? There exists a relative relationship between anatomic/physiologic severity and how an intervention may affect the patient; common sense isn't always common.(Figure 1)



Fugure 1. From: *PulmCrit- Tranexamic acid for traumatic brain injury (CRASH3). October 14, 2019 by Josh Farkas*

The physician's crystal ball or best guess vs clinical judgement of deciding who to treat comes at the expense of being incorrect, somewhat correct or, absolutely correct…….mind you, it has to come at lightning speed and based on significant uncertainty as to the extent of physical injuries, physiologic derangements, and the potential for macro and or micro multi-trauma. Moore, et al. 10 provided a Primer on 'trauma induced coagulopathy' that gives a solid foundation for understanding of trauma-related hemorrhage and the clinical and pathophysiological issues that relate to how best to identify and treat patients that are in either HYPO or HYPER-coagulable state due to traumatic injury.

OB/GYN and ENT, as well as other specialties have started to publish information on the use of TXA to reduce bleeding transfusions. Postpartum hemorrhage, head and neck surgery, GI bleeding, as well as orthopedic procedures, are all now following the leader (trauma) and using TXA; some without statistically significant outcomes in their data; others with small advantages to its use, and others with just trends. Some authors 'extrapolate data/information' from articles and promote wider use of TXA for bleeding. We need to question the validity of their thought processes and interpretation of data. Again, we do not yet have all of the answers to the wide variety of clinical/patient indications where TXA will offer an absolute benefit, benefit that is reproducible, predictable, and with few complications. I refer you to an author's correspondence to Moore's primer (Roberts & Agernon. ***The role of tranexamic acid in trauma – a life-saving drug with proven benefit***. Nature Reviews Disease Primers (2022) 8:34) and the subsequent reply by Moore, et al (Nature Reviews Disease Primers (2022) 8:35).

There is a side of TXA use that many choose to minimize, the real risk of VTE (DVT and PE), as discussed in several papers, both civilian and military. [11] Nothing is without risk, and no one has looked at the microcirculatory thrombotic events potential. Again, we need the data describing which patient subtypes are at higher risk of complications vs at a reasonable risk: benefit ratio. To date, no study on TXA has given us that definitive answer.

We will likely continue to use this medication until such time as it either is scientifically validated in specific patient types/injury types, or we will be left to our clinical judgement, like many other medical resources used around the country and world in the name of 'best injured and/or bleeding patient care.' Maybe the EAST.org PMG will provide answers?

I will conclude this syllabus with the expectation that we will continue to do 'our best' under the present circumstances and limitations on appropriate literature with the goals of decreased morbidity and mortality of our injured and or bleeding patients.

I would like to share one of my favorite quotes about surgeons from Sherwin B. Nuland, MD, From "The Wisdom of the Body" [12]

"***There is something compellingly stark, a kind of luxuriant bluntness, a no-frills directness, in the personality of the surgeon. No doubt all manner of human temperaments have experienced the lure of the operating room -- did Keats and others not as airy and unworldly as he seriously wish to become practicing surgeons? But, in the end, few measure up to the demands. For what is required of the surgeon is to revel in action and concrete accomplishment; to develop great manual dexterity; to translate perceptions into instant judgments, and these into actions that are irrevocable, momentous and dreadful -- all this, mind you, with lightning speed, in conditions of great stress and in an environment of high tension. What is expected of the surgeon is the impossible."***

****I would make the argument that this is the description of us, as surgeons, in the field of trauma.**

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VTE PROPHYLAXIS UPDATE

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EPIDEMIOLOGY OF VTE AND TRAUMA

Venous Thromboembolism (VTE) is comprised of Deep Vein Thrombosis (DVT) and Pulmonary Embolism (PE) and is a common complication after injury. Post-traumatic VTE is associated with significant mortality, morbidity, excess length of stay, and costs. PE affects over 1,000,000 patients and kills more than 100,000 Americans every year, mostly during or after recent hospitalization. The incidence of VTE in trauma patients ranges from 5% to 63%, depending on patient risk factors, prophylaxis given, and aggressiveness of surveillance. Trauma patients, especially those requiring major surgery and ICU admission, are at higher risk for VTE than other hospitalized patients. Spinal cord injury, traumatic brain injury, pelvic and/or long bone fractures, major surgery, and multiple transfusions are all independent risk factors for VTE after trauma. Understanding risk assessment and optimal VTE prevention is essential to reduce morbidity and mortality from VTE.

GUIDELINES AND RECOMMENDATIONS

Given the high incidence and risk of VTE, trauma surgeons should evaluate all injured patients for risk factors and prescribe appropriate VTE prophylaxis. Pharmacologic prophylaxis remains the most effective approach to prevent VTE. Pharmacologic prophylaxis medications primarily include low molecular weight heparin (LMWH) and unfractionated heparin (UFH).

For decades, VTE prevention in trauma has been a focus of evidence-based medicine guidelines. The Eastern Association for the Surgery of Trauma (EAST) was the first to publish a guideline in 2002. Since then, numerous organizations have published recommendations. Some have been offered by societies that cover VTE prophylaxis for a wide range of patient populations (i.e., American College of Chest Physicians [ACCP]). Others, including more recent guidance, come from our trauma specialty organizations (i.e., American Association for the Surgery of Trauma [AAST], American College of Surgeons-Committee on Trauma [ACS-COT], Western Trauma Association [WTA]).

Overall, the preponderance of the evidence supports the use of LMWH over UFH in injured patients. LMWH should be the go to, default medication in the vast majority of injured patients. Enoxaparin, dosed at 30 mg subcutaneous every 12 hours, has been widely accepted as the standard regimen in trauma patients since a major study published by Geerts et al. in 1996. However, newer data regarding dose adjustment for a more personalized medicine approach now exist and will be discussed later.

STANDARDIZED APPROACHES TO PRESCRIBING PROPHYLAXIS

Because the data for VTE prophylaxis in trauma (and in other patients) is so robust, this area has been a strong focus for evidence-based medicine. The translation of guidelines into clinical decision support tools can help clinicians make better decisions at the bedside for their patients. It takes 17 years for evidence from randomized clinical trials to reach patients. The role of clinical decision support tools is to shorten that time and make sure patients get what they should. While education is an important tool, evidence shows that it is not as effective as multi-pronged approaches to improve prescription of optimal VTE prophylaxis. Many toolkits exist, including a document from the Agency for Healthcare Research and Quality (AHRQ), which gives a roadmap for how to improve prevention of VTE. In hospitals that utilize electronic medical record systems for medication prescription, computerized clinical decision support tools can increase appropriate prophylaxis prescription and decrease preventable harm from VTE.

TIMING OF VTE PROPHYLAXIS INITIATION AFTER INJURY

For years, the concern for bleeding has made the trauma team delay initiation of VTE prophylaxis in injured patients, especially those with solid organ injury (SOI) or traumatic brain injury (TBI). However, newer data shows the safety and efficacy of earlier initiation of VTE prophylaxis within 24-48 hours after injury.

In a recent review of the literature on the timing of VTE prophylaxis in SOI patients, Schellenberg et al. summarizes the data from 10 studies and offers the following recommendation: “Venous thromboembolic event chemoprophylaxis initiation <48 hours of emergency department arrival is associated with a reduction in VTE without an increase in failure of nonoperative management or need for blood transfusion.”

Patients with TBI represent another population in which timing of initiation of VTE prophylaxis has been controversial due to the concern about the risk of intracranial hemorrhage expansion. The modified Berne-Norwood criteria, a tiered approach that suggests VTE chemoprophylaxis initiation in patients with TBI has shown efficacy and safety, is outlined in American College of Surgeons Trauma Quality Improvement Program best practice guidelines. Using this approach, it appears to be safe to initiate prophylaxis in low-risk patients if the findings on head CT are stable after 24 hours. In moderate risk patients, the recommendation is to hold prophylaxis for at least 72 hours at which time it may be initiated if the head CT is stable. In the high-risk patient population, recommendations are quite sparse due to lack of numbers of patients studied in this cohort, and practices remain quite varied.

FIXED VS. ADJUSTED DOSING OF VTE PROPHYLAXIS

The 30 mg twice daily fixed dose of enoxaparin (a LMWH) was based on the seminal work of Geerts et al. from 1996. However, patients vary in their weight, body mass index (BMI), and renal function (creatinine clearance), all of which likely lead to differential drug metabolism. In addition, we have learned incredible amounts about the coagulation cascade and the coagulopathy and hypercoagulable states of trauma in the last three decades. For these reasons, other dosing strategies have been proposed and studied. In the era of precision medicine, it is likely that this single fixed dose is not appropriate for every single patient.

Teichman et al. offers an excellent recent review of approaches for optimizing VTE prevention in injured patients. Numerous papers have now shown that standard dosing regimens of LMWH are insufficient in trauma. Alternate approaches to modify the LMWH dose have been proposed and include anti-Xa guided dosage, weight-based dosing, and dose modification based on thromboelastography. Unfortunately, there is no consensus, and it remains unclear which is the single best strategy.

NEW DRUGS FOR VTE PROPHYLAXIS IN TRAUMA

Direct oral anticoagulants (DOACs) include dabigatran, a direct thrombin inhibitor, and factor X inhibitors, including edoxaban, apixaban, rivaroxaban, and betrixaban. These medications are routinely used for treatment of patients with VTE and for prophylaxis against stroke in patients with atrial fibrillation or the other risk factors. More recently, there are data to support their use for VTE prophylaxis in certain highly selected patient populations, including orthopedic surgery and medically ill hospitalized patients. While there is no currently available FDA approved indication in trauma, some studies are now being published using these medications in these patients. In the future, their use will likely be more common.

Aspirin is routinely used for VTE prophylaxis in certain orthopedic surgery populations, in particular after joint replacement, specifically total knee and total hip arthroplasty. Until recently, the role of aspirin for VTE prophylaxis in trauma has been relatively limited. However, new data from a large randomized clinical trial funded by the Patient-Centered Outcomes Research Institute and published in the New England Journal of Medicine in 2023 is rapidly and dramatically changing practice. This pragmatic, multicenter study randomized 12,211 patients with orthopedic trauma, defined as "a fracture of an extremity (anywhere from hip to midfoot or shoulder to wrist) that had been treated operatively or who had any pelvic or acetabular fracture," to aspirin or LMWH for VTE prophylaxis. This study found that aspirin was non-inferior to LMWH for their primary and most secondary outcomes, although there was a significantly higher rate of DVT in the aspirin group.

EXTENDED PROPHYLAXIS AFTER HOSPITAL DISCHARGE

Outpatient prophylaxis for VTE has been well studied in certain patient cohorts. For example, this is the standard of care for orthopedic surgery patients after joint replacement surgery. There is relatively robust data on its use in patients undergoing surgery for abdominal and pelvic cancers. This approach to extended outpatient prophylaxis has been considered in certain trauma populations, but the data is not as strong. The newer data about aspirin does have an outpatient component, but the data in trauma patients without orthopedic injury is still somewhat lacking.

MISSED DOSES OF VTE PROPHYLAXIS

As physicians, we assume that all we need to do is prescribe a medication, and then it will reliably reach the patient every single time. However, is that always true? In the case of VTE prophylaxis, prescription is merely the first step. A nurse needs to give the dose (most likely an injection) to a patient who is willing to accept it. Data shows that approximately 10-15% of all VTE prophylaxis doses are not administered, and 40% of hospitalized patients miss at least one dose of their prescribed VTE prophylaxis. This pattern is very different for injectable VTE prophylaxis than for other medications. The leading cause of missed doses is patient and/or family refusal. Missed doses of VTE prophylaxis are associated with VTE events. The strongest data for this correlation is in patients with trauma, emergency surgery, and colorectal surgery.

The important reason to consider missed doses of VTE prophylaxis is that this is a modifiable risk factor for development of VTE events. We have published on multiple interventions that have decreased missed doses of VTE prophylaxis in hospitalized patients. A single online education session for nurses covering the importance of VTE prophylaxis decreases the odds of missed doses by 13%. Implementation of a patient engagement bundle using paper handouts and a 10-minute video decreases the odds of missed doses by nearly 50%.

NON-PHARMACOLOGIC APPROACHES TO VTE PREVENTION

Ambulation

Ambulation alone is not sufficient to prevent VTE in hospitalized patients. This is a common misconception, and we should try to correct this erroneous belief at any chance we get. This myth is a well-known source of bias and has been found to be a reason patients' miss doses of critically important VTE prophylaxis medications while in the hospital.

Graduated Compression Stockings and Sequential Compression Devices

Mechanical devices for prevention of VTE in trauma have been a mainstay of prophylaxis for decades. In brief, there is no proven benefit to graduated compression stockings. In fact, there is known associated harm (primarily pressure injury), and their use is now discouraged. Sequential compression devices (SCDs) may offer some additional benefit in VTE prevention and have not been shown to cause the same amount of harm. Therefore, they remain recommended as an adjunct for VTE prevention.

Inferior Vena Cava Filters (IVCF)

Prophylactic IVCF placement for primary VTE prophylaxis in trauma patients was a common practice for years. The rationale was that an IVCF would prevent PE in high-risk trauma patients who could not receive pharmacologic prophylaxis for a prolonged period. However, with earlier use of pharmacologic prophylaxis and more aggressive dosing, their IVCF use has decreased dramatically. Studies show a relatively small benefit, which is likely outweighed by their risks at the time of placement and long-term complications. Even when trauma surgeons planned to remove these filters, many remained in place when patients were lost to follow-up.

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Patient Educational Materials

17. Paper handouts http://bit.ly/bloodclots
    Watch the full video on YouTube (where it has been viewed over 300,000 times)
    https://www.youtube.com/watch?v=0o3yadu4DFw or at http://bit.ly/bloodclots

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INCISIONAL WOUND VACS: DO THEY LIVE UP TO THE HYPE?

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Incisional wound vacuums, also known as incisional negative pressure wound therapy (iNPWT), have gained popularity in recent years as a promising approach to wound management. First described in the early 90's, NPWT has revolutionized how we approach chronic wounds. It has been found to promote wound healing by increasing blood flow, promoting the formation of granulation tissue and decreasing edema, bacterial burden, and metalloproteinases. They can be used over closed incisions in an effort to decrease surgical site infections, which contribute more than 1.6 billion dollars in excess cost. This brief talk aims to evaluate the existing evidence surrounding the use of incisional wound vacs.

In 2009, Stannard et al. described the application of a vacuum device to a closed incision in an early case series with improved outcomes. Subsequently, Atkins et al. examined their use in sternotomy cases with improved wound complication rates. Finally a number of orthopedic studies appeared after 2009 when Reddix published work on wound complications after acetabular fractures.

In 2016, Hyldig et al. reported a large systematic review and meta-analysis on 10 randomized trials, concluding that when compared to standard postoperative dressings, iNPWT significantly reduced the rate of wound infection and seroma. However, they noted a large amount of heterogeneity between the included studies and did not believe that a general recommendation could be made.

A subsequent randomized trial in 2017 (the ProVac Study), done by Ruhstaller, failed to find any difference between iNPWT and standard dressings in terms of wound morbidity in patients after cesarean delivery.

TECHNIQUE

- Closure of the operative site in layers and skin is approximated
- Special silicone covered sponge with a slit that aligns with the incision is applied
- Suction is applied to the system with a range of -30mmHg to -125mmHg

DURATION OF APPLICATION

5-7 days

TYPES OF WOUNDS TYPICALLY TREATED

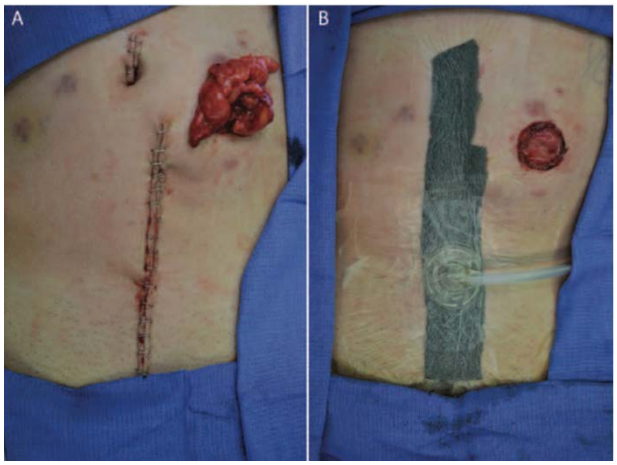

Figure 1. Clean contaminated or contaminated cases, colonic resection (Bonds, et al)

Figure 2. Neurosurgical or spinal surgery

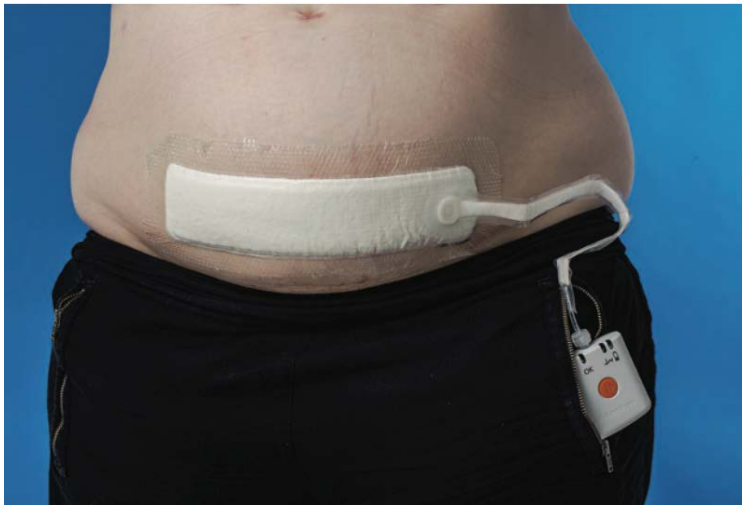

Figure 3. Clean abdominal incision

CONCLUSIONS

Unfortunately, there are a number of studies that both support and refute the use of iNPWT. There are a number of variables that increase the difficulty in studying and comparing groups. There are differences between application of NPWT over a closed incision versus an open wound. There is little controversy that for open wounds, NPWT improves rates of healing and granulation tissue. However, this has not translated as well to incisional vacs. At this time, there does not appear to be a clearly generalizable recommendation to support the use of iNPWT routinely.

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ANORECTAL EMERGENCIES

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Anorectal emergencies encompass a number of anorectal disorders that cause the alarming symptoms of acute anal pain, bleeding, or both, which prompt patients to seek emergency care. The anorectal emergencies included in this manuscript are anorectal abscess, anal fissure, acutely thrombosed external hemorrhoid, thrombosed or strangulated internal hemorrhoid, bleeding hemorrhoids, bleeding anorectal varices, and irreducible or strangulated rectal prolapse. The list of anorectal emergencies typically also includes perineal necrotizing fasciitis (Fournier gangrene), acute pilonidal abscess, retained anorectal foreign bodies, obstructing rectal tumors, and sexually transmitted proctitis; however, these will not be covered here.

Although many anorectal disorders presenting in an emergency setting are not immediately life-threatening, misdiagnosis and inadequate initial management can lead to increased morbidity and mortality. While many of these conditions may be successfully treated in an outpatient clinic, an accurate diagnosis and proper management is crucial and remains a challenge for many providers. A detailed history and careful physical examination, including digital rectal examination and anoscopy, are essential to establishing the correct diagnosis. In some cases, imaging examinations, such as endoanal ultrasonography and computerized tomography scan may be required. Choosing the appropriate treatment is contingent on making an accurate diagnosis. If in doubt, the provider caring for the patient should not hesitate to consult an expert (e.g., general or colorectal surgeon) about the diagnosis, proper management and appropriate follow-up. Surgical management plays a crucial role in the treatment of anorectal emergencies, aiming to alleviate symptoms, control infections, and prevent life-threatening complications.

DIAGNOSTIC TOOLS

1. **History and Physical Examination:** A detailed H&P is the most important initial step in diagnosing anorectal emergencies. The physician must actually perform a careful digital rectal examination (DRE) to assess the anus and distal rectum. Since patients are frequently already having significant pain, the use of 2% lidocaine jelly applied 15 minutes prior to the exam is key to ensuring an adequate examination.
2. **Imaging tests:**
    - **X-rays:** Flat and upright radiographs of the abdomen and pelvis may be performed to rule out the presence of foreign bodies, perforation, or obstruction. An enema containing contrast material may be administered to highlight the anatomy and identify any abnormalities.
    - **Ultrasound:** trans-rectal or trans-perineal ultrasound can provide detailed images of the anorectal region, helping to identify deep seated abscesses, fistulas, or fluid collections.

These specialized ultrasound techniques can provide high-resolution images of the anal canal and rectum. They are often used to evaluate conditions such as anal sphincter injuries, anal and rectal cancers, and deep seated abscesses and complex fistulas.

- **CT scan:** often used to assess more complex anorectal conditions, providing cross-sectional images of the area. looking for abscesses, fistulas, perianal or rectal masses, bowel perforation, and signs of inflammation
- **MRI:** particularly useful in assessing soft tissue structures, making it valuable for evaluating certain anorectal cases by providing detailed images to help diagnose complex conditions, such as deep pelvic abscesses, complex fistulas, tumors, and other pathology

3. **Anoscopy, sigmoidoscopy, or colonoscopy:** These procedures allow for direct visualization of the lumen of the anus and rectum to assess the mucosa and may help to identify internal hemorrhoids, anal fissures, fistulous openings, tumors, or other abnormalities. These procedures often require some form of sedation and anesthesia for patients already in pain and with anxiety related to their condition.
4. **Laboratory tests:** Depending on the suspected diagnosis, various laboratory tests may be helpful and usually include a complete blood counts and inflammatory markers, such as CRP to assess for infection or signs of inflammation. Stool tests may be required to evaluate for the presence of infection or blood. Lactate and serum sodium may also be helpful when assessing for necrotizing soft tissue infection.

ANORECTAL ABSCESS AND FISTULA IN ANO

Typical symptoms include localized pain, swelling, fever, and the formation of a tender lump, or spontaneous drainage. The generally accepted explanation for the cause of anorectal abscess is obstruction of an anal gland. Abscesses are localized collections of pus resulting from an infection in the anorectal region. Surgical management with incision and drainage is required to ensure complete eradication of the infection, as well as alleviate pain and prevent the spread of infection to surrounding tissues. Be sure that what you are seeing is not a necrotizing soft tissue infection or Fournier's gangrene.

Anorectal abscesses are described by the anatomic space in which they develop; ischiorectal (also called ischioanal) abscesses are the most common, followed by intersphincteric, supralevator, and submucosal locations. These abscesses develop more often in males than females, and although an abscess may occur at any age, the peak incidence is among 20- to 40-year-olds. In patients with an anorectal abscess, 30% to 70% present with a concomitant fistula-in-ano, and, of those who do not, approximately 30% to 50% will ultimately be diagnosed with a fistula in the months to years after abscess drainage.

Fistula-in-ano is caused by chronic infection and epithelialization of the abscess drainage tract that connects the perianal skin with the anal canal. Although anorectal abscesses are described by the anatomic space in which they form, a fistula-in-ano is classified in terms of its relationship with the internal and external anal sphincters using Parks classification. Anal fistulas may also be classified as "simple" or "complex."

Complex anal fistulas include transsphincteric fistulas that involve greater than 30% of the external sphincter, suprasphincteric, extrasphincteric, horseshoe fistulas and anal fistulas associated with IBD, radiation, malignancy, preexisting fecal incontinence, or chronic diarrhea. Recurrent or branching fistulas may also be described as complex. Given the attenuated nature of the anterior sphincter in women, anterior fistulas deserve special consideration and may also be considered complex. Simple anal fistulas have none of these complex features and, in general, include intersphincteric and low transsphincteric fistulas that involve less than 30% of the external sphincter. Surgical management of most simple fistulas

entails excising the abnormal tract (fistulectomy) or widely opening the abnormal tract (fistulotomy) to promote healing by secondary intention. This intervention is crucial to prevent recurrence and improve the patient's quality of life. Complex fistulas may require Seton placement, where a silicone or rubber band is placed through the fistula tract to promote drainage and prevent closure. Complex fistulas are often best referred to a colorectal surgeon for surgical management. Several complications may occur with these complex cases, including recurrence of the fistula, despite the procedure. Incontinence, though rare, may occur due to damage of the anal sphincter during fistulotomy.

ANAL FISSURES

An anal fissure is a linear tear within the anal canal that usually extends from the dentate line toward the anal verge. Although this benign anorectal condition is commonly encountered in practice, there is a limited population-level data describing its incidence. Trauma and irritation to the anal canal, often precipitated by either constipation or diarrhea, may lead to development of an anal fissure. The primary symptom is anal pain, provoked by defecation, and may last for several hours after defecation. The pain is usually sharp, feels like a tearing sensation or "passing glass," and can be debilitating because of the intensity of the pain. Bleeding may also be present, typically noted on the toilet paper as bright red when wiping. Anal fissures are most commonly located in the posterior midline (73%) but can be found in the anterior midline in 13% of women and 8% of men, with 2.6% occurring both anteriorly and posteriorly simultaneously. Lateral fissures or multiple fissures are considered to be an atypical presentation and require a more comprehensive evaluation because of the association with HIV infection, Crohn's disease, syphilis, tuberculosis, and hematologic malignancies. Treatment usually begins with lifestyle modifications, including: adequate hydration, high-fiber diet, stool softeners, and practicing good anal hygiene. Sitz baths are recommended to promote healing by increasing blood flow to the area, as well as for comfort. Topical creams or ointments containing nitroglycerin, nifedipine, or lidocaine are frequently used to relax the sphincter muscles and promote healing. When an acute anal fissure fails to heal with this conservative approach, a more invasive treatment may be required, including, Botox injection of the sphincter, lateral subcutaneous sphincterotomy. and/or anal fissurectomy.

HEMORRHOIDAL DISEASE

Acutely thrombosed external hemorrhoids, or thrombosed, strangulated, and bleeding internal hemorrhoid all can cause significant pain and impaired bowel function. Surgical management is often indicated for all of these conditions.

External hemorrhoid thrombosis is usually not subtle. A blue or purple nodule near the anal verge is present, and in some instances, may have already ulcerated with dark bloody drainage. Although some of these will resolve spontaneously within 72 hours, patients with continued pain beyond this time period should be offered incision and drainage. This can be performed as an outpatient in the office, clinic, or ED via incision and evacuation of the thrombus using local anesthesia. There is no need for any lab or imaging unless there are other concerns such as infection.

Surgical management for internal hemorrhoids may include hemorrhoidectomy, where the enlarged hemorrhoids are excised, or less invasive procedures, such as rubber band ligation or sclerotherapy. The choice of intervention depends on the grade of the hemorrhoidal disease, the degree of bleeding, and the patient's comorbidities. All patients with hemorrhoidal disease benefit from a high fiber diet, adequate hydration, the use of anti-inflammatory analgesics, warm Sitz baths, and stool softeners. Topical nifedipine may also be added to relax the sphincter in patients with significant spasm.

Grade IV hemorrhoidal incarceration can progress rapidly to strangulation, which can then lead to necrosis and gangrene. Manual reduction and digital compression of the hemorrhoids may be attempted in the ED under conscious sedation. The application of granular sugar has been described as a means to reduce swelling and ease reduction. Of note, this requires at least a cup of sugar and often takes an hour or more to significantly reduce the edema. In cases where strangulation and necrosis is already evident, the patient should be taken to the OR urgently. Once the patient is under general anesthesia, it is often helpful to attempt manual reduction and digital compression of the hemorrhoids prior to proceeding with excision. Patients undergoing urgent hemorrhoidectomy should receive preoperative IV antibiotics. Care must be taken to avoid injury to the anal sphincter, as tissue edema may distort the anatomy. It is also critical not to excise too large of portion of anoderm. Proceeding with excision of additional hemorrhoid columns should be undertaken cautiously. In the rare instances, a three column hemorrhoidectomy is required, the surgeon must allow for at least a 1 cm bridge of mucosal between the sites of excision to prevent a Whitehead deformity or anal stenosis. Oral antibiotics to cover anaerobes should be continued for one week postoperatively.

BLEEDING ANORECTAL VARICES

Patients presenting with rectal bleeding and a history of portal hypertension should be the clue to the differential diagnosis of bleeding anorectal varices, which are dilated submucosal veins that extend from the anal canal up to the middle rectum, and, at times, can be confused with bleeding internal hemorrhoids. Management of active variceal bleeding can be challenging. Correction of underlying coagulopathy is often required. Suture ligation, endoscopic ligation, and sclerotherapy may all be used. In recurrent and severe cases, a transjugular intrahepatic portosystemic shunt (TPS) may be required to lower portal pressure.

RECTAL PROLAPSE

Rectal prolapse is a condition of intussusception of the rectum through the anal canal where a full thickness of the rectum protrudes through the anal sphincter. This is seen in patients with weakened or damaged pelvic floor muscles, occurring most commonly in the elderly female, especially multiparous women and those with chronic constipation. Symptoms often include a feeling of fullness or protrusion from the anus, mucus discharge, difficulty with bowel movements, and bleeding. Differentiating prolapsed internal hemorrhoids from prolapsed rectum is often challenging. Concentric rings of mucosa and full thickness rectal wall outside the anus are signs that the protrusion is, indeed, rectal prolapse. The lack of radial folds or sulci typically present with prolapsed internal hemorrhoids is another clue. Immediate reduction of rectal prolapse is required to prevent strangulation, though strangulation leading to necrosis is rare. Once the prolapse is reduced, treatment options range from conservative measures, such as stool softeners and pelvic floor exercises, to surgical procedures for severe or recurrent cases. Reduction of the prolapse is typically done with manual pressure, gently pushing the rectum back into place under conscious sedation. Just as in the case of incarcerated prolapsed internal hemorrhoids, reduction may be difficult due to massive swelling and edema. Similarly, the use of granular sugar applied to the protruding rectum, as described earlier, may be helpful. In instances of strangulation with gangrene or inability to be reduced urgently, operative intervention and a perineal rectosigmoidectomy or Altemeier procedure is performed.

POTENTIAL LONG-TERM COMPLICATIONS AND RISKS ASSOCIATED WITH SURGICAL INTERVENTIONS FOR ANORECTAL EMERGENCIES

1. **Infection:** Surgical procedures carry a risk of infection. In cases of anorectal emergencies, the risk of infection is higher due to the presence of fecal material in the area. Infections can lead to wound complications, delayed healing, or abscess formation.
2. **Bleeding:** Surgery may result in bleeding, which can sometimes be severe. It may require additional interventions to control the bleeding.
3. **Anal stricture:** Scar tissue formation after surgery can cause narrowing of the anal canal, leading to difficulty in passing stool. This may require further treatment or surgery to relieve the constriction.
4. **Fecal incontinence:** Surgical interventions can sometimes damage the anal sphincter muscles, leading to fecal incontinence or difficulty in controlling bowel movements.
5. **Rectovaginal or rectourethral fistula:** In rare cases, surgery for anorectal emergencies can result in abnormal connections between the rectum and the vagina or urethra. This can cause fecal material to pass through the vagina or urine to pass through the rectum.

TO REDUCE THE RISKS AND PREVENT THESE COMPLICATIONS, SEVERAL MEASURES CAN BE TAKEN

1. **Preoperative evaluation:** Thorough assessment of the patient's medical history, physical examination, and proper investigation can help identify potential risks and plan the surgery accordingly.
2. **Antibiotic prophylaxis:** Administration of antibiotics before and after surgery can help prevent infections.
3. **Adequate surgical technique:** Experienced surgeons using appropriate surgical techniques can minimize the risk of complications during the procedure.
4. **Postoperative care:** Proper wound care, pain management, and early mobilization after surgery can aid in the healing process and reduce the risk of complications.
5. **Regular follow-up:** Regular follow-up visits with the surgeon can help monitor the healing process, identify any complications at an early stage, and provide appropriate treatment if needed.

In conclusion, anorectal emergencies encompass a range of conditions that require urgent attention due to their potential complications and impact on an individual's well-being.

Whether it be anal fissures, abscesses, rectal prolapse, or rectal bleeding, these conditions can significantly affect an individual's quality of life if left untreated. For patients presenting with symptoms such as pain, bleeding, or protrusion from the anal region, it is crucial to ensure accurate diagnosis and initiation of timely appropriate treatment. With timely intervention, most anorectal emergencies can be successfully treated, relieving symptoms and minimizing potential long-term complications.

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IMPLEMENTING A ROBOTIC PROGRAM IN A COMMUNITY HOSPITAL

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This syllabus is not intended to convince surgeons to develop or use a robotic platform. There are no financial relationships/disclosures from Intuitive. The objective of the information provided is to be unbiased and for educational purposes only.

In the past 50 years, minimally invasive surgery has become the standard of care for most elective surgical procedures. In recent years, there has been a shift toward minimally invasive surgery for non-elective or emergent procedures.[3] The methods used performing these cases remain up to fierce debate- laparoscopic vs robotic assisted. The hard truth is eventually, all hospitals will have a robotic platform. For the foreseeable future, surgeons will control their decision to use the robot or not. Pro-robotic surgeons can find literature to support the robotic platform; likewise, the naysayers can find literature refuting it. The bottom line is the robot is another tool in the work belt. When used appropriately by qualified and trained surgeons, it does not cause harm and may decrease open conversions, wound infections, length of stay, and postoperative pain. Is there an expense? Absolutely, but patient care with decreased morbidity should be our precedent. In some surgeon's hands, the same outcome may be possible with laparoscopy- hence the dilemma and data variances.

The most important factor in making a transition to a robotic program is doing it for the correct reasons- not for marketing or competition; but rather, belief in the technology and its ability to improve patient outcomes. Your journey down the pathway with the industry (which will have bias), is necessary for you to see first-hand to make an informed decision.

Trends in colorectal surgery from 2009-2015 for colectomy and proctectomy showed an increased use of the robotic platform and decreasing rate of open surgeries (Figure 1):

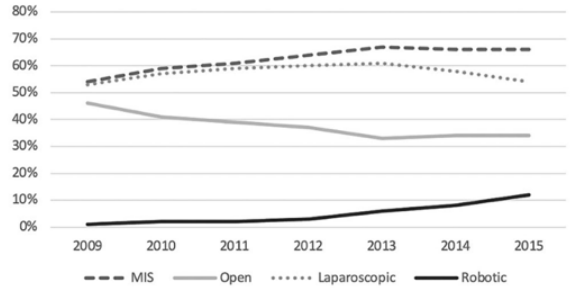

Fig. 2 Colectomy surgical approach over time

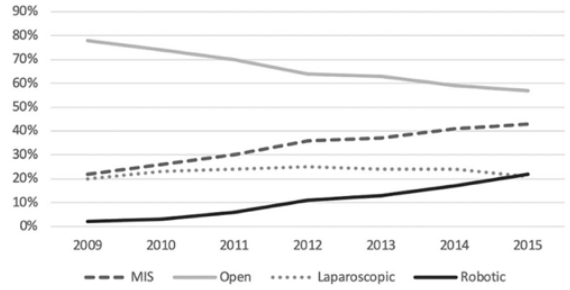

Fig. 3 Proctectomy surgical approach over time

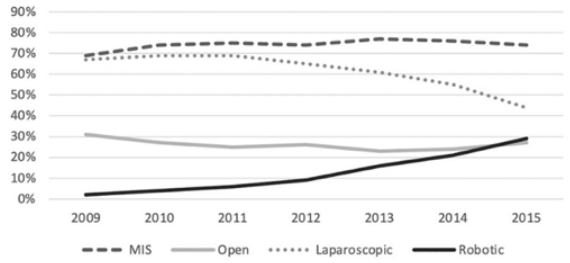

Fig. 4 Colectomy surgical approach over time among surgeons with increasing robotic utilization

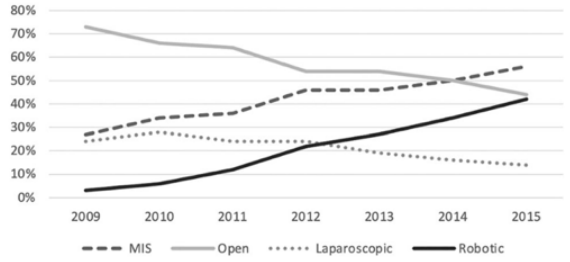

Fig. 5 Proctectomy surgical approach over time among surgeons with increasing robotic utilization

Figure 1. *Justiniano CF, et al. Is robotic utilization associated with increased minimally invasive colorectal surgery rates? Surgeon-level evidence. Surg Endosc. 2022.* [4]

For any surgeon or hospital contemplating a robotics program, questions must be answered: Why, How and What?

1. **Why?** – Increase number of MIS surgeries, improve patient care (LOS, open conversions, SSI), surgeon recruitment, hospital financials
2. **How?** – Commitment from surgeons, clinical administrators, executive team
3. **What?** – Results, data, improved outcomes.

WHY?

Why become a robotic surgeon? As stated, the answer should not be because of marketing or because of the competition. A surgeon pursuing robotic training must believe in the technology and commit to the training pathway. Frequent utilization and outcomes monitoring must be a priority.

There is conflicting evidence on the "buzz" words: SSI, LOS, open conversion. At our facility, all three have decreased with adoption of the robotic practice over the past three years. Others have found increased risks of CBD injuries (0.2 vs 0.7%) in laparoscopic vs robotic procedures[1]. An article in SAGES reported no significant cost difference between laparoscopic or robotic cholecystectomies, and there were zero CBD injuries in either group. There was a shorter LOS and less readmissions in the robotic group.[2]

1. Not just because of marketing. Not because it's what the competitor does
2. In our experience, it decreases length of stay, decreases open procedures, decreases SSI, and there is improved patient satisfaction
3. If the program is run correctly, robotic cases are PROFITABLE for your institution
4. Recruitment – most graduates looking at "rural" or smaller community hospitals expect a robotic system to be available. In the coming years, small community hospitals and critical access hospitals will need to have a robotic platform to recruit and retain new surgeons

HOW?

Initiation of a Robotics Program – Do you have the case volume, surgeons, market, and clinical and administrative support? Most of the demographic information is readily available from your C-suite (cases per year, percentage of market share captured, patient migration charts). To succeed, each program must have a dedicated surgeon champion. This person will chair the Robotics Steering Committee and be the liaison between the OR leadership and the administrative team. Most of the information needed to build the program will be supplied by the Intuitive representative assigned to your facility in the planning phase.

Development of a Robotics Steering Committee – the key stakeholders in the program, should be at the table to help form and direct the robotics program at your facility. This needs to be a physician run committee with administrative support for success.

Steering Committee Membership

1. Surgeon Champion
2. CEO
3. CFO
4. OR Manager
5. Marketing
6. Anesthesia representative
7. Robotic Surgeons
8. Robotics Coordinator (dedicated FTE time, CFA, RN, CST)

The committee should develop a strategic vision for the service line and steering committee. An example of this from Silver Creek Hospital: "The Silver Cross Hospital Robotics Oversight Committee is a ***multidisciplinary team*** which provides ***guidance over the development and operation*** of the surgical robotics program to ensure the delivery of the highest level of patient care in the most efficient and safe manner possible. In addition, the Robotics Oversight Committee ***monitors key internal and external indicators*** to ensure the organization, in collaboration with the surgeons, are ***maintaining or improving the quality of clinical care*** related to robotic surgery, providing exemplary customer service, maintaining fiscal responsibility relative to benchmarks, and ***continual improvement in process outcomes***. "

The steering committee should meet bi-weekly until the program is up and running.

Once established, monthly meetings are recommended.

a. Tasks of steering committee:
    i. Training requirements
    ii. Metrics: SSI, LOS, Narcotic Rx, Volumes, Utilization, Minor/Major complications, Delays, FCOTS, Turnover
    iii. Block assignments
    iv. M&M – open conversions,
    v. Credentialing requirements
    vi. Case volume requirement

There are incredible industry (Intuitive) resources for both new and experienced robotic surgeons. There are also excellent annual conferences for OR leadership and C-Suite administrators. It is important to keep all levels of the team engaged with these resources for program efficiency and support. Use the industry resources. Each year, Intuitive has a Connect Conference directed at a *clinical* audience to bring new and experienced robotic surgeons the most recent evidence and training sessions "in person." The 360 conference is aimed at executive and operative leadership to optimize service line development and achieve programmatic excellence tailored to your facility. Intuitive offers peer-to-peer resources in addition to on-site visits and observations. As part of the training pathway, surgeons are recommended to complete simulation training (at their own hospital). This training prepares surgeons for a cadaver lab in which where a DaVinci certificate may be obtained.

After implementation of the program, Intuitive offers Genesis Team consultation for efficiency improvement, as well as clinical team training (Nursing, Techs, SPD, Surgeons). Every nurse, tech and assistant in the operating room should be trained. It is not productive to have only a robotics team and a 'regular' team – this is a setup for failure. With everyone trained from the start, the transition to 24/7 robotics coverage will be much smoother with more commitment from staff.

The regional representative will work with the Steering Committee to establish goals and metrics to trend and report monthly. Each surgeon will have access to his/her case volume with case times and the ability to record outcomes online.

The Intuitive representative will also help with marketing and public engagement. This can be done with hernia screening, events, a public grand opening, OR tours, press releases or things as simple as inviting the local schools robotics clubs to participate in the simulation lab.

WHAT?

At this point, the data is changing. YOUR data should be reproducible and reliable. Many of the articles published from last decade were early adopters on different available platforms. The ancillary devices, (vessel sealers, staplers, mesh, Firefly), have also significantly advanced during this time. Future, prospective randomized trials will show the costs and risks and/or benefits of robotic surgery; but, for now, it is here to stay.

As a robotic surgeon, what metrics will be followed as a marker of success or indication for improvement? Initially, the goal should be focused on patient safety and equal/improved outcomes while implementing the program. These basic and easily obtainable metrics are:

a. Open conversions
b. Surgical site infections
c. Readmissions
d. Length of stay
e. Cost/ROI

With time, and continuing the former, more improvements in efficiency and efforts at cost reduction can be explored. Once case mastery is achieved with equal or better outcomes to that of laparoscopic cases, cost savings can be explored by using less robotic arms, instruments, suture, etc.

First, get good, then efficient, then economical.

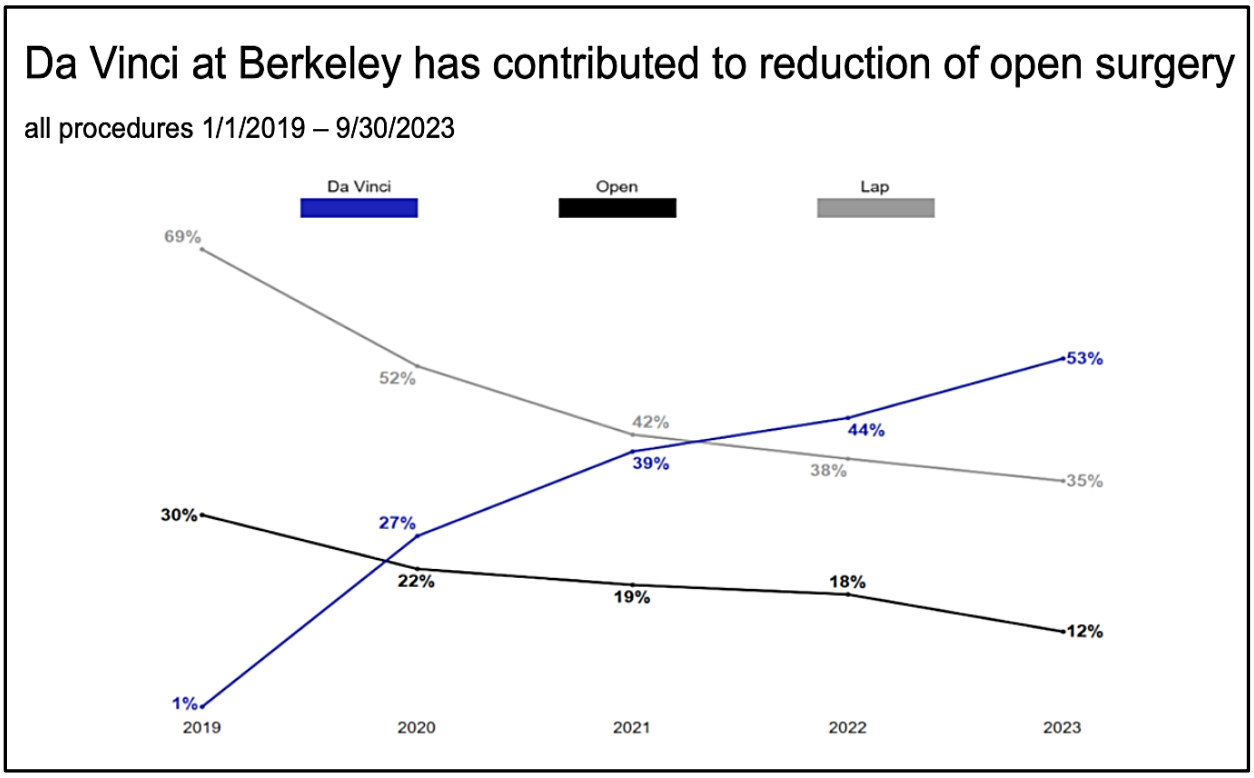

Figure 2. *Chart shows the reduction of open surgery at our facility after implementation of a robotics program. Overall, there has been a reduction in the percentage of open cases from 30% to 12% in the past 4 years.*

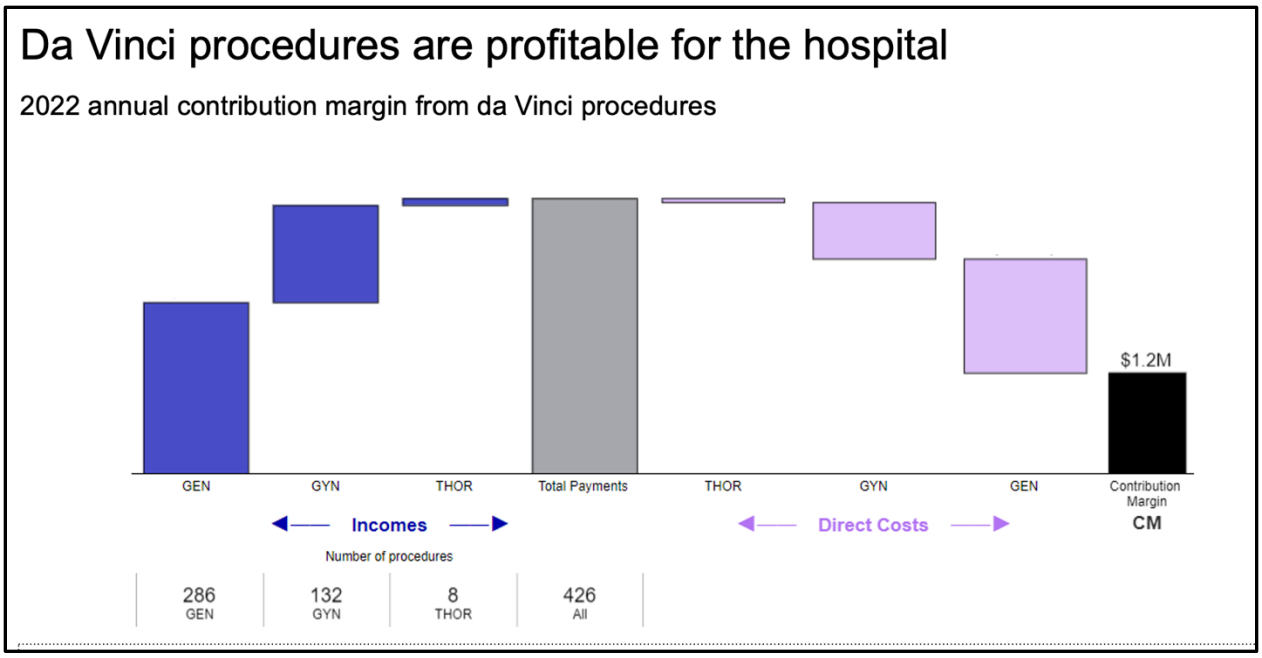

Figure 3. *This waterfall chart from our facility (with most financial data removed) shows the total income vs costs for robotic cases in 2022. There was a 1.2 million dollar profit margin, despite most cases being done by general surgery (cholecystectomies and hernias).*

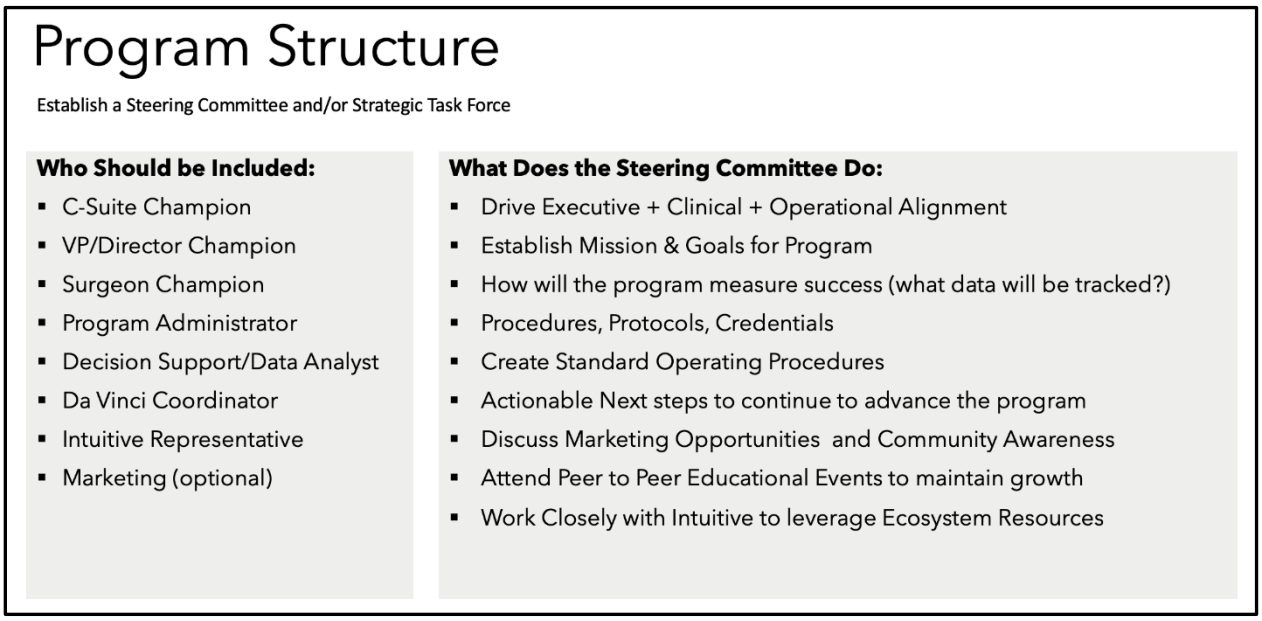

Figure 4. *Intuitive program development support slide*

SUMMARY

Development of a Robotic Surgery Program at a community hospital or critical access hospital is easily accomplished if the surgeon, administrators, and organization are mutually committed to programmatic success. With the rapid growth of robotic programs and procedures in the US over the past 10 years, it is evident that robotic surgery is here to stay. Once you decide on "why" to embark on the robotic journey, use the available industry resources to assist on "how" to get there. The "why and how" are directly related to the "what".

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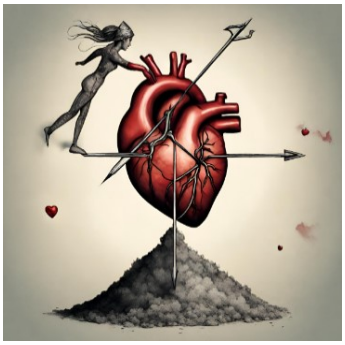
GETTING TO THE HEART OF THE MATTER: PERICARDIAL EXPLORATION



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KEY POINTS

- Cardiac injuries are highly lethal. Survival depends on the mechanism of injury, the extent and anatomy of the injury, time to presentation to a trauma center, and patient physiology, including blood loss, and the presence or absence of pericardial tamponade.
- An efficient trauma evaluation is critical. By rapidly identifying the number and location of wounds and the presence or absence of retained bullets the trauma team can gain a better understanding of the trajectory of the injury.
- Hemothorax may be evidence of a full thickness injury to the heart and pericardium that is decompressing into the thorax. This means that you can have a cardiac injury WITHOUT pericardial fluid.
- By far and away, the most useful tool for rapidly diagnosing cardiac injury is ultrasound. However, limitations do exist, including difficult body habitus, the presence of subcutaneous air, and operator skill.
- Pericardial window is the gold-standard for diagnosing cardiac injury. It is important to recognize that a pericardial window is a diagnostic procedure. It is not therapeutic. The surgeon must be prepared to perform a median sternotomy, should the pericardial window demonstrate blood that does not clear with irrigation. It is also critically important to recognize that hemodynamically unstable patients with blunt or penetrating injury and pericardial tamponade should undergo median sternotomy, not a pericardial window.
- Cardiac injury is effectively ruled out when pericardial fluid is found to be non-bloody. But what if it is bloody? In this case, blood and clot should be cleared with suction and irrigation. If the bleeding stops and the drainage clears, then the wound may be sealed, or the injury might be partial thickness. In these situations, sternotomy can be deferred in favor of pericardial drain placement and close observation in select patients. If bloody drainage continues to accumulate despite irrigation, then exploration is required.
- See QR codes to link to detailed operative videos from Behind the Knife's Trauma Surgery Video Atlas.

The treatment of cardiac injuries has a rich and fascinating history. From Hippocrates, Galen, and Boerhaave to Morgagni, Dupuytren, and Beck, many illustrious surgeons have opined on the diagnosis and treatment of cardiac injuries. In 1883, Theodor Billroth stated, "The surgeon who should attempt to suture a wound of the heart would lose the respect of his colleagues."[1] Today, it is quite the opposite. A trauma surgeon must be prepared to act decisively when faced with a cardiac injury. In this syllabus, you will find a practical, data-driven guide to the diagnosis and management of cardiac injuries (both blunt and penetrating with bleeding, but not blunt without bleeding).

PRESENTATION

Cardiac injuries are highly lethal. But not all injuries are created equal. While some patients teeter on the edge of hemodynamic collapse, others are entirely stable at presentation. Survival depends on the mechanism of injury, the extent and anatomy of the injury, time to presentation at a trauma center, and patient physiology, including blood loss and presence or absence of pericardial tamponade. A fascinating study from New Delhi used autopsy results to determine that only 11% of patients with cardiac injury (blunt or penetrating) reached the hospital alive.[2] Review of a 10-year experience at LA County-USC trauma center found 50% of patients with stab wounds survived, compared to 11% of those with gunshot wounds. Survival was highest in patients with single chamber injuries and in those with injury to the right ventricle.[3]

PATHOPHYSIOLOGY

Injury to the heart can be full or partial thickness. Full thickness injuries can result in exsanguination (most often into the left chest) or pericardial tamponade. The pericardium is a fibrous and relatively non-distensible sac. Even small volumes of pericardial fluid can lead to compression of the heart, especially the thin-walled right ventricle. Compression decreases filling/cardiac output and increases work/myocardial wall tension, creating a deadly cycle that can lead to hemodynamic collapse. Yet, pericardial tamponade may not be all bad. In theory, just the right amount of pericardial fluid/compression may slow and/or stop bleeding from a cardiac injury without catastrophic consequences to cardiac function. One retrospective study found pericardiac tamponade to be a predictor of survival,[4] while others have not.[5] As suggested by Asensio et al., "There appears to be a period of time in which pericardial tamponade provides a protective affect and thus leads to an increases survival rate. What remains undefined is that period of time, after which this protective effect is lost, resulting in an adverse effect in cardiac function."[1]

DIAGNOSIS

Trauma surgeons must maintain an extremely high index of suspicion for cardiac injuries. While full thickness, blunt cardiac injuries are extremely rare they can occur with any high-energy mechanism of injury. Penetrating injuries, on the other hand, are more common. In patients with penetrating injury, the presence of a cardiac injury should be assumed until it can be ruled out.

Trauma Survey

An efficient trauma evaluation is critical. By rapidly identifying the number and location of wounds and the presence or absence of retained bullets, the trauma team can gain a better understanding of the trajectory of the injury. Chest x-ray may show a widened mediastinum (although this is not a reliable diagnostic tool for cardiac injury) and/or hemothorax. Hemothorax may be evidence of a full thickness injury to the heart and pericardium that is decompressing into the thorax. This means that you can have a cardiac injury <u>WITHOUT</u> pericardial fluid.

Ultrasound

By far and away, the most useful tool for rapidly diagnosing cardiac injury is ultrasound. Evaluation of 172 patients with penetrating injuries in South Africa determined the sensitivity of ultrasound to be 87%, with a positive predictive value of 77%. There were 18 false negatives, 11 with associated hemothorax and 6 with pneumopericardium.[6] The presence of pericardial fluid following blunt trauma is rare and difficult to interpret. Data from the University of Texas in Houston's trauma registry identified 18 patients with "acute hemopericardium or cardiac rupture" from blunt trauma over an 8.5-year period (prevalence of 0.06%). Every one of these patients had a "major mechanism of injury" plus hypotension and/or the need for emergent intubation. Meanwhile, 38 patients had incidental or insignificant effusions (prevalence of 0.13%). None of these patients required intervention.[7] It is important to recognize the limitations of ultrasound, including difficult body habitus, the presence of subcutaneous air, and operator skill. Despite these limitations, ultrasound remains the gold standard for rapidly identifying cardiac pathology.

CT Scan

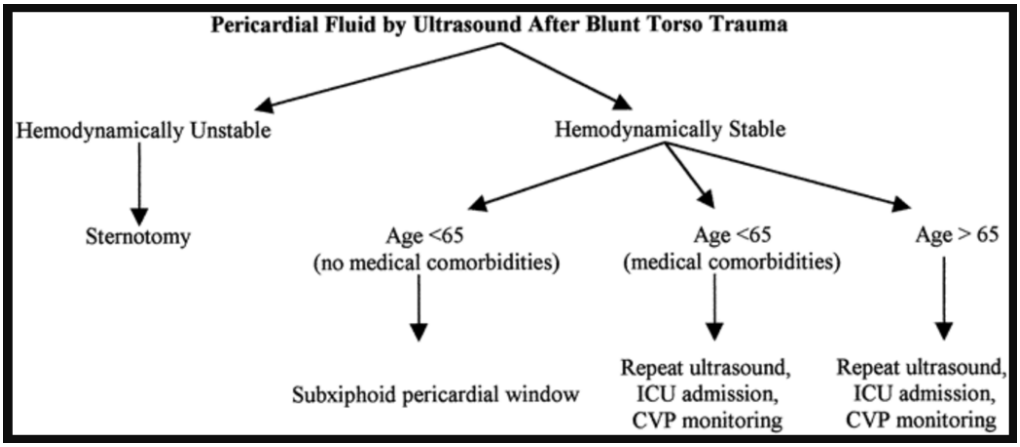
In hemodynamically stable patients with penetrating injury, CT scan has been shown to be a useful diagnostic tool as well. A 4-year review of patients being cared for at Harbor-UCLA medical center determined the presence of hemopericardium and/or pneumopericardium had a sensitivity of 76.9%, specificity of 99.7%, positive predictive value of 90.9%, and negative predictive value of 99.1% for cardiac injuries.[8] When it comes to blunt trauma, data is limited. Witt et al. identified 75 blunt trauma patients with pericardial fluid on admission CT scan over a 6-year period at a busy level 1 trauma center. Seven patients underwent operative management, six of whom had hypotension and/or EKG changes. Interestingly, none of these patients were found to have cardiac injuries that required repair. Of the patients managed non-operatively, none went on to need surgery, and none died.[9]

Pericardial Window

Pericardial window is the gold-standard for diagnosing cardiac injury. Still, it can be difficult to determine when a pericardial window is indicated. It is important to recognize that a pericardial window is a diagnostic procedure. It is not therapeutic. The surgeon must be prepared to perform a median sternotomy should the pericardial window demonstrate blood that does not clear with irrigation. It is also critically important to recognize that hemodynamically unstable patients with blunt or penetrating injury and pericardial tamponade should undergo median sternotomy, not a pericardial window.

In patients with penetrating injuries without pericardial tamponade, a pericardial window should be considered when the trajectory of the injury is concerning and there is pericardial fluid present, ultrasound and/or CT scan are unavailable or difficult to interpret, and/or the patient has hemothorax (e.g., the injury is decompressing into the chest).

The approach to blunt trauma patients with pericardial fluid on imaging but without tamponade depends on hemodynamic stability. Hemodynamically unstable patients require immediate intervention with pericardial window and sternotomy, as needed. However, hemodynamically stable patients require additional consideration, as elderly patients with relevant comorbidities will be more likely to have truly incidental pericardial fluid. In 2001, the team at the University of Louisville suggested the following algorithm:[10]



The available data suggests that most hemodynamically stable blunt trauma patients with pericardial fluid seen on imaging can be managed non-operatively. As previously mentioned, Witt et al. identified 75 blunt trauma patients with pericardial fluid on admission CT scan over a 6-year period at a busy level 1 trauma center. Seven patients underwent operative management, six of whom had hypotension and/or EKG changes. Interestingly, none had cardiac injuries required repair. Of the patients managed non-operatively, none went on to need surgery, and none died.[9] These findings are supported by another study of 30 patients.[11]

Pericardial Window: What Findings Mandate Sternotomy?

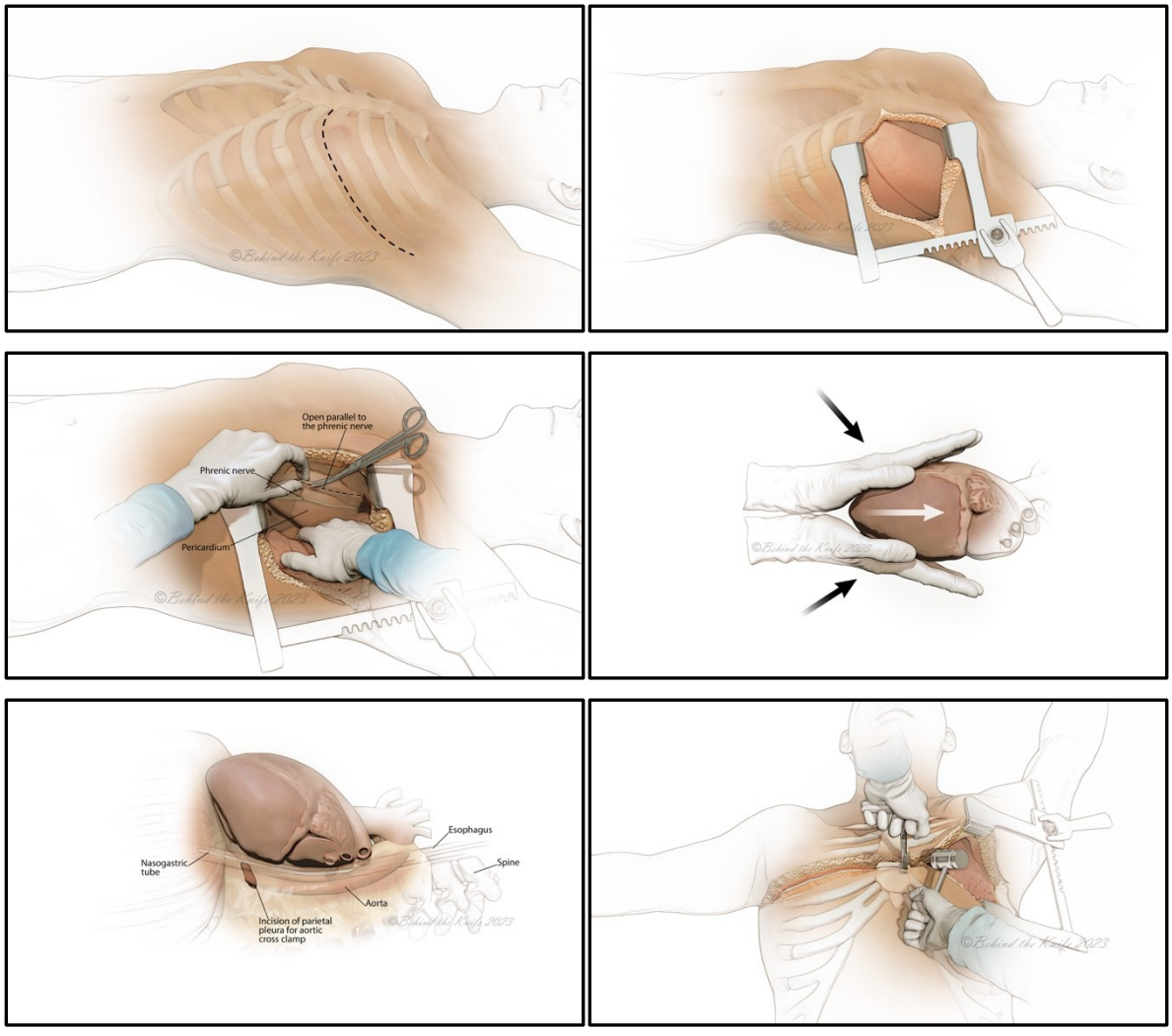
Cardiac injury is effectively ruled out when pericardial fluid is found to be non-bloody. But what if it is bloody? In this case, blood and clot should be cleared with suction and irrigation. If the bleeding stops and the drainage clears, then the wound may be sealed, or the injury might be partial thickness. In these situations, sternotomy can be deferred in favor of pericardial drain placement and close observation in select patients. If bloody drainage continues to accumulate despite irrigation, then exploration is required.

This recommendation is supported by literature from South Africa. A pilot study completed by Navsaria et al. in 2001 found that 71% (10 out of 14) patients with penetrating chest trauma had a nontherapeutic sternotomy performed for bloody drainage identified during pericardial window.[12] The same group went on to perform a randomized control trial in which hemodynamically stable patients with penetrating chest trauma resulting in hemopericardium, pneumopericardium, or clinical suspicion and equivocal imaging underwent pericardial window. Importantly, the window was performed *after* 24-hours of observation. The pericardial sac was "irrigated vigorously" with 500 cc of warm saline, and if active bleeding was identified, a median sternotomy was performed. If the bloody drainage cleared, then the patient was randomized to sternotomy or observation with drain placement. A total of 111 patients were randomized, 109 of which suffered stab wounds. Of the 55 patients who underwent sternotomy, 51 (93%) had either no cardiac injury[13] or a tangential/partial thickness wound. In all 4 patients with full thickness injuries, the wound had sealed by the time of surgery. Ultimately, no patients required surgery in the observation group. It should be emphasized that most patients were stabbed, and all of them were observed for 24-hours before the pericardial window was performed.[13] Similarly, Thorson et al. reviewed data from patients with chest trauma who underwent pericardial window (377 patients) and/or median sternotomy (110 patients). They found that 21 (38%) of patients with hemopericardium identified on pericardial window went on to have a non-therapeutic sternotomy.[14]

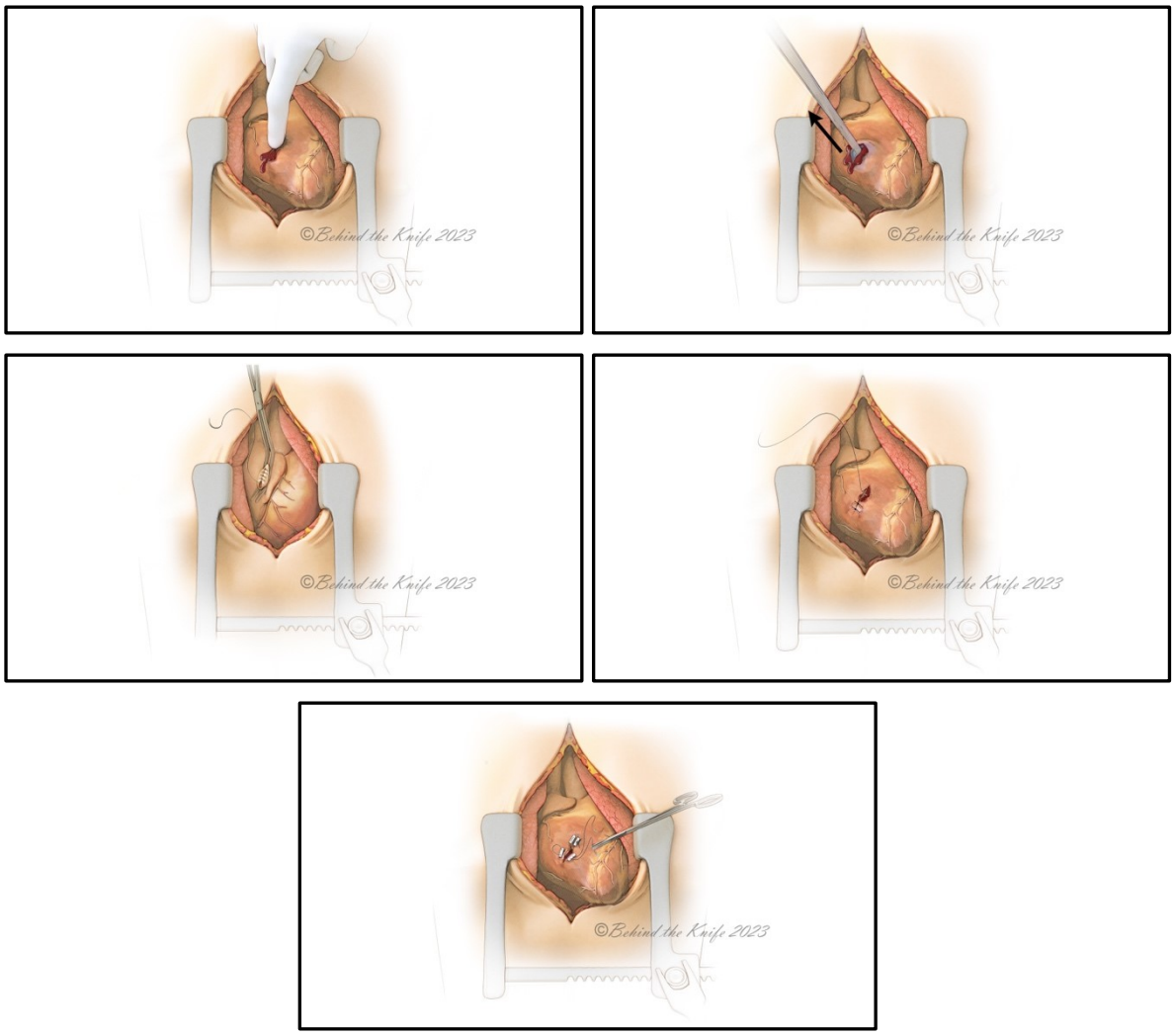
SURGICAL APPROACH

The following QR codes link to detailed operative videos from Behind the Knife's Trauma Surgery Video Atlas.

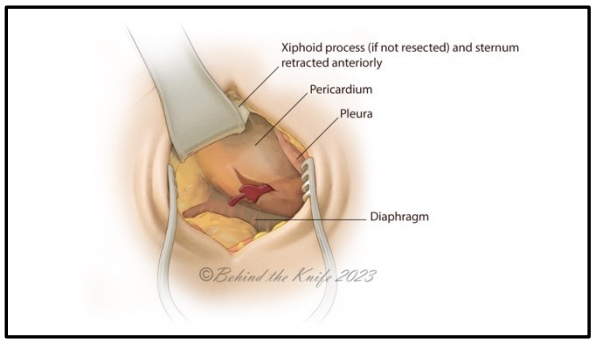
Resuscitative Thoracotomy/Clamshell Thoracotomy



Sternotomy with Cardiac Repair



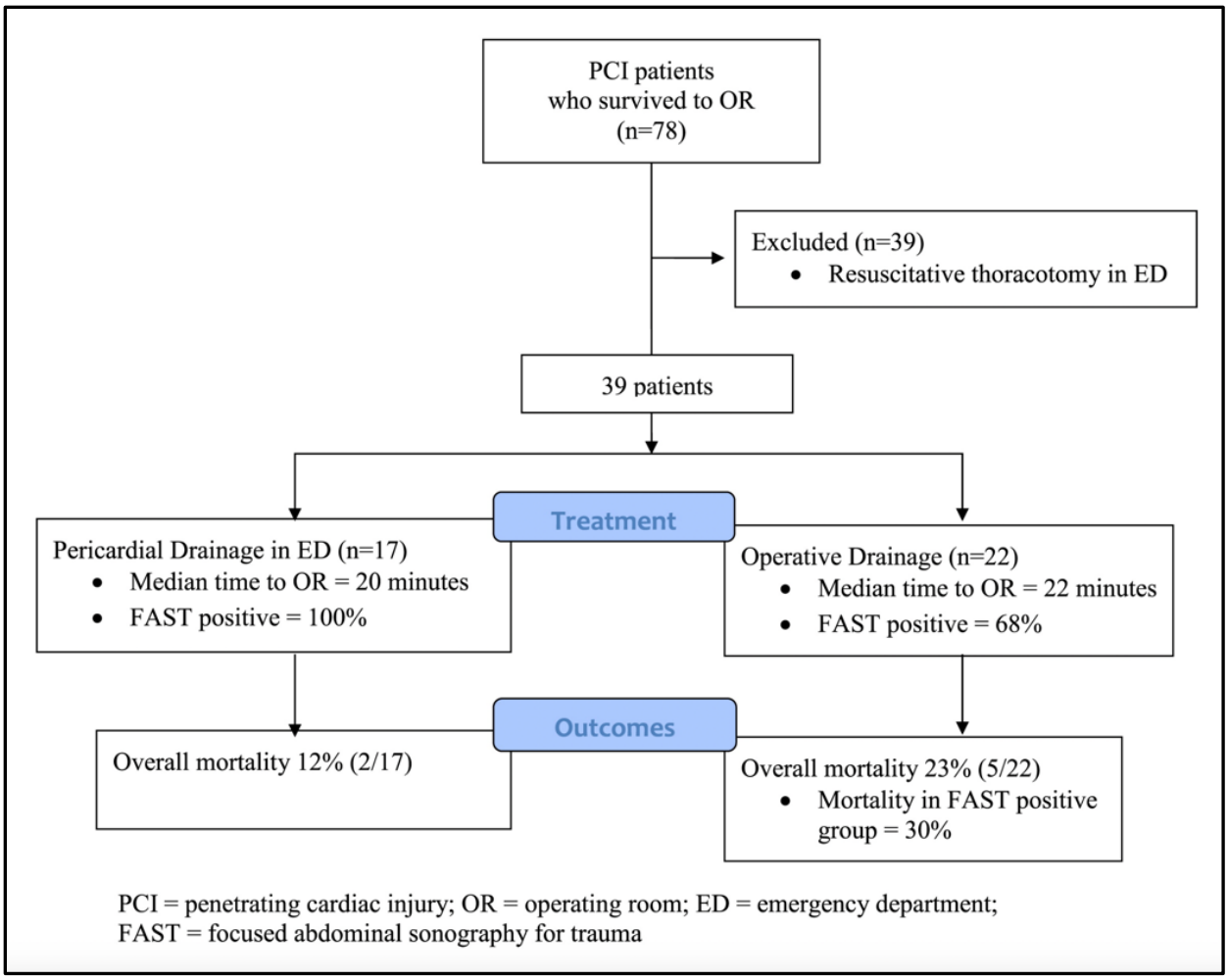
Subxiphoid Pericardial Window



The entire Behind the Knife Trauma Surgery Video Atlas contains 24 scenarios and can be found here:

DRAINAGE PROCEDURES

In hemodynamically unstable patients with pericardial tamponade, percutaneous pericardial drainage can be considered as a temporizing measure. However, there is limited data to support a drainage-first approach. In fact, there is only one contemporary study that reports on its usage. Jones et al. shared their experience at Denver Health over a 16-year period, where 17 patients with pericardial fluid on ultrasound underwent percutaneous pericardial drainage in the ED before going to the OR. Drainage was successful in all but one patient. Drainage volume ranged from 15 to 200 cc of fluid, there were no drain-related complications, and blood pressure improved in over half of the patients. There was also no delay in time to the OR.[15]



While the role for a drainage-first approach has yet to be fully defined, one setting where this may be useful is in patients who are facing delayed access to definitive surgical care.

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SESSION 10

CASE MANAGEMENT "STRICTLY RURAL"

Moderator: Andrew C. Bernard

Tuesday, April 16, 2024
3:25 – 4:45 PM
Palace Ballrooms 1-2
Palace Tower
Emperors Level – 4th Floor

Panelists: **Jennifer M. Gurney**
James Kempema
Michael A. Samatowka
Jeffrey J. Skubic
Jason L. Turner
Alison Wilson

SESSION 11

COMPLICATIONS OF TRAUMA & ACUTE CARE SURGERY

Moderator: Sydney J. Vail

Tuesday, April 16, 2024

4:45 – 6:30 PM
Palace Ballrooms 1-2
Palace Tower
Emperors Level – 4th Floor

4:45 – 5:00	**Infected Mesh: Preserve, Remove, or Replace?** **Andre' R. Campbell, MD, FACS, FACP, FCCM**
5:00 – 5:15	**Infected Hardware and Vascular Prostheses** **Ali Salim, MD, FACS**
5:15 – 5:30	**Taming the Beast: How to Approach EC Fistulas** **D. Dante Yeh, MD, FACS, FCCM, FASPEN**
5:30 – 5:45	**Bowel Obstruction in the Post Bariatric Surgery Patient** **Kenneth L. Wilson, MD, FACS**
5:45 – 6:00	**REBOA Complications and Pitfalls** **Demetrios Demetriades, MD, PhD, FACS**
6:00 – 6:30	**Panel Discussion**

INFECTED MESH: PRESERVE, REMOVE OR REPLACE?

Andre' R. Campbell, MD, FACS, FACP, FCCM MAMSE

Professor and Vice Chair UCSF Department of Surgery
Attending Surgeon Zuckerberg San Francisco General Hospital
San Francisco, CA

Mesh is commonly used by surgeons around the world. When the operation goes well without complication(s), both surgeon and patient are satisfied with the results, and the patient is followed clinically by the surgeon. This paper discusses mesh infections in patients undergoing abdominal wall surgery. It is estimated that after major trauma and abdominal surgery, the incidence of hernia formation is in the range of 20%. The type of mesh used in the repair is important.

The use of mesh in hernias was first described in the 1950s. It was recommended for use in the setting of minimal host response and adhesions, good vascularization, good host tissue incorporation and resistance to infection. Potential complications include mesh migration, seroma, foreign body reactions dehiscence, fistulas, pain, small bowel obstruction, and infection, the last being a serious and potentially devasting complication. It is an uncommon occurrence in the groin, estimated to be 2% to 4% of cases overall. For repair of open abdominal wall hernias, infection is estimated to occur in 6% to 10% of cases. When laparoscopic hernia repair is done for incisional hernias, the incidence is reported to be 3.6%. If the repair is done for acutely incarcerated hernias with ischemic bowel, the likelihood of infection increases, as it does if there is intraabdominal infection present at the first operation.

There are stages of prosthetic mesh infection post hernia repair. Although precautions are taken to assure no organisms are introduced, infection occurs when the mesh is implanted. Bacteria is typically introduced in the OR, potentially from many sources, including the skin, mucosa, hands of the operating surgeons, or the environment. Once bacteria are present in the wound and on the mesh, it causes reduced phagocytic activity of the immune system against the invading bacteria.

FORMATION OF BIOFILM

Over time, two factors help bacteria infect the mesh. The first is a reversible interaction between the bacteria and the mesh surface, mediated by physiochemical factors in the mesh, including chemotaxis, gravitational, and other factors. The second factor is related to irreversible adhesion of the bacteria to the mesh, which is aided by cell wall and molecular factors in the patient. Once bacteria adhere to the mesh, the bacteria have the capacity to form communities of microorganisms that bind together and form a biofilm. The biofilm has multiple strains of bacteria that form an extracellular matrix. Ultimately, the matrix helps to encapsulate and protect the bacteria so they can multiply and develop resistance to antibiotics. These incorporated bacteria form their own community and can act differently since they genetically modify themselves to resist antibiotics. The bacteria in the biofilm have a different phenotype than their counterparts inside a mesh. When a mesh infection develops biofilm, complete mesh removal is typically required.

A complex environment allows the biofilm to exist, and each biofilm has an induced mechanism, known as quorum sensing. This pathway allows the bacteria to communicate with other organisms in the biofilm. Each biofilm has different geographic areas; some internal, some external. The more internal zones are anaerobic, and the external zones are aerobic in nature. One of the amazing features of the biofilm is that the organisms have the ability to detach and move around to other regions within the biofilm. Many of

these biofilm forming bacteria are associated with hospital acquired and surgical site infections. Staphylococcus aureus and Staphylococcus epidermidis are the two main organisms responsible for mesh infection. The two other potential organisms involved are Streptococcus and Enterobacter.

Several factors promote mesh infection in patients. The moist environment promotes bacteria growth. The type of biomaterial the mesh is created from is also a factor of mesh infection. The typical mesh is synthetic. Some are laminar, reticular, or composite, and pore size can vary. In addition, synthetic mesh can be woven, knit, or yarn configuration. The monofilament or multifilament nature of the mesh can influence adhesion of the bacteria on the mesh. The complexity of the mesh can promote more infections. There are two large categories for prosthetic materials: synthetic and biological.

TYPES OF MESHES

Three types of synthetic mesh will be discussed – synthetic, laminar synthetic, and composite synthetic. Each one has different properties that affect susceptibility to infection. The commonly used synthetic materials are non-absorbable and include polypropylene (PP), polyester (PE), or polyvinylidenfluoride (PVDF) yarns. There are polyester meshes made of lactic acid, glycolic acid, and trimethyl carbonate (TMC). Each of these meshes has different sized pores. There is discussion in literature about the use of this mesh in an infected field. Though controversial, some surgeons have advocated use of this mesh when the field is infected. In addition, it is suggested that multifilament meshes are more susceptible to biofilm than monofilament prostheses. Meshes that are made of polyester are more susceptible to infection and bacterial adherence. Pore size is also an important factor in development of infectious complications. Mesh with larger pores has less contact area and may be less prone to bacterial colonization than mesh with smaller pores, also called heavyweight mesh.

The second type of mesh is laminar synthetic or sheet prostheses and is made of polytetrafluoroethylene (PTFE) or expanded PTFE (ePTFE). Another type of laminar synthetic materials includes the TMC sheet noted above . These types of mesh have larger surface areas and are susceptible to infection and colonization. This type of mesh has micropores that provide a fertile ground for bacteria to proliferate. When the bacteria settle into the micropores, they are protected against the action of macrophages that help fight off infection. Non-porous mesh is thought to reduce the risk of infection and can be used in an infected area.

The third type of synthetic mesh is the composite synthetic mesh, which is complicated in structure. One side is reticular, woven or knitted and non-absorbable, and the other side is absorbable. Data in the literature suggests these types of mesh are more susceptible to infection than others. They have a larger surface area because of their construction, allowing biofilm to adhere to the mesh and produce infections due to the increased surface area of the mesh.

The other type is a biological mesh made of materials such as dermis and small intestines - decellularized tissues that are rich in collagen. This mesh is made up of two groups. One has covalent bonds between the molecules and are cross-linked, while the second group has no cross-linked bonds. The cross linkages of these biomaterials are mediated by matrix metalloproteases. Whether these biological meshes should be used in the setting of infection is controversial.

RISK FACTORS

When deciding what type of mesh to use, it is important to identify risk factors for infection. A recent study of 2418 mesh hernioplasties showed a 7.2% rate of infection. The risk for mesh infection increases with advanced age, American Society of Anesthesiology score greater than 3, and tobacco use. Of all these factors, the worst is use of tobacco. Patients who had prior mesh placement also have an increased

risk of infection, as do patients with uncontrolled diabetes mellitus, obesity, and COPD. When planning for surgery, it is important to include risk factor modification to reduce the risk of infection.

When the abdominal wall is being reconstructed, mesh can be placed in several positions: intra-abdominally, retrorectus, or as overlay, which is over the abdominal wall closure. Several meta-analyses have shown that placement of mesh in the retrorectus position is helpful, with risk reported to be 2% versus 26% when it was not covered. Placement of mesh in the intraabdominal position can contribute to complications if the patient needs future reoperation. Other operative factors that have been identified to contribute to complications include surgical technique, prolonged operation, emergency operation, and inadvertent enterotomies. Mesh infection can occur in open surgery or laparoscopic surgery. When the laparoscopic approach is used, the incidence of infection has been reported to be zero to 3.6%, compared to 6% to 10% for open procedures.

There are many approaches to attempt prevention of mesh infection, the first being modifying the risk factors upfront, including weight loss prior to surgery, improving control of diabetes, and smoking cessation. Some authors have suggested prophylactic use of antibiotics postoperatively may be helpful. Use of biological mesh in the presence of infection has been suggested but is still controversial. If mesh is surgically removed, primary closure of the dirty wound can be done, understanding that there is increased incidence of herniation postoperatively. In general, attempting definitive closure in the setting of a deep spaced infection of the abdominal wall is not recommended. Some surgeons have used a wound vac to help close the wound over time.

The operative approach to dealing with patients with mesh infection is quite complex. When infection first occurs, early recognition and drainage is crucial, along with antibiotics. Once the acute process is managed, develop an operative strategy. If the patient has enterocutaneous fistula, the problem is more complicated. The fistula output has to be controlled, and the mesh needs to be removed, with closure of bowel when the patient is nutritionally maximized. This process can take a long time, so it is important to wait for the optimal time to proceed with surgery. Definitive repair of the hernia is accomplished, once all the infection has been removed. Some surgeons have tried to do a partial mesh excision without success.

In conclusion, mesh infection continues to be a serious complication after abdominal reconstruction. Having an organized approach up front is important, as is being alert to the potential of mesh infection postoperatively. Understanding the type of mesh used is important, since some types of mesh are more susceptible to biofilm formation than others. Modifying factors should be employed preoperatively, when possible, including smoking cessation, weight loss, and controlling the diabetic patient's blood sugar.

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INFECTED HARDWARE AND VASCULAR PROSTHESES

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LOCAL ANTIBIOTICS IN ORTHOPEDIC SURGERY

Open fractures with soft tissue injuries are prone to infection, even with early washout and debridement. Infection rates have ranged from 4-63%. These infections (known as fracture related infections) are associated with increased morbidity (including delayed wound healing, fracture nonunion, amputation) and mortality. Successful eradication of infection requires debridement of affected tissue, removal of loose implants or foreign bodies, creation of a stable fracture environment, dead space management, and systemic antibiotics. Administration of local antimicrobials in addition to systemic therapy may be helpful.

The adjunctive application of local antimicrobial agents offers the prospect of improved therapeutic efficacy over that achievable by systemic delivery alone. The antimicrobial agent is placed directly within the surgical field, and any vascular compromise at the fracture site or surrounding soft tissue does not limit local concentrations as it may do for systemically administered antimicrobials. In addition, with local delivery, the total drug amount may be reduced, yet the local concentrations exceed systemic administration. This potentially improves the impact of antimicrobial agents while reducing the risk of systemic toxicity.

Rationale

The use of local antibiotics is not a new concept utilized over 100 years ago with Joseph Lister, who pioneered safe, anti-septic surgery. Prior to Listers innovations, as many as 80% of all operations were complicated by infection. He was the first to apply local antiseptics to surgical wounds to treat open fractures. Local antibiotics provide high local concentrations with lower systemic levels than parenterally administered antibiotics. The delivery of local antibiotics can both supplement and sometimes obviate the need for systemic antibiotics. In certain instances, the target area of treatment may be avascular, preventing systemic antibiotics from reaching the targeted site. In these situations, local antibiotics may serve as the only effective option in treating the infection. The main advantage of local antibiotic therapy is the ability of an antibiotic to reach high local concentration while simultaneously having a low or undetectable systemic concentration, thereby avoiding certain negative side effects such as nephrotoxicity and decreasing the risk of developing antibiotic resistance.

Debridement remains critical in the treatment of fracture related infection and includes excision of necrotic and poorly vascularized bone and soft tissue with the removal of loose implants or foreign bodies. Debridement is followed by irrigation to further decrease the bacterial load. This debridement often creates a dead space, which is a poorly perfused defect allowing bacterial proliferation. The use of antibiotic coated carriers can help fill this dead space.

Delivery Systems/Carriers

Local antibiotics can be delivered with or without a delivery system. Carriers provide a means for burst, tapered, and sustained release antibiotics. The ideal local antibiotic delivery system would produce a high local antibiotic level at the target site. Variations in delivery system and formulation, as well as the antibiotics used can alter antibiotic elution and dilution profiles and the mechanical properties of their carriers. In the past 2 decades, several different local antibiotic delivery carriers have been used. They can largely be divided into 2 groups based on biodegradability of the delivery vehicle: absorbable and nonabsorbable. If absorbable, it would need to break down in a short period of time so it would not act as a foreign body once the antibiotic is eluded. The disadvantage of nonabsorbable carriers is the requirement for an extra surgery for carrier removal.

“Naked” local antibiotics, including aqueous or powder formulations, deliver antibiotics without a carrier. Aqueous formulations are one of the earliest described forms of local antibiotics in the literature and are injected into the wound after wound closure; whereas powdered formulations are placed into the wound prior to closure. These methods are advantageous as they cost less than other delivery methods; however, their effect is shorter lasting. To date, the application of antibiotics without any carrier has not been documented in human clinical trials focused on the treatment of fracture related infection, and further research is required to make recommendations.

Polymethylmethacrylate (PMMA)

Antibiotic-loaded bone cement may be considered the current gold standard for local antibiotic delivery in orthopedic surgery. Antibiotic loaded polymethylmethacrylate (PMMA) cement beads are the most popular nonbiodegradable modality used in conjunction with surgical debridement and systemic antibiotic therapy and have been used to treat and prevent bone and soft tissue infections for over 30 years. It was adopted as an antibiotic carrier in the 1970’s for the treatment of osteomyelitis due to its ability to occupy large amounts of dead space.

Antibiotic-loaded PMMA has been applied to multiple settings for the treatment and prophylaxis of infection. Common indications include the prevention of infection in total joint arthroplasty, open fractures, and the management of potential space in patients with large bone or soft tissue deficits. It has also been used to treat acute and chronic osteomyelitis, chronic infected nonunion, and periprosthetic joint infections. Contraindications are largely limited to patient hypersensitivity or allergy to specific antibiotics, as well as the presence of resistant organisms. The theoretic advantages of antibiotic beads include a high local concentration with low systemic levels, occupation of potential spaces following surgical debridement, low immunologic response, and a high surface area of the bead allowing for a rapid release of the antibiotic. Although many antibiotics have been used with PMMA, vancomycin, tobramycin, and gentamycin are the most commonly used. There are a number of studies that have demonstrated that local PMMA mediated antibiotics decrease infection risk and biofilm formation. Because PMMA is not absorbable, it requires a second surgery. In addition, although its ability to occupy dead space can be an advantage, in cases without bone loss, there may be insufficient space to allow for the placement of PMMA. For these reasons, PMMA is more commonly used either as prophylaxis in high energy open fracture situations with bone or soft tissue loss or in the treatment of infection in the setting of osteomyelitis and fracture related infection.

Some controversies concerning PMMA beads and other forms of nonbiodegradable local antibiotic therapy include length of implantation and the need for removal. Prolonged implantation may lead to drug-resistant bacteria. There is a risk that they act as a foreign body. Bead removal within 4-6 weeks from implantation has been recommended because beads progressively become incorporated within callus and entrapped in fibrous tissue, which likely reduces elution and can complicate retrieval.

A systematic review showed that despite the long experience with its use and the theoretical advantages, there are no well-executed prospective studies investigating the efficacy of antibiotic loaded PMMA beads in treating orthopedic infections. However, studies with respect to prophylaxis and prevention of fracture related infections describe improved clinical outcomes.

Absorbable Options

Biodegradable implants obviate the need for a second surgery for removal. Biodegradable antibiotic delivery vehicles can be broadly grouped into 4 different categories: bone graft, bone graft substitutes or extenders (ceramics), natural polymers, and synthetic polymers (hydrogels).

There have been a number of clinical studies examining antibiotic loaded bone grafts, but beneficial evidence is lacking and currently not recommended for use. Ceramics have been shown to have a similar outcome to PMMA with the primary advantage of being absorbable and not requiring a second surgery for removal. Some studies have shown that they maintain antibiotic concentrations longer than PMMA, leading to decreased infection and biofilm formation. Ceramics have been proven effective as an antibiotic carrier for treating osteomyelitis. There is also evidence that antibiotic loaded ceramics can be used for prophylaxis. Hydrogels have a shorter release period due to their rapid resorption and lack the same structural integrity as other carriers due to their gel like consistency. This makes them better suited for prophylaxis where it is less likely for dead space to be present, and longer antibiotic elution periods are not needed. Clinical studies are scarce, but they do suggest a reduced infection in patients with closed fractures.

Use for Prophylaxis

There is evolving evidence regarding the general efficacy of prophylaxis. Although there are multiple observational studies that validate the efficacy of local antibiotics in the prevention of surgical site infections in high risk fractures, there is only one published prospective randomized trial to evaluate efficacy. The Local Antibiotic Therapy to Reduce Infection after Operative Treatment of Fractures at High Risk of Infection (VANCO) trial evaluated the efficacy of local vancomycin in preventing surgical site infections after fracture surgery. This multi-center clinical trial collected data from 34 US trauma centers who participated in the Major Extremity Research Consortium (METRC). The trial randomized patients with open or closed tibia plateau or pilon fractures requiring staged treatment to either receive standard of care or 1 gram of vancomycin powder locally prior to wound closure. The time to event estimates for surgical site deep infection rates at 6 months follow-up was 6.4% in the group who received local vancomycin and 9.8% in the control group ($p= 0.06$). In a post hoc subgroup analysis, the rate of gram-positive infection was reduced from 6.8% to 3.3% ($p= 0.02$). The METRC group has an ongoing trial comparing the combination of vancomycin and tobramycin to local vancomycin alone.

How to Decide: Which Carrier and Which Antibiotic?

Indications, application techniques, dosages, types of antibiotics, elution properties, and pharmacokinetics are poorly defined, leading to a variation in clinical practice. There are also multiple variables in deciding which antibiotic to pair with the different carriers. PMMA uses an exothermic reaction to create the polymer, so thermal stability of the antibiotic is necessary. Beta lactam antibiotics are not heat stable and should not be used with PMMA, while common heat stable antibiotics include aminoglycosides, glycopeptides, tetracyclines, and quinolones and are routinely used. Since hydrogels are a water-soluble polymer, many different antimicrobial substances have been incorporated.

Summary in Orthopedic Surgery

Local antibiotics have a role in orthopedic trauma for both infection prophylaxis and treatment. Local antibiotics can be administered at much higher local concentrations with lower systemic levels. These high local concentrations of antibiotics have been shown to reduce the risk of infection as well as decrease biofilm creation and bacterial resistance. The use of local antibiotics in conjunction with systemic antibiotics may result in synergistic effects to further decrease the risk of surgical site infection. For established infections such as osteomyelitis, a combination of surgical debridement with local and systemic antibiotics seems to represent the most effective treatment. Many studies show promising results of their efficacy with few if any adverse effects. However, current high-level research is limited, and further well-designed studies are needed before definitive recommendations can be made.

LOCAL ANTIBIOTICS IN VASCULAR SURGERY

Prosthetic vascular graft infections occur in approximately 1-10% of patients and are associated with significant morbidity and mortality. The clinical presentation is variable and depends on the vasculature involved. Aortic graft infections can present with GI bleeding from aortoenteric fistula, rupture from a pseudoaneurysm, and sepsis. These infections are associate with a 20% mortality rate and 5-25% amputation rate. Peripheral vascular graft infections are also associated with significant morbidity, including sepsis, anastomotic disruption, thrombosis, limb loss, and up to 22% mortality.

Traditional management of prosthetic graft infections included complete graft explant with extra-anatomic or in situ revascularization. However, some patients are unable to tolerate vascular reconstruction or have limited bypass options. In addition, extra-anatomic bypass is associated with high mortality and morbidity such as thrombosis and re-infection. Graft preservation with the use of adjuncts such as antibiotic beads, serial wound debridement with irrigation and muscle flap coverage has been suggested as a viable option. The advantage of the graft preservation approach is to avoid complex reconstruction in patients who are likely to be severely ill or have had multiple previous revascularization procedures.

As noted above, non-absorbable antibiotic polymethylmethacrylate (PMMA) beads have been routinely used in orthopedic surgery for the treatment of chronic osteomyelitis and prosthetic joint infections. Studies have assessed the use of antibiotic PMMA beads for the treatment of prosthetic vascular grafts for both graft salvage and in-situ reconstruction with acceptable graft preservation and limb salvage rates. The rationale is similar to that in orthopedic surgery: to provide a high local concentration of antibiotics to treat a local infection that could help avoid graft removal. In a study of 40 patients with an extremity vascular surgery site infection, PMMA beads were used as part of a treatment algorithm. Graft preservation was achieved in 28 patients, in situ bypass in 8 patients, and graft removal in only 5 patients. At a mean follow up of 17 months, the limb loss rate was 21% and recurrent infection rate was 19.4%. The authors concluded that antibiotic loaded PMMA beads may serve as an adjunct in the management of vascular surgical site infections for graft preservation or in situ reconstruction. In another study of 31 patients treated for 37 grafts infections with the use of PMMA beads, graft preservation occurred in 32 cases. Limb salvage was achieved in 28 of the 32 preserved graft cases at a mean follow-up of 26 months. The reinfection rate was 12% in the graft preservation group.

Since these nonabsorbable beads require a second surgery for explantation, there has been interest in utilizing absorbable carriers. In a small study investigating the use of bio-absorbable antibiotic impregnated beads in infection eradication, graft preservation, and limb salvage in the setting of prosthetic graft infection, 6 patients who were not candidates for graft explant or extensive vascular reconstruction were followed for a mean of 7 months. All patients had infection resolution, healed wounds, and 100% graft patency, limb salvage, and survival. The authors concluded that bioabsorbable

antibiotic beads should be considered in high-risk patients, and graft preservation, infection suppression, and limb salvage could be achieved.

The long-term follow-up also appears to demonstrate favorable outcomes. In a study of 68 patients treated with antibiotic beads followed for over 6 years, amputation free survival rates were similar to a cohort of patients without infection (51% vs 57%). The authors concluded that bypass graft preservation with wound sterilization using serial antibiotic bead exchange is associated with excellent limb salvage and survival rates, similar to those of noninfected wounds.

Summary in Vascular Surgery

Although there is very limited data supporting its use, antibiotic beads may serve as an adjunct in the management of vascular prosthetic graft infections to preserve the grafts with acceptable limb salvage rates and low reinfection rates. Further clinical research is necessary to establish its role in vascular surgery.

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TAMING THE BEAST: HOW TO APPROACH EC FISTULAS

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Anastomotic leak with enterocutaneous fistulas (ECF) occur after 1% of both elective and emergent abdominal operations[1] and are traumatizing for both the patient and surgeon. Morbidity and mortality are high, and these patients often require complicated and prolonged multi-disciplinary care to cure this complication. The spontaneous closure rate ranges from 15-70%, but overall is about 30%. Spontaneous closure usually occurs in the first two months after ECF eruption in well-nourished patients or within a few weeks of nutritional recovery in malnourished patients. Even proximal and high-output fistulas have a chance to spontaneously close. For ECF requiring operative intervention, it is imperative to adequately prepare the patient for surgery to optimize the chances of operative success. Experienced centers can achieve operative success rates >90%.[2] Due to a lack of high-quality evidence on this rare complication, most of the recommendations in this lecture are drawn from personal experience and anecdotes from other fistula enthusiasts.

GENERAL STRATEGIES FOR OPTIMIZING SUCCESS

Spontaneous (Non-surgical) Closure

When first encountering an ECF (whether as your own complication or taking over for another surgeon), the first week should be spent "getting to know the fistula." My general approach is to place the patient on strict NPO and TPN *only for the purposes of understanding what is the baseline ECF output in the absence of GI tract stimulation*. Even with high-volume fistulas present for several weeks, I have occasionally been successful in curing a fistula with traditional bowel rest and TPN. If the patient experiences a dramatic decrease in fistula volume, but not enough to close the fistula, my next step is to add octreotide to try to further decrease the fistula volume. The literature on octreotide use in ECF is confounded by the fact that many of the studies are outdated (mostly from the 1980s and 1990s) and enrolled patients with both ECF and pancreatic fistulas. The safety and cost profile are favorable, though, and sometimes this medication can convert a low-output fistula into spontaneous closure, or convert a challenging high-output fistula to a more manageable low-output fistula. Subcutaneous octreotide injections often cause nausea, so it is preferable to give this medication as intravenous infusion or added directly to the TPN. If the ECF volume doesn't respond to doses as high as 1200 mcg/d, then octreotide is unlikely to provide benefit. Additional adjunctive therapies include loperamide, gastric acid suppression, and fiber supplementation; the goal of all these adjuncts is to slow down the GI tract and thicken the effluent to decrease the amount of fluid passing through the fistula. If 3-5 days of "maximal medical therapy" does not close the fistula, then we usually remove the NPO restriction and encourage the patient to begin oral or enteral nutrition. ***In the modern management of ECF, prolonged bowel rest is no longer recommended* beyond the "getting to know the fistula" phase.**

Micronutrient Deficiencies

ECF patients can develop micronutrient deficiencies very quickly, and routine screening can often uncover occult deficiencies in vitamins and trace elements that are (theoretically) important for wound healing. **For every ECF patient, I order the following screening panel: vitamin A, D, E, C, B1, B2, B6, B12, methylmalonic acid, iron, ferritin, transferrin, total iron binding capacity, iron saturation, folic acid, zinc, selenium, copper, ceruloplasmin, testosterone, and essential fatty acid panel**. More often than not, at least one occult micronutrient deficiency is present. If a deficiency is identified, I begin supplementing that micronutrient either in the TPN or via the enteral route, and I monitor the recovery with monthly lab follow-up. If no deficiencies are identified, I repeat the screening panel every 3 to 6 months. Anecdotally, the incidence of relative testosterone deficiency is fairly high (>30% in my practice) and if discovered, I will usually treat to target normal serum levels (300-1000 ng/dL in men; 20-40 ng/dL in women). The goal is to reverse the catabolic state and create the best milieu for wound healing and anabolic recovery.

Prehabilitation

ECF patients can become debilitated very quickly. Problems with leaking wound managers often limit the patient from participating in physical therapy (PT) and discourage the patient from leaving the supine position. The first step is to work closely with the enterostomal nurse to figure out a wound manager system that is durable enough to withstand ambulation and light physical exercise. During this period, I will often order resistance bands to the bedside and ask PT to teach the patient to perform arm and leg exercises in bed. Hand grip strength (dynamometry) is a well-validated assessment tool as a marker for nutritional and functional status. A dynamometer can be purchased online for <$30. There are age- and sex-adjusted normal ranges for grip strength, and this gives the patient an objective target to aim for.

Fistuloclysis

Depending upon the ECF location (proximal vs. distal) and output (high- vs. low-volume), the bowel distal to the fistula may be atrophic from disuse. Current nutritional society guidelines recommend obtaining distal enteral access and attempting to feed (i.e. fistuloclysis) or reinfusing the fistula effluent into the distal bowel.[3,4] Distal enteral access may be obtained either by directly cannulating the fistula ("fistula feeding tube") or through percutaneous or surgical access distal to the fistula. A fistula feeding tube should only be attempted once a trial of spontaneous closure has failed, as cannulating the fistula will guarantee that it will stay open. There are several benefits of fistuloclysis and succus reinfusion: 1) Liberation from TPN; 2) Ileal brake reflex can decrease upper GI tract secretions[5]; and 3) Maintaining distal bowel structure and function. Clinical studies have reported improvements in post-operative return of bowel function, hospital length of stay, and even ECF recurrence.[6,7]

Some caveats about distal feeding tube access: First, tunneling the feeding tube through the subcutaneous tissues (beyond the limits of the wound manager) can greatly decrease the rate of wound manager leakage (**Figure 1**). Second, the amount of distal bowel is not necessarily a limitation of the success of fistuloclysis. I have placed a fistula feeding tube into the hepatic flexure of the colon and successfully fed that patient over 1000 mL per day of elemental formula with bile refeeding; she was having two formed bowel movements per day.

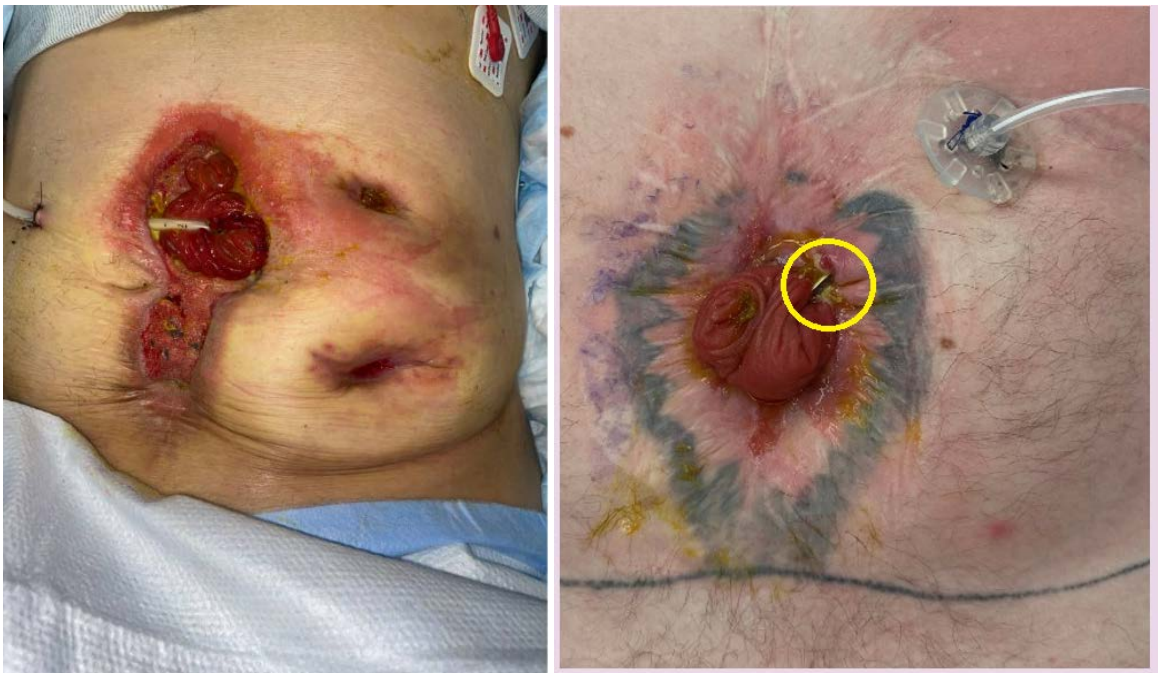

Figure 1. Tunneling a fistula feeding tube so it won't interfere with wound manager bag

Tunneling a fistula feeding catheter so that it exits the skin outside of the zone of the wound manager will greatly simplify wound care

OPERATIVE INTERVENTIONS

ECF patients often require curative fistula resection or may benefit from other intermediate operations, either in preparation for fistula resection or in lieu of fistula resection. It is useful to consider this in the context of how far out the patient is from the ECF complication.

Early (< 7 days)

If the anastomotic leak is identified within the first week after laparotomy, it is reasonable to attempt to re-enter the abdomen to either repair, resect, or exteriorize the bowel to a loop ostomy. If attempting to repair or resect, I recommend placement of a large sump drain (e.g. Davol Abramson) due to the high risk of anastomotic leak (**Figures 2 and 3**). This drain has proven very useful for controlling fistula output and is less likely to clog compared to standard closed-suction drains (e.g. JP or Blake drain). The third port allows for irrigation to dilute the effluent even further to avoid clogging.

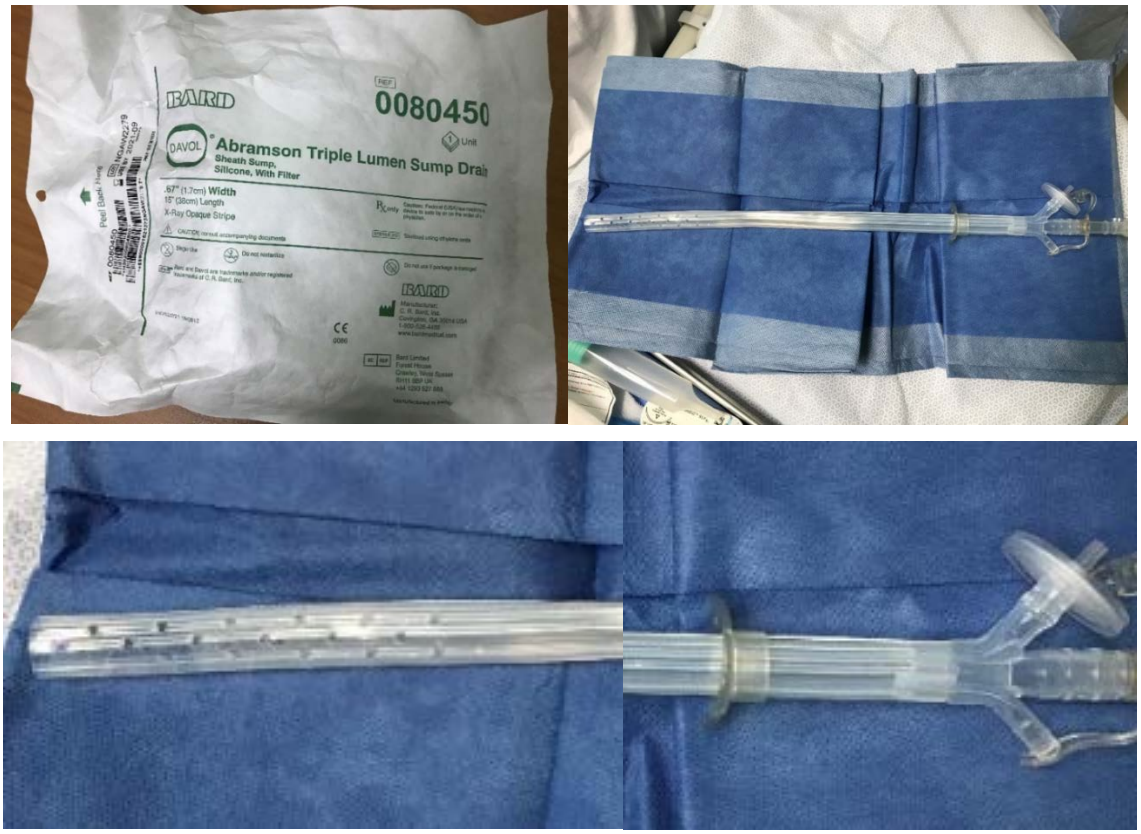

Figure 2. Bard Davol Abramson Triple Lumen Sump Drain

I usually begin irrigation (normal saline @ 50 mL/h) through the side port immediately after surgery in order to keep the center lumen patent while the tract is maturing

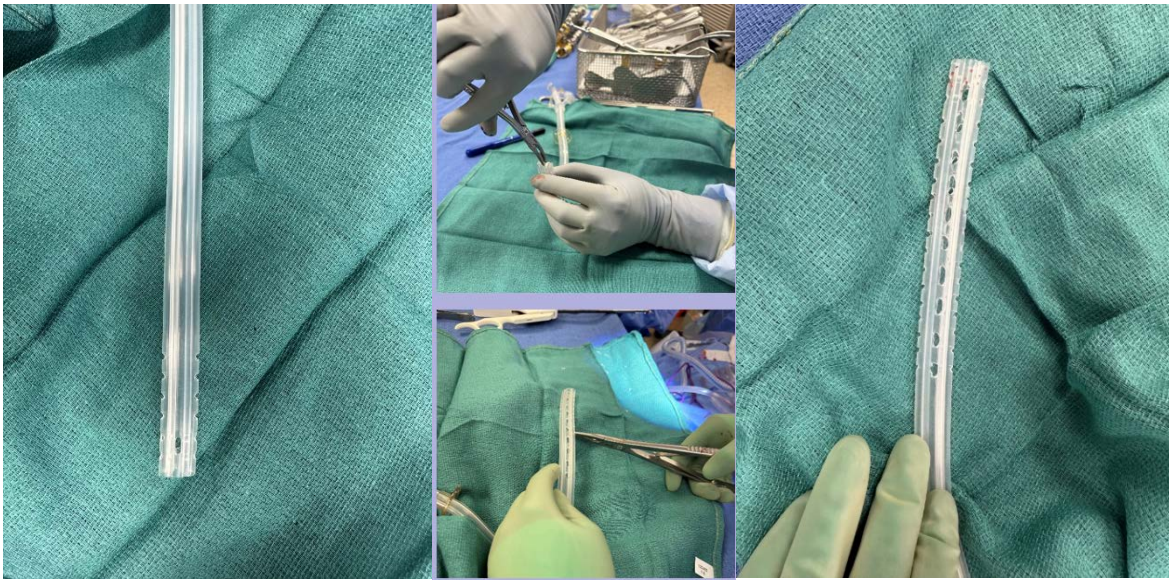

Figure 3. Modifying the Davol drain to make additional side holes

It is sometimes useful to modify the drain with a rongeur to create additional side holes

Exteriorizing the bowel to a loop ostomy avoids the risk of anastomotic leak within the abdomen and gives the surgeon an opportunity to restore future GI tract continuity without having to re-enter a hostile abdomen. Even high-volume proximal jejunostomies can be adequately managed with TPN and distal refeeding. Although the maximum TPN bag volume is 4 liters, you can easily give more volume by simply ordering 2 bags of TPN per day for that patient and running them in sequence.

If I am able to get back into the abdomen to address the fistula, I will also perform a distal *jejunopexy* with marking clips (**Figure 4**). This allows for easy future percutaneous jejunal feeding tube without committing to the morbidity of making a new hole in the bowel in the acutely inflamed state.

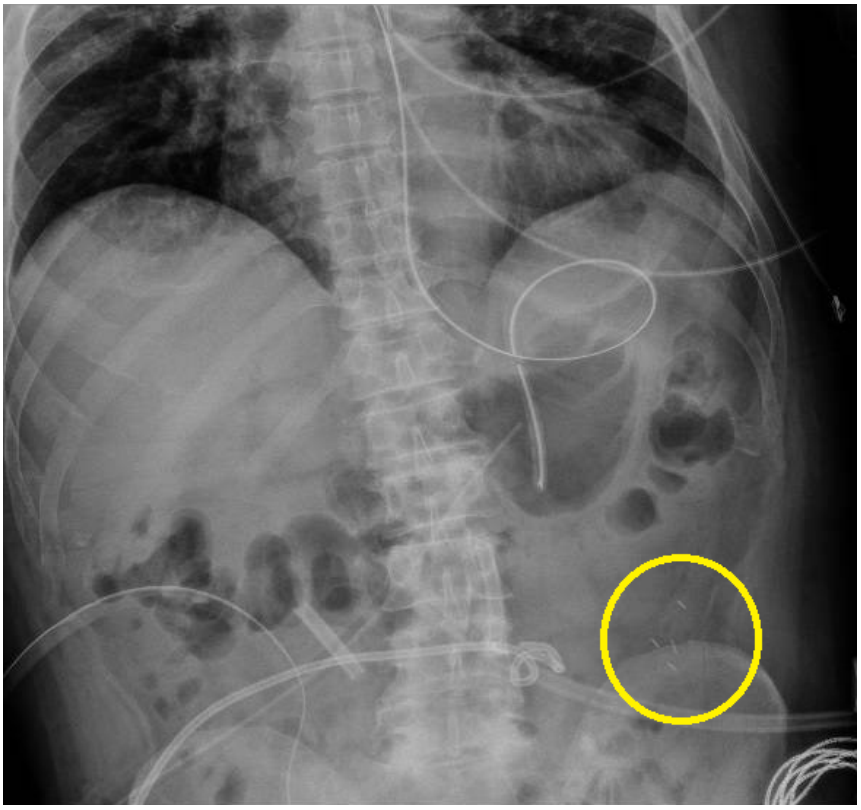

Figure 4. Jejunopexy marked with clips

Interventional Radiology can then enter the jejunum (distal to the anastomosis) in the center of the diamond for percutaneous distal feeding access.

If you take the patient to the OR and are unable to safely enter the abdomen, you can still benefit the patient by diverting the fistula off the midline (see next section). This will convert the uncontrolled fistula into a controlled fistula, improve the ability to manage the skin surface, and possibly increase the chances of spontaneous closure.

Intermediate (7 Days – 12 Months)

Beyond 7 days, the abdomen is usually too hostile to enter safely. During this intermediate period, the surgeon should attempt to: 1) Maximize medical therapy in an attempt at spontaneous closure (see above); or 2) Prepare the patient for eventual surgical resection. One potential factor determining spontaneous closure is the length of the fistula; short, squat fistulas are less likely to close; whereas longer, more tortuous fistulas seem more likely to close, possibly due to the “afterload” encountered by the effluent when needing to traverse long distances to reach the surface.

Diverting the Fistula Off Midline

My practice is to tunnel the Davol drain, positioning the tip overlying (or within) the fistula and bringing it out through the lateral abdominal wall. You can then close the skin over it. I always place an incisional VAC over the closed skin incision. Over time, the Davol tract will mature, and you can take it off suction and eventually gradually back it out. Once the drain is out, the exit site can be managed like a standard ostomy. On multiple occasions, turning a short uncontrolled fistula into a longer controlled fistula has resulted in spontaneous closure (**Figures 5 and 6**). Even if it doesn't close, though, the fistula will be easier to manage (**Figure 7**), and the patient will likely be better able to participate in physical therapy.

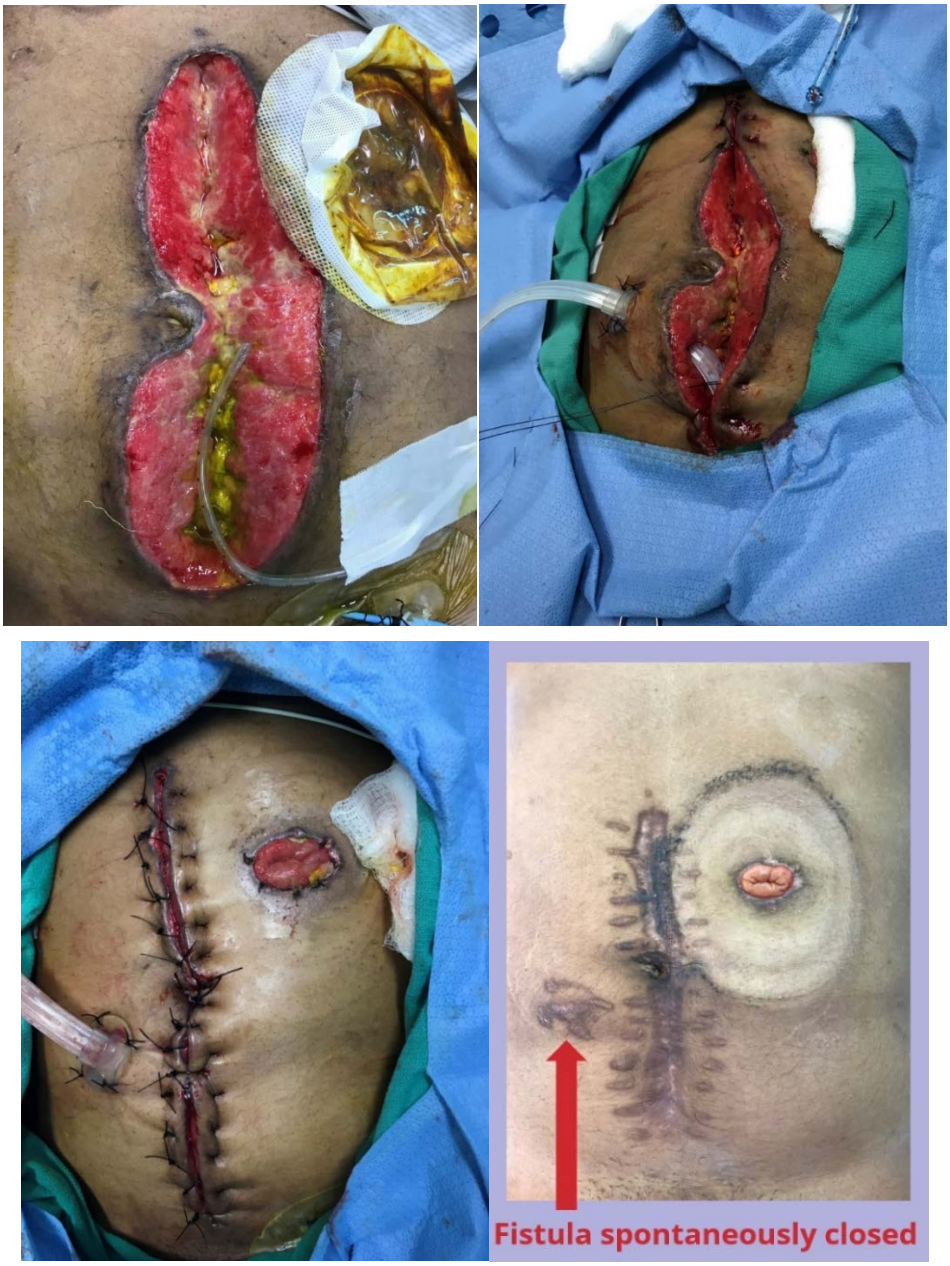

Figure 5. Converting uncontrolled midline fistula to controlled lateral fistula

Uncontrolled mid-jejunal fistula successfully controlled and diverted off midline; spontaneously closed several weeks later

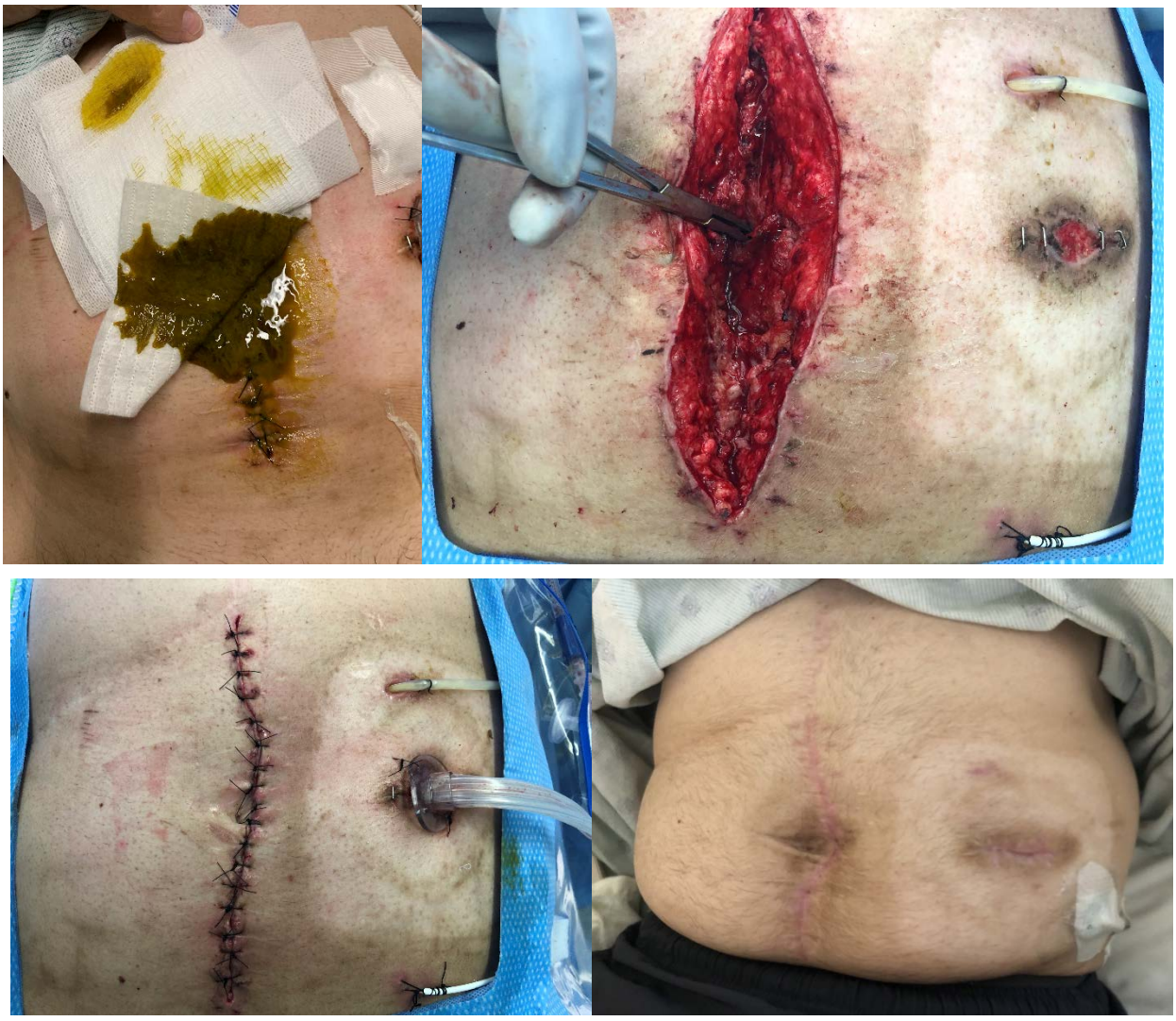

Figure 6. Another example of converting uncontrolled midline fistula to controlled lateral fistula

POD#5 s/p ileotomy reversal; unable to enter abdomen due to severe adhesions; Davol drain tunneled out through prior ileostomy site; spontaneously closed several weeks later

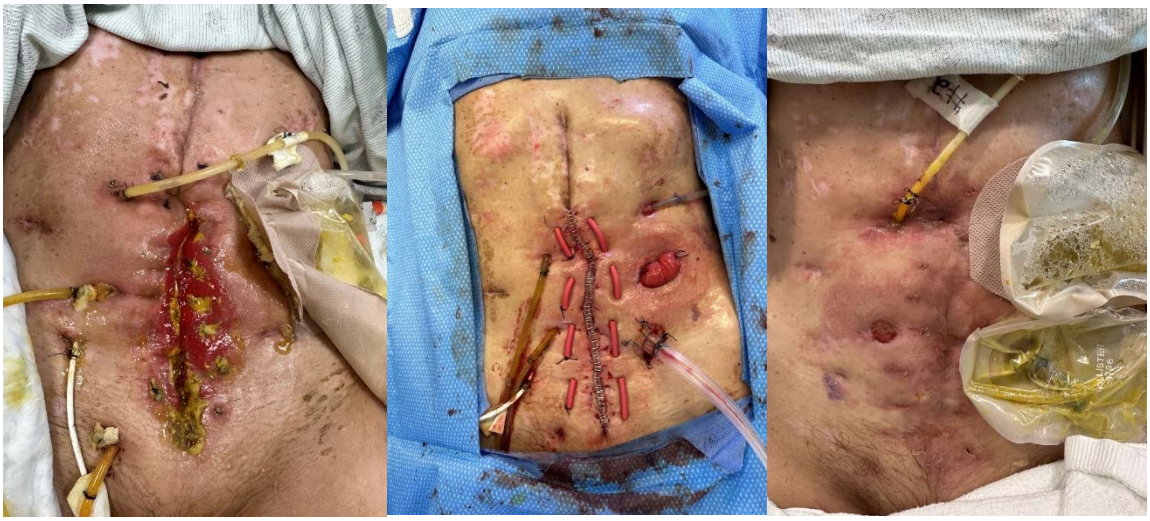

Figure 7. Wound care is greatly simplified when the fistula is diverted off midline

Uncontrolled duodenal fistula causing severe skin irritation and wound breakdown; Davol drain placed atop fascia and skin flaps raised to cover the midline; horizontal mattress skin retention sutures (with red rubber catheter bumpers) were used to reduce tension on the midline and the skin staples were spaced very close together to achieve a watertight seal; Midline healed and fistula controlled via lower ostomy bag

Late (>12 Months)

A wise sage once said "You can never operate too late on a fistula… only too early." Before scheduling an ECF resection, my patients must meet three criteria: 1) Macro- and micro-nutrients repleted; 2) Functionally prehabilitated; and 3) Twelve months since last major abdominal entry. Patients must be at or very close to their usual (pre-ECF complication) body weight and functional status. For handgrip strength, I want them to be at least 80% of their age- and sex-adjusted normal reference range. All micronutrients levels must be normalized, and if they have a skin graft over open abdomen, it must pass the "pinch test". Before embarking on this operation, I always map out the entire length of the GI tract using fluoroscopy: upper GI with small bowel follow-through, fistula contrast injection (both proximal and distal), and contrast enema.

CAVEATS

- Don't bother measuring how much bowel you removed. ALWAYS dictate in your op report how much bowel is remaining!
- No matter how good the anastomosis looks, I always perform a jejunopexy (**Figure 4**), just in case everything falls apart, and I need distal enteral access
- ECF patients often require abdominal wall reconstruction via component separation to achieve primary fascial closure. Be prepared to spend a lot of time trying to figure out how to close the abdomen
    - Although transversus abdominis release (TAR) is preferred, that plane is sometimes scarred and difficult to release without creating holes in the peritoneum

    - I often have to raise skin flaps to achieve skin coverage anyway, so I usually perform anterior component separation because the patient has already bought the morbidity of the skin flaps
        - Doing anterior component separation preserves the possibility of future posterior component separation or TAR
- Horizontal mattress skin retention sutures can help relieve tension off your midline incision (**Figure 7**)
- Incisional wound VAC can help seal your midline incision through physical apposition and also has been shown experimentally to increase blood flow to the wound margins[8]

CONCLUSIONS

Enterocutaneous fistulas are challenging to manage and require patience and tenacity by both patient and surgeon. Early intervention is possible before the abdomen becomes hostile to re-entry, though direct repair or resection/anastomosis have a high risk for failure in that setting. Exteriorizing the bowel may be a better course of action. Never rule out the possibility of spontaneous closure unless you have personally tried maximal medical therapy once the patient is adequately nourished. If the window of re-entering the abdomen has closed and maximal medical therapy has failed to close the fistula, diverting the fistula off midline will improve wound management and may even close the fistula. Wait at least 1 year before attempting definitive fistula resection, and make sure the patient is nutritionally/functionally optimized, including micronutrients and testosterone.

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BOWEL OBSTRUCTION IN THE POST BARIATRIC SURGERY PATIENT

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HISTORY

The prevalence of obesity in the United States has shown a steady upward trend and now affects up to one third of the adult population. There is no longer a dispute that obesity surgery is the most sustainable way to insure long-term weight loss. Despite its clear health benefits, the life-time risk of undergoing additional abdominal surgery after bariatric surgery is doubled. The exponential increase in gastric bypass surgeries performed has occurred with an increasing number of small bowel obstructions. The development of small bowel obstruction (SBO) following gastric bypass surgery can occur immediately or be delayed by months to years. SBO that occurs within 30 days of surgery is termed "early," whereas SBO that manifests 30 or more days after surgery is referred to as a "late." The incidence of SBO varies from 0.4% to 7.45%, and the variation is primarily attributable to differences in surgical techniques and the volume of procedures performed in a particular institution.

Roux-en-Y gastric bypass surgery (RYGBP), a combined restrictive and malabsorptive technique, is considered to be a standard procedure for achieving consistent sustainable weight loss. RYGBP produces a varied spectrum of complications that may occur in 3–20% of patients. The incidence of SBO after open RYGBP is lower than that after laparoscopic Roux-en-Y gastric bypass (LRYGBP), and SBO after open RYGBP is most commonly an open loop obstruction due to adhesions. Compared with its open counterpart, the laparoscopic approach results in lower rates of wound complications, incisional hernias, and a shorter hospital stay. With exponential increase in the volume of laparoscopic bariatric surgical procedures, there has been an increase in the reported incidence of procedure-related complications, including small bowel obstructions. The laparoscopic approach has produced a decrease in postoperative SBO secondary to adhesions and incisional hernias. In an elaborate review including 3464 patients, a reported higher frequency of both "early" and "late" obstructions in laparoscopic bypasses occurred when compared with open cases. Similar findings were noted in 2 prospective trials, as well.

SBO CLASSIFICATION AND SITE IDENTIFICATION

SBO after bariatric surgery may be classified according to the timeline of presentation after surgery, anatomic site of obstruction, or underlying cause. The most common obstructive cause is an internal hernia, followed by adhesive disease, jejunojejunostomy stenosis, incisional hernia, intussusception, and hemobezoar. The position of the alimentary limb (antecolic versus retrocolic) influences the incidence of SBO. An "ABC" taxonomic system based on the anatomic site involved in SBO has RYGB: Alimentary limb (A), biliopancreatic limb (B), or common channel (C). The "ABC" Taxonomic system further delineates SBO in each of the limbs further categorized as either acute or chronic.

Alimentary Limb		Biliopancreatic Limb		Common Channel	
Acute	**Chronic**	**Acute**	**Chronic**	**Acute**	**Chronic**
Petersen hernia	Internal hernia	Jejunojejunostomy stenosis	Internal hernia	Incarcerated abdominal wall hernia (trocar site or incisional)	Internal hernia
Intussusception of the Roux limb	Mesocolic constriction of the Roux limb	Intussusception	Anastomotic stricture	Volvulus around the Roux limb	Adhesions
Intraluminal or intramural hematoma		Intraluminal or intramural hematoma		Intraluminal or intramural hematoma	
Jejunojejunostomy stricture		Mesenteric hematoma			
Tight mesocolic stricture		Volvulus			
Mesocolic hematoma					

DIAGNOSIS AND TREATMENT

Gastric bypass patients with suspected SBO can present with nondescript pain, nausea, vomiting and distension with some subjective decrease in the passage of flatus or bowel movements. Subtle findings, such as tachycardia and tachypnea, can be harbingers to a high grade small bowel obstruction before peritonitis and perforation. Simple post-operative tachycardia in obese patients should be taken as a herald to a serious sign of a potential abdominal catastrophe in the post-surgical bariatric patient. For this reason, it is now conventional to say that “a tachycardia of over 120 beats per minute is an indication for surgical exploration unless proof to the contrary exists.” Nausea and vomiting, the dominant symptoms of small bowel obstructions, can be seen in fewer than half of gastric bypass patients.

The most common, long-term complication after RYGBP is an internal hernia, which usually occurs metachronously after relevant weight loss. The complexity of the anatomy following LRYBP reconstruction calls for early imaging when a SBO complication is suspected. Upper gastrointestinal examination is vital in the evaluation of symptomatic patients after RYGBP for the detection of SBO, particularly within 4 months of surgery. However, the sensitivity of radiological studies to diagnose bowel obstruction after gastric bypass is fairly low, and an afferent limb obstruction may present as completely normal after obtaining a small-bowel contrast series. The radiological diagnosis of bowel obstruction can be quite challenging and easily overlooked by surgeons and radiologists who are not intimately familiar with post–gastric bypass anatomy. Radiological diagnosis of internal hernias, the leading cause of postoperative LRYGBP bowel obstruction can be very difficult because of the variable appearance and configurations of the alimentary limb, biliopancreatic limb, and common channel anastomosis.

CT scan of the abdomen is an important modality to diagnose an internal hernia SBO after RYGB if clinically suspected. Computed tomography of the abdomen is recommended, as its sensitivity and specificity have been reported to exceed 80%. The presence of a dilated gastric remnant, swirling of the mesenteric vessels, or dilatation of the small bowel present on CT imaging can be very useful to diagnose an internal hernia after LRYBP. CT scanning of the abdomen and pelvis can still have a high false negative rate and has been found to be misleading or negative in patients presenting with just pain after LRYBP.

SURGERY

Diagnostic laparoscopy is more accurate than CT scan of the abdomen in patients presenting with abdominal pain after RYGB and might help identify internal hernias in patients with pain and a normal CT scan. In the face of subtle signs and equivocal radiologic findings, a high clinical suspicion should be

maintained, and surgical exploration undertaken immediately. Patients with SBO after LRYGB are particularly prone to vascular compromise of the bowel, leading to an ischemic bowel perforation. In a recent study, 8 of the 93 deaths within 30 days of bariatric surgery were from SBO; 5 of those deaths were from obstruction of the bypassed biliopancreatic limb 2–6 days after surgery. Acute dilation of the gastric remnant with subsequent staple line rupture or gastric wall perforation is usually caused by obstruction of the biliopancreatic limb or common channel. If clinical suspicion is high, exploration should still be pursued to prevent subsequent perforation and peritonitis, even if the imaging findings are equivocal. The results of early SBO treatment between laparoscopic and open management for early SBO differ significantly. Laparoscopic management results in fewer complications. The laparoscopic approach combined with endoscopy can manage SBO effectively in a carefully selected patient group. The ability to complete the reoperation laparoscopically varies with etiology and location of the obstruction.

- A negative CT scan of the abdomen and pelvis cannot rule out the presence of an internal hernia after RYGB.
- Diagnostic laparoscopy is important in evaluating patients with abdominal pain post Roux-en-Y gastric bypass (RYGB).
- Patients with negative radiographic studies, including CT scan of the abdomen and persistent abdominal pain, may need diagnostic laparoscopy to rule out the presence of an internal hernia.

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REBOA COMPLICATIONS AND PITFALLS

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Resuscitative endovascular balloon occlusion of the aorta (REBOA) has been used as a damage procedure and has been promoted by national trauma society guidelines for hemorrhage control in the abdomen and pelvis. Although this concept was first introduced 70 years ago during the Korean war, this technique became popular in the past two decades. Currently, REBOA has been used, not only for trauma, but also for other causes of abdominal bleeding, such as post-partum hemorrhage, and gastrointestinal bleeding, despite the questionable outcomes. Most studies use survival as the primary outcome, with some focusing on local access site REBOA-related complications, such as hematoma, pseudoaneurysm, and need for amputation. However, recent studies evaluated the role of REBOA in the development of other complications, such as venous thromboembolic complications (VTE), extremity compartment syndrome, ARDS, and acute kidney injury (AKI)

REBOA-SURVIVAL

The quality of data supporting survival benefits with REBOA is poor and based on small series and personal opinions. A joint statement from the American College of Surgeons Committee on Trauma, the American College of Emergency Physicians, the National Association of Emergency Medical Services Physicians, and the National Association of Emergency Medical Technicians regarding the clinical use of REBOA in civilian trauma centers in the USA, said that the quality of clinical evidence to support REBOA use in trauma patients is poor, with no Class I or II data, and, thus, the existing data must be interpreted with caution.[1]

The first large studies using the Japanese Trauma Data Bank reported significantly higher mortality rates after REBOA use in severe torso trauma.[2,3] More recent large studies confirmed these findings. In a 2019 study by Joseph, et al., 140 trauma patients who underwent REBOA placement in the ED were matched with a similar cohort of 280 patients with no-REBOA. There was no significant difference between groups in 4-hour blood transfusion. The mortality rate was higher in the REBOA group, as compared with the no-REBOA group (35.7% vs 18.9%, P = 0.01).[4] Another recent study from the Japanese Trauma Data Bank, analyzed 3149 multi-trauma patients with severe pelvic trauma and hypotension, 256 of whom were treated with REBOA. The REBOA group had worse mortality, despite adjusting for major comorbidities.[5] In another recent study of isolated severe pelvic fracture (AIS≥3) (excluded associated injuries with AIS >3 for any region other than lower extremity), 93 REBOA patients were propensity score matched to 279 similar patients without REBOA. REBOA patients had higher rates of in-hospital mortality (32.3% vs 19%, p = 0.008).[6]

ORGAN DYSFUNCTION

The ischemic-reperfusion systemic effect produced by aortic occlusion, especially longer than 30 minutes, is another concern that has been confirmed in experimental work.[7] Large retrospective clinical studies reported significantly higher incidence of acute kidney injury (AKI).[4,5]

ACCESS-RELATED COMPLICATIONS

The incidence of catheter access complications has been declining with the use of newer, smaller diameter, and better-designed devices. The initial catheter size of 14 F was replaced by 7F and currently 4F. Studies have shown that smaller sheath systems are associated with fewer vascular complications.[9,10] Manzano-Nunez, et al. in systematic review and meta-analysis of 13 studies with a total of 424 patients, reported a 5.6% of groin access-related complication rate.[11]

However, despite these improvements, the incidence and nature of the catheter-related complications remain significant. In a recent study, Laverty, et al. examined arterial access related ischemic complications in patients undergoing femoral access for REBOA and reported an 8.6% incidence of extremity ischemia and/or distal embolism.[12]

VENOUS THROMBOEMBOLIC COMPLICATIONS

Tissue ischemia or hypoxia stimulate is an inflammatory response, that results in endothelial damage, release of inflammatory mediators, activation of platelet and leukocyte aggregation, and generation of thrombin and clot.[13,14]

There are concerns that REBOA deployment creates a combination of venous stasis by reducing the arterial blood flow to the pelvis and the lower extremities and an inflammatory response secondary to the ischemia/reperfusion injury, associated with the occlusion and restoration of the arterial blood flow to the tissues. This combination could increase the risk of venous thrombosis and VTE complications. Recent work has established the significantly higher incidence of VTE complications in patients treated with REBOA.

In a 2023 study, 339 REBOA trauma patients were matched with 663 patients with no REBOA. Propensity score matching was done after matching for age, mechanism, gender, SBP<90, pulse>120, GCS<9, ISS, co-morbidity, femoral or tibial fractures, lower limb vessel injuries, head/ chest/ spleen/ liver/ kidney/ hollow viscus/ pelvis AIS≥3, preperitoneal packing, laparotomy, immediate fixation of pelvis/femur/tibia, VTE prophylaxis, and angioembolization of the pelvis. REBOA patients were significantly more likely to develop VTE (14.7% vs. 10.0%, p = .025) and pulmonary embolism (PE) (5.3% vs. 2.7%, p = .037).[15]

In another study in 2023, which included patients with isolated severe pelvic fracture (AIS≥3), 93 REBOA patients were propensity score matched to 279 similar patients without REBOA. The patients were matched for age, ED vital signs, ISS score, AIS 3 for head, face, neck, chest, abdomen, extremity and spine, AIS 3 for specific abdominal organ injuries (liver, spleen, kidney, mesentery), pelvis AIS (3, 4, and 5), hollow viscus injuries, laparotomy, preperitoneal packing, angioembolization, and comorbidities. REBOA patients had higher rates of venous thromboembolism (14% vs 6.5%, p = 0.023) and DVT (11.8% vs 5.4%, p = 0.035). In multivariate analysis, REBOA use was independently associated with increased venous thromboembolism.[16]

EXTREMITY COMPARTMENT SYNDROME

The ischemia and reperfusion produced by the REBOA balloon inflation and deflation create an environment promoting the development of extremity compartment syndrome (CS), especially in the presence of tibia or femur fractures or vascular or extensive soft tissue injury.

In a recent 2023 study, 534 patients who received REBOA within 4 h of admission were compared to 1043 patients without REBOA, after propensity score matching for demographics, vital signs on admission, comorbidities, injury severity of different body regions, pelvic and lower extremity fractures, vascular trauma to the lower extremities, fixation for fractures, angioembolization for pelvis, preperitoneal pelvic packing (PPP), laparotomy, and venous thromboembolism prophylaxis. Overall, patients in the REBOA

group had significantly higher rates of CS than no REBOA patients and were 5.4 times more likely to develop lower extremity CS [5.4% vs 1.1%, p < 0.001, OR: 5.39]. The risk of CS remained significantly higher in the subgroups of patients with or without pelvic or lower extremity fractures. The risk of CS was particularly high in REBOA patients with lower extremity vascular injuries [11.2% vs 1.1%, p<0.001, OR (95% CI) OR 8.12]. The fasciotomy and AKI rates were significantly higher in the REBOA group (5.8% vs 1.2%, p < 0.001 and 12.9% vs 7.4%, p< 0.001 respectively). The fasciotomy rates were significantly higher in the REBOA group, especially in patients with associated lower extremity vascular injuries (14.7% versus 2.6%).[17]

CONCLUSIONS

The current indications and techniques for REBOA deployment in trauma patients are associated with increased mortality and acute kidney injury. In addition, REBOA is associated with an increased risk of other complications, such as VTEs, lower extremity compartment syndrome, and need for fasciotomy. A pause and reevaluation of this damage control technique is warranted.

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SESSION 12

MEET THE PROFESSOR / DISCUSS THE ISSUES

RECEPTION / DANCE

Tuesday, April 16, 2024
7:00 – 9:00 PM
Augustus Ballroom
Palace Tower
Emperors Level – 4th Floor

SESSION 13

HENRY C. CLEVELAND FORUM ON CONTEMPORARY ISSUES IN TCCACS

Moderator: Jay A. Johannigman

Wednesday, April 17, 2024

7:00 – 8:30 AM
Palace Ballrooms 1-2
Palace Tower
Emperors Level – 4th Floor

7:00 – 7:10	**You've Been Served - Dealing with Malpractice Issues and Lawsuits** **Sydney J. Vail, MD, FACS**
7:10 – 7:25	**How to Recruit, Retain, and Compensate in the Rural Setting** **Jeffrey J. Skubic, DO, MSc, FACS**
7:25 – 7:40	**Entrustable Professional Activities: Ready or Not, Here they Come** **D. Dante Yeh, MD, FACS, FCCM, FASPEN**
7:40 – 7:55	**Use of APPs to Strengthen the Practice and Continuum of Care** **Chris Cribari, MD, FACS**
7:55 – 8:10	**Standing with Ukraine: Collaborations to Support Frontline Surgeons** **Jay A. Johannigman, MD, FACS**
8:10 – 8:30	**Panel Discussion**

MALPRACTICE: YOU'VE BEEN SERVED, NOW WHAT?

Sydney J. Vail, MD, FACS

LTC, MC, US Army Reserve
Division of Trauma, SCC, and Burns
Valleywise Health Medical Center
Phoenix, AZ

This paper will be divided into two parts. The first relates to the professional aspects and the second will discuss the personal side of being sued. I am not offering 'legal advice,' I am offering insight into many aspects of being sued that you may or may not be aware of.

NOTE: The standards and regulations for medical malpractice can differ from state to state. Consult an attorney that specializes in malpractice law for definitive answers.

My career, since beginning medical school in 1985, spans 39 years this year, and I have been named in 3 malpractice suits; I was not the primary defendant on any of them and dropped from each case after my deposition was given.

PART 1, PROFESSIONAL ASPECTS

Every surgeon's nightmare…you receive a notification of legal action; you are named as a defendant in a medical/surgical malpractice case, i.e., you've been served. This is the first phase of a malpractice suit against you. From an AMA Benchmark Survey,[1] nearly one-third (31.2%) of U.S. physicians in 2022 reported they had previously been sued. Being sued is not always related to a bad outcome or having committed malpractice. Poor communication with the patient/family, a misunderstanding of something discussed, or an unrealistic expectation of the surgical outcome are all potential non-procedural initiators of a lawsuit. A retained foreign body (sponge or instrument), wrong site surgery, failure to properly diagnose an injury that leads to death or disability, or incorrect procedure are all examples of typical and common initiators of a lawsuit.

There are several issues related to 'being served' that you need to know about to best deal with the multiple processes and personal issues that will be initiated after 'being served.'

Once you have been served, notify your employer or insurance carrier if in private practice. There are several 'Do-Nots':

- Don't discuss the case with colleagues or friends without first speaking to your attorney assigned to the case; can discuss generalities with spouses but ask your attorney first
- Don't review any medical records without your attorney present and in control of a copy of them
- Don't edit/revise/add anything to the medical record once you've received notice or are aware of pending litigation (prior to receiving a subpoena)
- Don't feel like or believe you are in charge of all aspects of your legal defense; follow the lead and advice of your attorney. You will have and are entitled to your opinions and can assist in facilitating building your defense.
- Don't minimize the necessity of reading all details of the complaint against you, any and all depositions, expert witness statements, etc.

First, the definition of malpractice is appropriate to know. The plaintiff, the party bringing the suit against you (the defendant), must prove 4 elements of negligence under tort law.

- There is a duty to the patient
- Once a duty has been established, the plaintiff must show that there was a breach of this duty; the standard of care was not met
- There must be a direct and causal link between a failure to meet the standard of care and the failure resulted in an injury to the patient; must prove that negligence caused injury or harm, and that, without the negligence, harm would not have happened
- Last is damages; there must be injury to the patient due to the above elements that can include, but are not limited to:
    a. Suffering
    b. Enduring hardship
    c. Constant pain
    d. Considerable loss of income
    e. Disability
    f. Death

Surgery (medicine) involves risk, and not every negative outcome is grounds for a malpractice lawsuit. There is a term I use, "Mal-occurrence," that differentiates a negative/unexpected outcome or complication that has no associated negligence and is more common in our practices. Bad things (complications, death/disability) do happen in the field of trauma that can be due to factors not in our control, i.e., degree of injury, degree of physiologic decompensation/shock before patient arrived to treatment facility, etc. Getting a wound infection when all appropriate pre/during/post procedure guidelines and standards of care were followed happens and is a mal-occurrence, not malpractice. A decapitated patient has no chance of survival, regardless of what a family believes you did right or wrong and blames you for a 'preventable' death.

A medical malpractice lawsuit must demonstrate negligence on the physicians part. Negligence requires proving, based on the medical facts of the case, that the alleged deviation from the standard of care and the patient's injury were cause and effect.

The second phase is termed 'discovery,' which includes requests for documents, depositions, and interrogatories.

- Any and all documents associated with the care of the patient, typically in/out patient hospital or clinic records, notes, and or letters you may have made outside of the medical record
- Depositions involve providing testimony under oath to find out what you know about the case and to preserve your testimony for trial
- Interrogatories are written question(s) that is/are formally put to one party in a case by another party and <u>which must be answered</u>

An integral part of this process is the naming of 'expert witnesses.' Who and why another physician is deemed an "expert" is often an area of contention. There are companies that advertise to attorneys to provide "expert witnesses," as well as law firms that explain online how to find an expert and, for purposes of this syllabus, an expert in trauma surgery.[2,3] Some of these people you may know professionally,

socially, or by name alone, but what factors in their background make them a true “expert”? Being in practice for 5 years vs 35 years, performing a few procedures 1000 times or 100’s of procedures 10-20 times, or having your name on several medical journal articles are just some of the ways surgeons are identified as “experts.” You have a responsibility/obligation to your defense, after careful review of an expert’s opinion given during their deposition, to read, detail, take notes, and discuss issues with your attorney. It’s your opportunity to “build a case” against the plaintiff and their experts. Is there a conflict of interest with an expert? Is the expert’s opinion based on their practice or data that is challengeable and or questionable? Do they actively practice in the area they are giving an opinion, i.e., experience? Is their expert witness a professional expert, i.e., someone whose major portion of income is derived from legal cases? These questions can be answered and used by your attorney to challenge the integrity and qualifications of an expert. Remember, the expert is basing an opinion on the medical record. Retrospective reviews have biases that real time experience may not have (hence, why you need to document well!!!)

Expert Witness Guidelines

The American College of Surgeons has a ***Statement on the Physician Acting as an Expert Witness*** on its website from April 1, 2011[4] and contains recommended qualifications to act as an expert. I recommend reading and maintaining that reference to check your experts against it.

The AMA has several policies regarding expert medical testimony.[5,6,7,8]

- Policy H-265.992 encourages peer review and discipline of unprofessional or fraudulent conduct from physician expert witnesses.
- Policy H-265.993 is an AMA declaration that providing medico-legal expert witness testimony is considered as the practice of medicine and should be subject to peer review.
- Policy H-265.994 encourages members to act as impartial experts and warns that it will assist medical societies in disciplining physicians who provide false testimony. This policy also seeks to ban expert contingency fees in personal injury legislation, because such fees "threaten the integrity and the compensation goals of the civil justice system." Finally, this policy sets forth the AMA’s minimum recommended requirements for qualification as an expert witness, which include that:
    - the witness must have comparable education, training, and occupational experience in the same field as the defendant;
    - the witness’ occupational experience must include active medical practice or teaching in the same field as the defendant;
    - the occupational experience must have been within five years of the date of the occurrence that gives rise to the claim.

Although these policies are not necessarily legally binding on physicians or on AMA members, they conceivably could be used as evidence against physicians deemed to have testified unprofessionally.

Legal Liability for Expert Witness Testimony[9]

Because expert testimony has been deemed admissible does not mean that the testimony necessarily is appropriate or credible. Courts have even acknowledged "a judge’s ruling that expert testimony is admissible should not be taken as conclusive evidence that [the testimony] is responsible."[10]

When a trial court is faced with a decision whether to allow questionable testimony, lawyers often argue that jurors should be the ones to determine whether to believe the expert and what weight to place on

an expert's testimony. Unfortunately, when faced with contradictory expert opinions on the same issue, jurors may not have the ability to separate real science from pseudo- science. Although medical experts still may testify about any opinions they wish, unsubstantiated opinions in medical malpractice cases are drawing closer scrutiny. In some cases, experts who provide unsubstantiated opinions are finding that they and their testimony have become the targets of legal actions. This gives the defendant the opportunity to argue the opinions of the experts used against them. Doing your due diligence can pay huge dividends when arguing the reliability, validity, and strength of an opposing expert witness. Use the internet to search and explore each named expert to learn their background, education, publications, and any other "interesting" information that you (your attorney) could potentially use to your advantage.

I suggest looking at this example website, "experts for hire." Remember that experts are used by both the plaintiff and defendant: https://www.seakexperts.com/specialties/trauma-surgery-expert-witness

> *Trauma Surgery Expert Witnesses*
>
> *The SEAK Expert Witness Directory contains a comprehensive list of trauma surgery expert witnesses who testify, consult, and provide litigation support on trauma surgery and related issues. Trauma surgery expert witnesses and consultants on this page may form expert opinions, draft expert witness reports, and provide expert witness testimony at deposition and trial. The issues and subjects these trauma surgery expert witnesses testify regarding may include: Trauma Surgery, General Surgery, Surgical Critical Care, Sepsis, Surgical Complications, Abdominal Pain, Abdominal Surgery, Breast Cancer, Gallbladder Surgery, Laparoscopic Surgery, Shock, Traumatic Brain Injury, Wound Care, Acute Care Surgery, and Appendix Surgery.*
>
> *Use the search box above to further refine your search for trauma surgery expert witnesses by keyword and state. Attorneys contact the experts directly – with no middleman*.

You may recognize names/faces and ask what makes them an expert; qualified in their field most likely, leaders in the field maybe?

Awards and Monetary Payouts

From an attorney website about malpractice awards:[11]

Many factors influence the amount of your payout, including federal and state laws. Some states have caps on awards.

- The type and gravity of negligence
- The severity of the injury
- How much of an impact your medical malpractice-related injuries have on your life
- How much medical care you'll need in the future
- The amount of evidence you provide to prove your claim
- The strength of your medical records and overall evidence
- Economic and non-economic damages
- Testimony from medical experts
- Your age
- The ability of your medical malpractice attorney
- The medical malpractice laws and regulations in your jurisdiction
- The quality of legal representation
- Insurance coverage
- Impact of your injury on partners/family members

If you want to see what your state paid out in malpractice awards, reference these website articles. [11,12]

Documentation: Friend or Foe

Documentation is paramount to explain what you saw, what you were thinking, and the status of the patient when assessed. This documentation will form the basis of your defense, allowing for recognition of the circumstances that you encountered and that a non-participant (attorney/jury/expert witness) will read to form a basis of understanding of what went on, without the ability to be there experiencing the episode "real time."

Detailed documentation of the observed patient, the history provided (and from whom/where it was obtained), pre-existing issues, presence or absence of risk factors based on mechanism of injury, PMH/PSH/meds or allergies, etc., physical examination, medical decision-making, and treatment plan is critical, as 58% of lawsuits are dropped before they get started.[13] The primary reason is that some cases have enough information in the chart to convince the plaintiff's attorney that a victory is unlikely, so the attorney is unwilling to assume the time and financial risk of taking the case.

While following clinical guidelines does not guarantee protection, and there is no clear standard at this time that specialty society or other guidelines clearly represent standard of care at trial, basing your care on clinical guidelines is likely to significantly strengthen the defense and may even prevent the case from going to trial.

Always discuss questions, issues, and anything related to your case with your attorney. You need to be the greatest advocate for yourself and your defense; don't 'rollover' and give up from frustration or anxiety about being sued. The odds are in your favor to come out of it with either a settlement without going to court, a dropped case, or one found in your favor by a court.

A recent article gives us hope (statistically): *"Our results could not confirm the often claimed increase in litigation procedures in the field of orthopedic and trauma surgery. Patients who underwent elective surgery were significantly more likely to file complaints than emergency patients."* [14]

PART 2, PERSONAL ASPECTS

An accusation of malpractice, regardless of whether or not substandard care was involved, creates a cascade of responses in you that may have significant psychological, cognitive, spiritual, and physical effects, known collectively as "***litigation stress."***

According to the American Pyschological Association, stress effects on the body, stress affects all body systems, including the musculoskeletal, respiratory, cardiovascular, endocrine, gastrointestinal, nervous, and reproductive systems.

There is a quote I use, both in our field of Surgery/Critical Care with educating others, as well as my law enforcement and military endeavors, "Stress is a matter of perception, and perceptions can be changed through the training process."[15] How many of us have formal education and or training, either as a resident or attending on legal matters (malpractice)?

In our residency program at Valleywise Health Medical Center/Creighton University-Phoenix, our students, residents, and staff were given an educational opportunity most had never experienced. It was published in the *ACS Bulletin* February 1, 2017**: The Art of the Deposition: Teaching Residents About Medical Liability.** I encourage you to read this to use at your institution. Preparation for dealing with the stressors experienced after you are notified about a malpractice suit brought against you pays dividends.

"A Trauma Surgeon On Trial" By Errington C. Thompson, MD, FACS, FCCM. ACS Bulletin January 6, 2018. This is from the introduction: "*It has been more than a year since I sat in the Buncombe County courthouse,*

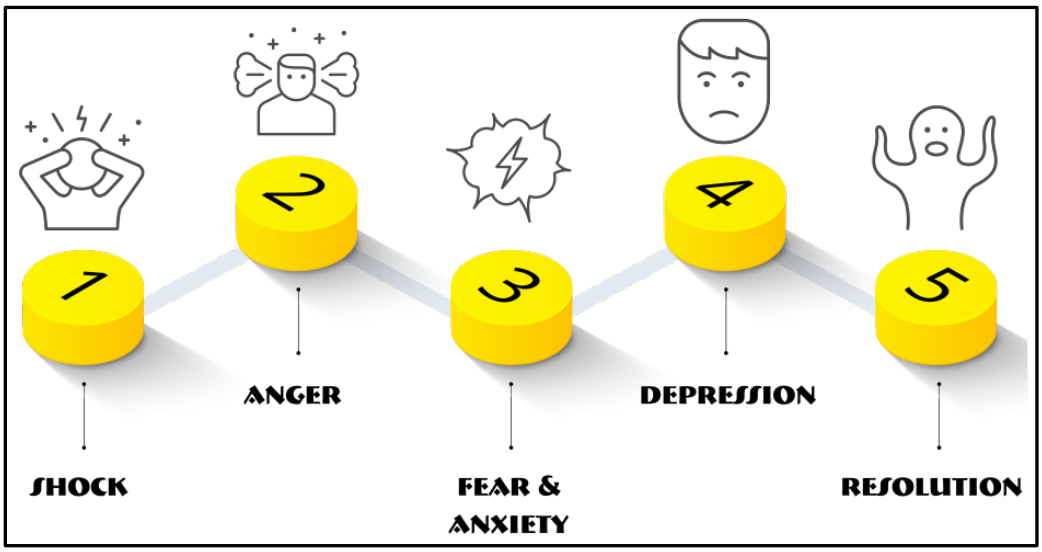
Asheville, NC, with my career hanging in the balance. At the time, the unfairness of it all was overwhelming. Looking back now, I see it as a cautionary tale for other trauma surgeons."

Several articles have been written by and for physicians and or surgeons about surviving malpractice litigation. A company that provides medical professional liability insurance, education, and support for physicians published a great article that I recommend reading. In his article, Dr. Baron offers two common idioms to remember if you are sued for malpractice.[16]

"You are not alone; you will survive."

He also writes, physicians have an exaggerated sense of responsibility. "We will overwork to clear our own conscience that everything has been done and done correctly." "We have an exaggerated sense of self-doubt that we missed something, so we check and recheck." "These traits foster a compulsiveness that makes us good physicians but can backfire on us when we are accused and sued for malpractice." "The loss or grief we feel is sometimes described as a loss of innocence."

These feelings are similar in many ways to the stages of grief first described by Kübler-Ross. The emotions described below do not always happen in a serial or linear manner. The processes of a malpractice lawsuit and our processing of emotions can cause us to cycle through these phases again and again.



The psychological and physiological issues that we can experience are real and can lead to depression, traumatic events, and substance abuse/impairment that can cause a cascade of events that can impact not just you but also your family, friendships, and your career. Loss of confidence, self-esteem, and potential income all contribute to the vicious cycle that you need to break out of, whether with colleague, family assistance, or professional help. We must try to understand this insult to our professionalism, is not 'personal', but professional, and we must try and separate the two to begin to overcome the sense of 'grief' that we feel at being sued.

The odds remain in your favor. Most malpractice cases never make it to the courtroom; only about 7 percent get to the point of a jury trial, according to medicalmalpractice.com. Focus your energy on your defense to give you the best chance of getting the suit behind you and not being on the wrong end of a jury decision.

Another good article on the process and psychological aspects to expect to experience if you end up in court, with solid advice on how to approach the case is *The Verdict Is In: Surviving a Medical Malpractice Trial*, by Michael R. Canady, MD, MBA, CPE, FACS.[17]

Many surgeons could, otherwise, because of our innate personalities, find that mental efforts, time, energies, and talents directed toward planning your defense with your attorney helps mitigate some of the negative stressors you dwell on and have a difficult time getting past, once that subpoena is in your hand. Do consider speaking with a family member (spouse), therapist, or your attorney to help decompress and work through your frustrations. The better you remain mentally sharp, just like preparing and performing a complex surgical procedure, the better prepared your case will be, and, you'll, at least, have the opportunity to feel like you did your true best.

Back to perceptions and stress. Actively participating in seminars, M&M, Grand Rounds, national meetings, etc., can help prepare you for what may have been "unknown" to you, which, in itself, can be a stressor. Knowledge can change it into something that you are familiar with, making it easier to deal with more rationally and more emotionally detached (remaining objective).

I'll end with good news articles from Medscape Medical News > Business of Medicine.[18]

- Doc Sues Patient's Family and Attorney, Wins Case; Should a Physician Sue for Malicious Prosecution?
- Surgeon Beats $27 Million Malpractice Case After Contentious Trial

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HOW TO RECRUIT, RETAIN, AND COMPENSATE IN THE RURAL SETTING

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DEFINING THE PROBLEM

The rural physician shortage is a significant challenge that many regions around the country face. This shortage can have severe implications for the health and well-being of rural populations, leading to limited access to healthcare services. Several factors contribute to the rural physician shortage:

1. Geographic Isolation

- Rural areas are often characterized by vast distances and geographic isolation, making it less attractive for physicians to practice in these regions.
- Limited infrastructure and transportation options may discourage healthcare professionals from choosing rural locations.

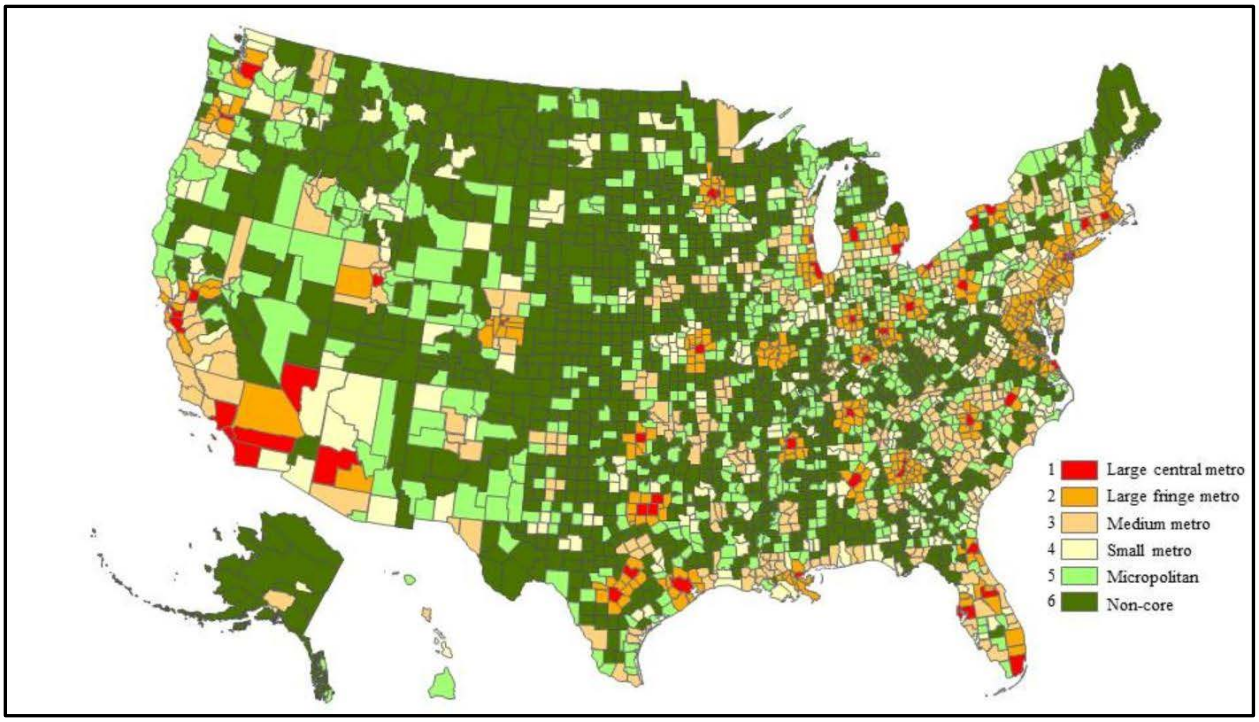

Figure 1. CDC NCHS 2013 Urban-rural Classification Scheme for Counties

2. Workforce Distribution Disparities

- Many healthcare professionals, including physicians, tend to concentrate in urban and suburban areas where there are more job opportunities, amenities, and access to professional networks.
- Rural areas struggle to attract and retain healthcare professionals due to a lack of competitive job markets and opportunities for career advancement.

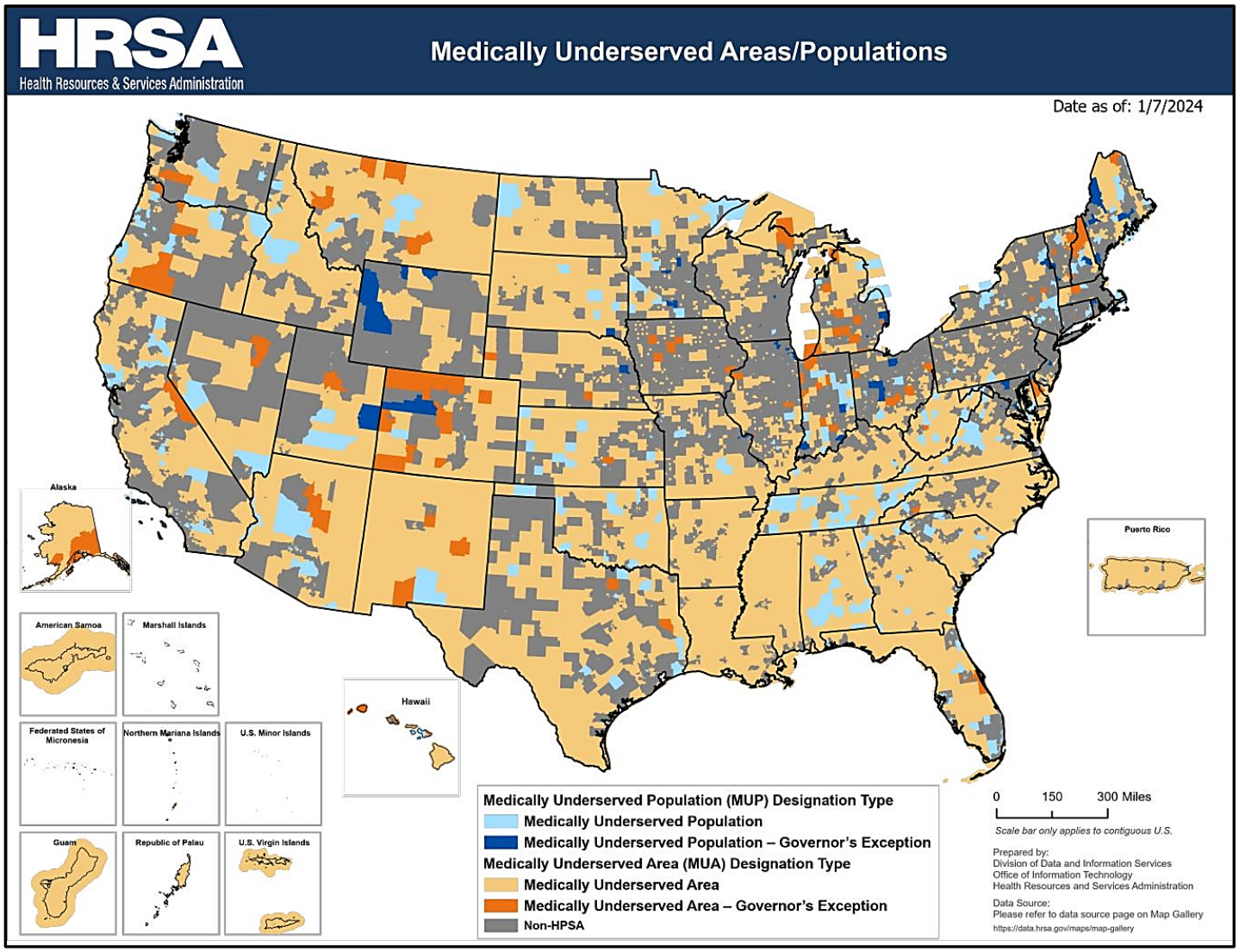

Figure 2. Medically underserved areas using data from HRSA

3. Limited Healthcare Facilities

- Rural areas may have fewer hospitals, clinics, and medical facilities, leading to a reduced demand for healthcare professionals.
- The absence of specialized medical services in rural settings can be a deterrent for physicians seeking diverse and challenging professional environments.

- The volume for many specialties may not be enough to support the region having a full time specialist.
- Healthcare facilities may not have specialized equipment needed for specialty physicians.

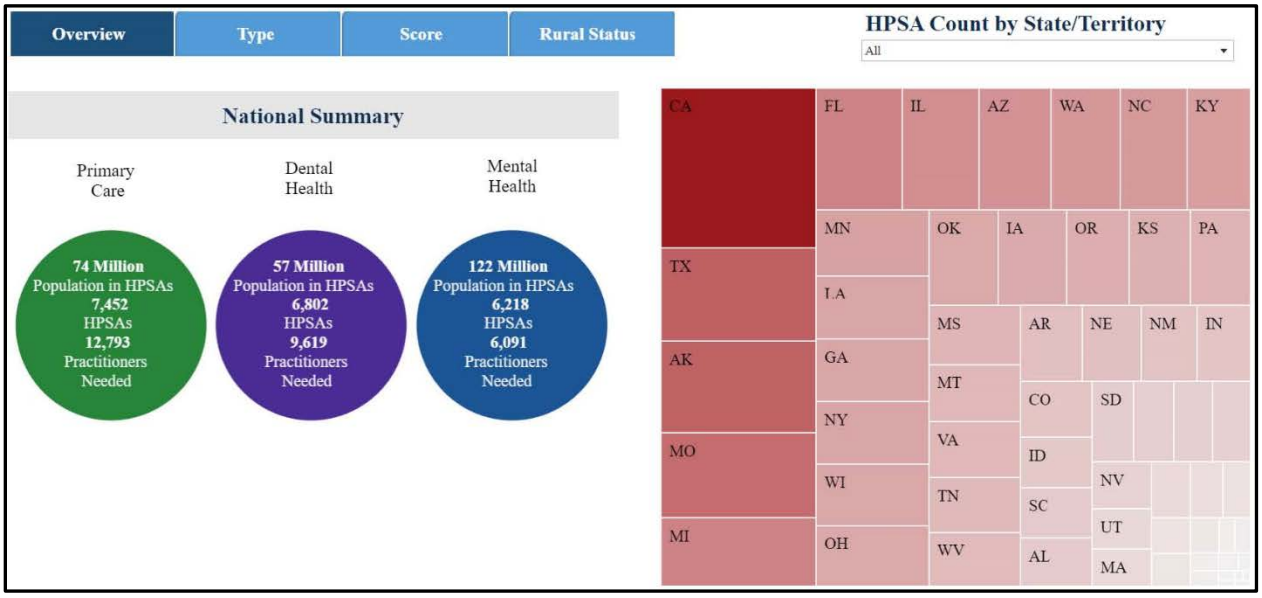

Figure 3. Healthcare Workforce Shortage Areas Tool available on Data.HRSA.gov

4. Economic Factors

- Rural areas often have lower average incomes and fewer economic opportunities, compared to urban counterparts. Physicians may be dissuaded by the potential for lower salaries and limited economic prospects in rural settings.

5. Educational and Training Opportunities

- Limited access to medical education and training facilities in rural areas may result in a smaller pool of locally trained healthcare professionals.
- Physicians who have trained in urban areas may be less inclined to relocate to rural regions.

6. Lifestyle Considerations

- Rural living may not align with the lifestyle preferences of some physicians, especially those who value access to cultural amenities, entertainment, and a variety of recreational activities.

7. Professional Isolation

- Rural healthcare professionals may experience professional isolation due to a lack of colleagues and limited opportunities for collaboration and networking.
- Rural physicians may also not be comfortable working alone in an environment without colleagues / partners backing them up.

POSSIBLE SOLUTIONS

1. Funding

- If hospitals lie within a hospital tax district, this money can be used to supplement physician salaries and other expenses.
- Federal money can be shared through the hospital to the physician.
- Health professional shortage areas (HPSA) and medically underserved areas (MUA) may qualify for grants / student loan forgiveness programs.

2. Rural – Urban Hospital Affiliation

- A formal cooperation between a larger urban healthcare system and a rural healthcare organization can allow for multiple benefits.

    1. Rural hospitals that lie within a HPSA or MUA might qualify for federal or regional funding that may be inaccessible to the large urban counterpart.
    2. The rural hospital can contract the urban health system to provide care lacking in their region. Monies obtained from special status of the rural system and be passed to the urban health system in this manner.
    3. Physicians from the urban health system can work part time, full time, or rotate at the rural health system. This may allow for longevity of the program, as the physicians do not necessarily need to live near the rural health system, as many prefer to live in urban areas close to the urban health system.
    4. An affiliation allows the physician working in the rural area to be backed up by his counterparts or partners currently working at the urban health system. For complex problems or complications, the physician has a built in system for transfers to trusted sources.
    5. It allows a rural hospital to have access to specialized services, without having to have the ability to completely fund it.
    6. An affiliation connects the rural community to specialized care available at the urban hospital that would otherwise be non-sustainable in the rural area.
    7. Establish a high school student program for those interested in practicing medicine or other healthcare activities for a career one day.
    8. Establish a medical student/resident rotation at the rural facility. Some may have an interest in working there after training.
    9. Encourage physicians at the rural hospital to participate in grand rounds at the urban institution.
    10. Offer CME courses.

3. Identifying Candidates

- Military Physicians – They may be accustomed to working in austere environments and can adapt well to civilian life in a rural community
- Missionary Physicians – May have a desire to work in a MUA while still remaining within the confines of the United States.

- Physicians in Government Service – They may already have experience working in rural parts of the United States, such as for the National Health Service or Indian Health Service.
- Academic Physicians – Occasionally interested in leaving academia after a few years for a more lucrative practice.

4. Promoting the Community

- Rural practice may allow a junior attending to advance in their career more quickly than when working in an area saturated with other physicians.
- Some physicians may enjoy the challenge of rural work, which offers a broader spectrum of practice.
- Rural living is amenable for many physicians' families and offers many appealing aspects such as:
    1. small town life
    2. no traffic commuting
    3. small classrooms
    4. safety
    5. low cost of living
- Recruiting physicians originally from a rural area, but practicing or completing training in an urban area, generally yields a higher success rate.
- Candidates with any tie to the rural region will be potential hires, i.e., candidate has family there, spouse is from there, close friend is from there, etc.
- The rural hospital can maintain a list of those who left the area to complete training. Create a program, ""Bringing back our own." Have annual events (holidays work well) that these individuals can attend when back home visiting family. These physicians can be recruited later.

5. Retainement

- Allow physician the chance to "build something."
- The physicians must feel supported while working in an area where they will interact with like colleagues less often. You need to have programs where the physician can feel they are part of something larger than themselves.
- Embrace families. Family events at the hospital help the new physicians' families feel welcomed by the community. These events can be at the rural hospital or even at the urban healthcare counterpart.
- Develop wellness programs and programs to prevent physician burnout.
- Increase rural physician reimbursement over time.
- Know what other competitive hospitals in your region are offering.

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ENTRUSTABLE PROFESSIONAL ACTIVITIES: READY OR NOT, HERE THEY COME

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Our current general surgery residency training model can be considered "time-based" education, whereby trainees are assigned to a particular rotation (e.g. colorectal surgery) for a standardized length of time (with little to no flexibility), with the assumption that upon completion of that fixed time, the learner has achieved the educational goals. Because learners vary in starting ability and learning rate, standardizing the training time necessarily results in variable outcomes. Some residents will not be ready for unsupervised practice, whereas others were ready long before the end of the rotation. In contrast to time-based education, *competency-based education (CBE)* seeks to ensure that all graduates achieve a minimum degree of clinical competency, regardless of the amount of time required. Although CBE is logistically more difficult to implement, the standardization of educational outcomes ensures a consistently higher quality product (graduating surgeons). American surgical training is actually rooted in CBE through Halsted's training model. Trainees were only allowed to graduate when Dr. Halsted deemed them to be competent. Now, as back then, the goal is to train learners to be ready for safe and unsupervised practice.

An important step in the transition to CBE is to reframe our assessments in terms of competency. Currently, to take the qualifying board examination, the resident submits a case log listing the number of specified operations, along with their role (e.g. trauma laparotomy, chief resident). However, these self-reports do not convey any information about whether or not the trainee can safely perform this operation unsupervised. Assessments about competency are usually determined by clinical competency committees (CCC) based on end-of-rotation summative evaluations which can vary in quailty and often contain irrelevant or vague statements ("good kid." "works hard," "superstar," "technical skills below expected level of training.") Without rigorous faculty training and standardization to a shared mental model, current assessments are limited by issues such as *rater leniency bias* (generosity error), *range restriction* (using only part of the entire scale), *halo effects* (subjective bias based on irrelevant information), poor discrimination between trainees, low intra- and interrater consistency, and lack of documentation of deficits, amongst others.[1]

HISTORY AND DESCRIPTION EPAs

In the modern era, the concept of *Entrustable Professional Activities (EPAs)* can be traced to an editorial by Ten Cate in 2005[2] and is conceptualized as **real-world physician tasks that constitute what clinicians do in their daily work and that require specific training and yield measurable outcomes**.[3,4] EPAs are the activities that we perform that define our specialty.[5] Importantly, EPAs focus on *outcomes of care*, in contrast to the current competencies and milestones, which focus on trainee abilities.[5] Awarding entrustment to a trainee effectively verifies that the learner can safely and effectively perform that professional activity without supervision.[5]

Trust implies a "willingness of one party to be vulnerable to the actions of another party, based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party."[6] There are at least three different kinds of trust:[6]

- ***Presumptive trust*** – based solely on credentials (for example, diplomas, institutions, or letters of support) without any prior interactions with the trainee and is usually present by default.
- ***Initial trust*** – based on first impressions. Influenced by trainee variables and supervisor variables (ex: trust propensity). Vulnerable to halo effects and self-fulfilling prophecy effects.
- ***Grounded trust*** – based on prolonged and repeated interactions with the trainee and used to justify decisions to empower the trainee to act without supervision

EPAs seek to formalize the numerous informal entrustment decisions that we already perform on a daily basis in clinical settings with our learners. For example, "I trust this resident to close the skin while I go out to talk to the family," or "I trust the fellow to teach the ICU resident how to insert a central line," or "I don't trust this intern to obtain informed consent for this elective esophagectomy." Entrustment decisions are made along a continuum ranging from observation only to teaching others.

At this level, the trainee has permission to:	Explanation
1. Observe (limited participation)	At early stages, it is the privilege of the trainee to be present and observe what he or she will be expected to do at the next stage. Gradually, the trainee can start doing parts of the activity.
2. Act with direct supervision	At this stage, the trainee may carry out the full activity independently. The supervisor is in the room watching and can intervene or take over at any time deemed necessary. Part of this level can include coactivity – that is, the activity is done collaboratively with a senior individual.
3. Act with indirect supervision	At this stage, the trainee may carry out the full activity independently without a supervisor present in the room but available within minutes. It includes the availability of supervision by telephone for advice.
4. Act without supervision (practice-ready)	At this stage, the trainee may carry out the full activity with no supervisor available on short notice. The trainee reports post hoc the same or next day. This stage gradually extends into fully and mature unsupervised practice, but as long as the trainee is in training, he or she acts under "clinical oversight" or "backstage supervision." This stage marks the grounded trust that should allow for certification to take full responsibility for an entrustable professional activity.
5. Provide supervision	This level is awarded when a senior trainee may act in a supervisory role for more junior trainees. The trainee must have shown the ability to provide supervision.

Table I. Levels of Entrustment[6]

Entrustment decisions can be *ad hoc* (applies only to that particular instance), or they may be *summative* or *structural* (establishing formal recognition that from now on, the trainee may do this activity at that level of supervision).[1,7] Structural entrustment decisions can even be acknowledged with a *statement of awarded responsibility (STAR)*.[7] The requirements for structural entrustment are more rigorous than ad hoc entrustment and may be reserved only for program directors or clinical competency committees. **Operative skills alone, however, are not sufficient for psychomotor EPAs, as a technically proficient resident may lack the clinical judgment to perform an activity without supervision.** However, once standardized, accepted, and granted, STARs can be used for certification and privileging of the trainee across rotations and institutions. For example, a PGY3 resident may begin their trauma surgery rotation equipped with STARs awarded from prior rotations: exposure and isolation of the femoral vessels (STAR awarded by vascular surgeon), midline laparotomy (STAR awarded by hepatobiliary surgeon), and performance of bedside ultrasound (STAR awarded by intensivist). However, based on a recent thoracic surgery rotation, he/she can begin a video-assisted thoracoscopic surgery only under direct supervision. Knowledge of these prior entrustment decisions can help direct a supervisor's educational efforts.

To better understand the factors affecting a decision to entrust a trainee with a professional activity, Choo et. al. conducted a deductive qualitative analysis, interviewing internal medicine residents and attendings to yield 535 discrete factors which were then organized and mapped to thematic domains: Trainee, Supervisor, Task, and Systems.[8] Some factors are modifiable (ex: trainee honesty, medical knowledge, and communication), whereas most other factors are not modifiable.

Trainee	**Supervisor**	**Task**	**Systems**
Characteristics specific to the trainee that either promote or discourage trust	*Characteristics specific to the supervisor that either promote or discourage trust*	*Details or characteristics of the task that encourage or impede contacting the supervisor*	*Unmodifiable factors not related to personal characteristics or knowledge of trainee or supervisor*
Confidence and overconfidence	Approachability	Case complexity	Workload
Accountability	Clinical attributes	Family / ethical dilemma	Institutional culture
Familiarity / reputation	Institutional obligation	Interdepartmental collaboration	Clinical experience of trainee
Honesty	Experience and expertise	Urgency / severity of illness	Level of training
Leadership	Observation-based evaluation	Transitions of care	Duty hours / efficiency pressures
Communication	Educational obligation	Proximity of colleagues and support staff	Philosophy of medical education
Specialty		Team culture	Patient expectations for attending involvement
Medical Knowledge		Time of day	
Recognition of limitations			

Table II. Factors affecting Entrustablity[8]

Several additional interesting findings from this study deserve mention: 1) Trainee absences, even those complying with workhour regulations, negatively affected the attendings' willingness to entrust; 2) Some degree of uncertainty was encouraged by attending physicians because it signals trainee insight into the limitations; 3) The interactions on the first day/call night together had outside influence on future entrustment decisions; 4) Medical knowledge was the most important clinical skill-related factor in entrustment decisions.[8]

In a similar study, Sandhu et. al., interviewed general surgery residents and faculty from 41 institutions to identify behaviors that influence entrustment leading to operative autonomy.[9] From the attending perspective, preoperative behaviors (e.g. going to clinic, knowledge about patient, "patient ownership," resident conference presentations, and insight to call the attending if there are complications before operating) strongly influenced entrustment decisions. Teman et. al., conducted an anonymous online survey of 116 attending surgeons, and the factors most commonly listed as important to increasing resident autonomy in the operating room were the resident's observed clinical skill and the attending's confidence level with the operation. Factors cited as preventing resident autonomy included focus on patient outcomes, emphasis on efficiency, and expectations of attending involvement by both hospital and patients.[10] In another study, Torbeck et. al., first asked PGY4 and PGY5 to list general surgery faculty who give the most and least autonomy in the operating room. These surgeons were then interviewed to identify behaviors and techniques from the attending perspective.[11] Not surprisingly, the main "triggers" for granting autonomy included familiarity and trust in the resident's capabilities, evidence of resident advance preparation, and the attending's self-confidence in fixing resident mistakes. The main cited factors for not granting autonomy include a deep sense of moral obligation to the patient, lack of advance preparation by the resident, and early-stage career of the attending.[11]

In a study of anesthesia trainees, Weller et. al., asked supervisors to score their trainees using the conventional system and also using a new assessment system ("trainee independence score") focused on the need for direct or more distant supervision.[12] Compared to the conventional score, the new supervision score was significantly more reliable; a reliability coefficient of 0.7 was obtained with only nine assessments with the trainee independence score, and this coefficient was unachievable, even with 50 conventional score assessments. The supervision score also overcame the leniency bias. Several trainees were identified that required closer supervision than expected for their year of training, while none were identified using the conventional score system. Others have also reported that compared to conventional scoring systems, EPA-based assessments provide better discrimination of clinical performance and may better identify learners at the low- and high-end extremes.[13]

To summarize, the current literature suggests that compared to our current assessment framework, **using a supervision/entrustment assessment framework is valid and improves reliability, efficiency, and earlier detection of lagging learners.** Trainees are more apt to interpret the feedback as progress towards safe independent practice, rather than comparison against their peers, and residents are more comfortable receiving lower scores when framed in entrustment terms.[13] Residents seeking to increase the likelihood of being granted autonomy should focus on modifiable factors, such as increasing medical knowledge, preparing for the operation, willingness to acknowledge uncertainty, and recognize limitations.

IMPLEMENTATION INTO GENERAL SURGERY RESIDENCY TRAINING

EPAs have already been implemented in other countries (Netherlands and Canada) and within other specialties in the United States (Pediatrics and Internal Medicine). In 2016, the American Board of Surgery (ABS) formally committed to the EPA framework.[14] An initial retreat with broad stakeholder representation resulted in a comprehensive list of approximately 50 potential EPAs. Next, a smaller group met to identify 20-30 EPAs that could accurately represent the scope of general surgery and, finally, a small leadership group arrived at five EPAs that represent undeniable core skills of a general surgeon:

1) Evaluation and management of a patient with inguinal hernia
2) Evaluation and management of a patient with right lower quadrant pain
3) Evaluation and management of a patient with gallbladder disease
4) Evaluation and initial management of a patient with blunt or penetrating trauma
5) Provide general surgical consultation to other health care providers

The first four EPAs describe evaluation and management of a symptom or narrow disease process and are evaluated across the preoperative, intraoperative, and postoperative phases of care; the final EPA about providing general surgical consultation to other providers focuses on a broad professional activity that requires important essential nontechnical skills like professionalism and communication.[3]

Next, the ABS partnered with the American College of Surgeons (ACS), the Accreditation Council for Graduate Medical Education (ACGME) Surgery Review Committee, and the Association of Program Directors in Surgery (APDS) to conduct a pilot study to determine the feasibility and utility of EPAs in general surgery residency training.[14]

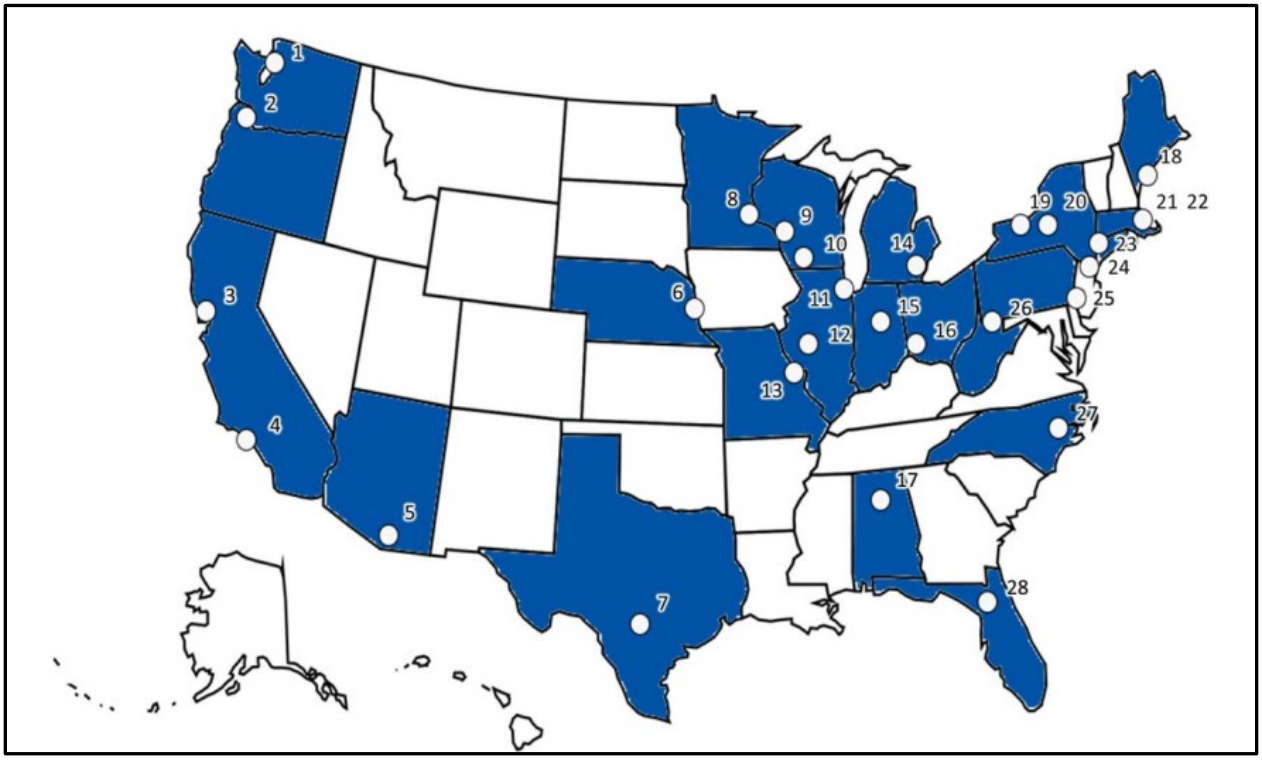

Figure 1. Sites participating in the General Surgery EPA Pilot Study

Twenty-eight sites (representing a variety of geography, size, and community- vs. university-based programs) participated in this pilot study, which ran from July 2018 to June 2020. Each site was assigned two EPAs to implement and given freedom to determine the best method of collecting EPA microassessments. Some used physical cards, and others used electronic methods. A total of 6,272 formative microassessments were collected, and 1,763 summative entrustment ratings were assigned to 497 unique residents. Each microassessment took an average of 45 to 90 seconds to complete. The average number of observations for entrustment was 3.24 (SD 3.61), with a median of 2 (IQR 3). Several important findings should be highlighted. First, PGY1 residents were mostly entrusted at the level of direct supervision, and PGY5 residents were entrusted mostly at unsupervised practice or teaching others. Aside from the consultation EPA, the degree of entrustment progressively increased by resident level. This supports the content validity of the EPAs. Second, there was significant overlap between PGY4 and PGY5 residents in the degree of entrustment, suggesting that residents at both senior levels can achieve readiness for unsupervised practice. The investigators concluded that widespread implementation of EPAs across a variety of general surgery programs is possible and provides meaningful data about the ability of graduating chief residents to perform core activities of general surgery without supervision.

Given the success of the pilot study, the ABS Board of Directors recommended to continue moving forward with implementing this competency-based assessment framework incorporating EPAs into general surgery training in a phased approach.[3] However, many questions remain. For example, how many EPA microassessments are required to make a summative entrustability assessment of an individual resident? How many EPAs are necessary to encompass the entire scope of general surgery? If a resident is applying to a sub-specialty fellowship program (such as cardiothoracic surgery) and plans to restrict their future scope of practice, do they need to achieve practice-readiness for all EPAs in general surgery to graduate?

CONCLUSIONS

EPAs are a form of competency-based workplace assessment that formalize the numerous entrustment decisions that we are already performing on a daily basis. With emphasis on measured outcomes and safe, independent practice, EPAs use nonpejorative language to determine the level of supervision required for a trainee to perform a particular professional activity. A pilot study has demonstrated feasibility in a range of practice settings, and the American Board of Surgery has committed to moving forward with widespread phased implementation in general surgery training.

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ACUTE CARE SURGERY ADVANCED PRACTICE PROVIDERS

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Over the past two decades, advanced practice providers (APPs) have become an essential piece of the healthcare workforce. The Accreditation Council for Graduate Medical Education (ACGME) restrictions on resident work hours, instituted in 2003, are cited as a driving force behind the increased utilization of nurse practitioners (NP) and physician assistants (PA). Even prior to academic medical centers experiencing the effects of resident work hour restrictions, trauma centers without resident support found that a trauma surgeon/physician assistant model was beneficial. In 1996, our Level II trauma center at Poudre Valley Hospital hired our first PA and immediately noted a marked improvement in our team's bandwidth and efficiency. Several studies have since codified our initial impression.

In 1998, The Hurley Medical Center, a Level II trauma center, reported their use of physician assistants was associated with more timely throughout, with a 43% decrease in transfer time to the operating room, 51% decrease in transfer time to the intensive care unit, and a 20% decrease in transfer time to the floor. The overall length of stay decreased 13%, and the length of stay for neuro-trauma intensive care unit patients decreased 33%. They summarized APPs contribute significantly to trauma services, enhancing efficiency, improving patient outcomes, and providing a viable alternative in settings where surgical residency programs are not available. The authors described the APPs role as multifaceted, encompassing patient care, service organization, and working practices.

In 2014, the trauma service at Vanderbilt reported on preventable delays occurring after the ACGME resident work hour restrictions combined with a 16% increase in their patient census. They noted the need for their nurses to have a consistently accessible provider for the coordination of care. They instituted the use of an experienced acute care nurse practitioner (ACNP) on their stepdown unit five days a week for a pilot program. Collins et al. reported that after adding the ACNP, the average LOS decreased to 6.4 days from 7.2 days, a 0.8-day reduction. Per patient, there was a $9,111.50 savings in hospital charges, for a reduction of $27.8 million dollars in hospital charges over the 12-month pilot program. A confidential survey administered to attending physicians showed that 100% agreed that a nurse practitioner in the stepdown area was beneficial and helped throughput. Dayshift nurses were surveyed, and 100% agreed or strongly agreed that the ACNP was knowledgeable about the patient's plan of care, was experienced in the care of trauma patients, and improved patient care overall.

In the context of orthopedic trauma care, APPs have been shown to be of significant benefit. The recently published American Academy of Orthopedic Surgeons and the Orthopedic Trauma Association guidelines for the provision of orthopedic trauma services recommend the inclusion of hospital-based APPs. Althausen et al. published a retrospective case review 1104 trauma patients with orthopedic injuries. They reported that inclusion of an orthopedic trauma PA results in patients being seen 205 minutes faster ($P = 0.006$), total Emergency Room (ER) time decreased 175 minutes ($P = 0.0001$), and time to surgery improved 360 minutes ($P = 0.03$). Operating room parameters were minimally improved, but

postoperative DVT prophylaxis increased by a mean of 6.73% (P = 0.0084), postoperative antibiotic administration increased by 2.88% (P = 0.0302), and there was a 4.67% decrease in postoperative complications (P = 0.0034). Average length of stay was also shown to have decreased by 0.61 days (P = 0.27). Additionally, they found that APP billing collections from patient care covered 50% of their costs for salary and benefits. Although the APPs collections do not cover their costs, the indirect economic and patient care impacts were clear. They concluded that by increasing emergency room pull through and decreasing times to Operating Room (OR), operative times, lengths of stay, and complications, their existence is clearly beneficial to hospitals, physicians, and patients, as well.

Eaton et al. reported their multicenter (8 academic centers) electronic survey results on *service based* APPs at 8 academic centers. Respondents agreed that APPs decrease workload (88%), length of stay (72%), contribute to continuity (92%), facilitate care coordination (87%), enhance patient satisfaction (88%), and contribute to best practice/safe patient care (83%). Fewer agreed that APPs contribute to resident education (50%) and quality improvement (QI)/research (36%). Although 93% acknowledged variability in the APP level of function, 91% reported trusting their clinical judgment.

Katz et al. examined the role APP's play in performing diagnostic and therapeutic procedures in acute care settings, the education provided in PA and NP programs, and the additional post-graduate training required to achieve competency and comfort in performing procedures. Several APP surgical and critical care fellowships have been created over the past 10 years to address these additional training needs. Our experience at the University of Colorado is the completion of an APP surgical fellowship markedly decreases the time required in orientation and proctoring of newly hired APP's.

Woo et al., in an effort to find the best available evidence on the impact of advanced practice nursing on quality of care, clinical outcomes, patient satisfaction, and cost in emergency medicine and critical care settings reported their literature review from 2006-2016. Fifteen studies were included in their analysis. They concluded that the involvement of NPs in emergency and critical care improved the length of stay, time to consultation/treatment, mortality, patient satisfaction, and provided cost savings.

Halter et al. published a systematic review of the English literature published from 1995-2017. A narrative synthesis was undertaken. 5472 references were identified and 161 read in full; 16 were included, with seven from emergency medicine, six from trauma and orthopedics, two from hospital based internal medicine, and one from mental health. Of note, none from geriatrics, an area of APP specialization that many trauma services throughout the United States are exploring to meet the needs of the escalating number of elderly trauma patients. All studies were observational, with variable methodological quality. In emergency medicine, trauma, and orthopedics, the addition of APPs reduced waiting and throughput times. Analgesia prescribing, operative complications, and mortality outcomes were variable. In internal medicine, outcomes of care provided by APPs and doctors were felt to be equivalent.

Hollenbeck et. al., in a 2023 retrospective study using national Medicare claims, reported the number of advanced practice providers increased by 13%, from 6713 to 7596 between 2010 and 2016. The largest relative increases occurred in general (46.9%) and urologic (27.6%) surgical practices. The year after an advanced practice provider was added to a surgical practice, the odds of complications were 17% and 16% lower at 30- and 90-days post-procedure, respectively. Additionally, 90-day readmissions were 18% less likely, and length of stay was 0.33 days shorter (a 7.1% reduction). Average 30-day and 90-day episode spending was $1294.73 and $1427.76 lower, respectively ($p < 0.001$). The authors concluded that the addition of advanced practice providers to single-specialty surgical groups is associated with improvements in surgical outcomes and access, and called for future work to clarify a best practice for APP deployment.

Trauma/Acute Care Surgery continues to face workforce challenges. Between physician shortages, an increase in the complexity of the patients cared for, and the marked increase in the number of geriatric fall patients, the addition of advanced practice providers and the expansion of their roles has been a vital part of the solution to address these current challenges. APP's working alongside surgeons deliver high-quality collaborative and patient-centered care to patients with time-sensitive surgical needs. They are an integral member of the team responsible for gathering patient history, performing physical exams, ordering and interpreting diagnostic tests, and coordinating various aspects of patient care. Moreover, APPs actively participate in surgical procedures, assisting surgeons by providing intraoperative support, as well as independently performing a variety of bedside procedures (i.e. arterial line and central line placement, chest tube insertion and removal, and laceration repair). APPs have become vital in ensuring smooth transitions of care from admission through to recovery. APPs perfectly fit the role of the charismatic and knowledgeable guide, guiding our acute care surgery patients through their journey. The inclusion of APPs on trauma and acute care surgery teams clearly enhances the provision of care for acutely injured and critically ill patient and is acknowledged and supported by the Eastern Association for the Surgery of Trauma, the Society of Trauma Nurses, and the American Association of Surgical Physician Assistants. Advanced practice providers have emerged as indispensable members of the Acute Care Surgery service. The transformation of healthcare delivery through effective utilization of the workforce may alleviate the impending rise in demand for health services. However, this evolution has not been without challenges and objections. To affect sustainable change, we must be well versed in explaining the proven benefits to our hospital administrators and remain cognizant and prepared to address the challenges and basic objections raised by skeptics.

BENEFITS OF INTEGRATING APPs IN ACUTE CARE SURGERY

Improved patient flow and expedited care

APPs contribute significantly to streamlined patient management, leading to prompt treatment initiation and reduced time to surgery. Their ability to perform critical tasks, such as triaging patients, conducting initial assessments, ordering diagnostic tests, performing minor procedures, and coordinating multidisciplinary care helps expedite patient care, reduces wait times, and optimizes patient flow through the hospital, ensuring necessary interventions are delivered in a timely manner.

Enhanced continuity of care

APPs can provide consistent and continuous care throughout a patient's hospital stay. Working closely with the surgeons, consultants, and other healthcare providers, they reduce communication gaps and help prevent unnecessary delays and duplication of services, ensuring seamless care coordination and appropriate follow-up. APPs can promptly identify deteriorating patients, anticipate complications, and initiate appropriate interventions. This proactive approach and attention to detail augments patient outcomes, resulting in reduced morbidity and mortality rates. APPs become the trusted patient and family advisor, providing continuous support and guidance.

Reduced length of hospital stay

With their specialized training and expertise, APPs can efficiently handle post-operative care and manage common complications. By closely monitoring patients, APPs can identify issues early and intervene promptly, reducing failure to rescue and potentially reducing the length of hospital stays and associated costs. Additionally, their collegial partnership and daily communication with discharge planners help avoid delays in disposition by early identification of obstacles to discharge.

Increased access to care

Acute surgical conditions often require urgent intervention to prevent complications and improve patient outcomes. In an era marked by limited healthcare resources and growing patient demands, the integration of APPs in acute care surgery can significantly enhance healthcare access and availability. APPs help meet the growing demand for care by providing assistance in patient management and treatment and improving access to the surgical team. This is especially relevant in facilities without resident support, in underserved areas, or during periods of provider shortages. By working collaboratively with surgeons, APPs can help expand the capacity of the healthcare team and ensure timely access to surgical services.

Improved efficiency and cost-effective resource utilization

APPs can effectively manage a range of acute conditions, allowing for efficient allocation of healthcare resources. They can perform and interpret tests, prescribe medications, and develop treatment plans, freeing up valuable surgeon time for more complex cases. This utilization of the APP skillset al.lows surgeons to focus on higher-level surgical interventions. APPs can assist ACS surgeons in the operating room, perform minor procedures, manage post-operative care, and assist with discharge planning. By providing appropriate follow up care in the clinic setting, APPs can help reduce unnecessary admissions, avoidable readmissions, and, thus, overall cost of care.

Improved patient satisfaction

With the increasing demands on the healthcare system, patients often face challenges in obtaining timely appointments and spending extended periods in emergency departments. APPs play a crucial role in reducing patient wait times, streamlining the care process, and improving communication with patients and their families. Their presence results in enhanced patient-provider interactions, as APPs can often spend more time with patients, addressing their concerns, and providing education on their condition. These factors contribute to increased patient satisfaction and improved overall healthcare experience. Our APPs are the welcoming host, making patients feel valued, and making certain the patient's needs are promptly addressed.

Facilitating research and innovation

By actively participating as a member of the acute care surgery team, APPs can contribute to clinical research, quality improvement initiatives, and the implementation of evidence-based practices. Compliance with clinical practice guidelines is also improved. APP's involvement helps drive innovation, improves outcomes, and contributes to the overall advancement of surgical care.

There is no arguing that the inclusion of APP's as a vital member of the acute care surgery team has provided tremendous benefits to our patients and to our program, but implementation of the role was not without several challenges that had to be addressed.

CHALLENGES OF INTEGRATING APPs INTO AN ACS SERVICE

Scope of practice

Clearly defining the APP's scope of practice within the ACS team is crucial. Monitoring that they work within their scope and continuously building their individual competencies without encroaching on the roles of others are essential.

Team dynamics

Integrating APPs within an established ACS team requires adjustments to team dynamics and workflows. A culture of effective communication and collaboration among team members is essential for successful integration.

Training and resources

Providing adequate training and educational resources to the APPs to promote their clinical competence and professional growth is required. Instilling the philosophy of life-long learning is a key to addressing this challenge. Ongoing education and support are necessary to keep them up-to-date with the ever changing field of medicine.

Legal and regulatory considerations

Adhering to the legal and regulatory requirements for practicing APPs is often complex. This requires proper credentialing, supervision, and privilege delineation, which is often confusing, with significant variability across different health systems and between different states.

Resistance to change

Resistance from surgeons or other healthcare providers who may feel threatened or uncertain about the role of APPs on the ACS team can be a challenge. Overcoming such resistance requires communication and demonstration of the value of APPs to the team.

Overall, integrating APPs on to an ACS team can bring several benefits, but it requires careful planning, effective communication, and ongoing support to address the associated challenges.

OBJECTIONS

The five basic objections to the utilization of ACS APPs must also be understood, and surgical leaders need to be well versed in how to address them.

Objection 1: Competence and Training

One common concern regarding ACS APPs is their level of competence and training compared to physicians. While it is true that physicians undergo extensive education and training, APPs also undergo rigorous academic programs, followed by certification and additional fellowship training and specialization (i.e. APP surgical or critical care fellowship training). Additionally, APPs often have years of experience in various healthcare settings before pursuing advanced practice roles. Collaborative approaches involving both physicians and APPs within ACS teams can ensure comprehensive care by capitalizing on a collective knowledge base.

Objection 2: Collaboration and Supervision

Another objection revolves around the perceived lack of collaboration and supervision in the relationship between ACS APPs and surgeons. To address this, implementing a collaborative practice model is paramount. Effective models incorporate daily morning reports, evening handoff rounds, regular group meetings, clear clinical practice guidelines and protocols, and a culture of interdisciplinary teamwork. The surgeons and APPs on the team should work together to define clear roles, responsibilities, rules of communication, and lines of supervision. This work fosters mutual trust, leading to seamless and harmonious coordination of care.

Objection 3: Continuity of Care

Concerns may arise that APPs, due to their nature of working shifts, lack the ability to provide continuity of care to patients. However, this objection can be mitigated with staggered scheduling and a well thought out care delivery model that facilitates effective handoffs and communication. Proper documentation, shared decision-making, and standardized protocols enable the smooth transition of patient care between providers, ensuring that patients receive consistent and well-coordinated care throughout their healthcare journey.

Objection 4: Patient Safety and Outcomes

Critics worry that utilizing ACS APPs may compromise patient safety and outcomes. However, numerous studies have demonstrated that patient outcomes improve with the addition of APP's to the care team. By adhering to evidence-based protocols, participating in continuous education and training, and maintaining a culture of safety, ACS APPs contribute to high-quality care delivery while ensuring patient safety and positive outcomes.

Objection 5: Cost-effectiveness

Skeptics argue that incorporating ACS APPs into the healthcare system may not be cost-effective. However, extensive cost analyses have consistently shown that utilizing APPs can reduce healthcare costs without compromising patient care quality. Lower salaries in comparison to physicians, improved patient throughput, decreased length of hospital stay, decreased complications, decreased readmissions, and increased efficiency are all contributing factors to the overall cost-effectiveness of implementing ACS APPs.

In conclusion, the provision of acute care surgery necessitates a coordinated and multidisciplinary approach to promote optimal patient outcomes. ACS APP's are skilled professionals with unique expertise that enhances and optimizes our care delivery. By effectively addressing the five basic objections, including competence and training, collaboration and supervision, continuity of care, patient safety and outcomes, and cost-effectiveness, surgical leaders can ensure this transforming addition to our care delivery model is sustained. As the demand for acute surgical services continues to grow, the role of APPs will only become more vital in delivering efficient, comprehensive, and patient-centered care.

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STANDING WITH UKRAINE: COLLABORATIONS TO SUPPORT FRONTLINE SURGEONS

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In the year and a half since Russia's full-scale invasion, Ukraine has recaptured 54 percent of occupied territory, while Russia still occupies 18 percent of the country. Ukraine's 2023 offensive has achieved minor territorial gains, but the frontlines have remained stable for almost a year. Both sides have dug in, making breakthroughs increasingly difficult, and the number of military casualties has climbed to an estimated half a million. Meanwhile, Russia continues to bombard Ukrainian cities and blockade its ports, and Ukraine has stepped up drone attacks on Russian ships and infrastructure. Since January 2022, Ukraine has received nearly $350 billion in aid, including $77 billion from the United States, though it warns of donor fatigue. Fighting and air strikes have inflicted nearly 22,000 civilian casualties, while 5.1 million people are internally displaced, and 6.2 million have fled Ukraine. 17.6 million people need humanitarian assistance.

In June 2023, Ukraine launched a much-anticipated counteroffensive, attempting to break through Russian defenses eastward in Donetsk province, including around Bakhmut, and southward in Zaporizhzhia province, which forms the "land corridor" to Crimea. Zelenskyy said Ukraine aims to liberate 18 percent of occupied territory in the current phase, but Ukrainian forces have met stiff resistance and suffered heavy losses against hardened Russian defensive positions, air superiority, and minefields. Nonetheless, Ukraine has made small gains on the ground and has stepped up attacks on bridges to Crimea, Russian ships, and buildings in Moscow. As 2024 begins, the Ukrainian advance has stalled. Russian troops are now pushing to recapture ground lost since Kyiv's counteroffensive began in early June.

Kyiv has scored small but symbolic successes along the banks of the Dnieper River – known as the Dnipro in Ukrainian. The waterway has served as a formidable demarcation line between Ukrainian and Russian forces since the liberation of Kherson in November 2022.

But in the second half of 2023, Kyiv's troops began expanding cross-river raids into a sustained presence in settlements along the Russian-occupied east bank. Ukrainian forces there have not broken out of their small riverside footholds, but Moscow's troops have also proven unable to dislodge them. What is both intriguing and depressing is that the battle in Ukraine is a retreat into trench warfare and horrific casualty generating

scenarios of the World War One. The technologic advancements have created an exponentially more lethal battlefield dominated by drones, cruise missiles, hypersonic weaponry, and aerial weaponry capable of delivering a level of destruction previously unwitnessed. The conflict between Ukraine and Russia is emerging as a war of attrition, and one that may linger on for many years, with an ongoing sobering (and horrific) burden of suffering and loss of lives (civilian and military). By June 2023, the UN Human Rights Office recorded nearly nine thousand civilian deaths and over fifteen thousand civilian injuries since Russia's full-scale military invasion of Ukraine on February 24, 2022. The violence has internally displaced nearly six million people and forced nearly eight million to flee to neighboring countries, including Moldova and Poland, a NATO country where the United States and other allies are helping to accommodate the influx of refugees.

A U.S. intelligence report revealed Russia has lost approximately 315,000 troops to death or injuries since the invasion of Ukraine began two years ago, putting Russia's losses staggeringly higher than the Kremlin has reported and far outpacing Ukrainian losses. In September 2022, Russia's Ministry of Defense confirmed that 5,937 Russian soldiers had been killed in combat. It also claimed 61,207 Ukrainian soldiers had been killed and 49,368 wounded by this point. In December 2023, the Ministry updated its claim of Ukrainian military casualties to 383,000 killed and wounded. In addition, the DPR confirmed that by 22 December 2022, 4,163 of their servicemen had been killed and 17,329 wounded. Subsequently, leaked US intelligence documents cited that Russian forces suffered 110,000 casualties by 28 February 2023. It is uncertain what the true casualty counts are on either side of the conflict – but the cost of this conflict is most certainly staggering. It also, once again, harkens to a magnitude and brutality of armed conflict not witnessed since the trenches of the Battle of the Somme (WWI) or the Beaches of Normandy.

THE MEDICAL CONSIDERATIONS

The conflict in Ukraine has reset the medical paradigms established over the two decades of US military presence in Iraq and Afghanistan. The conditions and casualties generated in Ukraine are dramatically different than those encountered over the last half century of conflict(s) involving US fighting forces (Vietnam, Desert Storm, Operation Iraqi Freedom, Operation Enduring Freedom, and Operation Freedom's Sentinel). How is the current conflict in Ukraine Medically different?

1) The mechanism of wounding
2) The provision of forward care at the edge of the battle area
3) Medical evacuation
4) Definitive care at the Role IV/V level

Mechanism of Wounding

Combat operations in the Middle East over the last two decades were highlighted by the signature wounding mechanism of the Improvised Explosive Device (IED). IED's result in devastating injuries but in limited numbers confined to the immediate area of detonation. The conflict in Ukraine has witnessed a retreat to the classical artillery onslaught at greater distances with weaponry that delivers a much greater energy and destructive power. As a result, the generation of casualties (both military and civilian) is increased in an exponential fashion.

Medical Evacuation

Since the Korean conflict, US forces have traditionally enjoyed air superiority, which, in turn, assures the ability to rapidly evacuate casualties from the forward area. The introduction of rotary wing evacuation via the Bell H-13 Sioux (the iconic MASH helicopter) was possible only in the condition of "safe to fly." Over the next seventy years, US medical evacuation policy was assembled with the assumption that rotary wing (and subsequently fixed wing) evacuation was (relatively) safe and possible. As a side note, it is interesting that the concept of the "Golden Hour" was never actually validated with peer reviewed evidence until 2009 when Secretary of Defense Robert Gates mandated that all US military casualties would be evacuated and arrive at a surgically capable facility within sixty minutes of the call for evacuation (the 9-line call). The analysis of the data demonstrated that the percentage killed in action fell from 16% to 10%, and the case fatality rate dropped from 14% to 8% following the effective implementation of the clearing policy.[1]

The conflict in Ukraine demonstrates a remarkable and significant retreat into history with respect to medical evacuation. All forms of transport, air and ground, remain disputed and significantly hazardous. Since the first month of conflict, medical evacuation has been by ground vehicles or litter borne/man carried evacuation. In addition, the provision of field care has grown increasingly hazardous, as Russian forces have targeted field medics, ambulances, and forward aid stations with artillery and drone attacks. It is estimated that the average life expectancy of a Ukrainian medic is 16 days at the forward area. The sum effect of battlefield conditions is that the mortality rate for both civilians and military members who die in the field (Killed in Action) before evacuation to surgical care is undoubtedly much higher than experienced by US forces in recent conflicts. As a result, those hardy enough to survive the delay in evacuation to eventually arrive to medical care are less severely injured and have already passed a survival test.

Definitive Care In Country

The author was privileged to participate in the provision of casualty care during a sponsored trip to Lviv Ukraine in May of 2022. A total of twelve teams of surgeons, nurses and medics from US Trauma centers rotated on a two-to-four-week basis into the country to assist in providing trauma care. The Global Surgical and Medical Support Group (GSMSG) was the sponsors. Many members of the faculty of Trauma, Critical Care and Acute Care Surgery participated in these rotations. The funding for this project has not been sustained, and the rotation is no longer available. The opportunities to volunteer in provision of casualty care in Ukraine are currently fragmented and limited secondary to the strategic and political considerations of the ongoing conflict.

The American College of Surgeons has endorsed the teaching of ATLS in the Ukraine. In addition, the ASSET course has been taught in Poland to Ukrainian physicians and medics who have travelled to participate in these courses. At present, a requisite for teaching these ASSET courses is that the individual must be a federal employee. Interested parties should contact Dr. Mark Bowyer at the Uniformed Services University to volunteer.

The author spoke with the director of GSMSG in preparation for this presentation. Currently, the opportunities for medical teams rotating into the country in support of medical operations is limited to (retired) special forces medics who are familiar with operating in an unsecured environment. Full surgical support/teaching teams, such as those rotating in 2022, are currently not funded or rotating into the country. The hazards posed to medical personnel increase with geographical location, moving to the eastern regions of the country.

The Brigham and Women's Hospital has forwarded small teams to teach ATLS and Stop the Bleed over the past two years. These are especially important programs but remain limited in scope and opportunities.

A FINAL NOTE FROM THE AUTHOR

It remains a privilege to participate in both Trauma and Acute Care Surgery (Dr. Mattox's conference) as well as to provide trauma care in unique situations such as Ukraine. Having deployed on multiple occasions as a member of the US military and then subsequently as a supported ACS surgeon by Global Surgical and Medical Support Group, I have been blessed with many unique experiences. Reflecting on the past and now current experience in Ukraine, I can only hope that there is resolution soon that will end the continued, and costly human experience and devastation. I would be reluctant, under current conditions, to recommend volunteering services to the country, especially in the Eastern conflict area. The conditions that I was privileged to travel under were secured by experienced retired military special forces personnel and medical professionals who mitigated risks as much as possible. Unfortunately, these same support systems are no longer available in any robust or reliable form. There are many small and dedicated singular efforts attempting to provide care for the Ukrainian people and their brave military forces. I am familiar with some, but not all of them. I would recommend caution in volunteering for these efforts in country, especially in the Eastern region, without an abundance of caution and research.

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SESSION 14

ANNUAL TRAUMA DEBATE

Moderator: Ali Salim

Wednesday, April 17, 2024

8:30 – 9:30 AM
Palace Ballrooms 1-2
Palace Tower
Emperors Level – 4th Floor

8:30 – 9:00	**Resolved: Just Say Yes to All Trauma Transfers** • **Carlos V.R. Brown, MD, FACS - Pro Position** • **Matthew J. Martin, MD, FACS , FASMBS - Con Position**
9:00 – 9:30	**Resolved: Intraosseous is the safe, effective method for initial administration of fluid and blood** • **Zaffer A. Qasim, MBBS, FRCEM, FRCPC (EM) Edic - Pro Position** • **Bellal A. Joseph, MD, FACS - Con Position**
9:30 – 10:00	**Break & Visit Exhibits** **Palace Ballroom 3, Palace Tower** **Emperors Level – 4th Floor**

ANNUAL TRAUMA DEBATE
Resolved: Just say yes to all trauma transfers

Carlos V.R. Brown, MD, FACS

PRO POSITION

Professor of Surgery
Chief, Division of Acute Care Surgery
Dell Medical School
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Patients are transferred from hospital to hospital because someone needs help. For whatever reason, the transferring facility cannot care for the patient that has arrived at their hospital. This may be due to lack of resources, lack of personnel, lack of specialty, etc. This monograph will review the ins and outs of hospital transfers and discuss how to transfer a patient more effectively and more efficiently, from either the transferring or receiving facility.

The Emergency Medical Treatment and Labor Act (EMTALA) was enacted by Congress in 1986 as part of the Consolidated Omnibus Budget Reconciliation Act (COBRA) of 1985 (42 U.S.C. §1395dd). EMTALA was designed to prevent hospitals from transferring uninsured or Medicaid patients to public hospitals without, at a minimum, providing a medical screening examination to ensure they were stable for transfer. This law requires Medicare-participating hospitals with emergency departments to screen and treat the emergency medical conditions of patients in a non-discriminatory manner to anyone, regardless of their ability to pay, insurance status, national origin, race, creed or color.

Hospitals have three main obligations under EMTALA:

1. Any individual who comes and requests must receive a medical screening examination to determine whether an emergency medical condition exists. Examination and treatment cannot be delayed to inquire about methods of payment or insurance coverage. Emergency departments also must post signs that notify patients and visitors of their rights to a medical screening examination and treatment. Signage that could deter patients from seeking emergency care could be an EMTALA violation.
2. If an emergency medical condition exists, treatment must be provided until the emergency medical condition is resolved or stabilized. If the hospital does not have the capability to treat the emergency medical condition, an "appropriate" transfer of the patient to another hospital must be done in accordance with the EMTALA provisions.
3. Hospitals with specialized capabilities are obligated to accept transfers from hospitals who lack the capability to treat unstable emergency medical conditions.

The Mayo Clinic has come up with seven tips for safe and efficient trauma transfer (https://www.mayoclinic.org/medical-professionals/trauma/news/7-tips-for-a-safe-and-efficient-trauma-patient-transfer/mac-20479361), and these include ensure patient stability, call early, make

certain a transfer is required, provide organized information, choose appropriate mode of transfer, try to avoid a double transfer, and trust the process.

1. Ensuring Patient Stability

Ensuring patient stability is likely the most important component of patients transfer and is one of the EMTALA requirements. Stabilizing interventions should be focused on the primary survey, with particular attention to airway, breathing, and circulation. Patients with a compromised airway or altered mental status should be intubated. Any pneumothorax or hemothorax should be treated with a tube thoracostomy. Hemodynamically unstable patients should have the cause of instability identified and treated. The most common causes of hemodynamic instability in trauma patients include hemorrhagic shock, tension pneumothorax, cardiac tamponade, blunt cardiac injury, and neurogenic shock. Patients in hemorrhagic shock should have IV access and should be resuscitated. If the transferring facility has blood available, then the patient should receive a balanced or 1:1:1 resuscitation. If no, or minimal, blood is onsite, then crystalloid may be the only option and vasopressors may be required to maintain hemodynamics during transfer.

The sources of potential traumatic hemorrhage include the chest, abdomen, pelvis, extremities, and external. Thoracic hemorrhage will most often present as a hemothorax on CXR, and this should be treated with a chest tube. Most causes of thoracic hemorrhage can be treated with chest tube alone and do not require a thoracotomy. However, if surgery is required, then the patient should be transferred as soon as possible after chest tube placement. Obviously, abdominal hemorrhage cannot be managed in the emergency department, and if there is no surgeon available and willing to perform a laparotomy, these patients should be transferred immediately. Pelvic fractures can be easily seen on plain pelvic x-ray, and any patient with a pelvic fracture should be placed in a pelvic binder. Extremity fractures and dislocations should be reduced and splinted. Finally, any external hemorrhage should be controlled with wound closure or packing with hemostatic agents.

Tension pneumothorax must be treated prior to transfer, and while it may be temporized with a needle thoracostomy, a tube thoracostomy should be placed as definitive treatment. Cardiac tamponade should be diagnosed using the pericardial view of the FAST exam. If present, tamponade should be treated prior to transfer as it will lead to cardiac arrest without intervention. While the definitive treatment for cardiac tamponade requires surgical intervention, with either a sternotomy or thoracotomy, these may not be feasible, and the tamponade should be temporized prior to transfer using pericardiocentesis. Blunt cardiac injury may be difficult to diagnose prior to transfer but may be suspected based on abnormal EKG findings, and more information about cardiac function may be obtained using the pericardial view of the FAST exam. Arrhythmias should be treated, and vasopressors may be needed to support cardiac function prior to transfer. Neurogenic shock can be treated with fluid resuscitation and vasopressors to address any hypotension and bradycardia.

While stabilizing the patient is essential prior to transfer, just as important is avoiding unnecessary interventions or tests that may delay the transfer. In particular, no tests should be performed that will not change management at the transferring institution. The best example of this is obtaining any CT scans. In general, unstable patients should not be taken for a CT scan, and this obviously applies to an unstable awaiting transfer. The only imaging an unstable trauma patient needs prior to transfer are a chest x-ray, FAST exam, and AP pelvis. Taking this patient to CT is unnecessary and potentially unsafe.

2. Call Early

Calling early is the most important first step in an efficient trauma transfer. Communication with the receiving facility should start the moment you know you cannot take care of the patient in front of you and need a transfer. This may occur after the EMS encode, upon patient arrival, during the

primary survey, or anytime along the course of care. This should be direct physician-to-physician communication and should be a two-way discussion, rather than a directive or argument from either facility.

3. Make Certain a Transfer is Required

Two suboptimal situations after a trauma transfer are the patient who is discharged from the ED of the receiving facility and a patient whose care is deemed futile and dies soon after arrival. The patient who is discharged from the ED likely did not need to be transferred. This can be mitigated with a discussion over the phone or telemedicine to reassure the transferring facility that the patient can be safely discharged. Futility is a more complicated and nuanced decision, that, once again, should be determined through a thoughtful conversation between physicians at the transferring and receiving facility. There also might be an opportunity to involve experts in futility, such as a palliative care team, to aid in the discussion.

4. Provide Organized Information

The transmission of information from the transferring facility to the receiving facility is paramount to a safe and effective transfer. The transferring physician should have thoroughly evaluated the patient and have all necessary information readily available during the transfer discussion. This will include information on the history of the event, findings of the primary and secondary survey, lab results, imaging information, and reason for requesting transfer. Similarly, the physician at the receiving facility should listen carefully to the presentation and should avoid arguing about the transfer or asking for unnecessary labs or additional imaging prior to transfer.

5. Choose the Appropriate Mode of Transfer

The decision to transfer by ground or air is complex and multifactorial. Depending on the situation, ground transport may provide basic life support, advanced life support, or, in some cases, a mobile intensive care unit (MICU) ambulance. Air transport can be fixed-wing or rotor-wing, depending on local resources. One consideration when transferring from a rural area is that using a local ambulance to provide the transfer may disrupt EMS care for that region for a long period of time during the transfer process.

6. Avoid a Double Transfer

Similar to patients who are discharged from the ED or subsequently die after futility has been determined, is the situation where transfer occurs twice because the initial facility receiving the transfer does not have the capability to handle the initial transfer, so the patient must be transferred a second time. This issue stems from poor communication on the front end of a transfer. The transferring facility needs to be clear about the reason for transfer and the receiving facility needs to be sure it can provide the care requested. This situation can occur when facilities transfer to their preferred facility, rather than to the closest appropriate facility. Factors other than what is best for the patient should not be part of the decision to transfer.

7. Trust the Process

Everyone involved in the transfer of a patient has to trust everybody has the patient's best interest in mind, and there is no hidden agenda or secondary gain behind the transfer. The transferring facility needs help, and the receiving facility can provide the care needed. It is as simple as that.

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ANNUAL TRAUMA DEBATE
Resolved: Be selective!!

Matthew J. Martin, MD, FACS, FASMBS

CON POSITION

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Los Angeles County + USC Medical Center
Professor of Trauma and Acute Care Surgery
Division of Upper GI and General Surgery
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"Empathy is biased, pushing us in the direction of parochialism and racism. It is shortsighted, motivating actions that might make things better in the short term but lead to tragic results in the future. It is innumerate, favoring the one over the many."

- Paul Bloom*, Against Empathy*

BLUF (BOTTOM LINE UP FRONT):

1. Locoregional and national trauma systems have shown a clear benefit to trauma patients in reducing morbidity and mortality.
2. These trauma systems involve a network of Level 1 thru 4 trauma centers that provide trauma care and a hub and spoke model of each major trauma center (Level 1 and 2) and their referring centers (both lower level trauma centers and non-trauma centers).
3. The improved outcomes with trauma systems are the result of triaging patients to the RIGHT PLACE that can deliver the RIGHT CARE as quickly as possible.
4. Many trauma surgeons/centers have advocated an approach of “Just Say Yes” or “Accept Everything” regarding trauma transfer requests, with the rationale of “doing the right thing for the patient.” However, this often does not help or may even significantly harm some patients.
5. The word, “triage,” implies assessment of the patient and then transferring patients based on their need, which is defeated by the “ACCEPT EVERYTHING” approach.
6. The majority of trauma transfers are usually appropriate, but there is a significant subgroup of patients who do not require transfer to a higher level of care based on their injuries (if any) or the care and follow-up are available locally.
7. Patients with isolated minor head trauma and a negative CT scan do not require transfer or inpatient management. Patients with isolated rib fractures and good pain control do not require transfer.
8. Most patients with tiny and clinically silent intracranial contusions or hemorrhage can be safely managed at any Level 2 and most Level 3 centers, per the Brain Injury Guidelines (BIG) criteria.

9. Additional reasons for inappropriate transfer may include lack of insurance or type of insurance, patient intoxication and/or behavioral issues, need for spine clearance despite negative imaging and exam, simple orthopedic or maxillofacial injuries with specialists available locally, etc.
10. Risks/adverse effects of inappropriate transfers include injuries during transport, overtreatment, unnecessary radiation exposure/repeat imaging, excessive hospital bills and financial toxicity, utilization of scarce resources, increased healthcare costs, job dissatisfaction by trauma team members, decreased trainee interest in trauma, loss of a tiered local trauma system, and many others.

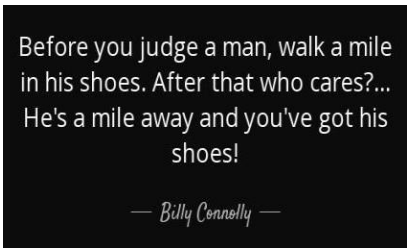
SOME RECENT ACTUAL CASE EXAMPLES

- Intoxicated patient with simple facial lacerations transferred to Level 1 trauma center due to "behavioral issues"
- Patient with closed femur fracture and no insurance transferred to trauma center while similar patient from the same facility with insurance admitted and repaired by ortho
- Patient s/p ground level fall with reported "subarachnoid hemorrhage" by referring physician. Actual radiology report is "tiny radiolucency, likely artifact," and patient discharged shortly after transfer without admission
- Young healthy patient s/p bicycle crash with two isolated left-sided rib fractures and no other injuries, transferred because local team "not comfortable" managing this. Discharged with oral pain medications shortly after arrival
- Patient in low speed MVC with normal head CT, transfer to level 1 trauma center requested to manage "concussion"
- Patient s/p CPR for cardiac arrest due to myocardial infarction and admitted to cardiac ICU at outside hospital. Transfer to level 1 trauma center requested due to the presence of three rib fractures from the CPR
- Patient DNR/DNI with nonsurvivable intracranial bleed requested transfer to Level 1 trauma center to "pronounce death"
- Young patient s/p assault with isolated nasal fracture, negative CT scan of cervical spine, and no neurologic deficits, but requested transfer to Level 1 trauma center because the referring physician was "not comfortable clearing the c-spine"
- Patient with stable pelvic fracture and grade 1 splenic laceration accepted for transfer to Level 1 trauma center. Referring facility insisting on transfer via helicopter due to the fact that an ambulance wouldn't be available for 2 hours
- Patient in low speed MVC with negative pan-scan, trauma transfer requested because "patient is on Xarelto"

A TALE OF TWO TRANSFERS

1. 37 yo patient in motorcycle crash with pelvic fracture, open humerus fracture, grade 3 splenic laceration. Initial evaluation at community hospital and transferred to Level 1 trauma center 60 miles away. Undergoes splenic angioembolization and pelvic fixation and discharged to rehab after 7-day hospital stay.

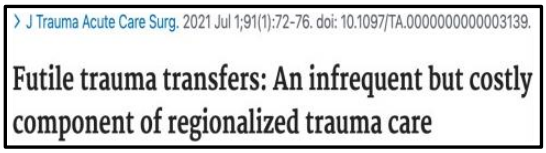
2. 25 yo patient s/p assault to face and arm, found to have an isolated nasal fracture and a small forearm laceration that is repaired. Transferred to Level 1 trauma center 180 miles away and has no indication for admission. He now has no clothes, no friends/family who can drive him home, and he is uninsured. He is admitted overnight to facilitate setting up transportation home. He is discharged the following day and has to pay for a bus ticket home. He is unable to go to his job that day and is fired. He later receives a large bill from both hospitals that include trauma activation fees from both centers. He is unable to pay these medical expenses with his minimum-wage salary and ends up declaring bankruptcy.



Our goal should be to maximize the stories like #1 above and to eliminate the stories similar to #2 above. This can ONLY be done through a rational approach to secondary trauma triage for transfer requests and selective acceptance and denial based on considerations of BOTH the likelihood of benefit and the likelihood of harm.

SELECTED DATA AND REPORTS ON TRAUMA TRANSFERS

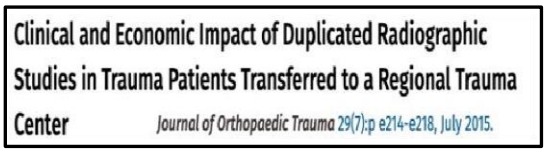
- One-third of transfers had hospital stay < 48 hrs
- 1.5% were “futile” transfers
- Total cost $1.7 million over 2 years at one center
- Estimated cost of $27 million/year nationwide



- 27% of transfers discharged home from ED
- 64% did not require any intervention before d/c
- Commonly hand, face, and ophtho injuries
- Potential role for telemedicine to reduce transfers

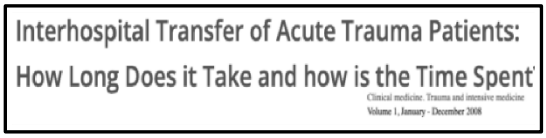
- Prospective 5-month study at Level 1 center
- 52% of transfers deemed “inappropriate”
- Most transfers after-hours and on weekends
- Increased rate of uninsured patients transferred

- 513 transfers over one-year time period
- 48% had duplicated radiographic studies
- Reasons: inadequate data transfer, poor quality or inadequate study, physician preference.



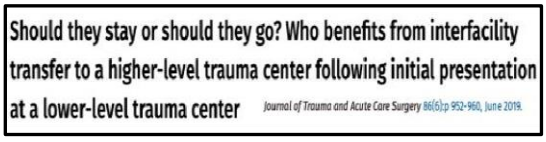
- 1% of all transfers were “futile” – death, hospice, or comfort measures within 48 hrs
- Age, GCS, SBP, and ISS were predictors
- Role for scoring systems and telemedicine

- Multicenter study of trauma transfers over 2 yrs
- Time to transfer request 126 mins, additional 120 mins to transfer
- 60% of transfer time not related to transport



- 4,796 transfer patients (adult and pediatric)
- 24% adult & 49% pediatric overtriaged with no interventions required
- 36% of these were from 5 institutions (out of 72)

- NTDB study of patients at Level III/IV centers
- 57% benefited from transfer, 43% had no benefit
- Specific injury severity factors predict benefit
- No benefit in minimally injured patients



- NTDB study of patients with ISS<10
- Multiple non-injury transfer factors identified
- Increased transfers for: men, children, Black race, nighttime, comorbidities, and Medicaid

Are Patients Being Transferred to Level-I Trauma Centers for Reasons Other Than Medical Necessity? *The Journal of Bone & Joint Surgery* 88(10):p 2124-2132,

- Study of 6,380 transferred pediatric patients
- 27% of transfers classified as “preventable (PT)”
- 29% were discharged from Emergency Dept
- 15% air transport with $19,000 mean charge

Original Article — Journal of Pediatric Surgery

Preventable transfers in pediatric trauma: A 10-year experience at a level I pediatric trauma center

- Statewide analysis, pts with ISS > 15
- Risk-adjusted admission differences by insurance
- Private insurance 1.6 odds ratio of transfer
- Large geographic variation in discrepancies

The extent to which geography explains one of trauma's troubling trends: Insurance-based differences in appropriate interfacility transfer

Journal of Trauma and Acute Care Surgery 93(5):p 686-694,

- Transfers to Level 1 from other Level 1 centers
- 70% for brain, spine, or cerebrovascular injuries
- 76% had specialty coverage at referring center
- Increased costs and length of stay for transfers

Are all trauma centers created equal? Level 1 to level 1 trauma center patient transfers in the setting of rapid trauma center proliferation

Journal of Trauma and Acute Care Surgery 89(5):p 920

"We are the state's only Level I trauma center, but we saw we could not sustain our current course and started talking publicly about other centers' ability to handle lower-level trauma cases,"

Desperate to stop the flow of red ink, Level I trauma center will deny transfers

March 1, 2005

REPRINTS

Desperate to stop the flow of red ink, Level I trauma center will deny transfers

- 5 rural facilities became Level 3 designated
- Transfers reduced from 30% to 22%
- Adjusted odds of transfer reduced by 32%
- No increase in mortality or complications

Rural Level III centers in an inclusive trauma system reduce the need for interfacility transfer

Journal of Trauma and Acute Care Surgery 85(4):p 747-

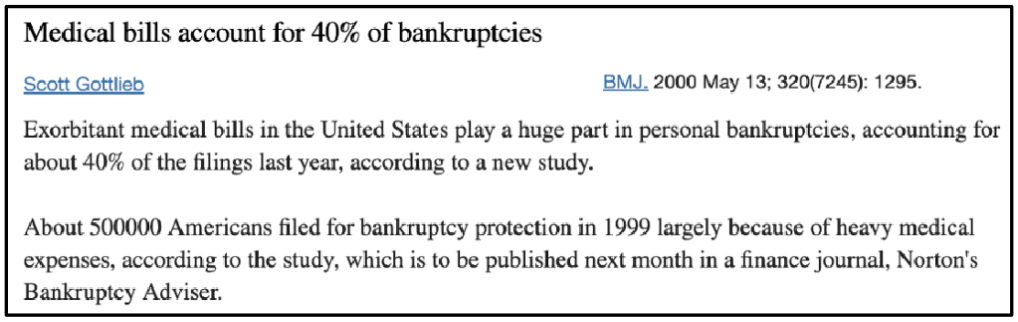
UNNECESSARY TRAUMA TRANSFERS: THE HIDDEN PENALTIES

As trauma surgeons, we rarely are involved or even are aware of the financial impacts of our decisions on our patients. Patients are frequently hit with massive bills for hospitalizations related to trauma, and even those with adequate insurance may face significant deductibles and other out of pocket expenses, out of network charges, and denial of coverage for claims related to an unnecessary transfer. In addition, they often face separate large bills for the interfacility transportation by ambulance, or even higher charges if helicopter transport was utilized. Finally, there is wide variability in the "trauma activation fee" that hospitals charge, and patients who are transferred may be billed for trauma activation fees from both facilities.

100 million people in America are saddled with medical debt

The U.S. health system now produces debt on a mass scale, a new investigation shows. Patients across the country face gut-wrenching sacrifices.

BY NOAM N. LEVEY, KAISER HEALTH NEWS JUNE 16, 2022 2 PM CENTRAL

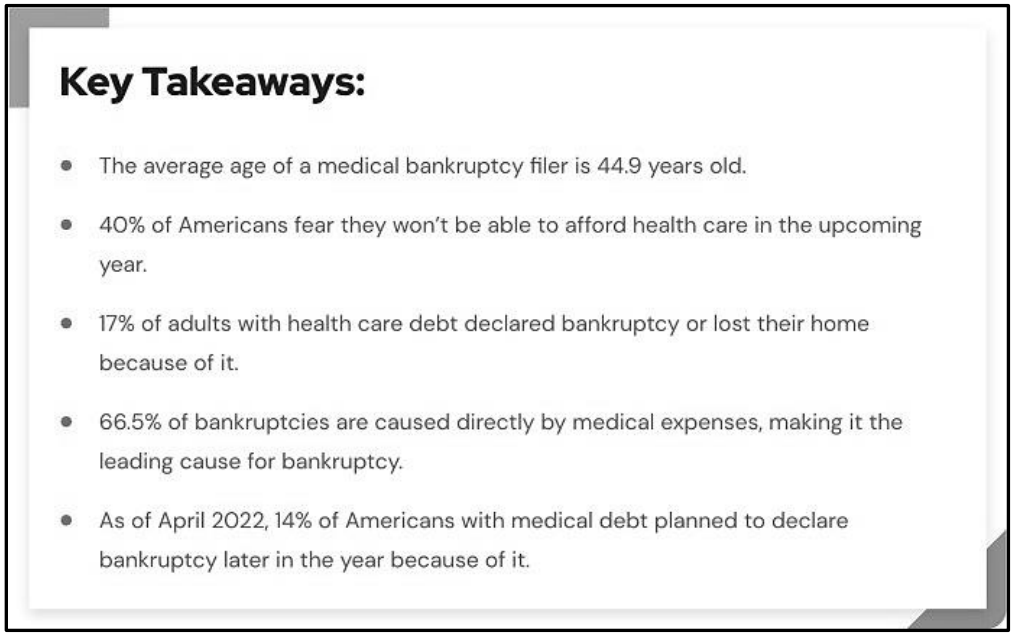


Medical bills account for 40% of bankruptcies

Scott Gottlieb BMJ. 2000 May 13; 320(7245): 1295.

Exorbitant medical bills in the United States play a huge part in personal bankruptcies, accounting for about 40% of the filings last year, according to a new study.

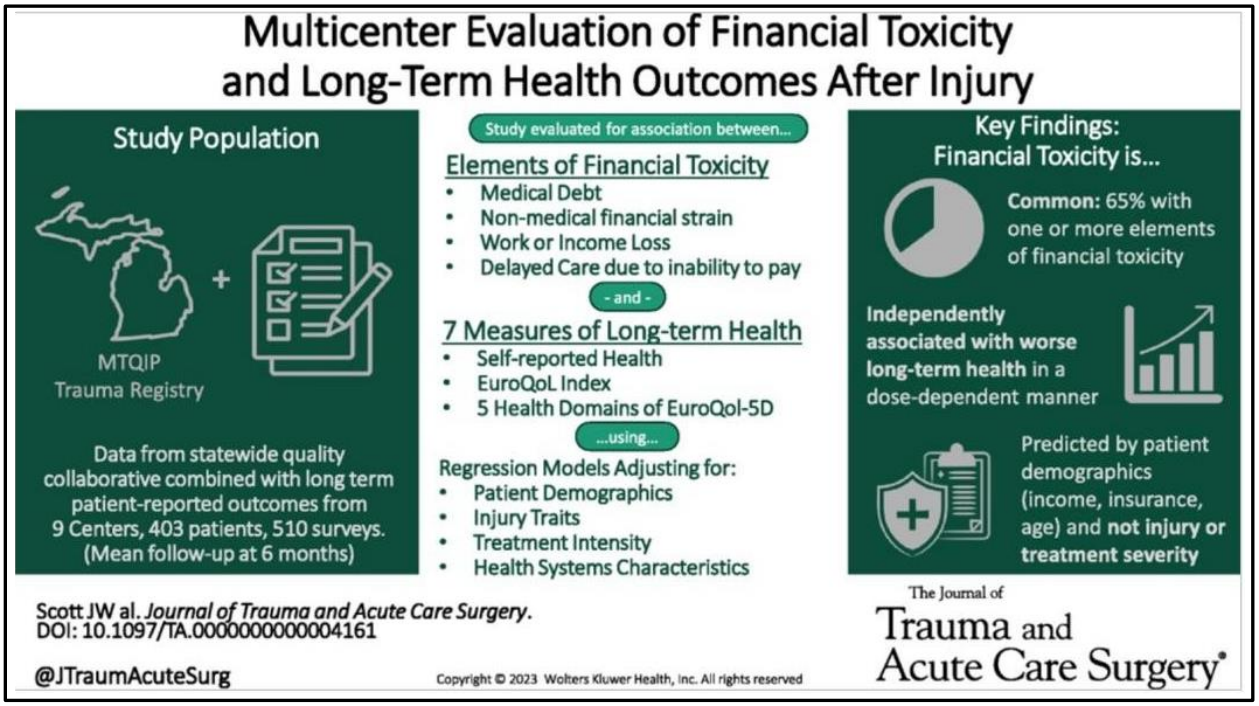
About 500000 Americans filed for bankruptcy protection in 1999 largely because of heavy medical expenses, according to the study, which is to be published next month in a finance journal, Norton's Bankruptcy Adviser.

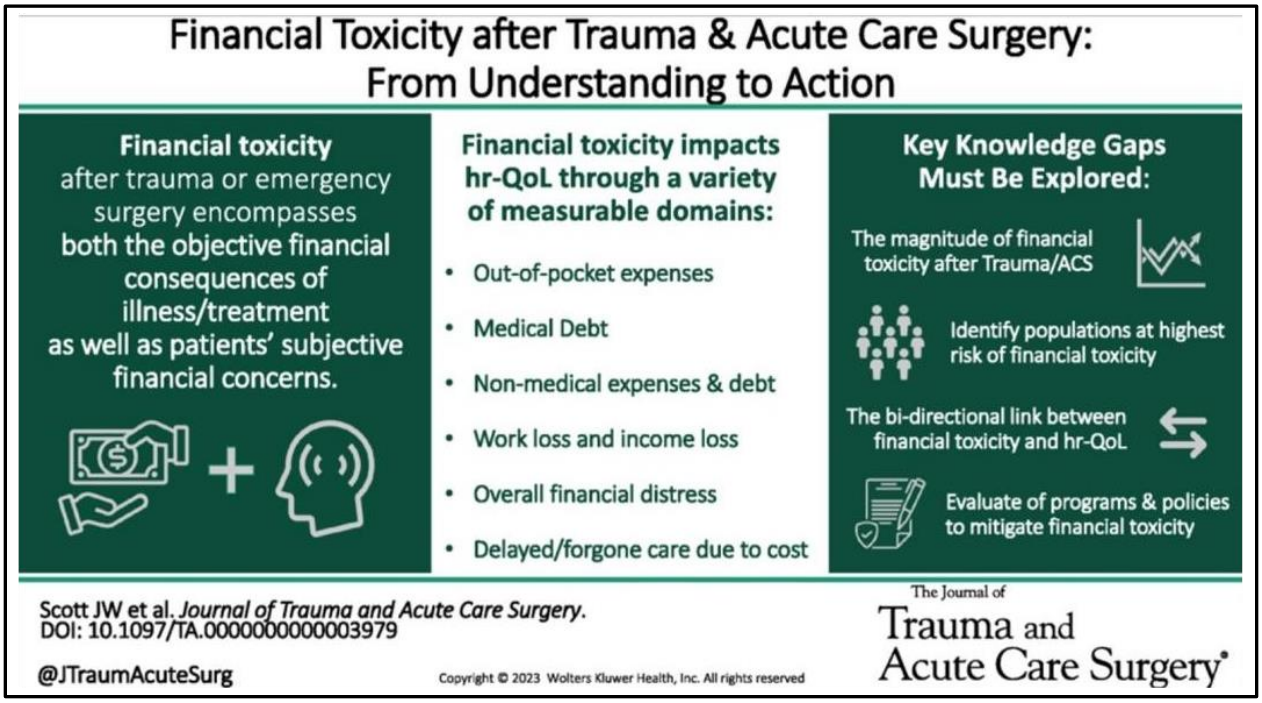


Key Takeaways:

- The average age of a medical bankruptcy filer is 44.9 years old.
- 40% of Americans fear they won't be able to afford health care in the upcoming year.
- 17% of adults with health care debt declared bankruptcy or lost their home because of it.
- 66.5% of bankruptcies are caused directly by medical expenses, making it the leading cause for bankruptcy.
- As of April 2022, 14% of Americans with medical debt planned to declare bankruptcy later in the year because of it.

FINANCIAL TOXICITY AFTER TRAUMATIC INJURY





WHAT CAN WE DO TO REDUCE UNNECESSARY TRANSFERS?

1. Trauma triage and transfer protocols that incorporate evidence-based guidelines on what patient and injury types should be transferred to a major trauma center
2. Mandatory state-wide utilization of teleradiology to allow for review of relevant imaging between the receiving and requesting facility
3. Encouragement and appropriate reimbursement for telemedicine consultation on potential transfer patients
4. Two-way education focused on receiving centers understanding the capabilities and limitations of the referring centers, and on enhancing referring facilities comfort level and care protocols to provide local care for less severe injuries
5. Machine learning and artificial intelligence tools to enhance the speed and accuracy of trauma transfer decisions
6. Insurance and billing reform to reduce costs/charges of transfers, and clear communication and notification of the patient regarding the likely out-of- pocket costs to them for an interfacility transfer
7. Scheduled intermittent reviews of trauma registry data on all transfers and provision of feedback to referring centers on their transfer patterns and outcomes of those transferred patients
8. Establishing clear definitions and metrics for what constitutes a "preventable" or inappropriate" trauma transfer
9. Support for community and rural facilities to become Level III or IV trauma centers
10. **BUT MOST IMPORTANTLY – stopping the "Say Yes to Everything" approach!!! It's not good for centers, systems, trauma team members, or the patients.**

EMTALA: POLICY, PRACTICE, AND RESPONSIBILITIES

"EMTALA" is often invoked during these transfer situations, particularly if there is a disagreement about the need or appropriateness of transfer. The EMTALA rules and obligations are often cited incompletely or incorrectly. Below is a description and definitions of the medical and legal responsibilities under EMTALA.

The Emergency Medical Treatment and Labor Act is a Federal law enacted by Congress in 1986 as part of the Consolidated Omnibus Budget Reconciliation Act (COBRA) of 1985 (42 U.S.C. §1395dd). Referred to as the "anti-dumping" law, it was designed to prevent hospitals from refusing to treat patients or transferring them to charity or public hospitals because they were unable to pay or had Medicaid coverage. EMTALA requires hospitals with emergency departments to provide emergency medical care to everyone who needs it, regardless of ability to pay or insurance status.

Hospitals have three basic obligations under EMTALA:

1. First, they must provide all patients with a medical screening examination to determine whether an emergency medical condition exists without regard for ability to pay for services.
2. Second, where an emergency medical condition exists, they must either provide treatment until the patient is stabilized, or if they do not have the capability, transfer the patient to another hospital.
3. Third, hospitals with specialized capabilities are obligated to accept transfers if they have the capabilities to treat them. Medical care cannot be delayed by questions about methods of payment or insurance coverage.

SOME KEY POINTS

- Does not apply to "stable patients," although definition of stable never laid out
- Transferring facility must "provide all medical treatment within its capacity"
- Patient care during transfer is the responsibility of the REFERRING provider and NOT the receiving provider or hospital
- ANY patient coming to an ED triggers the EMTALA obligations at that facility; thus, an evaluation and management by the referring facility are mandatory, by law
- The criteria and triggers for trauma transfer are frequently vague and widely varying. Establishing universal and widely agreed-upon criteria can help optimize the transfer process while minimizing unnecessary transfers and over-triage (see California state example).

CENTRAL CALIFORNIA REGIONAL TRAUMA SYSTEM

Suggested Criteria for Consideration of Transfer to a Trauma Center

EMERGENCY TRANSFER: Call Trauma Center immediately for immediate acceptance. **Avoid unnecessary studies that would delay the transfer.** Contact EMS Dispatch and request a "**stat**" or "**immediate**" ambulance. The goal is to transfer the patient within 1 hour of arrival.

- **Blood Pressure**
  - **Blood Pressure less than 90**
  - **Labile BP despite 2L of crystalloids**
  - **Patient requires blood products to maintain their blood pressure**
- **GCS**
  - **Less than or equal to 8 or lateralizing signs (intubate)**
- **Penetrating injuries to the head, neck, chest or abdomen**
- **Fracture/dislocation with loss of distal pulses and/or ischemia**
- **Pelvic ring disruption or unstable pelvic fracture**
- **Vascular Injuries with active arterial bleeding**

URGENT TRANSFER: Call Trauma Center and initiate transfer as soon as any of the following are identified. Avoid unnecessary studies. The goal is to transfer the patient less than 4 hours of arrival.

- **Central Nervous System**
  - **GCS deteriorating by 2 during observation**
  - **Open or depressed skull fracture**
  - **GCS less than 14 with abnormal CT scan (not meeting criteria above)**
  - **Spinal cord injury**
- **Chest**
  - **Major chest wall injury with more than 2 unilateral rib fractures**
  - **Bilateral rib fractures with pulmonary contusion**
  - **Bilateral pulmonary contusions**
  - **Wide mediastinum or other signs suggesting great vessel injury**
  - **Cardiac injury**
- **Pelvis/Abdomen**
  - **Intra-abdominal injury confirmed by CT scan or ultrasound demonstrating abdominal fluid**
- **Major Extremity Injuries**
  - **Open long-bone fractures**
  - **Two or more long bone fractures**
  - **Crush injury/mangled extremity**
- **Multi-System Trauma**
  - **Burns with associated injuries (Transfer to a combined Trauma/Burn Center)**
  - **Major injury to more than two body regions**
  - **Signs of hypo-perfusion with a base deficit worse than -6**
- **Other**
  - **Co-Morbid Factors (consider these special circumstances when deciding whether to transfer)**
    - **Adults greater than 55 years of age with significant trauma**
    - **Children less than 6 years of age with significant trauma**
    - **Significant torso injury with advanced co-morbid disease (cardiac or respiratory disease, insulin-dependent diabetes, morbid obesity, or immunosuppression)**
    - **Pregnancy greater than 20 weeks gestation**
    - **End Stage Renal Disease requiring dialysis**

ANNUAL TRAUMA DEBATE
Resolved: Intraosseous is the safe, effective method for initial administration of fluid and blood

Zaffer A. Qasim, MBBS, FRCEM, FRCPC (EM) Edic

PRO POSITION

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Intraosseous (IO) access is a method of delivering fluids and medications directly into the bone marrow, typically the long bones such as the tibia or humerus. This technique is often used in emergency situations, particularly in trauma scenarios where obtaining intravenous (IV) access may be challenging or time-consuming.

While intraosseous access is a valuable tool in trauma and emergency medicine, it is important to note that it is typically considered a bridge to more definitive vascular access. Once the patient's condition stabilizes, efforts should be made to establish traditional intravenous access for ongoing treatment.

TYPES OF IO ACCESS

There are different types of intraosseous access, and the choice of method may depend on factors such as patient age, anatomical considerations, and available equipment. The common types of IO access include:

1. **Manual IO Access:** This involves manually inserting an IO needle into the bone marrow using the thumb or finger to apply pressure. This technique is generally used in emergency situations and is considered a basic method.
2. **Mechanical IO Access:** These devices use a spring-loaded mechanism to insert the IO needle into the bone. The device is typically placed on the bone surface, and upon activation, the needle is quickly and forcefully inserted into the marrow. This method is relatively quick and requires less manual force.
3. **Power Drill Devices:** Some IO devices are designed to be used with a power drill. These devices use a drill to insert the IO needle into the bone marrow, providing a rapid and controlled method of access. This type of IO access is commonly used in both pre-hospital and hospital settings.

SITES OF IO ACCESS

The choice of IO access method and site may depend on the patient's age, the clinical situation, and the preferences or training of the healthcare clinician. In emergency situations, the goal is to establish vascular access quickly and efficiently to facilitate the delivery of life-saving interventions.

1. **Tibial Access:** The tibia is a commonly used site for IO access, particularly in adults and older children. The flat surface of the proximal tibia allows for relatively easy needle insertion.
2. **Humeral Access:** The proximal humerus is often used for IO access in pediatric patients, as well as in adults when tibial access is not feasible. The humeral head provides a suitable location for needle insertion. Care must be taken after needle insertion, as internal and external rotation of the humerus may dislodge or bend the needle.
3. **Sternum Access:** In certain situations, the sternum may be considered as an alternative site for IO access. However, this is less common and may be used when other sites are not accessible. Of note, this site requires a specific type of IO needle.

METHODS OF INFUSION THROUGH IO NEEDLES

1. **Continuous Infusion:** Once the IO access is established, fluids and medications can be administered continuously through the IO needle. This is essential for maintaining vascular access during resuscitation efforts.
2. **Bolus Infusion:** In certain situations, medications or fluids may be administered as a bolus through the IO needle. This can be important for rapidly delivering drugs or fluids in critical conditions. Largely any medication that can be administered through the IV route can be given through an IO.

FLOW RATES THROUGH IO NEEDLES

Larger IO needles generally allow for higher flow rates. Commonly used IO needle sizes range from 15 to 25 gauge, with the smaller gauges providing faster flow rates. The viscosity of the fluids being infused can affect flow rates. Blood and blood products, for example, may have different flow characteristics compared to crystalloid fluids.

Pasley et al. demonstrated the following flow rates with 0.9% saline administered under pressure (300mmHg):

Outcome	Sternum	Humerus	Proximal Tibia
Mean Flow Rate	93.7 mL/min	57.1 mL/min	30.7 mL/min
1st Attempt Success Rate	100%	100%	81%

In comparison to IV catheters of various gauges, the following table demonstrates representative flow rates when fluid is administered to gravity:

Gauge	Approximate Flow Rate to Gravity (mL/min)	Time to Infuse IL (min)
14G	250	4
16G	150	7
Cordis	130	8
18G	100	10
15G Humeral IO	80	13
16G Distal Port Triple Lumen	70	15
15G Tibial IO	70	15
20G	60	17
22G	35	29
18G Prox Port Triple Lumen	30	34

The bone marrow is a highly vascular tissue, and once an IO needle is properly inserted into the bone, it provides direct access to the circulatory system. The marrow contains a network of blood vessels, allowing for the rapid infusion of fluids and medications.

BENEFITS OF IO ACCESS IN TRAUMA

Benefits of intraosseous access in trauma include:

1. **Rapid Access:** Intraosseous access provides a quick and reliable alternative when obtaining traditional intravenous access is difficult or time is of the essence. This is crucial in trauma situations where delays in treatment can have serious consequences. Both Chreiman et al and Dumas et al showed IO access was at least as fast as obtaining peripheral IV access.
2. **Increased Success Rates:** Intraosseous access has high success rates, even in situations where peripheral or central venous access is challenging due to collapsed veins, shock, or other factors. This makes it a valuable option for emergency medical personnel. Both Chreiman et al and Dumas et al showed that even though IO access was at least as fast as obtaining peripheral IV access, IO access was more likely to be successful and allowed for more expeditious resuscitation.
3. **Versatility:** Intraosseous access can be established in a variety of clinical settings, including pre-hospital, emergency room, or critical care environments. It is particularly useful when patients are in extremis and immediate intervention is required.
4. **Fluid Administration:** Intraosseous access allows for the rapid administration of fluids, blood products, and medications directly into the vascular system. This is crucial for resuscitation efforts in trauma cases where maintaining blood volume and pressure is essential.
5. **Pediatric Use:** In children, finding suitable veins for traditional IV access can be challenging. Intraosseous access is often preferred in pediatric trauma cases because it is relatively easier to establish and has proven to be effective in this population.
6. **Stable Access Point:** Once established, intraosseous access provides a stable route for fluid and medication administration. This stability is especially important in situations where patients may be moving or require transportation.
7. **Broader Range of Medication Administration:** Intraosseous access allows for the administration of a wide range of medications, including antibiotics, analgesics, and vasoactive drugs, making it a versatile option for various clinical scenarios.

8. **Training Simplicity:** Training healthcare providers to use intraosseous access is generally simpler compared to advanced venous access techniques. This makes it a valuable option in situations where medical personnel may not have extensive experience or training in intravenous procedures.

DISADVANTAGES OF IO ACCESS

While IO access is a valuable and life-saving technique in emergency situations, it does have some disadvantages and considerations. Here are some of the potential drawbacks of IO access:

1. **Risk of Infection:** IO access involves puncturing the skin and penetrating the bone, which can introduce the risk of infection. Strict aseptic technique is crucial to minimize this risk.
2. **Local Complications:** Local complications at the site of IO insertion may include pain, swelling, and tissue damage. Improper technique or inappropriate site selection can contribute to these issues.
3. **Limited Duration:** IO access is considered a temporary measure. Once the patient's condition stabilizes, efforts should be made to establish more traditional intravenous access for ongoing treatment.
4. **Infiltration of Medications:** Medications administered through IO access may infiltrate into the surrounding tissues, especially if the device is not properly secured. This can reduce the effectiveness of the treatment.
5. **Restricted Fluid Types:** Some IO access devices may have limitations on the types of fluids or medications that can be administered. Compatibility with blood products or certain medications may vary.
6. **Complications with Obesity:** In obese patients, locating suitable sites for IO access may be challenging, and the effectiveness of IO devices can be reduced in patients with increased soft tissue thickness.
7. **Risk of Fracture:** There is a potential risk of bone fracture during IO insertion, especially if excessive force is applied or if there are underlying bone disorders.
8. **Needle Dislodgement:** The IO needle can be dislodged if not properly secured, which may result in a loss of access and require reinsertion.
9. **Professional Training Required:** Proper training is essential for healthcare providers to effectively and safely establish IO access. In situations where personnel are not adequately trained, there is an increased risk of complications.

Despite these disadvantages, the benefits of IO access, such as rapid and reliable vascular access in emergency situations, often outweigh the risks. In critical scenarios where obtaining IV access is challenging or time-consuming, IO access remains a crucial tool for administering life-saving interventions. Clinicians must be aware of the limitations and potential complications associated with IO access and use it judiciously in appropriate clinical situations.

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ANNUAL TRAUMA DEBATE

Resolved: Intraosseous Is the Safe, Effective Method for Initial Administration of Fluid or Blood

Bellal A. Joseph, MD, FACS

CON POSITION

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Access devices used in trauma cases must be able to administer large amounts of blood products promptly and provide flow rates that allow for frequent patient evaluation, enabling therapy adjustment based on specific physiological parameters. Although there has been a recent increase in the use of intraosseous (IO) access for trauma patients, current guidelines recommend IO catheters as a temporary solution until definitive intravenous (IV) access can be established, rather than as a replacement for it.[1,2]

Despite endorsement of use, the efficacy and evidence supporting the use of IO catheters in modern trauma resuscitation are highly debated.[3] Additionally, the lack of comprehensive studies comparing outcomes of patients resuscitated with IO devices versus those with IV catheters is another obstacle preventing the widespread adoption of IO access as a substitute for IV access. In the remainder of this review, we will discuss the major drawbacks of IO access devices that healthcare professionals should consider before considering them as a primary route of access for resuscitation of unstable trauma cases.

INTRAOSSEOUS ACCESS FLOW RATE

Despite the reported higher rates of success in IO vs. IV access among hemodynamically unstable trauma patients [4,5] and non-trauma population[6-8], one of the major concerns regarding the use of IO devices is the inadequate flow rates of blood products.[9] In 2014, Burgert et al. conducted an intervention study on swine models to compare the transfusion rates of IO and IV access.[10] The authors found that it took approximately twice as long to transfuse 900 mL of blood using IO compared to IV access. Later on, in a prospective observational study on volunteer professional military personnel, 450 mL of autologous whole blood from each participant was collected and reinfused with IO vs. IV routes, using gravity only.[11] Notably, the IO groups had a median infusion rate of 32.4 mL/min, which was nearly half of the IV group's rate of 74.1 mL/min. The study used the sternal site, which is known to have the fastest flow rate compared to the humeral and tibial insertion sites.[12]

One commonly overlooked factor is the impact of a patient's initial blood pressure on the flow rate at different IO accesses. Studies found in animal models experiencing hemorrhagic shock, the flow rate is significantly lower compared to those with normal blood volume.[13] Despite the limited studies comparing the flow rates between IO vs IV access in normotensive and hypotensive models, an animal study on a piglet model showed that hypovolemia results in average decreased infusion rates of 32% within various sites of IO accesses.[14] It is worth noting that IV access was found to be the most effective method for

immediate volume replacement, as even with IO access using 300 mmHg pressure, the flow rates were significantly lower compared to IV access.

The utilization of IO access exploits the vascularity of cancellous bone, which is the sponge-like bone found inside the hard external compact bone. Cancellous bone consists of a porous structure made up of spicules or trabeculae and hematopoietic red marrow. It is important to acknowledge that the properties of cancellous bone vary significantly based on factors such as age, gender, and ethnicity.[15-17] In addition, it should be noted that the IO catheter itself does not restrict the flow rate of blood products, as it belongs to the same size category as the IV catheters commonly used in trauma patient resuscitation. Therefore, the parameters of the IO space, including bone density, play a crucial role in defining this area. Haris et al., utilizing Darcy's Law and accounting for the low flow rates of blood transfusion into the IO space, argued that transfusing blood via the IO route does not yield substantial results in the resuscitation of trauma patients.[3] They, in fact, recommended that medical personnel receive training in ultrasound technologies as an alternative to enhance successful peripheral IV access and to completely avoid the IO route when blood transfusion is necessary.

A blood loss of 150 ml/min or more is considered a major hemorrhage, according to one definition.[18] This implies that current data indicate insufficient transfusion flow rates through a single IO catheter in trauma patients experiencing shock. This is a crucial acknowledgment by those who support the use of IO devices in trauma cases. Consequently, some experts recommend the use of two catheters during the initial resuscitative phase to ensure adequate transfusion volumes and as a temporary solution until definitive access can be obtained.[4,19-21] It is important to consider this recommendation when comparing IO devices with other access route alternatives.

POTENTIAL FOR RED CELL HEMOLYSIS

Another contentious issue regarding utilization of IO devices is the possibility of red cell hemolysis.[22] This is of particular significance in the context of trauma, where prompt replenishment of sufficient blood volume is crucial for patients. Based on theoretical models, the only adjustable factor for medical professionals to enhance the flow rate in an IO system during a device closure reperfusion procedure is pressure.[3] Heightened pressure not only places strain on the connections within the infusion system itself, but also amplifies the shearing forces exerted on the fluid. These shearing forces have the potential to induce red blood cell destruction, resulting in loss of oxygen-carrying capacity and subsequent development of rhabdomyolysis.

Despite previous studies on animal models attempting to address the concern regarding the red cell hemolysis,[10,21,23-25] one crucial aspect has been overlooked - the bone densitometry of these models does not accurately reflect that of young adult humans. A recent systematic review, consisting of nine papers on red cell hemolysis following IO blood transfusion, revealed a lack of high-quality evidence regarding the risks associated with red cell hemolysis in IO blood transfusion.[22] However, findings from one study suggest that the use of a three-way tap to administer blood transfusion to young adult male patients with trauma may increase the likelihood of red cell hemolysis. Notably, among the nine papers included, seven were animal studies, while only one prospective human study was reported. This human study documented a significant increase in lactate dehydrogenase levels and a decrease in hemoglobin levels following the infusion within the IO groups.[11]

COMPLICATIONS

Despite a dearth of data comparing the rates of complications between IO and IV access, various studies have examined the complications of IO access at specific sites, and these should be taken into consideration before utilizing them.[26] This current review does not express a preference for or against using IO in terms of complications; instead, it highlights vital examples for readers to consider. In an online

questionnaire-based study of 386 Scandinavian physicians, 1,802 clinical cases of IO use were reported, of which nearly one-fourth (23.4%) were indicated following a hemorrhage.[27] The authors concluded that the overall complication rate exceeded what is typically reported from model and cadaver studies, with responders reporting that 68.6% experienced some form of complication during the procedure, infusion, or late after the infusion. While this study included factors like severe patient pain as a complication, it also shed light on the challenges faced by clinicians and patients when employing IO devices. Consequently, future research on IO devices should encompass all stages of IO use.

Although previous research has demonstrated the safety and feasibility of IO access in pediatric patients[28], it can be challenging to successfully cannulate the hardened bones of adult patients using IO devices.[29] Hence, variations in osseous anatomy between pediatric and adult patients are expected to affect the type and severity of complications associated with IO cannulation. A recent comprehensive analysis of complications related to intraosseous catheterization in adult patients revealed an overall complication rate of 4.6% following successful IO catheter insertion.[30] Major complications noted in this study included extravasation or displacement of the catheter (2.8%), device malfunction (1.8%), injury to surrounding tissues (0.1%), bleeding (0.04%), tissue necrosis (0.02%), and infection (0.01%). It is important to note that these complication rates can vary significantly across different studies due to the influence of operator experience. For instance, the extravasation rate has been reported to range from 1 to 22% in various studies.[31]

Notably, needle dislodgement is a complication that has been found to be more prevalent in humeral IO accesses (20%) compared to tibial IO accesses (9%).[32] If the chosen needle is insufficiently long to fully penetrate all layers of subcutaneous tissue, the intraosseous needle will not be able to completely enter the bone matrix, resulting in a failed attempt or dislodgement. Furthermore, constant movement and activity can significantly increase the risk of unintentional needle dislodgement. Similar rates of needle dislodgements have been reported in other studies, with rates of 10%, 16%, and 15% for femoral, humeral, and tibial sites, respectively.[33]

THE GOAL IS TO IMPROVE OUTCOMES

Despite expanding literature on the role of IO access in the resuscitation of trauma patients, its impact on patient outcomes remains unclear.[34] A recent multi-institutional study of 581 adult (≥16 years) hypotensive (systolic blood pressure ≤90 mm Hg) trauma patients showed that despite no difference in time to access between patients with IO vs peripheral IV (PIV) access, IO had higher success rates than PIV (93% vs. 67%) and remained higher after subsequent failures (85% vs. 59%).[35] However, this study did not provide any data on patient-centered clinical outcomes such as early and late mortality or complications. Another systematic review on the "efficacy" of IO access for trauma resuscitation revealed that the success rate of IO access on the first attempt was significantly higher than that of IV access for trauma patients, and the mean procedure time for IO access was also shorter. However, no information on patient outcomes was included in the review.[5]

Despite the limited literature in trauma patients, in 2021, a prospective, parallel-group, cluster-randomized study compared the outcomes of patients with out-of-hospital cardiac arrest (OHCA) who were resuscitated with “IV only” against “IV + IO”.[36] Interestingly, they found that using IO when IV failed led to a higher rate of vascular access, prehospital adrenaline administration, and faster adrenaline administration. However, it was not associated with a higher return of spontaneous circulation (ROSC), survival to discharge, or good neurological outcome. Another study by Mody et al., evaluating 19,731 patients with OHCA, of which 3068 patients received IO access, demonstrated that IO access attempt was associated with worse ROSC and survival rates: (4.6% vs. 5.7%, $p = 0.01$) for survival to discharge, (17.9% vs. 23.5%, $p < 0.001$) for sustained ROSC and (2.8% vs. 4.2%, $p < 0.001$) for survival with favorable neurological function.[37] Based on this studies and multiple other medium to high-level studies, despite higher rates of successful access through the IO route, no differences in survival and clinical outcomes are

expected, when using IO in the resuscitation of adult and pediatric patients with OHCA.[38-40] In fact, a prespecified analysis of a randomized, placebo-controlled clinical trial by Daya et al. showed that point estimates for the effects of drugs in comparison with placebo were significantly greater for the IV than for the IO route across virtually all outcomes and beneficial only for the IV route.[41] However, the study was underpowered to statistically assess interactions. Although resuscitation of patients with OHCA is out of the scope of this study, the above-mentioned study and multiple other studies are brought as a signal to interpret these findings carefully, as while IO access may offer faster access or a higher success rate, it may lead to lower survival rates and poorer neurologic outcomes.[40,42]

ULTRASOUND GUIDED IV: IS THIS THE ANSWER?

IV access can be challenging in patients with severe hemorrhagic shock. However, research has demonstrated that using ultrasound guidance for peripheral IV access is both feasible and significantly increases success rates compared to traditional methods.[43] In an animal study on six sedated male sheep with a BP of less than 90 mmHg, the authors found that while accessing the vein blindly was successful in one out of six punctures, ultrasound guidance increased the access to eight out of nine punctures with a median time of 65 seconds.[44] A systematic review, including right studies on comparing US guidance with the traditional approach, showed that the ultrasound-guided technique reduced the number of punctures and time needed to achieve IV access, and increased the level of patient satisfaction, although it did not result in a decreased number of complications.[45] In fact, this difference was particularly evident in patients with a known or predicted difficult IV access. Overall, the findings suggest that using ultrasound guidance for peripheral IV access is more effective than traditional methods, leading to greater success in cannulation, a reduction in the number of punctures, a decrease in procedure time, and increased patient satisfaction.[46]

Although to date, there is no study on the comparison of IO access vs US-guided IV access, comparing the reported numbers of attempts and success rates shows promising results in favor of considering the US-guided IV access approach, if we encounter patients with difficult IV access even in the prehospital settings.[47,48] Moreover, an encompassing strategy involves providing advanced education to healthcare providers, particularly those in frontline care.[49,50]

SUMMARY

Despite the recent trend toward using IO access as the primary access route of resuscitation in adult trauma patients in hemorrhagic shock, there are several important aspects that previous studies have not adequately addressed. Concerns such as the inadequate flow rate and the potential for red cell hemolysis through IO and bone space need to be further investigated. Moreover, it should be recognized that IO access can be an extremely painful procedure, at times surpassing the pain caused by the patients' primary injury. If not performed by an experienced professional, there can be multiple complications associated with IO insertion. Importantly, it is crucial to consider that timely resuscitation of trauma patients ultimately aims to improve clinical outcomes, an aspect that has not been sufficiently assessed in previous studies comparing IO vs IV access for hemorrhagic trauma patients.

While studies supporting the use of IO primarily focus on its higher success rate compared to intravenous (IV) access, there are several reasonable solutions to this issue. These include proper education, simulation-based training, and, notably, the utilization of ultrasound-guided IV access. Research has shown that ultrasound guidance can double the success rate while reducing procedural time by nearly half, making it a promising alternative. Thus, it is necessary to wait for studies in a representative population to demonstrate the clinical success of the IO technique in effectively resuscitating hemodynamically unstable trauma patients. Until then, IO access should be considered as the bridge for definitive access when multiple attempts for peripheral and central access have failed.

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SESSION 15

WE HAVE MET THE ENEMY...

Moderator: Kenneth L. Wilson

Wednesday, April 17, 2024

10:00 – 11:30 AM
Palace Ballrooms 1-2
Palace Tower
Emperors Level – 4th Floor

10:00 – 10:15	**Human Trafficking: How to Detect? What to do?** **Alexander L. Eastman, MD, MPH, FACS, FAEMS**
10:15 – 10:30	**Second Victim Phenomenon** **Alison Wilson, MD, FACS**
10:30 – 10:45	**Facing Futility: When to Say When in Kids and Adults** **Bryan A. Cotton, MD, MPH, FACS**
10:45 – 11:00	**Three's a Crowd: Proliferation of Trauma Centers** **Natasha Keric, MD, FACS**
11:00 – 11:15	**Victory out of Tragedy: Organ Donation Challenges** **Ali Salim, MD, FACS**
11:15 – 11:30	**Panel Discussion**

DETECTING HUMAN TRAFFICKING AND HOW TO RESPOND

Alexander L. Eastman, MD, MPH, FACS, FAEMS

Chief Medical Officer (A)
US Customs and Border Protection
US Department of Homeland Security
Lieutenant and Chief Medical Officer
Dallas Police Department
Dallas, TX

BLUF

The scourge of human trafficking (HT) is present in all 50 states, and victims are missed daily in healthcare institutions around the United States and around the world. More disturbingly, nearly 88% of HT survivors reported accessing healthcare services during their trafficking situation. Of these, 68.3% were seen in an emergency department. Surgeons, healthcare institutions, and medicine/public health in general focus their efforts on events that happen commonly. HT is clearly no "zebra," and, hence, trauma surgeons, emergency physicians, and all those who staff trauma centers and emergency departments must not just maintain vigilance or a high index of suspicion, but must also often actively consider the diagnosis.

INTRODUCTION

By some estimates, more than 1 million victims of HT are trafficked across international borders annually. In the United States, more than 50,000 victims are trafficked into this nation and at least 400,000 victims are being trafficked domestically.[1] The United States represents the largest destination and market for human trafficking victims. Facilitated by a complicated network of transnational criminal organizations (TCOs), as well as domestic criminal organizations, HT represents a >$30B industry worldwide. Along the US southern border, HT now outpaces narcotrafficking in many jurisdictions.

THE SCOPE OF THE PROBLEM OF HUMAN TRAFFICKING

By virtue of its underground nature, the scope of HT can be difficult to quantify and currently represents one of the top two or three sources of income for organized crime organizations worldwide. By 2004, there were nearly twice as many victims enslaved as during the African slave trade.[1] With a multitude of variants, HT can most simply be divided into two types: sex trafficking and labor trafficking. Table I lists some of the more common variants of human trafficking.

Table I. Common Variants of Human Trafficking

- Forced labor
- Debt bondage (migrant laborers)
- Forced child labor
- Sex trafficking

Common sources of victims in the United States are Mexico, central/Latin America, and East Asia. While this presentation is focused on recognition, HT remains one of the most vexing public health challenges across the globe. Currently, more than 40 million people are in modern slavery worldwide, 24.9 million in forced labor; 15.4 million in forced marriage. This translates into more than 5 people / 1000 with 25% of HT victims being children.[2] Women are overrepresented in victims with more than 99% of sex trafficking

victims being female and 58% of other types of human trafficking. Since 2000 and the passage of federal law on the topic, this has been an enforcement priority with a large number of resources dedicated to combatting this problem. Healthcare institutions remain underprepared and under trained at both victim identification and intervention once identification is made or suspected.

DEFINING HUMAN TRAFFICKING

For the purposes of training and facilitating victim identification, it remains best to ignore the complex and challenging legal definitions of HT and focus on its most simple meaning. Human trafficking occurs when a person is induced by force, fraud, or coercion to most commonly:

- Work under the total or near-total control of another person or organization (slavery or involuntary servitude)
- To pay off a loan by working instead of paying money for an agreed-upon or unclear period of time (debt bondage) or even without an agreement as to the timeframe (peonage)
- Perform a sex act for money or anything of value (if under 18, force, fraud or coercion is not required)

While not an all-encompassing definition, these represent the most common scenarios where a HT victim will be encountered in a trauma center or emergency department. However, while according to US Immigration and Customs Enforcement (ICE) these are the most common criminal scenarios, HT victims being trafficked in "less criminal/more mainstream" appearing endeavors like domestic servitude, labor in a prison-like factory, or, commonly, migrant agricultural work can often be encountered in an emergency department.

For healthcare workers, one of the frequent barriers to victim identification is misunderstanding the critical concepts of force, fraud, and coercion that underpin the crime of a HT. In the broadest sense, these terms include any situation where an individual is forced to do something against their will or where they are tricked into doing something by someone who is lying to them (or concealing the truth). Using force to compel another's action can be active and physical or indirect and psychological (including the simple threat of force). This includes threats of harm or physical restraint, instilling the belief that noncompliance will result in harm or serious bodily injury or abuse (or threatened abuse) through legal processes. Fraud in HT involves intentional deception to compel another person's action or to give up something of value to them without compensation. Coercion describes any other type of compulsion, constraint, or restraint, physical or emotional. Each of these serves to empower the criminal trafficker to compel a victim to take actions against their will. Specifically with regard to human trafficking that has a nexus to the international boundaries of the United States, human traffickers often charge exorbitant fees, compounded with interest, making it difficult for victims to ever pay their debts. Because of a lack of legal immigration status, reporting is even more unlikely for fear of deportation.[2]

THE CRITICAL SKILL OF VICTIM IDENTIFICATION

Because of the complexities of its origins, as well as the myriad ways that victims are controlled and abused, there are some that have called HT an "invisible crime." While its signs can be subtle and difficult to detect to those without formal training, like many other things, there is a constellation of "symptoms" that can be recognized, as they often appear in combination. Also, like many other difficult to ascertain diagnoses, the maintenance of a high index of suspicion has helped many providers identify victims at their first interaction with the healthcare system, instead of much later or even when it is too late.

Once armed with an understanding of the basics of HT and a healthy dose of suspicion, providers are able to recognize the syndrome fairly readily. Table II lists common indicators of HT that are often present on the retrospective evaluation of healthcare provider encounters.[1] However, it is also important to

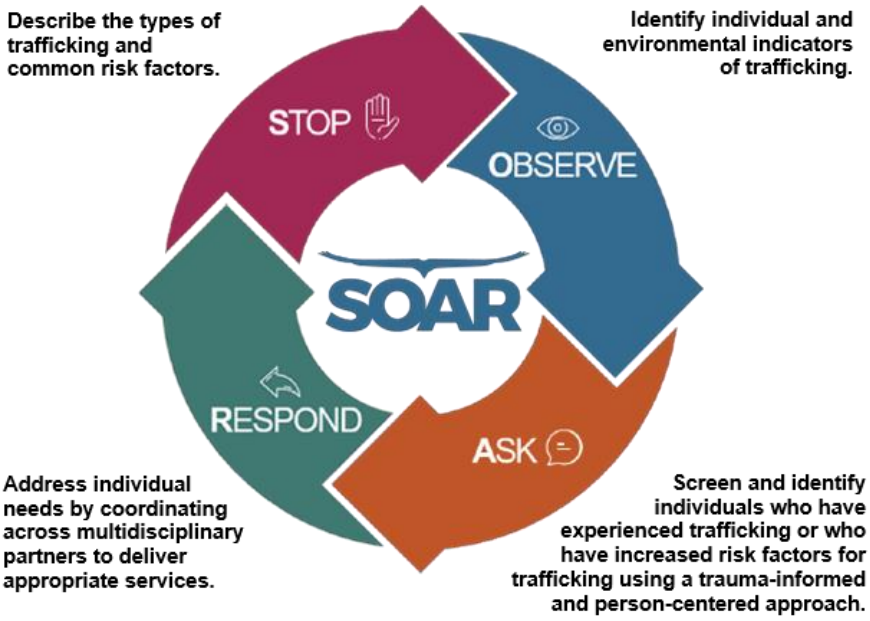
recognize that there is such variation in cases that no one combination or sign will lead to making the definitive "diagnosis." Providers should work closely with their local and federal law enforcement agency counterparts to craft a comprehensive approach to detection, confirmation, and intervention in HT cases when they present.

Table II. Common Indicators of Human Trafficking

- Lacks control of identification documents or travel documents
- Lives and works in the same place
- Lacks freedom of movement
- Seems to be restricted from socializing, attending religious services or contacting family
- Seems to have been deprived of basic life necessities, such as food, water, sleep or medical care
- Shows signs of having been abused or physically assaulted. Such signs range from the more obvious, such as broken bones, to the more subtle, such as branding or tattooing
- Seems submissive or fearful in the presence of others
- Seems not to control his or her schedule
- Seems to lack concrete short- or long-term plans
- Seems to lack knowledge about the place where he or she lives
- Appears to date much older, abusive or controlling men

While a number of trauma-informed screening tools have been developed, one set of very effective healthcare-focused educational programs that is integrated with a screening tool has been developed by the US Department of Health and Human Services Administration for Children and Families (ACF). Their "SOAR to Health and Wellness" training is the foundational course that is designed to assist healthcare professionals begin their foundational development in the identification and response to human trafficking victims. Figure 1 shows the fundamentals of the SOAR program. References for additional information are available below.

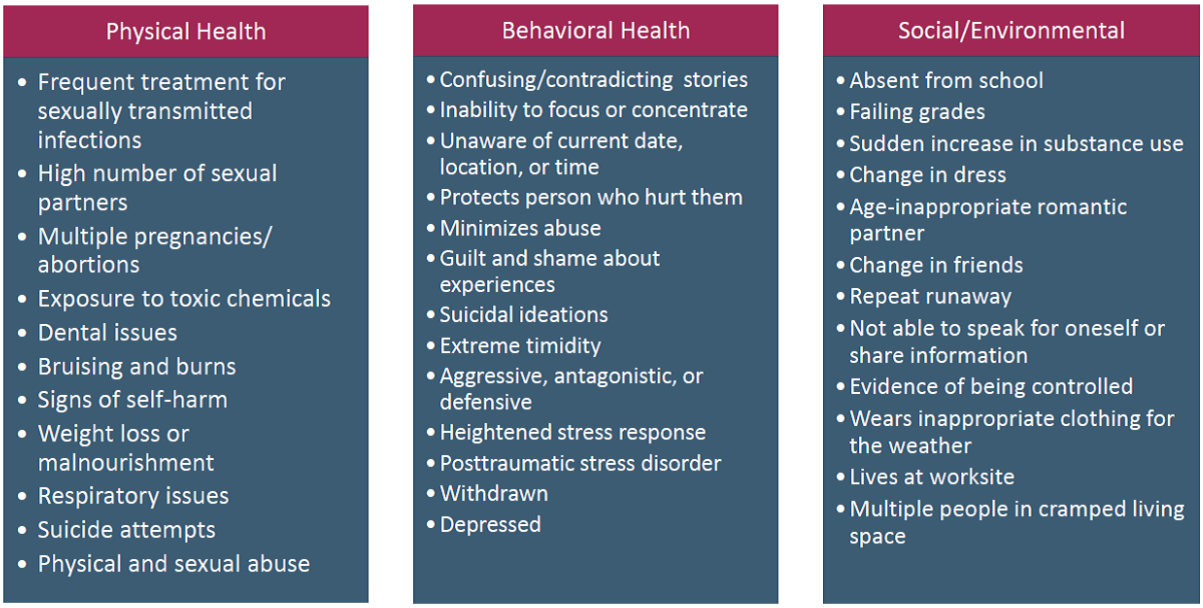
Figure 1. SOAR Program Fundamentals



Adapted from the National Human Trafficking Training and Technical Assistance Center, 2023.

Once familiar with the SOAR framework, most programs are able to develop locally informed training to facilitate identification and intervention for detection of HT victims. Most importantly for providers, is truly understanding the breadth of presenting complaints or symptoms. Figure 2 lists a relatively comprehensive list that is organized by the major categories of physical, behavioral and social/environmental clues that are present at recognition. Clinicians who may be faced with making the critical initial identification of a HT victim should ensure that they are intimately familiar with these findings.

Figure 2. Physical, Behavioral and Social/Environmental Indicators of Human Trafficking



INTERVENTIONS FOR HUMAN TRAFFICKING VICTIMS

Despite our propensity for action, surgeons must realize that with a criminal enterprise as sophisticated as those involved in HT, interventions to counter same must be well coordinated and must be multidisciplinary. While there is reticence in many centers toward intimate working relationships with law enforcement agencies, with some even advocating against such, HT victims often require such close, coordinated efforts. Leaders crafting interventions to be used by those who suspect or diagnose HT must be focused on safety, discretion, and ensuring that all interventions are victim/survivor focused.

First and foremost, when crafting an intervention strategy in a healthcare setting, establishing a non-judgmental setting and a safe space for action is critical. This means that in order for a victim of HT to feel safe and empowered for an intervention, they must be cared for by an observant, nonjudgmental, and knowledgeable team of providers and support staff. Often times, the first step has to be separation from a potential perpetrator, which can be a tricky endeavor. Most healthcare providers are reticent to employ subterfuge as a tactic in the care of patients; however, ordering tests and imaging are common strategies to remove handlers from the bedside when needed—enabling a private conversation when appropriate.

Ensuring that providers and support staff are knowledgeable about HT is also vital. Education on recognition and intervention, as described above, is foundational, but providers MUST also understand mandatory reporting laws and how to utilize them to the victim's benefit. With HT, it is not sufficient to simply see something and say something, but instead to see something, say something, AND Do Something.

An actual intervention must be discreet and subtle enough to not exacerbate an already anxious HT victim. Figure 3 shows the Department of Homeland Security's national HT hotline.

Figure 3. DHS Blue Campaign Hotline

This hotline can serve as a one-stop access point for both intervention and law enforcement resources and has helped to bring the multitude of federal resources together and integrate them with state, local and healthcare resources in one place. This hotline is an excellent first call particularly in the early stages of developing a discreet, safe intervention plan. Additionally, connecting survivor with resources is critical and their must be a focus on the development of local resources that can assist in an intervention.

Finally, and most critically, healthcare providers must remember that HT perpetrators steal the autonomy from victims, and this remains the crux of their ability to control HT victims actions. To ensure the maximum likelihood for success, providers and institutions must not be seen as taking even more control from the victim. According to the DHS guide for interventions, "We must fight the tendency to fix the problem immediately and, instead, let the survivors guide conversations and actions." Our role is to give HT victims their power back.

CONCLUSIONS

Human trafficking is a vexing and complicated worldwide public health problem. It is present in nearly every emergency department and trauma center in the United States. Because most providers are under-informed regarding human trafficking indicators, identification remains challenging, and victims are missed regularly. The consequences of a missed victim identification not only put the individual victim at risk, but also potentiate and empower transnational criminal organizations that engage in HT. Interventions must be victim-focused, empowering and knowledgeable, but also must be discreet in order not to place the victim at additional risk. Despite a large amount of available resources, providers and institutions must preplan local arrangements for interventions, for the time and space will not exist to attempt to do so at the time of need. A defined, smart and nuanced strategy for detection and intervention will save lives.

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THE SECOND VICTIM SYNDROME

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The realization of the interdependent relationship of physician wellness with patient outcomes has become more of a point of discussion. The physician who is struggling with depression or dependency is not able to perform at the top of his or her level, and, therefore, may not have optimal patient outcomes. Additionally, mental well-being is linked to longevity of one's career. As topics such as physician burnout and suicide rates become more prevalent in discussions, it is important to focus upon the root cause of these issues. Surgeons are noted to be in a high-risk category for burnout, substance abuse, and suicide. The intensity of the profession, daily stressors, and the invasive nature of the work, all put a significant burden on the surgeon to always have the correct diagnosis and surgical plan. When an error occurs and a patient is harmed, the impact on the surgeon can be very profound. Though all surgeons work to eliminate mistakes and errors, they are part of human existence. Just as mistakes are human, so are the emotions and mental implications of that error on that surgeon. This phenomenon has become known as the second victim syndrome.

DEFINITION AND INCIDENCE

Errors in medicine can occur in a variety of settings and circumstances, even in the most regulated systems. As the complexity of diseases, treatments, and patient illness increases, so do the number of providers and teams involved in patient care. This makes for an extremely complex system and introduces numerous opportunities for breakdowns in communication, desynchrony in timing therapies, and, ultimately, errors. Medical errors are estimated to occur at a rate of 1.5 million per year and are estimated to contribute to just over 250,000 deaths annually.[1] These errors decrease the patient's quality of life and increase morbidities, costs to the patient, and it is estimated to cost the medical system over 20 billion dollars per year.[2] As healthcare delivery is evolving into larger and larger systems, efforts to minimize errors, streamline and standardize care, and strive for quality care are becoming a central focus. We are seeing a shift in culture from a very physician centric system to team-based systems. Now, often referred to as the Culture of Safety, efforts have been put in place to encourage disclosure of events so that lessons may be learned to minimize the chance of recurrence. A shift in philosophy to a "no blame" or "no fault" medical culture now predominates.[3]

Surgery, however, is somewhat different in the direct and invasive nature of the work. When an error occurs in surgery, it is often immediately obvious to all in the operating room. If it is a failure in technique, misidentification of structures or specimens, or wrong surgery, the surgeon is often the one who is decision maker or caused the error. This leads to a large degree of responsibility and stress for those in the field. The term, "Second Victim," was coined by Albert Wu in 2000 and is defined as a syndrome of emotional and psychosomatic distress and symptoms experienced by the individual who committed the error.[4] Originally described focusing on physicians, it is now applied to any healthcare provider.[5,6] This all

fits in a framework of definitions where the first victim is the patient to whom the error occurred, the second victim is as described above. The third victim has been described as the healthcare system, and the fourth victims are patients who are harmed subsequently by providers unable to perform at their best because of the impact of the error.[7] The incidence of this entity is difficult to quantitate, as there is not a standard for screening, and it is a relatively new topic of discussion. However, among the various studies, the incidence is noted to range from 10-43%.[8]

CHARACTERISTICS OF SECOND VICTIM SYNDROME

Second victim syndrome, at times, is equated to a form of post-traumatic stress disorder in healthcare professionals. With that, some of the same physical and mental symptoms occur with intrusive, disturbing thoughts and sleep disturbances being very common.[9] Anxiety, embarrassment, depression, guilt, anger, and sadness are prominent features. Physical manifestations commonly include headaches, fatigue, insomnia, pain, and intestinal problems.[10] It has been estimated that approximately 50% of healthcare professionals will experience second victim syndrome at least once in their career.[11] Surgeons and those in procedural based careers, such as anesthesia and OB/GYN, appear to be impacted more drastically than other types of providers. This is thought to be due to the more obvious connection to a technical error and the impact upon the patient.[12] It is now recognized that second victim syndrome can be seen in all healthcare providers and is associated with errors, such as a medication or therapy errors. This has been seen to occur across all demographic backgrounds and across all stages of career and experience. Though there are differences as to the types of emotions experienced by surgeons that seem related to years in practice and experience level, there is no immunity to these feelings provided by experience.[13]

The impact on the provider/surgeon can be profound. There may be signs of depression, self-isolation, and doubt that may lead to the surgeon withdrawing from certain types of practice or procedures. The individual may become much more defensive in the work up and approach to patients, which may subject future patients to additional testing, etc. The individual may develop very maladaptive behaviors and become disruptive in the workplace. This period of time may also result in other maladaptive behavior, such as drug or alcohol abuse or even suicide. If not dealt with in a constructive way, these individuals may end in a cycle of acute stress disorder or even prolonged PTSD. [14,15,16,17]

STAGES OF PROGRESSION

Scott et. al. described six stages of the natural history of second victim syndrome. In the initial stage 1) Chaos and Accident Response, the provider realizes the error, with the response being to get help and stabilize the patient. The provider is often distracted and may need someone to assume care, and this is marked with questioning how this happened, followed by a period 2) of Intrusive Reflections, a period where the practitioner has repeated and intrusive thoughts of the event. He/she may have severe doubt about their skills and lack confidence. There may be severe mood and sleep disturbances. They are at risk of self-isolating. Restoring personal integrity 3) is a period marked by professional unease worrying about peer acceptance and coping with fear of potential job issues. Enduring the Inquisition 4) deals with coping with the pressures of "event" responders, reliving the event while answering questions from investigations, administration and others. This may cause even more self-doubt or loss of confidence. Depending on the culture, this may further deepen the physical and psychosocial feelings. Stage 5 is Getting Emotional First Aid, where the individual seeks some type of support whether peer or professional counseling. The final stage 6) is Moving On, which can have three distinct paths, depending on the environment and the coping of the provider. One outcome is "Dropping Out," the provider leaves the institution or even the career. The second is "Surviving". The individual is coping but has residual thoughts and doubts. The third outcome is "Thriving," in which the individual has gained insight but can maintain balance and return to full practice.[18] These stages can all be influenced by the individual's personality,

coping strategies, resilience, and maturity, but also by the environment and response of those also in the work environment.

SUPPORT AND INTERVENTIONS

Traditionally, many surgeons have quietly dealt with the emotional impact on their own, which may be a contributing factor to things such as burnout and some of the high rates of divorce and substance abuse.[19] However, the last decade has seen a focused effort on developing support systems. Hechi et. al. describes a surgery specific peer support group that has been piloted and tested. In this program, surgeons in the department identified others thought to be strong listeners and have perspective to be able to be trained in providing other surgeons support after an adverse event. Professional training is provided to the peer supporters and participate in multi-faceted evaluations that identify adverse events. When a significant event occurs, a peer supporter is assigned to the individual who then meets regularly and formally to assist in the process.[20] This program seems to have been accepted and endorsed as useful in decreasing intensity and duration of many aspects of second victim syndrome. As the concept of the mental and emotional impact of an error or adverse outcome can lead to suboptimal performance of a key healthcare provider, systems are working to identify methods to mitigate the impact. Though peer to peer is the most common model of both formal and informal support networks, there has been a call to broaden opportunities. Systems, such as proactive staff education, mandatory debriefing and follow up, as well as enrollment in employee assistance programs have all been described. Though many agree that support is needed, there is not consensus as to what the most effective support model would be.[21,22,23]

SUMMARY

Much discussion has evolved surrounding the impact of a medical error on healthcare providers, in addition to the patients directly experiencing the impact. How that individual provider deals with the error in conjunction with the feedback and effects from the environment, particularly work environment, will determine the duration and long-term impact on that provider. As with all events involving humans, emotional responses and coping and defense mechanisms are complex and rely heavily on the individual's skills. Recognizing errors do not happen in a vacuum, and that others will need to process the implications is important in setting expectations and developing compassionate, yet accountable, systems of support.

AUTHOR'S REFLECTIONS

The following is solely the reflections and opinions of this author and does not represent the program committee, meeting leadership, or any institution. We are humans and, with that, we have a conscience and emotions. When we make a mistake that causes discomfort, pain, or frank harm to another human, it is natural to feel sadness, regret, and shame among other feelings. This is true in day-to-day human existence. As a surgeon, patients come to us, vulnerable and in need of help and place their profound trust in our knowledge and skills. This trust and yielding of their health and well-being into our hands makes coping with an error even more profound. These emotions are appropriate and the sign of a surgeon with a conscience, soul, and ethics. Certainly, individuals may deal with these feelings in maladaptive ways, or the environment may cause unwarranted guilt or blame. It is ironic; however, to call this a "syndrome," which implies that it is abnormal. In an attempt to bring attention to the impact and potential problems, the term, "Second Victim Syndrome," itself is very problematic. Instead of recognizing emotions as normal, we make this appear abnormal and give it a syndrome name. Stating the individual who committed the error is the second victim of the error seems to inappropriately imply that the individual was helpless and had no role in the event. Though, most likely, this is not the intent, it is what the word choice conveys to many. This term is very problematic in how we may relate to our patients, families, and others. It seems almost insulting to the patient, who endured the error, to be called the first victim, and second in line of the "victims" is the one who made the error. It is very important to recognize

surgeons and others in healthcare do make mistakes, are fallible, and are human. With this humanity comes sadness, empathy, and remorse for the hurt, which is a sign of an ethical surgeon. In fact, the emotional impact and, at some level, sharing the suffering alongside the patient can be some of the greatest healing for patient and surgeon. Perhaps a different name or defining a syndrome when the coping becomes maladaptive is a better approach. Perhaps what we should really worry about is the surgeon who does NOT feel these emotions, or is responsible for the patient's suffering, or those who truly believe they are now the victim. As surgical educators, we should encourage awareness and normalize these feelings. We should teach coping skills and teach individuals to seek help with struggling, but we cannot remove the humanity and emotions from our craft.

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FACING FUTILITY: WHEN TO SAY WHEN IN KIDS AND ADULTS

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The last two decades have seen increased efforts at early identification of those likely to require life-saving interventions, such a rapid response teams, massive transfusion delivery, extracorporeal membrane oxygenation, and emergent surgical procedures.[1-3] However, it was not until recently that this same level of interest was directed at limiting early interventions in severely injured patients where such efforts might be futile. Not surprisingly, it was the COVID-19 pandemic and its disruption of vital supply chains that brought this to the forefront. During the early months of the COVID pandemic, a 50% reduction in blood donations was offset by a significant drop in demand for products due to restrictions on elective surgery.[4] However, as society and its institutions began reopening, with surgical schedules returning to "normal" and trauma volumes rebounding, the supply of blood required was unable to keep up. Adding to this was an increase in trauma, particularly penetrating trauma, resulting in an estimated 12% surplus usage, combined with a loss of plasma products to convalescent programs.[5] Finally, with increased attention to mass shootings and hospital disaster preparedness, surgeons and physicians have found the need to urgently address unforeseen critical shortages and vulnerabilities in the delivery of care.[6]

While it took the extremes of the COVID pandemic to expose the fragility of the healthcare system, the state of the industry had been problematic for decades, with many providers in the US practicing for years with little regard for resource utilization. While blood is but one of many precious resources we have shown disregard for, it is one, in particular, for which there is often no adequate substitute. Doughty and colleagues responded by evaluating a triage tool for rationing of blood in massively bleeding patients in anticipation of the COVID-shortage.[7] This tool and its processes were aimed at providing a transparent, fair distribution of available blood resources. Their guideline would be triggered when a less than 2-day national supply was noted, with each hospital triaging bleeding patients to transfusion or assess for futility at predefined increments. The predominate factors guiding these triage lists SOFA scores, need for ongoing transfusions, and likelihood of arrest from hemorrhage.

With continued improvements in prehospital care and advancing technology for life support in the ICU, however, patients with poor to grave prognoses can be sustained for prolonged periods.[7] As such, an increasing number of investigators have looked at futility in the trauma population, particularly among those receiving massive transfusion, MT (>10 units red blood cells) or even ultra-massive transfusion, UMT (>20 units of red blood cells in 24 hours). Morris and colleagues evaluated MT patients and noted that while mortality increased with transfusion volume and age, a significant percent of older adults successfully resuscitated.[8] The authors argued that age alone should not be considered a contraindication to high-volume transfusion. Investigators from Johns Hopkins agreed that while age and transfusion volume alone could not be used as markers of futility, a nadir pH of <7.00 was associated with nearly 100% mortality in those MT patients 65 years of age and older.[9] When investigators mined the ACS-TQIP database for over 5,000 UMT patients admitted between 2013 and 2018, they were unable to identify a futility threshold for mean RBC transfusion rate calculated within 4 or 24 hours.[10] However, the database

query noted that all patients with a mean RBC transfusion rate of ≥7 units per hour calculated within 24 hours of arrival experienced in-hospital death.

But what about 2024? Since that study whose patients only included those admitted between 2013 and 2018, significant improvements in prehospital care have occurred, including the rapid expansion of blood product availability in the field. Perhaps early blood transfusion in the field, particularly with whole blood, could help patients avoid physiologic exhaustion, bettering tolerating their initial blood loss, which might lead to improved outcomes. Investigators evaluated this with the specific hypothesis that blood transfusion volumes would be a poor marker for futility after the availability of prehospital blood transfusions. Clements et. al. evaluated 2,299 patients who received emergency-release blood products in the prehospital or emergency department setting.[11] They evaluated those that received a MT up to 50 units in four hours and those received a super-UMT (>50 units in the first *four* hours). The investigators found that those in the super-UMT group were more likely to sustain penetrating injury, have lower field and arrival blood pressure, and received larger prehospital and emergency department resuscitation volumes. Predictably, patients in the super-UMT group had lower survival than those in the ≤50 cohort (31 vs. 79%; $p < 0.05$). However, there was no futility threshold for these patients, with a 22% survival rate at 150 units in the first four hours. Moreover, patients whose resuscitation began with whole blood had 43% increased odds of survival compared with those who received only component therapy and higher 30-day survival at transfusion volumes >50 U.

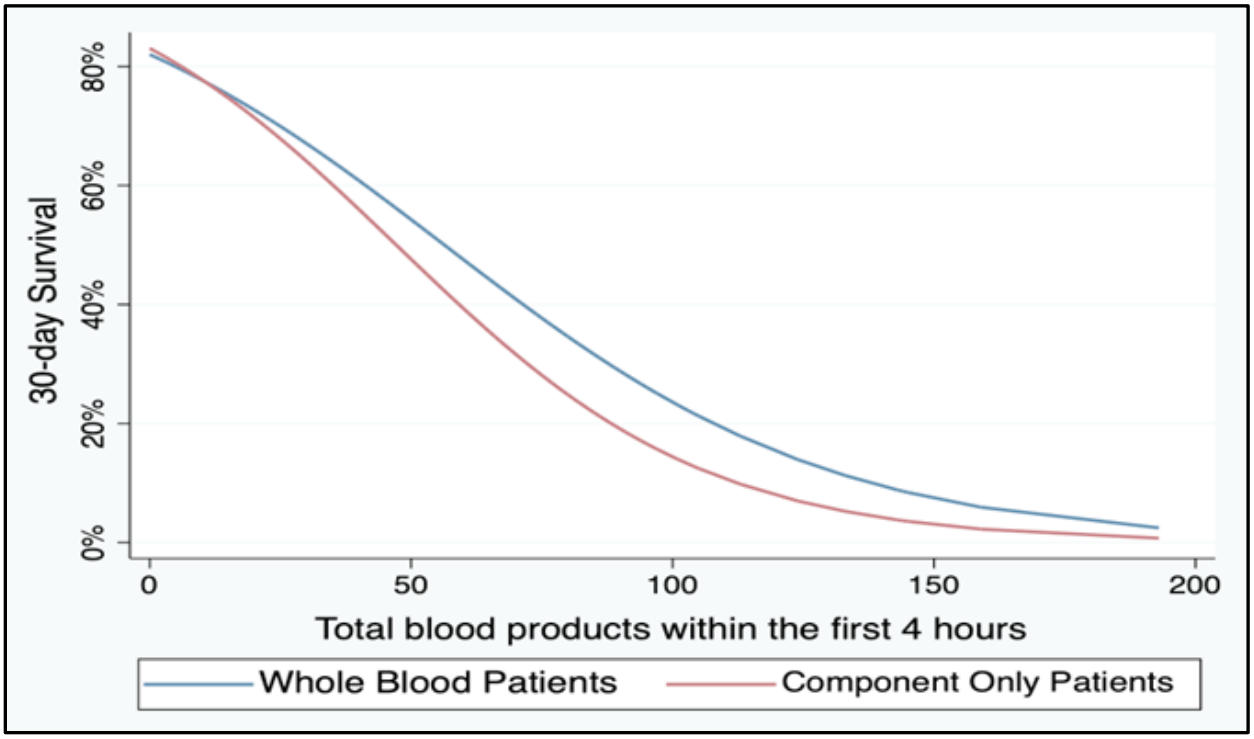

Figure 1. Patient receiving WB had 43% increased odds of survival compared to those receiving COMP (1.43, 95% C.I. 1.09-1.87, p=0.009)

Similarly, Gurney and colleagues hypothesized that in combat settings there would be no general threshold where blood product transfusion became futile to the bleeding soldier.[12] The investigators evaluated survival in 11,476 combat casualties who received at least one unit of blood product at US military medical treatment facilities during combat settings, between 2002 and 2020. They found that

nearly 80% of combat casualties receiving greater than 100 units of blood survived to 24 hours. As with the Clements study in civilian patients, these authors also concluded that, while responsible blood stewardship is critical, futility should not be declared based on high transfusion volumes alone.

So, if the number of units or the rate at which they are transfused is *not* a cut-off, what is? In 2011, a group of investigators evaluated 704 massive transfusion patients from 23 trauma centers in the hopes of identifying cut-points of futility.[13] The authors aimed to identify combinations of two or more variables that might predict greater than 90% mortality. Despite an exhaustive examination of extreme biochemical and physiologic variables, the authors were unable to identify variables that determined 100% mortality and struggled to find those with even 90% prediction. The only combination that exceeded 90% was severe brain injury (with head AIS score of 5) and age of 65 or greater. More recently, Van Gent and colleagues evaluated these same variables with extreme cut-offs in three separate study populations of severely injured patients receiving transfusions.[14] The authors set out specifically to identify arrival labs and hemodynamics, available early in the patient's resuscitation, that would predict 100% mortality (futility). They began by querying a previously collected single-center database of all trauma patients 15 years and older who met highest level trauma team activation and were admitted between 2010 and 2016. This generated several values with 100% positive predictive value (PPV) for death (**TABLE I**). This included cardiac arrest at any point with return of spontaneous circulation (ROSC) plus any of the following: initial rapid thrombelastography LY-30 value of 30% or more, base deficit of 10 or greater, or natural field GCS of 3.

	PPV	NPV	Sensitivity	Specificity
Lactate ≥10 and LY-30 ≥90%	**100%**	**88%**	**6%**	**100%**
Lactate ≥12 and LY-30 ≥50%	**92%**	**88%**	**10%**	**99.9%**
Lactate ≥12 and LY-30 ≥70%	**94%**	**88%**	**8%**	**99.9%**
Lactate ≥12 and LY-30 ≥80%	**98%**	**88%**	**7%**	**100%**
Lactate ≥12 and LY-30 ≥90%	**100%**	**88%**	**4%**	**100%**
Lactate ≥16 and LY-30 ≥50%	**91%**	**88%**	**9%**	**99.9%**
Lactate ≥16 and LY-30 ≥70%	**93%**	**88%**	**7%**	**99.9%**
Lactate ≥16 and LY-30 ≥80%	**98%**	**88%**	**6%**	**100%**
Lactate ≥20 and LY-30 ≥50%	**91%**	**88%**	**8%**	**99.9%**
Lactate ≥20 and LY-30 ≥70%	**93%**	**88%**	**7%**	**99.9%**
Lactate ≥20 and LY-30 ≥80%	**98%**	**88%**	**5%**	**100%**

Table I. Development dataset cut-points for arrival laboratory values achieving near-fatal or universally fatal outcomes.

These values, as well as other combinations with PPV of 90% or greater, were then validated with two other data sets: a prospective, single-center dataset from 2017 through 2021 of severely injured patients receiving any emergency release blood (including prehospital products) and a multicenter, randomized trial of hemorrhagic shock patients (PROPPR) (**TABLE II**). The developmental dataset was comprised of 9,509 patients with a median age 36, median ISS 17, and in-hospital mortality of 17%. The first validation dataset was comprised of 2,137 patients with a median age 38, median ISS 28, and in-hospital mortality of 30%, while the multicenter validation dataset was comprised of 680 patients, median age 34 and ISS 26, in-hospital mortality of 24%.

	PPV	NPV	Sensitivity	Specificity
ROSC and LY-30 ≥30%	**100%**	**88%**	**3%**	**100%**
ROSC and Lactate ≥12	**97%**	**88%**	**4%**	**99.9%**
ROSC and base deficit ≥ 10	**100%**	**87%**	**2%**	**100%**
ROSC and field GCS 3	**100%**	**87%**	**2%**	**100%**

Table II. Development dataset cut-points for near-fatal or universally fatal outcomes.

The validation sets identified patients whose PPV reached or approached 100%, including the following combinations: arrival systolic 50 mmHg or less plus lactate of 15 or more or LY-30 of 30% or greater; arrival systolic of 70 mmHg or less plus LY-30 of 90% or greater; and ROSC plus LY-30 of 30% or greater, lactate 12 or greater, or base deficit of 12 or more. Using three variables to achieve 100% PPV for death, the authors were also able to identify an additional combination of arrival systolic of 70 mmHg or less, lactate of 15 or greater, and LY-3- of 30% or more. While several combinations of arrival vitals and labs had 100% PPV, multiple combinations of less extreme values were noted to exceed 97% mortality; however, these were not universally fatal (**TABLE III**).

	PPV	NPV	Sensitivity	Specificity
ED SBP≤50 and LY-30≥30%	**100%**	**78%**	**33%**	**100%**
ED SBP≤70 and LY-30≥90%	**98%**	**78%**	**33%**	**100%**
ED SBP≤50 and Lactate ≥15	**100%**	**77%**	**31%**	**100%**
ED SBP≤70, Lactate>15, & Lysis>30	**100%**	**77%**	**30%**	**100%**
ROSC and LY-30 ≥30%	**100%**	**78%**	**33%**	**100%**
ROSC and lactate ≥12	**100%**	**76%**	**29%**	**100%**
ROSC and base deficit ≥12	**98%**	**72%**	**4%**	**100%**
ROSC and Field GCS 3	**99%**	**77%**	**27%**	**100%**
ED SBP≤50 and LY-30≥30%	**100%**	**78%**	**33%**	**100%**
ED SBP≤70 and LY-30≥90%	**98%**	**78%**	**33%**	**100%**
ED SBP≤50 and Lactate ≥15	**100%**	**77%**	**31%**	**100%**

Table III. Validation dataset cut-points for values achieving near-fatal or fatal outcomes

The authors then generated a table of cut-points that they defined as the STOP criteria or Suspension of Transfusions and Other Procedures (**TABLE IV**). Of note, among datasets, up to 10% of patients with 100% predicted mortality consumed >100 units of blood products during their early resuscitation. Extreme admission physiology and laboratory values, with and without traumatic arrest and ROSC, are capable of predicting 100% mortality in severely injured adults. However, additional validation likely required prior to widespread adoption.

Suspension of Transfusions and Other Procedures (STOP) Criteria for 100% Futility		
	PPV	**NPV**
Arrival SBP ≤50 mmHg and LY-30 ≥30%	**100%**	**78%**
Arrival SBP ≤50 mmHg and lactate ≥15	**100%**	**77%**
Arrival SBP ≤70 mmHg, lactate ≥15, and LY-30 ≥30%	**100%**	**77%**
ROSC and lactate ≥12	**100%**	**78%**
ROSC and LY-30 ≥30%	**100%**	**76%**
ROSC and field GCS of 3	**100%**	**77%**

Table IV. Predictors of 100% futility using the STOP criteria

While numerous investigators have attempted to identify such futility cut-points as those described above, children are almost universally excluded from these evaluations. From a resuscitation and transfusion futility perspective, Reppucci and colleagues evaluated injured children and adolescents between 2 and 18 years old from the Trauma Quality Improvement Program database.[15] Examining those patients with complete age and blood transfusion data who met the MT definition of 40 mL/kg/24 hours, 633 patients were included. who met the MT definition of 40 mL/kg/24 h. Similar to the above adult studies, the authors were unable to identify an upper transfusion volume threshold to predict mortality in pediatric trauma patients, regardless of mechanism. In a study of 118 pediatric trauma patients younger than 13 years and found pulseless and apneic after having had an injury, Brindis and colleagues noted that only 5% survived.[16] Moreover, all of these "survivors" were neurologically impaired with devastating anoxic brain injury. Capizzani and co-authors did achieve 100% mortality prediction in a small study of 30 patients with prehospital traumatic cardiopulmonary arrest.[17] The authors identified 100% mortality in those with >15 minutes of CPR, with neurologically devastated "survival" with either nonreactive pupils, no pulse, or disorganized ECG on arrival. These authors and others have noted the importance of objective measures to better forecast futile care and inform both physicians and parents, as well as set reasonable expectations and steward resource utilization.

Building on these previous few studies in children and adolescents, and aiming for similar absolute cut-points produced in adults, Kalkwarf and colleagues set out to identify extreme laboratory values, both isolated and in combination, that could be used to predict 100% mortality in severely injured children.[18] The investigators evaluated all pediatric trauma patients (less than 16 years of age) who met highest level trauma team activation and were admitted to a single center between 2010 and 2016. Among their 1,292 pediatric patients, there was a 10% mortality rate. While there were significant differences in gender, race, and mechanism among survivors or non-survivors, those who died were significantly younger (median age 11 vs. 14; p=0.007) and higher ISS (median 30 vs. 12; p <0.001). Similar to adults, there were multiple extreme values that were greater than 90% predictive of mortality, but achieving 100% was more elusive. Single arrival lab values that achieved 100% PPV were base deficit of 22 or greater, lactate 15 or higher, pH of 6.95 or less, INR of 3.0 or greater, or platelets 30,000 or less. As with adults, fibrinolysis by rapid thrombelastography was a predictor and achieved 100% futility as a single value at 50% or higher. Consistent with the low platelets, rapid thrombelastography maximal amplitude of 30 mm or less was 100% fatal. While the authors were unable to identify physiologic criteria for cut-offs, they were able to identify several combinations of extreme lab values that achieved 100% mortality (**TABLE V**). In the presence of traumatic brain injury, these patients tolerated even less extreme values before 100% fatality was noted. The authors concluded that extreme admission laboratory values, with and without brain injury, are capable of predicting 100% mortality in severely injured children. While they did note that

validation of their single center findings was warranted, they argued that, if supported, these cut-points provide objective data which should initiate discussion within pediatric trauma community regarding cessation of resuscitation in such patients.

Suspension of Transfusions and Other Procedures (STOP) Criteria for 100% Futility		
	PPV	**NPV**
Arrival pH ≤7.00 and INR ≥2.0	**100%**	**58%**
Arrival base deficit ≥20 and INR ≥2.0	**100%**	**55%**
Arrival pH ≤7.05 and LY-30 ≥20%	**100%**	**56%**
Arrival base deficit ≥12 and LY-30 ≥20%	**100%**	**70%**
TBI and INR ≥2.0	**100%**	**63%**
TBI and LY-30 ≥20%	**100%**	**89%**

Table V. Futility cut-points for children and adolescents

CONCLUSIONS

Major improvements in trauma care over the last decade have improved survival rates in the severely injured. The unintended consequence is the presentation of patients with nonsurvivable injuries in a time frame in which intervention is considered and often employed due to prognostic uncertainty. In light of this, discerning survivability in these patients remains increasingly problematic. Evidence based cut-points of futility can guide early decisions for discontinuing aggressive treatment and use of precious resources in severely injured patients arriving in extremis. The STOP criteria provide futility cut points to help guide early decisions for discontinuing aggressive treatment of patients in extremis. Even in children, these extreme admission lab values are capable of predicting 100% mortality and futility of additional care in severely injured children with a high level of accuracy.

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THREE'S A CROWD: PROLIFERATION OF TRAUMA CENTERS

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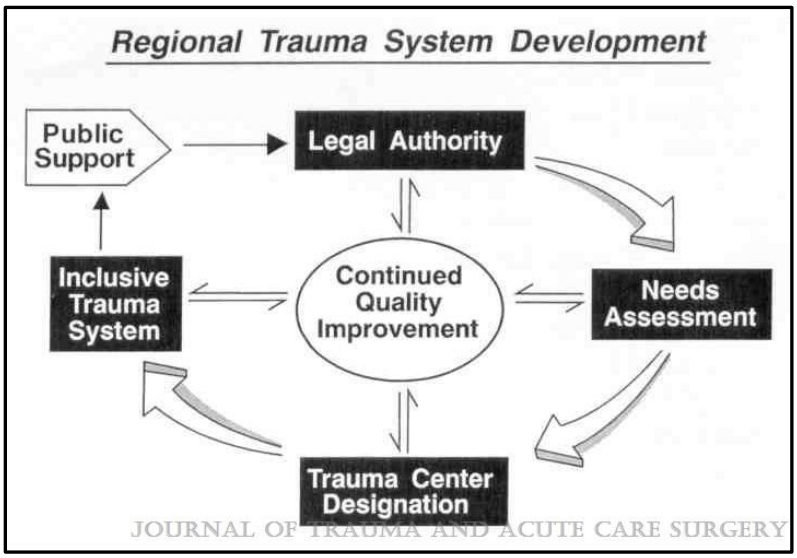

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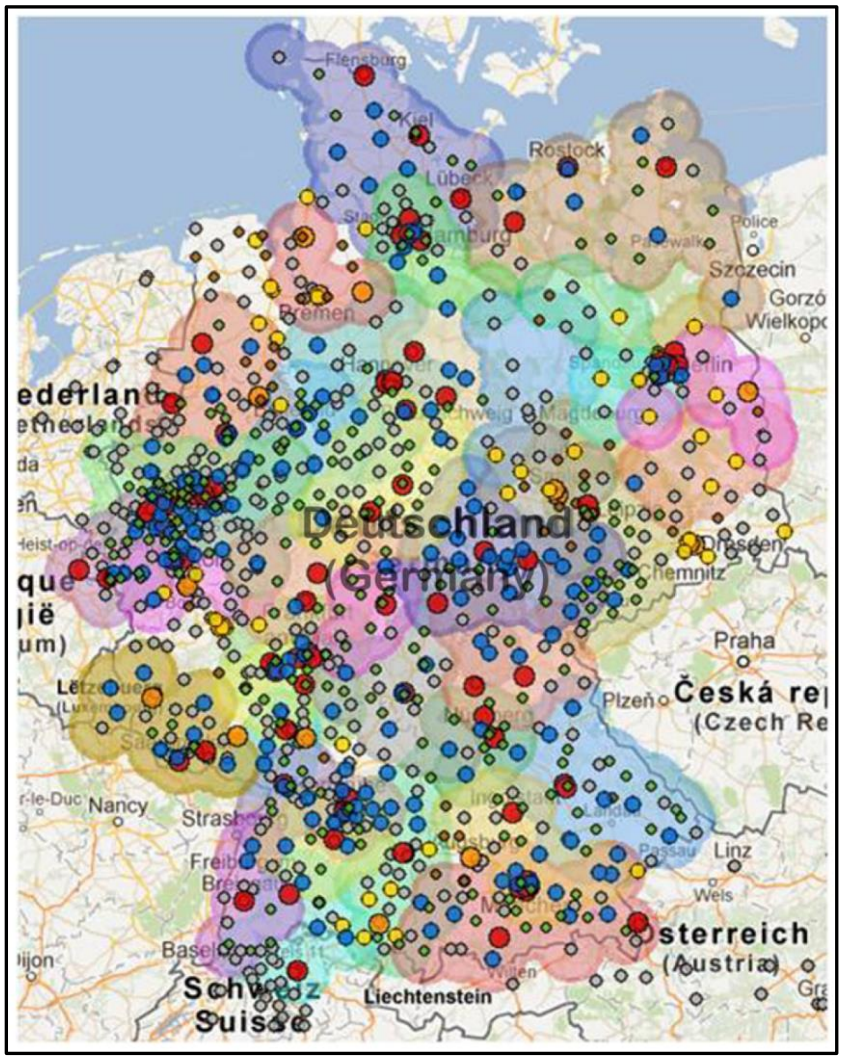
HISTORICAL BACKGROUND AND CURRENT SCOPE OF THE PROBLEM

- In 1966, the landmark white paper, "Accidental Death and Disability: The Neglected Disease of Modern Society," was published calling for financial support and specialized centers to mitigate the epidemic of traumatic injury as the leading cause of death in the US.
- By 2005, 15.9% of all US residents (46.7 million Americans living in mostly rural areas) had no access within an hour to a level I or II trauma center.
- Between 2009 and 2012, more than 200 US trauma centers opened, majority being Level II centers in urban and suburban hospitals
- In 2015, the ACS COT proposes the Needs-Based Assessment of Trauma Systems (NBATS-I) to address the mounting concern that uncontrolled growth of trauma centers could create adverse competition in saturated areas while ignoring underserved areas.
- The relationship between trauma center volume and outcomes has been challenged with findings suggesting proliferation is not associated with improved outcomes.
- Geospatial access to trauma centers has interstate variability as it relates to mortality and outcomes.

CURRENT MAP OF TRAUMA CENTERS IN GERMANY (ROUGHLY THE SIZE OF CALIFORNIA)

- Germany has 3 levels of care in its trauma network:
    - Supra regional centers (red) are equivalent to a US Level I trauma center
    - Regional centers (blue) are a US Level II
    - Local centers (green)
- The current population of **Germany** is **83,272,566**
- The goal is a *maximum* of 30 min from scene to trauma center admission in the regional trauma center network
    - If possible, the severely injured patient (ISS $\geq$ 16) should be transferred directly to a regional or superregional trauma center
    - If the transportation time > 30 min, the patient should be admitted to a local trauma center
- By 2014, Germany is completely covered with 55 trauma networks and 900 trauma centers, allowing overlapping coverage of helicopters and trauma network.



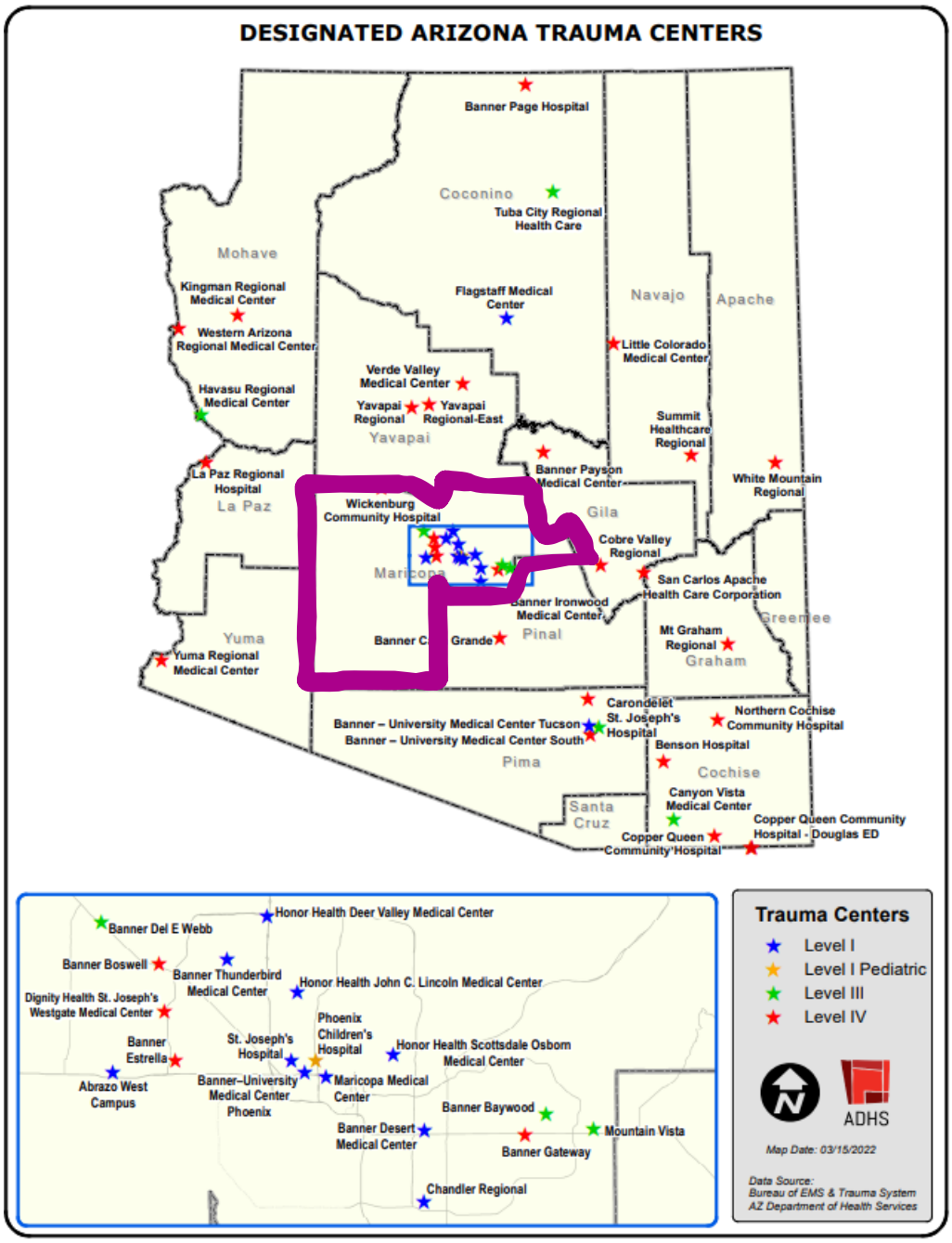
CURRENT MAP OF US TRAUMA CENTERS

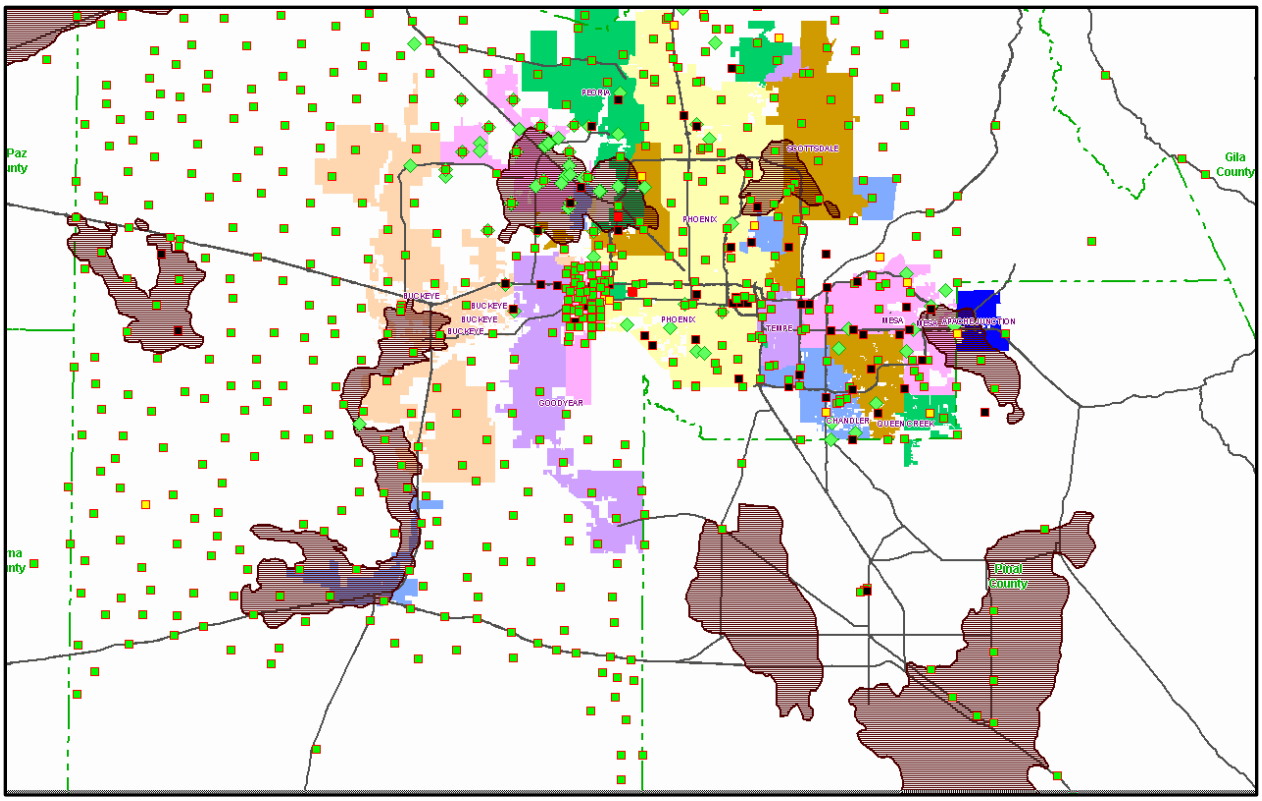
- Current population size in the **US** is **341,814,420**
- There are > 600 Level I and II Adult and Pediatric Trauma Centers in the US (State Designated and ACS verified)
- Level I criteria: admit at least 1,200 trauma patients yearly or have 240 admissions with an ISS ≥15

Current map of Adult and Pediatric Level I* and Level II* Trauma Centers in the US Alaska has a level II and Hawaii a level I Trauma Center. *Trauma Center Association of America*

CURRENT MAP OF TRAUMA CENTERS IN STATE OF ARIZONA

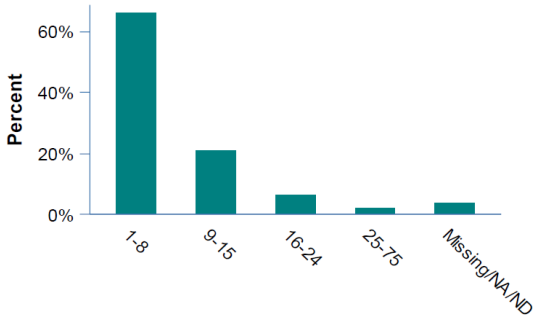
- Population size of **Arizona** is **7,547,837** and 6th largest state by size
- Maricopa County, which is home to 4.1 million people, is the largest county
- State Designated and ACS Verified Level I and II Adult and Pediatric Trauma Centers
    - Phoenix (within Maricopa County outlined below) (11) within an 18-mile radius
    - Flagstaff (1)
    - Tucson (2)


DESIGNATED ARIZONA TRAUMA CENTERS
Banner Page Hospital
Coconino
Tuba City Regional Health Care
Mohave
Kingman Regional Medical Center
Western Arizona Regional Medical Center
Havasu Regional Medical Center
La Paz Regional Hospital
La Paz
Flagstaff Medical Center
Navajo
Apache
Little Colorado Medical Center
Verde Valley Medical Center
Yavapai Regional
Yavapai Regional-East
Yavapai
Summit Healthcare Regional
Banner Payson Medical Center
White Mountain Regional
Wickenburg Community Hospital
Gila
Cobre Valley Regional
Maricopa
San Carlos Apache Health Care Corporation
Banner Ironwood Medical Center
Greenlee
Yuma
Banner C Grande
Pinal
Mt Graham Regional
Graham
Yuma Regional Medical Center
Carondelet St. Joseph's Hospital
Northern Cochise Community Hospital
Banner – University Medical Center Tucson
Banner – University Medical Center South
Benson Hospital
Pima
Cochise
Canyon Vista Medical Center
Santa Cruz
Copper Queen Community Hospital - Douglas ED
Copper Queen Community Hospital
Honor Health Deer Valley Medical Center
Banner Del E Webb
Banner Boswell
Banner Thunderbird Medical Center
Honor Health John C. Lincoln Medical Center
Dignity Health St. Joseph's Westgate Medical Center
Phoenix Children's Hospital
Banner Estrella
St. Joseph's Hospital
Honor Health Scottsdale Osborn Medical Center
Abrazo West Campus
Banner–University Medical Center Phoenix
Maricopa Medical Center
Banner Baywood
Banner Desert Medical Center
Mountain Vista
Banner Gateway
Chandler Regional
Trauma Centers
Level I
Level I Pediatric
Level III
Level IV
ADHS
Map Date: 03/15/2022
Data Source:
Bureau of EMS & Trauma System
AZ Department of Health Services



GIS map of the population of Maricopa County

Figure 11: Trauma proportion by injury severity score



Data source: Arizona State Trauma Registry 2021

Table 9: Trauma incidence and mortality proportion by injury severity score

Injury Severity Score	Count	Percent	Deaths	Mortality Proportion
1-8	43,160	65.99%	386	0.89%
9-15	13,678	20.91%	365	2.66%
16-24	4,325	6.61%	262	6.05%
25-75	1,585	2.42%	635	40.06%
Missing/NA/ND	2,648	4.04%	68	2.56%

STAB Annual Report 2022

DOES PROLIFERATION OF TRAUMA CENTERS AFFECT OUTCOMES?

- Hospitals' interest in seeking trauma center designations has increased citing need for more effective and efficient care, improved triage, shorter transport times with reduced consumption of EMS resources.
- However, increasing the number of trauma centers, especially in a mature trauma system has raised concerns for duplication of services, dilution of experience, degradation of quality and increased costs.
- Recent literature has focused on challenging trauma system development by showing that proliferation of trauma centers did not lead to improved outcomes in the face of higher costs and decreased the volume of injuries necessary for training and education.

a. **Transport times and the golden hour**

- The concept of the golden hour signifies the need for the patient to receive definitive care within 60 minutes from time of injury and has been a standard by which transport times and outcomes has been measured.
- Although great advances have been made to increase trauma center coverage, gaps still exist, especially for rural communities.
- Gaps also exist in urban communities, such as Jones et al, reported, that despite a threefold increase in the number of state designated trauma centers in Arizona, transport time has not decreased in urban or rural areas.

b. **Patient volume**

- The ACS COT sets standards for a Level I trauma center to admit at least 1200 injured or 240 severely injured patients (ISS >15) per year.
- No such standards exist for Level II trauma centers.
- Clinical expectations are the same for Level I and Level II trauma centers.
- Jones et al., looked at level I to level I trauma center transfers in Arizona, as it relates to disparity in resource and expert capability in an environment with extreme proliferation of trauma centers.

c. **Mortality**

- Amato et al, in a recent paper, reported that despite a 30% increase in the number of high level (I and II) trauma centers in a 15-year period, population access to these centers only increased by 6.9%.
- Counties with high injury mortality had the lowest high-level trauma coverage.

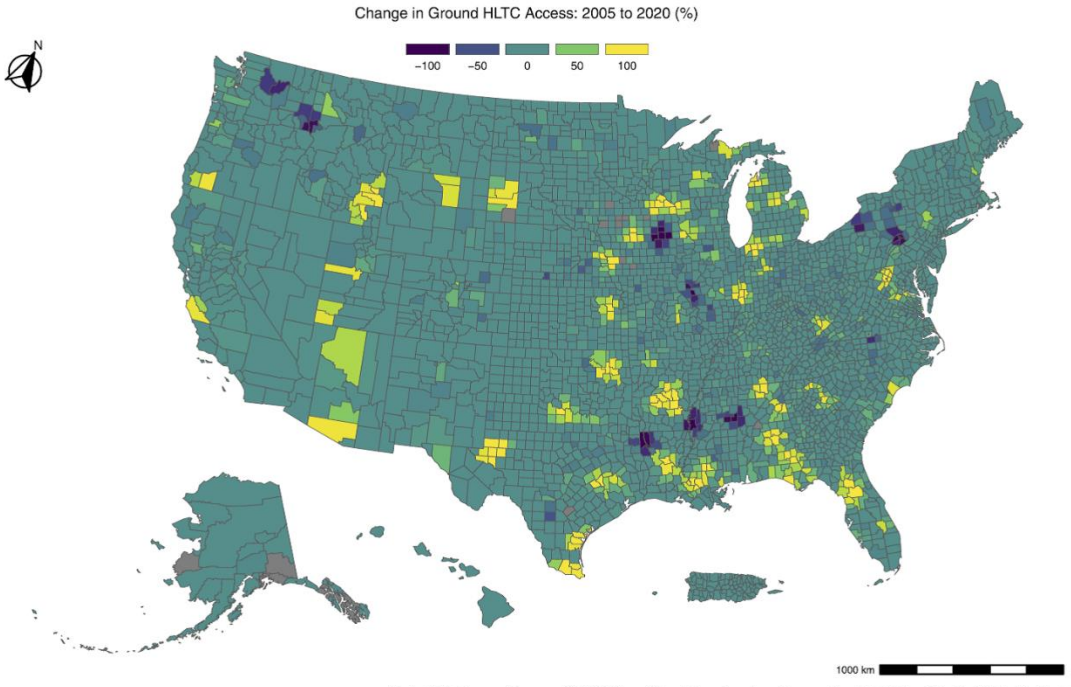


Figure 1. Visualization of the percentage change in county-level access to ground HLTC care within 60 minutes between 2005 and 2020. Counties with increased coverage are lighter (yellow), decreased coverage darker (purple), and counties with constant coverage are in between (green).

Amato et al., J Trauma Acute Care Surg. 2023 Jun 1;94(6):755-764

- Zhou et al, reported that after almost doubling the number of level I trauma centers in Phoenix, Arizona in a 7-year period, patients experienced more inter-facility transfers, longer ICU length of stay ventilator days and was an independent predictor of mortality.

d. **Cost:**

- Trauma center designation has become more financially desirable for hospitals, which has affected mature systems in place due to changes in payer mix index with the addition of new centers.
- Opening of new centers in a mature system unfavorably affects payer mix in the existing centers.
- Data suggests that high density of urban trauma centers may be due to financial motivations rather than community need.

e. **Social determinants of health**

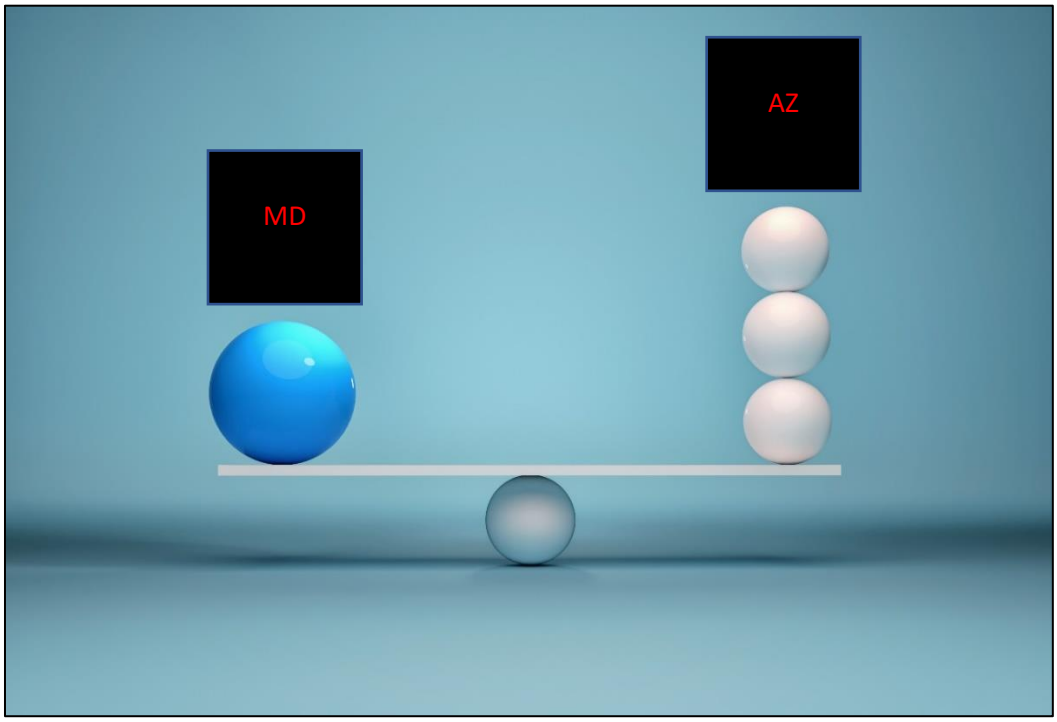
- Social determinates of health, such as poverty and unemployment rates, affect population health.
- The density of poverty and violence may be inversely proportional with density of trauma centers.

- Rural trauma care continues to be a substantial challenge with impediment to timely access.

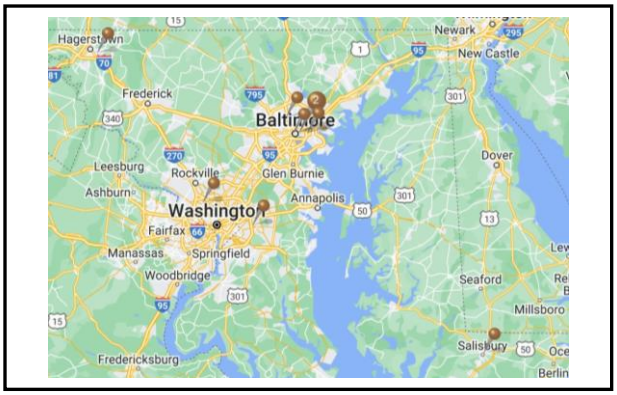
DOES PROLIFERATION OF TRAUMA CENTERS AFFECT QUALITY?

- It is rather challenging to make this assumption from the literature and research.
- Current metrics focus on demand (volume) and capacity (supply) of a trauma center but there are no standard methods to define how these relate to quality.
- This leads to difficulty in making a needs assessment and many have called for better metrics to help regionalize trauma system care.
- The Needs-Based Assessment of Trauma Systems (NBATS-I) assessment tool was proposed as a method to estimate trauma centers in a region but has had some limitations for certain states.

DOES ANY TRAUMA REGIONAL SYSTEM HAVE THE RIGHT BALANCE?



- **Population of Maryland is** 6,144,760
- **Trauma centers**
  - **Level I (2)**
  - **Level II (4)**



Final Disposition of Patients: Primary Admissions Only

(3-Year Comparison)

Source: Maryland State Trauma Registry

Final Disposition	June 2019 to May 2020	June 2020 to May 2021	June 2021 to May 2022
Inpatient Rehab Facility	7.4%	8.4%	8.1%
Skilled Nursing Facility	10.5%	10.8%	13.4%
Residential Facility	1.3%	1.2%	1.2%
Specialty Referral Center	4.2%	4.4%	4.3%
Home with Services	6.3%	7.8%	8.1%
Home	56.3%	52.6%	51.2%
Acute Care Hospital	2.6%	3.0%	2.4%
Left Against Medical Advice	2.5%	3.2%	2.6%
Morgue/Died	5.3%	5.1%	5.0%
Left without Treatment	0.0%	0.0%	0.1%
Hospice Care	0.7%	0.9%	0.9%
Jail	1.2%	1.0%	0.9%
Psychiatric Hospital	1.3%	1.2%	1.3%
Elopement	0.3%	0.3%	0.3%
Other	0.1%	0.1%	0.2%
TOTAL	100.0%	100.0%	100.0%

Note: "Primary Admissions" refers to all patients except those treated and released from the emergency department within 6 hours of emergency department arrival.

Injury Severity Scores (ISS) by Injury Type: Primary Admissions Only

(June 2021 to May 2022)

Source: Maryland State Trauma Registry

ISS	Blunt	Penetrating	Total
1 to 12	77.5%	66.6%	76.0%
13 to 19	12.5%	13.4%	12.6%
20 to 35	8.6%	15.5%	9.6%
36 to 75	1.4%	4.5%	1.8%
TOTAL	100.0%	100.0%	100.0%

Note: "Primary Admissions" refers to all patients except those treated and released from the emergency department within 6 hours of emergency department arrival.

Injury Severity Scores of Patients with Penetrating Injuries: Primary Admissions Only

(3-Year Comparison)

Source: Maryland State Trauma Registry

ISS	June 2019 to May 2020	June 2020 to May 2021	June 2021 to May 2022
1 to 12	69.9%	68.8%	66.6%
13 to 19	12.1%	12.6%	13.4%
20 to 35	12.8%	13.7%	15.5%
36 to 75	5.2%	4.9%	4.5%
TOTAL	100.0%	100.0%	100.0%

Note: "Primary Admissions" refers to all patients except those treated and released from the emergency department within 6 hours of emergency department arrival.

Injury Severity Scores of Patients with Blunt Injuries: Primary Admissions Only

(3-Year Comparison)

Source: Maryland State Trauma Registry

ISS	June 2019 to May 2020	June 2020 to May 2021	June 2021 to May 2022
1 to 12	78.1%	78.0%	77.5%
13 to 19	12.3%	12.2%	12.5%
20 to 35	8.3%	8.3%	8.6%
36 to 75	1.3%	1.5%	1.4%
TOTAL	100.0%	100.0%	100.0%

Note: "Primary Admissions" refers to all patients except those treated and released from the emergency department within 6 hours of emergency department arrival.

Injury Severity Scores of Patients with Either Blunt or Penetrating Injuries: Primary Admissions Only

(3-Year Comparison)

Source: Maryland State Trauma Registry

ISS	June 2019 to May 2020	June 2020 to May 2021	June 2021 to May 2022
1 to 12	76.8%	76.8%	76.0%
13 to 19	12.3%	12.2%	12.6%
20 to 35	9.0%	9.1%	9.6%
36 to 75	1.9%	1.9%	1.8%
TOTAL	100.0%	100.0%	100.0%

Note: "Primary Admissions" refers to all patients except those treated and released from the emergency department within 6 hours of emergency department arrival.

SUMMARY AND NEXT STEPS

- Trauma systems were originally envisioned as a public service to combat the epidemic of traumatic injury.
- Trauma care gaps still exist in underserved rural and urban areas.
- Proliferation of trauma centers might not correlate with improved outcomes.
- Trauma center designations have become more financially desirable.
- Allocation of trauma centers based on population need is a work in progress.
- Geospatial mapping is proving to be a good tool for identifying geographic needs and social factors for trauma center development.
- More research is needed to help define quality metrics as they relate to effective regionalized trauma system implementation and trauma center care.

VICTORY OUT OF TRAGEDY: ORGAN DONATION CHALLENGES

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The technological advancements in transplantation today have made organ donation a common and culturally accepted practice. As of January 2024, there were over 103,000 patients on the Organ Procurement and Transplantation Network (OPTN)/United Network for Organ Sharing (UNOS) waiting list. Despite the continued advances in the field of transplantation, ongoing challenges continue to limit the accessibility of this life saving procedure for a significant number of patients with end organ failure. There is no bigger challenge than the availability of organs for transplantation. In 2023, there were 42,601 organ transplants performed from 21,200 donors, and over 6200 patients died while waiting for an available organ. This disparity in organ supply and organ need continues as more and more patients are added to the transplant waiting list. The transplant community continues to work on ways to expand the donor pool and have made significant advances in recent years to improve the quality and quantity of organs available for the transplantation. Efforts that include targeting peri-transplant donor tissue damage, organ preservation, combating rejection, and even revisiting xenotransplantation, all to meet the demands of the ever-growing population of recipients.

The majority of transplanted organs come from donors after neurologic determination of death (DNDD). These patients have catastrophic brain injury and often have complex physiologic responses to the injury. Intensivists, therefore, play a crucial role in their management and ensuring that these patients preserve the option of organ donation. Understanding the complex physiology and implementing appropriate management strategies are keys to helping address the most significant challenge to organ transplantation.

IDENTIFYING POTENTIAL DONORS

There are three major sources of organs used for transplants: Cadaveric "brain-dead" donors (donors after neurologic determination of death, DNDD), cadaveric "cardiac death" donors (donors after circulatory determination of death, DCDD), and living (related and unrelated) donors. Currently, the majority of transplanted organs come from donors after neurologic determination of death. In 2023, there were 36,241 (85%) deceased donor transplants while there were only 6,360 (15%) living donor transplants. DCDD currently comprise 30% of all deceased donors. This number has more than doubled in the past 10 years and accounts for the rise in organ donors during that same time period.

REFERRAL OF POTENTIAL DONORS

Once the potential donors have been identified, Organ Procurement Organizations (OPOs) must be involved in the management of the donation process. This referral step should be taken as early as possible because early referral is associated with better outcomes, including higher consent rates and conversion rates. Early referral gives the OPOs the opportunity to form relationships with the caregivers, educate them on the details of the process, and attend to the unique ethical and social needs of each

situation. In a study of families that denied donation, it was found that fifty-three percent of them did not receive adequate education and the next of kins that decided against donation usually had less understanding of brain death than those that agreed to donation.

Of note, the task of obtaining consent to donate should not be carried out by the physician but should be left to the staff of the OPOs, since they have the necessary training and experience.

TEAM MANAGEMENT APPROACHES TO DONATION

Like any successful process, the organ donation process requires teamwork. Aside from the primary physician, other members of the healthcare team play critical roles in guiding the families and supporting them in their grief. A senior physician should interact with the families early in the process and be identified as a ready source of support.

The presence of OPO staff housed within the hospital is also crucial for optimal donation outcomes. These in-house coordinators are usually nurses trained in organ procurement, and they form strong bonds with donor families; providing support, ensuring the timings of discussions are appropriate, and adapting the approaches to the cultural backgrounds of the families. They also ensure timely donor referral via donor surveillance, organize regular staff education sessions, and daily monitor the donation activities of the hospital. Implementation of in-house coordinators has been shown to increase consent and conversion rates significantly. Hospitals that operate this system have been shown to have up to 28% greater consent rates and 48% greater conversion rates, when compared to other hospitals with similar resources but without in-house coordinators. Other improvements in outcomes shown after the implementation of in-house coordinators include higher referral rates, lower family decline rates, and increased organs transplanted per donor. This effect is more marked in centers with minority populations. The reasons for the better outcomes in hospitals with in-house coordinators can be linked to the better access they have to the patients and the ease of relationship-building with the clinical and management staff of the hospital.

PATHOPHYSIOLOGY OF BRAIN DEATH

Neurologic death is caused by the herniation of cerebral contents due to supranormal intracranial pressures. Early pontine ischemia results in a catecholamine surge with hypertension, known commonly as the first stage of the Cushing's reflex. As ischemia progresses caudally to the vagal nucleus in the medulla oblongata, the loss of baroreflector reflexes and unopposed sympathetic activity results in a profound hyperdynamic state. This sympathetic vasoconstriction causes compromise of end organ perfusion. As the brain continues to herniate, a sudden cardiovascular collapse can develop, in part due to direct catecholamine-induced myocardial injury and subsequent cardiac dysfunction, as well as destruction of pontine and medullary vasomotor centers. The effects of this hemodynamic instability can cause marked damage to potentially donatable end-organs. Profound hypotension develops due to loss of sympathetic tone, amplified by the development of diabetes insipidus (DI) due to an infarcted posterior pituitary. The physiologic changes that manifest as different portions of the brain become injured during the herniation process present a multifaceted challenge to the treating intensivist. These physiologic alterations result in diffuse vascular regulatory disturbances and widespread cellular injury. Major swings in hormone levels are seen. Severe alterations also occur in metabolism, immunology, and coagulopathy. Understanding these physiological responses is important for the optimal care of the injured patient and maximal utility of donated organs.

SYSTEMIC SEQUELAE OF BRAIN DEATH

Cardiovascular System

Two distinct profiles of hemodynamic activity are seen during the process of neurologic death. Brainstem ischemia causes a catecholamine surge as the medulla endeavors to maintain cerebral perfusion pressure and improve local tissue oxygenation. This response manifests as increases in heart rate, blood pressure, cardiac output and systemic vascular resistance. ECG changes and cardiac arrhythmias are common and are thought to be due to both metabolic and electrolyte abnormalities, as well as infarction of the conduction system. Untreated arrhythmias may become completely refractory to management if not treated early and aggressively.

The second phase of cardiovascular activity, characterized by hemodynamic collapse, coincides with brainstem herniation and results in the loss of sympathetic activity causing profound vasodilatation, myocardial depression, and low levels of serum catecholamines. The hemodynamic effects can be amplified by hypovolemia due to diabetes insipidus, which is often present concurrently.

Pulmonary System

Increased systemic pressures and left atrial pressures during the catecholamine surge can result in elevated pulmonary artery pressures and subsequent endothelial damage, leading to direct pulmonary damage due to capillary leak. During cardiovascular collapse, intravenous fluid administration needed to maintain systemic blood pressure can cause further pulmonary damage due to volume overload, pulmonary capillary leak, and resultant development of pulmonary edema. Increased pulmonary capillary permeability as well as decreased pulmonary resistance make the lungs particularly sensitive to increases in volume loading.

Lung protective strategies commonly used in the Intensive Care Unit should continue to be performed in the potential organ donor. Pulmonary toilet maneuvers such as chest percussion, postural drainage, recruitment maneuvers, and serial bronchoscopy can also improve lung function.

Renal System

Sympathetic storm and the subsequent cardiovascular collapse have a deleterious effect upon the renal system. Hypoperfusion of the juxtaglomerular cells of the kidney activates the renin-angiotensin-aldosterone axis, causing salt and water retention as well as vasoconstriction, which in turn can lead to compromised renal blood flow, glomerular and tubular injury, and ultimately renal insufficiency. This directly compromises kidney viability and post-transplantation function, and underscores the need for active hemodynamic management in donors. The maintenance of urine output to a minimum of 0.5cc/kg/hr, while avoiding the massive diuresis of diabetes insipidus, is the goal of reno-protective resuscitation.

Hepatic System

While the overall inflammatory process of brain death seems to have less of an effect on the liver, hypernatremia (sodium >155mmol) has been associated with increased rates of transplanted liver allograft loss.

Coagulation and thermoregulation disorders

Disorders of coagulation are a direct consequence of the release of thromboplastin, cerebrogangliosides, and plasminogen-rich substrate from traumatized brain tissue. Hypothermia and acidosis, along with the dilution of clotting factors, fibrinogen and platelets, can contribute to a state of disseminated intravascular coagulation and uncontrollable bleeding. Massive transfusion protocols are often required. Hypothermia

should be proactively addressed with patient warming devices, including heated intravenous fluids and ventilated gases.

THE ROLE OF PROTOCOLS IN ORGAN DONATION

Because of the complexities involved in the caring for the critically ill patient and the numerous considerations for optimizing donation, it is useful to have written guidelines to direct the steps taken during the organ donation process. Most organ donors donate after neurological determination of death and may have been earlier managed with the goal of optimizing brain tissue outcome. Many intensive care units have Catastrophic Brain Injury Guidelines (CBIGs), which are useful in guiding patients with neurological injuries to recovery.

For the potential donor with severe irreversible neurologic injuries, however, care shifts from maximizing neurologic recovery to the maintenance of the remaining organ systems. Often, there are conflicts about which organ systems to prioritize, as attempts to optimize one system may be deleterious to another. Unless the intensivist knows a priori that a particular organ will not be suitable for transplantation, one is faced with a delicate balancing act between the competing needs of several different organ systems. Therefore, the use of a checklist of standardized critical care endpoints, or Donor Management Goals (DMGs), or donor management protocols, will be beneficial in guiding care providers to optimize the number of organs suitable for transplant from donors.

RESUSCITATION OF POTENTIAL DONORS

Optimal and aggressive critical care of the potential donor begins long before the declaration of death. To ensure that the donor organs would be of utmost benefit to the recipients, efforts must be made to ensure optimal organ status through the process of referral, consent, and organ recovery. Because brain death is associated with profound physiologic alterations that result in diffuse regulatory disturbances and widespread cellular injury, severe alterations in metabolism, endocrine function, and coagulopathy are commonly observed in potential donors. The following components of resuscitation would be useful in addressing some of these responses.

Hemodynamic Monitoring

To guide resuscitation and support, a recommended practice is instituting some sort of hemodynamic monitoring. Echocardiography is routinely used to assess the left ventricular function of a potential donor heart. The use of non-invasive methods that measure pulse pressure variations have been introduced to the care of organ donor.

Fluid resuscitation

Due to severe intracranial swelling, there is disruption of the function of the posterior pituitary leading to low or absent levels of vasopressin in up to 90% of organ donors. The consequence of this is cardiovascular collapse and hypotension with neurogenic diabetes insipidus (DI) occurring in nearly half of all DNDDs. Without adequate intervention, this could result in a massive hypoosmolar diuresis and electrolyte abnormalities. The loss of intravascular volume leads to profound hypotension. It is therefore a high priority to maintain optimal fluid status, through fluid management, in order to preserve perfusion. Fluid resuscitation is recommended to maintain a CVP of 8 mm Hg to 12 mm Hg and a systolic arterial pressure of between 90 mm Hg and 140 mm Hg.

The role of vasopressin

After the achievement of adequate fluid resuscitation, vasopressin should be considered as the first-choice hemodynamic therapy. Vasopressin, (or Anti-Diuretic Hormone, ADH) acts upon its V1 subtype receptors found in vascular smooth muscle which are responsible for its vasopressor activity, as well as the V2 subtype found in renal collecting duct epithelia which increase water permeability and is responsible for its anti-diuretic activity. 1-desamino-8-D-arginine vasopressin (DDAVP) is highly selective for the V2 subtype alone and may be used as an adjunctive treatment for DI.

Administration of vasopressin acts to inhibit the diuresis of DI and the resultant hypotension due to its catecholamine sparing effects and ability to counteract vasodilatation. Vasopressin is also usually seen to be deficient in donors who require catecholamine support.

The role of thyroxine

The hemodynamic instability in DNDDs is partly due to low circulating levels of thyroxine. These low levels lead to diminished production of adenosine triphosphate, causing myocardial dysfunction, accumulation of lactate, and resultant circulatory collapse. Therapeutic replacement with T3 has been associated with complete reversal of anaerobic metabolism and subsequent stabilization of cardiac function when applied to DNDDs. It has been demonstrated that hemodynamically unstable organ donors require a significant decrease in, or complete lack of, vasopressor support after T4 administration. In addition, the use of thyroid hormone has been associated with significant improvements in cardiovascular status, reductions in inotropic support, and decreases in donors lost from cardiac instability. A “T4 protocol” is recommended in situations where there are increased vasopressor requirements. This protocol consists of 1 ampule 50% dextrose, 2 g of solumedrol, 20 units regular insulin, and 20 mcg of thyroid hormone (T_4), followed by a continuous infusion of 10 mcg/h.

The role of insulin

After the development of neurologic death, insulin levels have been measured to decrease to 50% of baseline at 3 hours, and even further to 20% at 13 hrs. The resulting hyperglycemia has profound effect on allograft function. Hyperglycemia is well known to impact renal function. In addition, osmotic diuresis resulting from glucose spillage may contribute to the diuresis seen in brain death. Keeping glucose levels under 150 mg/dL using parenteral insulin yields renal allografts with lower creatinine levels.

The role of steroids

The systemic responses known to follow brain death include a massive inflammatory response characterized by elevations in plasma levels of inflammatory mediators such as interleukin-6 and tumor necrosis factor. This increase in cytokine levels can be detrimental to the function and survival of grafts from organ donors. Steroids exert anti-inflammatory effects by decreasing levels of serum cytokines. The use of steroids has been shown to improve pulmonary function and lead to the utilization of lungs that may have been previously deemed unacceptable for transplantation.

MANAGING POTENTIAL COMPLICATIONS

Brain death is associated with numerous complications such as disseminated intravascular coagulation (DIC), diabetes insipidus (DI), neurogenic pulmonary edema (NPE), hypothermia, and cardiac arrhythmias. There are major swings in various hormones such as Cortisol, vasopressin, thyroxine and insulin. The effects of these hormones are sometimes synergistic and may cause dramatic changes in the physiological status of the potential donor. Understanding and anticipating these complications is important for the managing physician. Early identification of these complications coupled with adequate supplementation is necessary to maintain hormonal balance, hemodynamic stability and organ perfusion.

CONCLUSION

Organ donation is an important process that ensures availability of organs for individuals whose only opportunities for survival lie on receiving transplants. Efforts to ensure the success of every step of the process are, therefore, of utmost importance. Recommendations for all institutions that care for the critically ill patient include incorporating skilled team-driven approaches to the consent process, protocol-guided steps for the management of potential donors, and adequate balance of the physiological status of donors. Optimal hemodynamic management, multi-drug hormone replacement therapy, and efficient organ recovery are strategies to improve organ yield and the viability of donor organs.

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SESSION 16

MATTOX COMMENTARY AND REVIEW OF PRESENTATIONS

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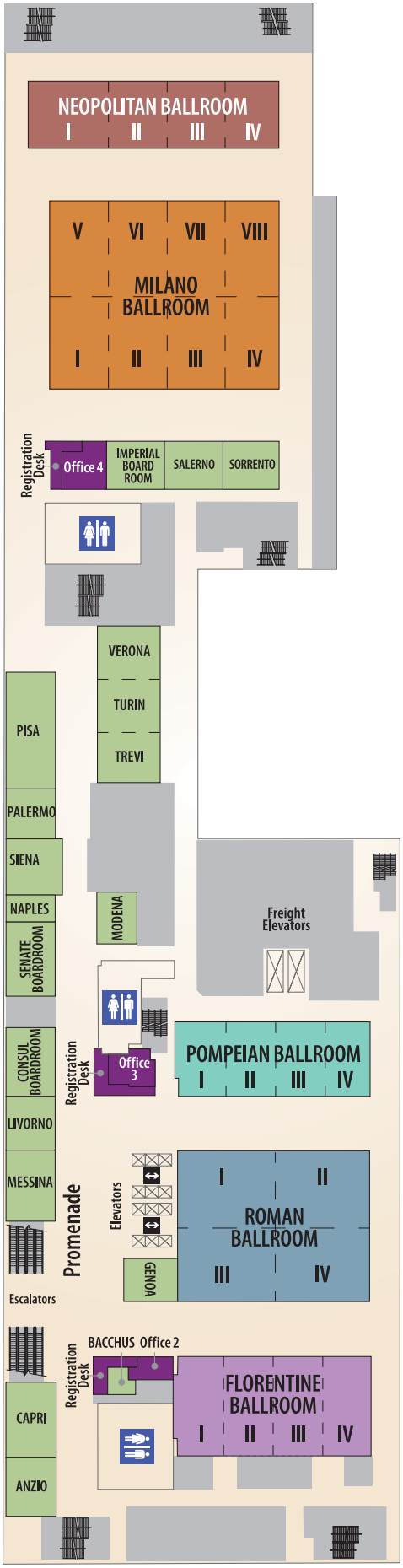

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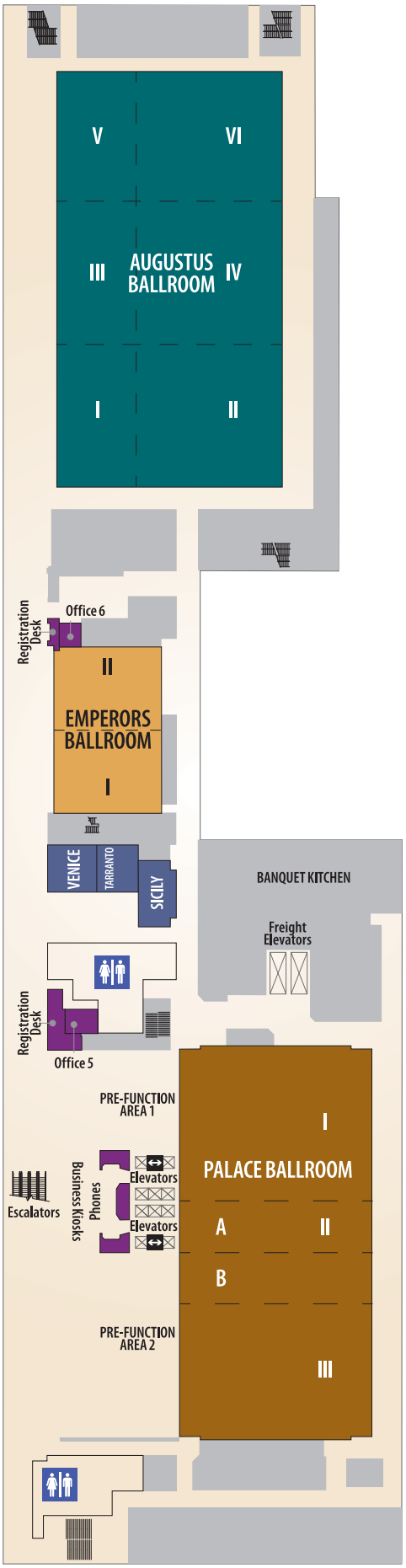

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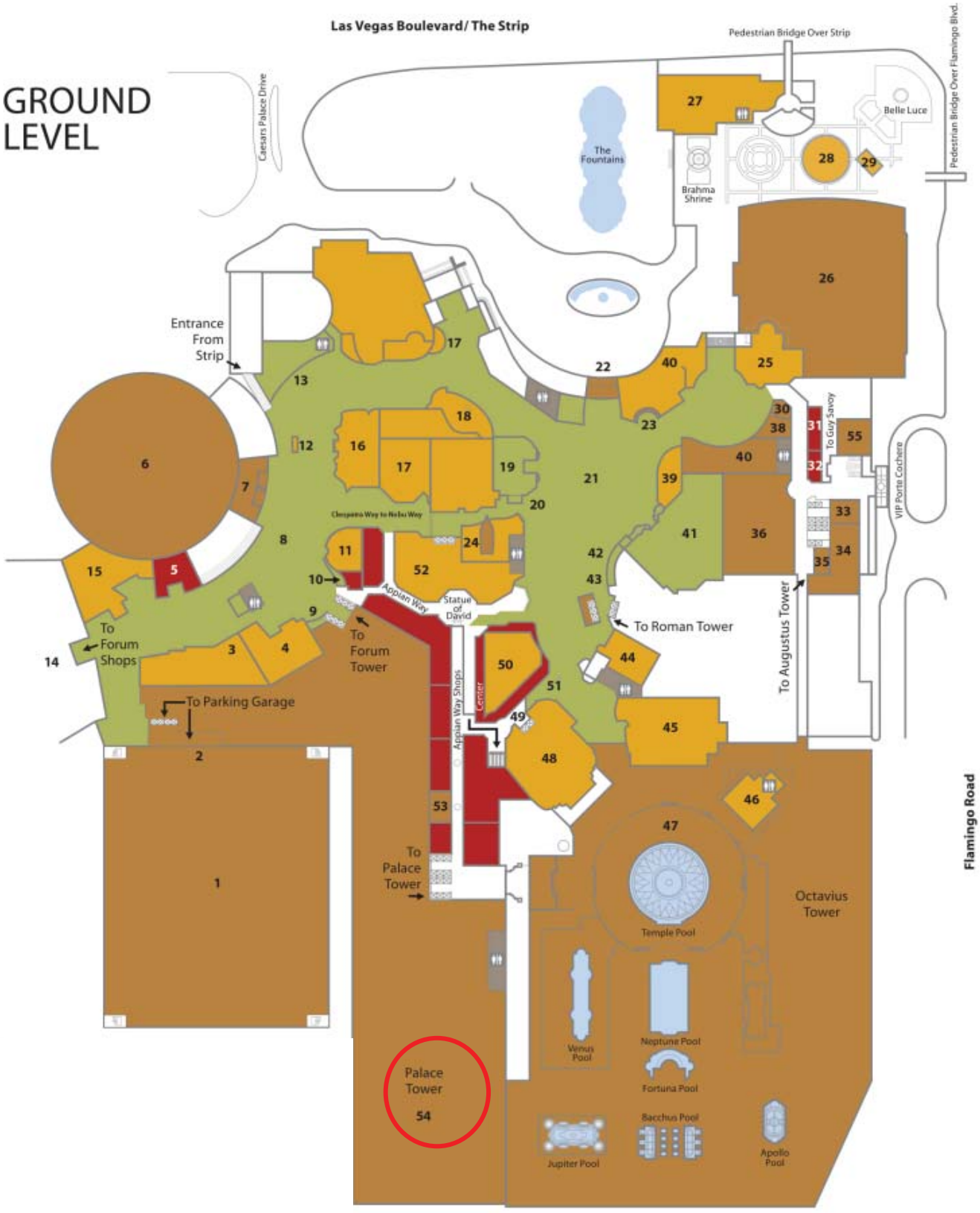

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