THORACIC TRAUMA: THE ABCs AND BEYOND

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Professor and Associate Chair for Research, Department of Surgery, JABSOM/University of Hawaii Manoa


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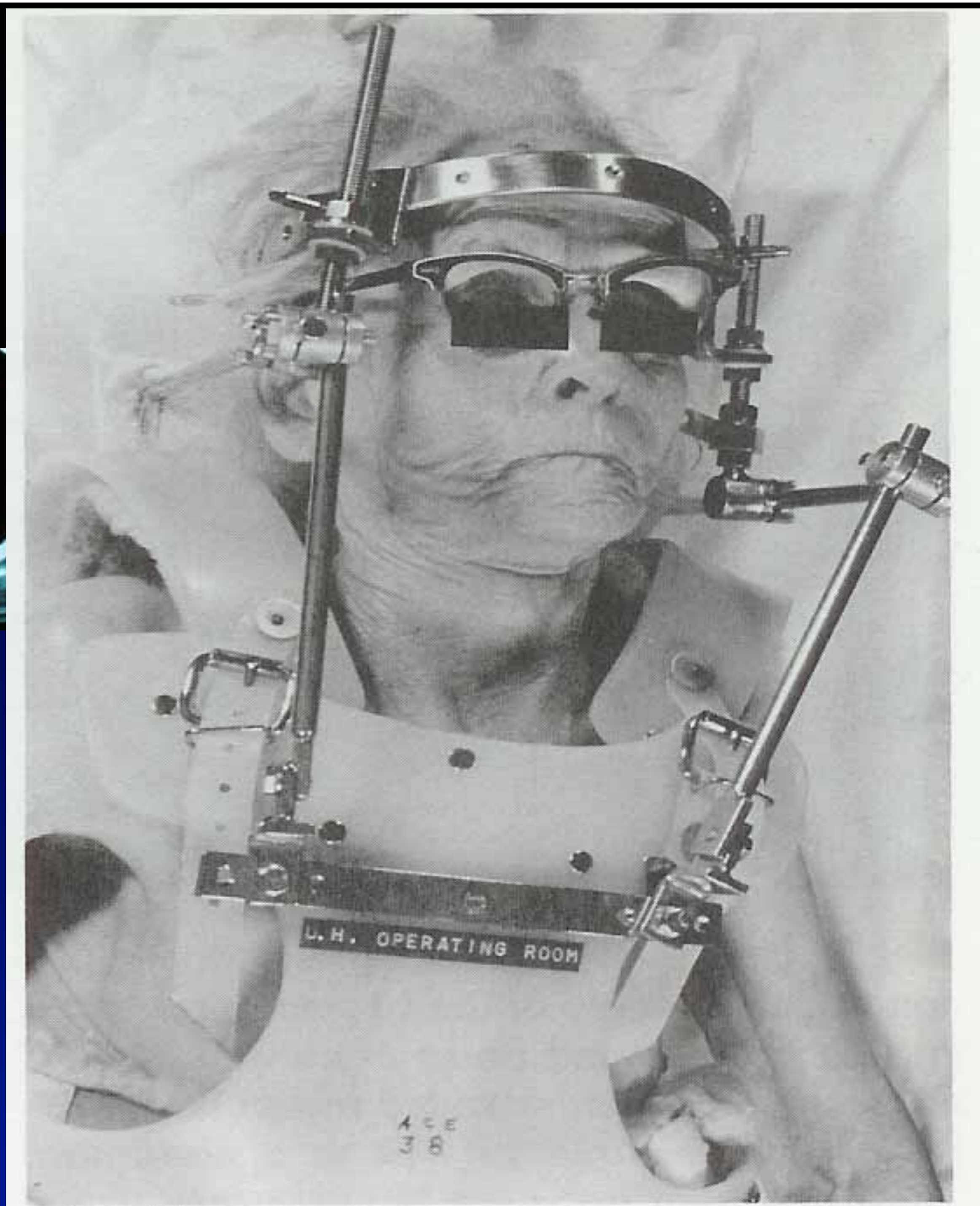
Se: 2


U.H. OPERATING ROOM

OUTLINE

- Immediate Threats to Life
- Other Stuff

"A" - AIRWAY CONTROL

Intubate for Coma (GCS ≤8)

Consider Intubation if:

- Maxillofacial / Neck Trauma
- Laryngeal Fracture
  (Hoarse, SQ Emphysema, Fracture)
- Aspiration

PEARL

If the Patient Says He is Having Difficulty Breathing…

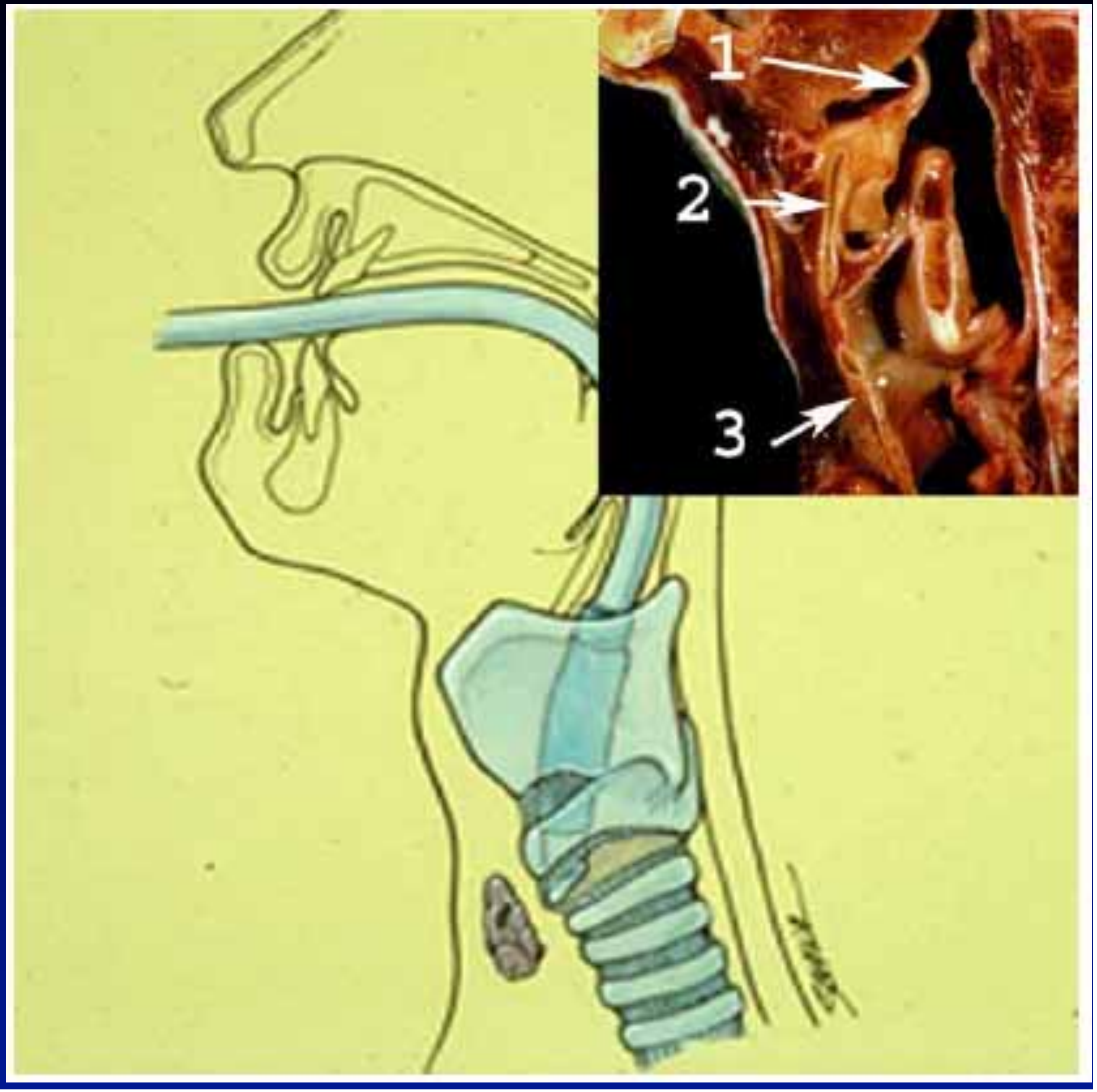
BELIEVE HIM!!!!

AIRWAY INJURY DIAGNOSIS

- Neck Trauma
- Dyspnea
- Dysphonia/Aphonia
- Stridor/Wheezing
- Hemoptysis
- Subcutaneous Emphysema
- Air Leak from Wound
- Pneumomediastinum
- Air Leak from Chest Tubes

AIRWAY PITFALL

- Intubation May Obstruct Airway
- Intubate with Bronchoscope if Available
- Secure Airway = No More Emergency



SURGICAL AIRWAY

- Cricothyroidotomy
- Size $\leq$6.0
- Percutaneous Insufflation (30-45 min)
  - 12-14 ga
  - 15 L/min with side-hole (1:4 sec)

"B" - IMPAIRED VENTILATION

- Tension Pneumothorax
- Open Pneumothorax
- Pulmonary Contusion / Flail Chest
- Massive Hemothorax

MYTHBUSTING

1. Suspected tension PTX should be decompressed in the 2nd intercostal space, midclavicular line
2. 36 Fr chest tube should always be used in the trauma patient with HTX or PTX
3. A retained hemothorax should be treated first with a second chest tube
4. Occult PTX must be treated with chest tube in the mechanically ventilated patient

TENSION PNEUMOTHORAX

"One-Way Valve"

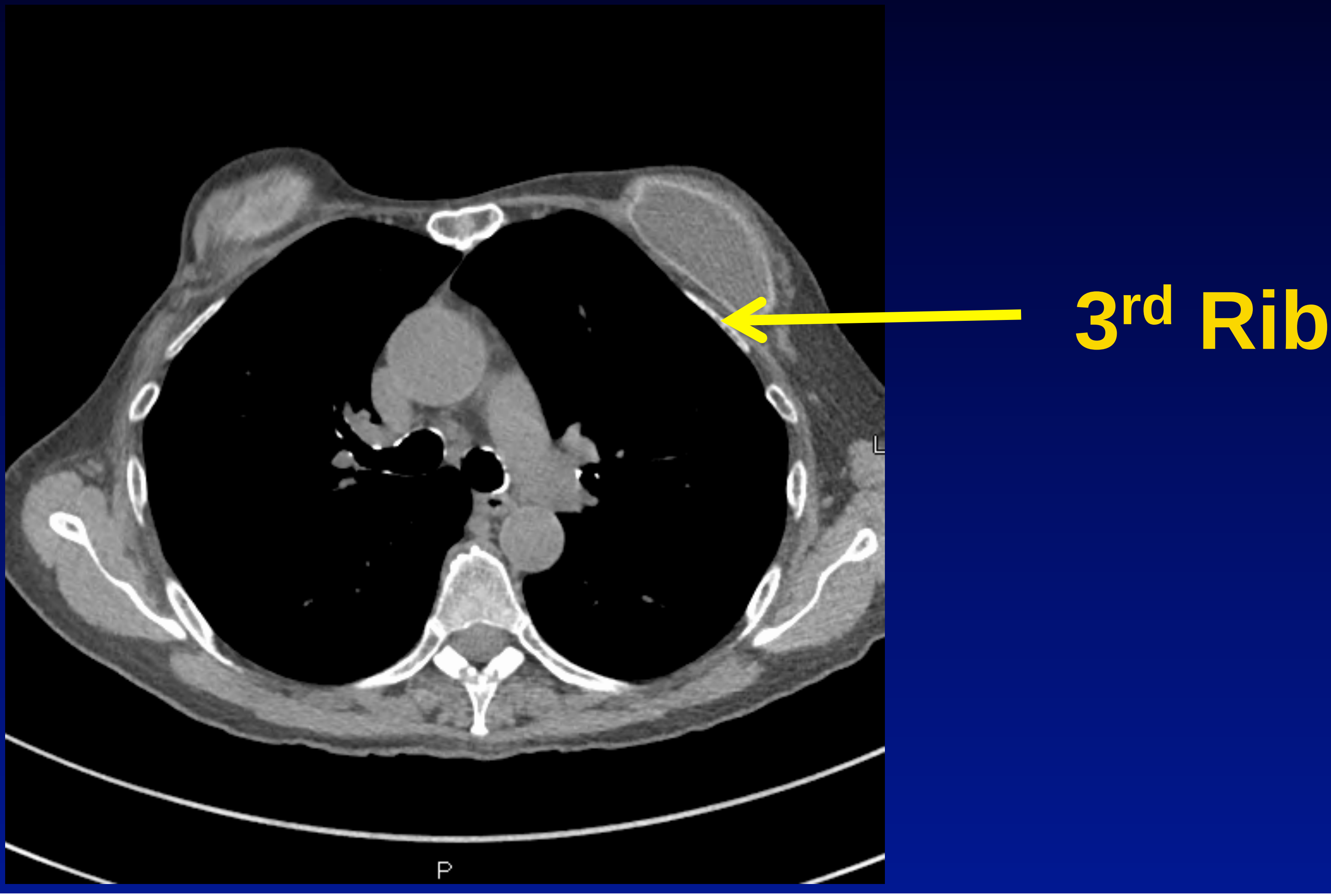
↓ Venous Return, Ventilation

Dx: Distended Neck Veins, Tracheal Deviation, Hyperresonance

Rx: Needle Decompression / Tube Thoracostomy

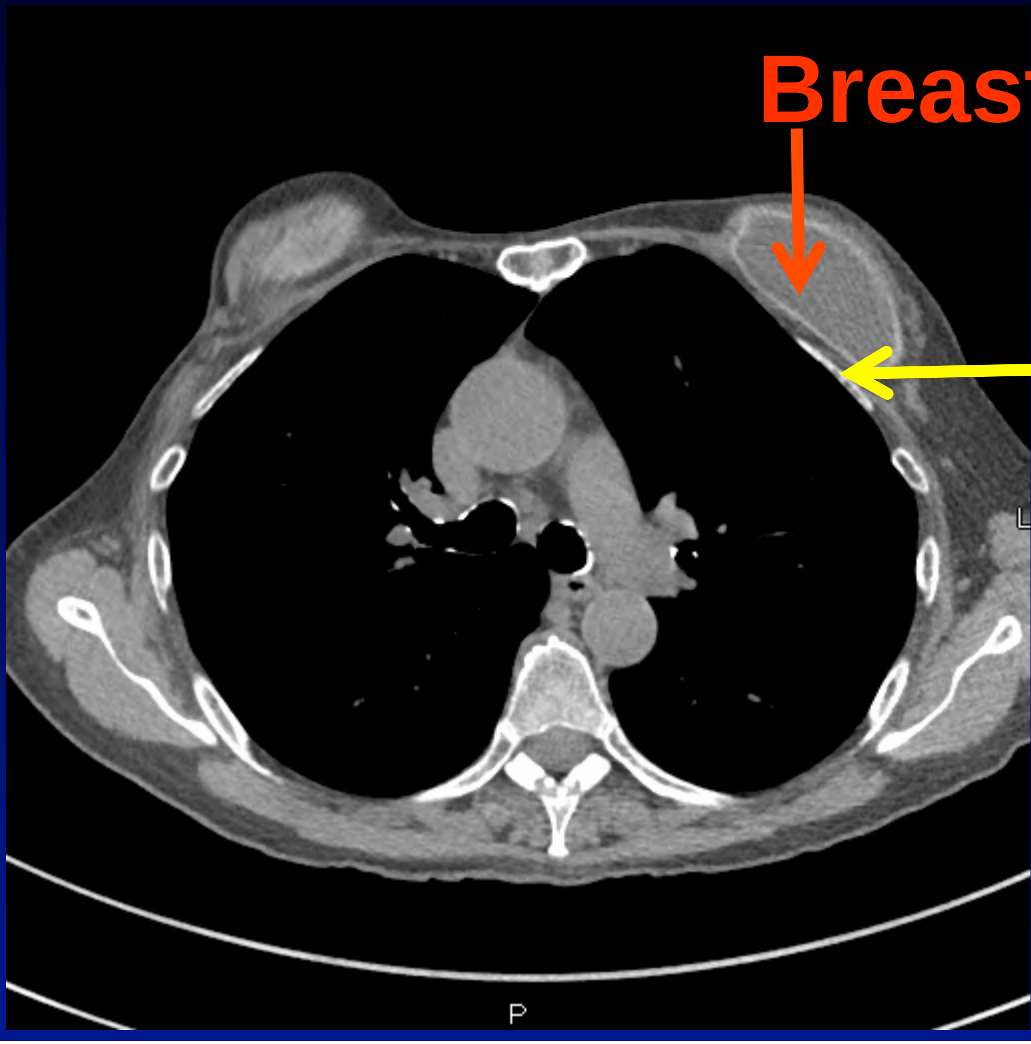
NEEDLE DECOMPRESSION

2nd Intercostal Space, MCL



NEEDLE DECOMPRESSION

2^{nd} Intercostal Space, MCL



Needle Thoracostomy: Implications of Computed Tomography Chest Wall Thickness

Melissa L. Givens, MD, Karen Ayotte, MD, Craig Manifold, DO

Conclusions: In this study, a catheter length of 5 cm would reliably penetrate the pleural space of only 75% of patients. A longer catheter should be considered, especially in women. **Key words:** needle thoracostomy; catheter; com-

Acad Emerg Med 2004; 11:211

Needle Thoracostomy: Implications of Computed Tomography Chest Wall Thickness

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Acad Emerg Med 2004; 11:211

Needle Thoracostomy: A Cautionary Note

I submit that to maximize the safety and optimize the efficacy of this procedure, the catheter should be inserted in the midaxillary line through the fifth intercostal space. If the procedure is truly done for appropriate indications (i.e., tension pneumothorax), there is minimal danger of injuring any vital structures. Because this is the thinnest part of the chest wall in most patients, the need for longer catheters is obviated as well.—**Walter L. Biffl, MD** (wlbiffl@usasurg.org), *Division of Trauma and Surgical Critical Care, Rhode Island Hospital and Brown Medical School, Providence, RI*

Acad Emerg Med 2004; 11:795

Is routine tube thoracostomy necessary after prehospital needle decompression for tension pneumothorax?

Kathleen M. Dominguez, M.D., A. Peter Ekeh, M.D., M.P.H., Kathryn M. Tchorz, M.D., Randy J. Woods, M.D., Mbaga S. Walusimbi, M.D., Jonathan M. Saxe, M.D., Mary C. McCarthy, M.D.*

Am J Surg 2013; 205:329

case report of injury to the pulmonary artery and cardiac tamponade is particularly unnerving.[5] Some authors have suggested lateral chest wall placement to reduce the risk for injury to hilar structures,[6] but there are no data to support this theoretically appealing approach. Because air rises in the anterior chest of a supine patient, it is most accessible in this position.

Parachute use to prevent death and major trauma related to gravitational challenge: systematic review of randomised controlled trials

Gordon C S Smith, Jill P Pell

Conclusions As with many interventions intended to prevent ill health, the effectiveness of parachutes has not been subjected to rigorous evaluation by using randomised controlled trials. Advocates of evidence based medicine have criticised the adoption of interventions evaluated by using only observational data. We think that everyone might benefit if the most radical protagonists of evidence based medicine organised and participated in a double blind, randomised, placebo controlled, crossover trial of the parachute.

BMJ 2003; 327:1459

Evaluation of 8.0-cm needle at the fourth anterior axillary line for needle chest decompression of tension pneumothorax

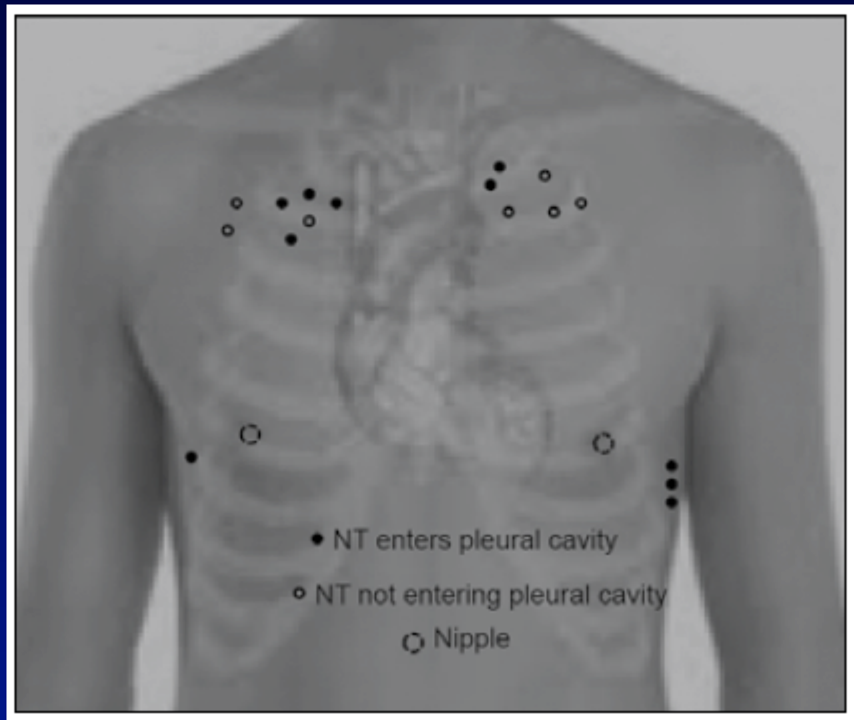
Samuel J. Chang, MD, Samuel Wade Ross, MD, MPH, David J. Kiefer, MD, William E. Anderson, MS, Amelia T. Rogers, BS, Ronald F. Sing, DO, *and* David W. Callaway, MD, *Charlotte, North Carolina*

	CWT, mm
L-4AAL-close	**39.6** (17.1) (14.2–94.5]
R-4AAL-close	**39.9** (18.3) [13.6–116.6]
L-4AAL-p	**37.6** (17.7) [11.5–108.4]
R-4AAL-p	**37.7** (19.6) [12.3–113.9]
L-2MCL	**46.7** (15.4) [17.8–98.9]
R-2MCL	**43.4** (13.9) [18.7–91.9]

J Trauma Acute Care Surg 2014; 76:1029

Needle Thoracentesis Decompression: Observations From Postmortem Computed Tomography and Autopsy

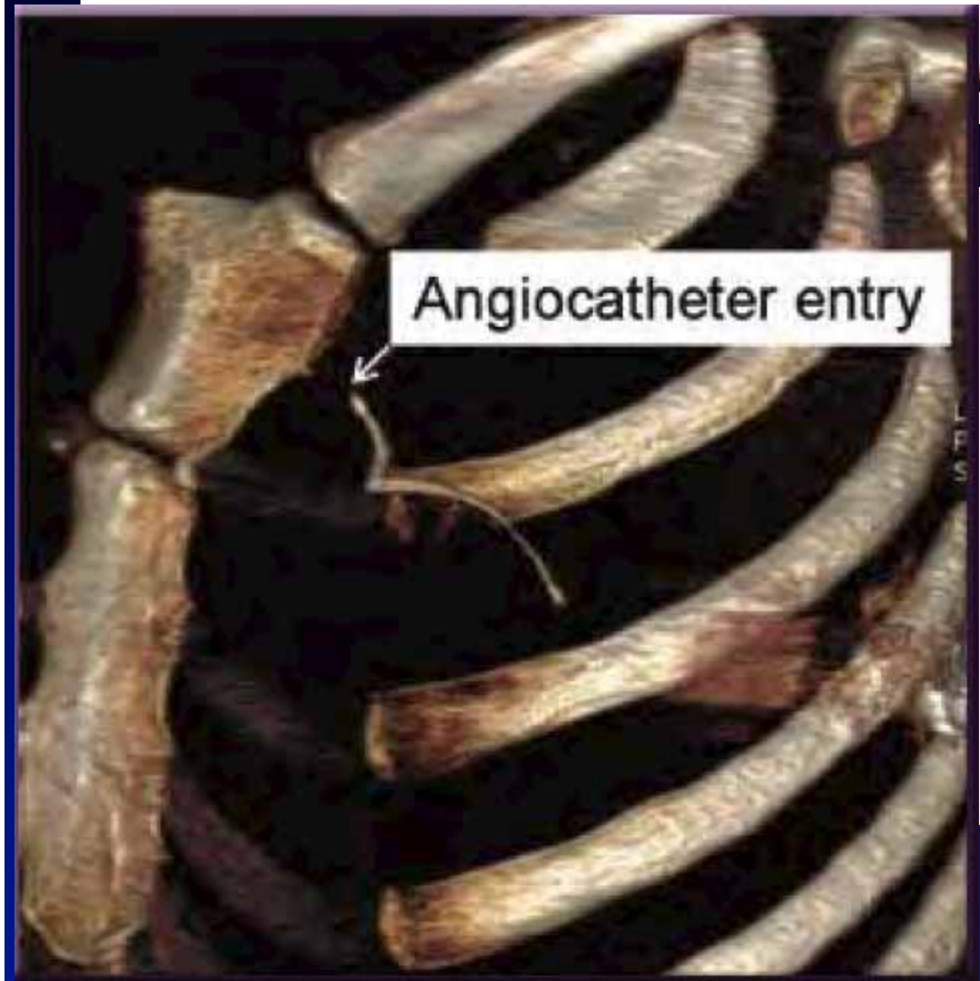
H. Theodore Harcke, MD; Robert L. Mabry, MD; Edward L. Mazuchowski, MD

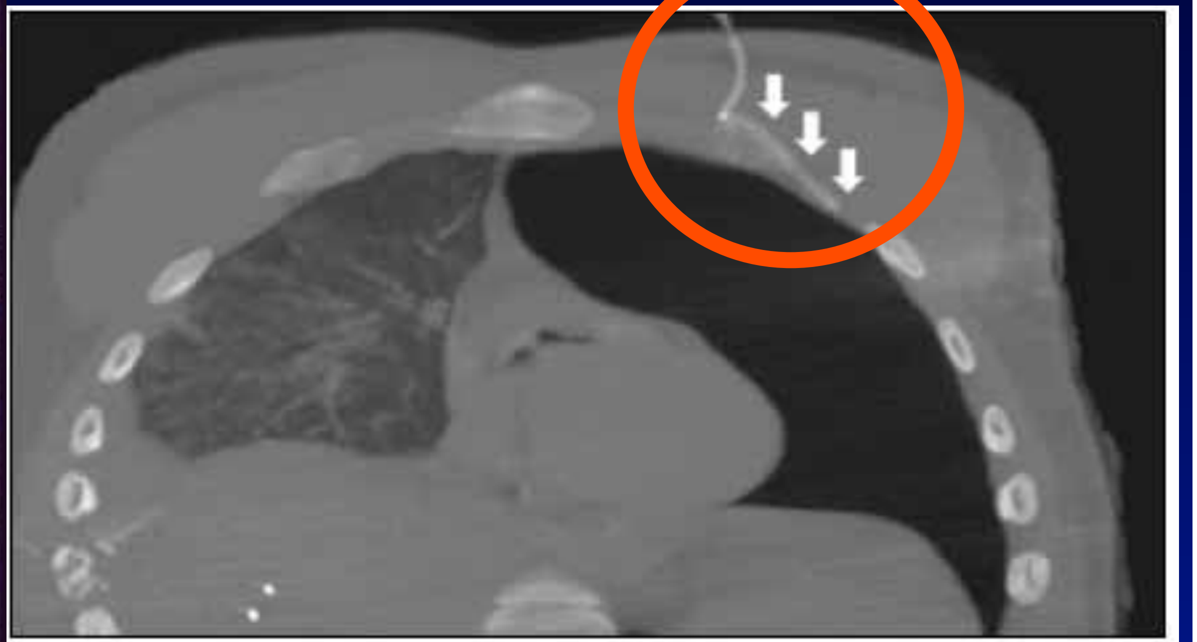


J Spec Oper Med 2013; 13:53

Needle Thoracentesis Decompression: Observations From Postmortem Computed Tomography and Autopsy

L. Mabry, MD; Edward L. Mazuchowski, MD





J Spec Oper Med 2013; 13:53

Modified Veress needle decompression of tension pneumothorax: A randomized crossover animal study

Dafney Lubin, MD, Andrew L. Tang, MD, Randall S. Friese, MD, Matthew Martin, MD, DJ Green, MD, Trevor Jones, BS, Russell R. Means, BS, Rashna Ginwalla, MD, Terence S. O'Keeffe, MBChB, Bellal A. Joseph, MD, Julie L. Wynne, MD, Narong Kulvatunyou, MD, Gary Vercruysse, MD, Lynn Gries, MD, ***and*** **Peter Rhee, MD,** *Tucson, Arizona*

J Trauma Acute Care Surg 2013; 75:1071

Modified Veress needle decompression of tension
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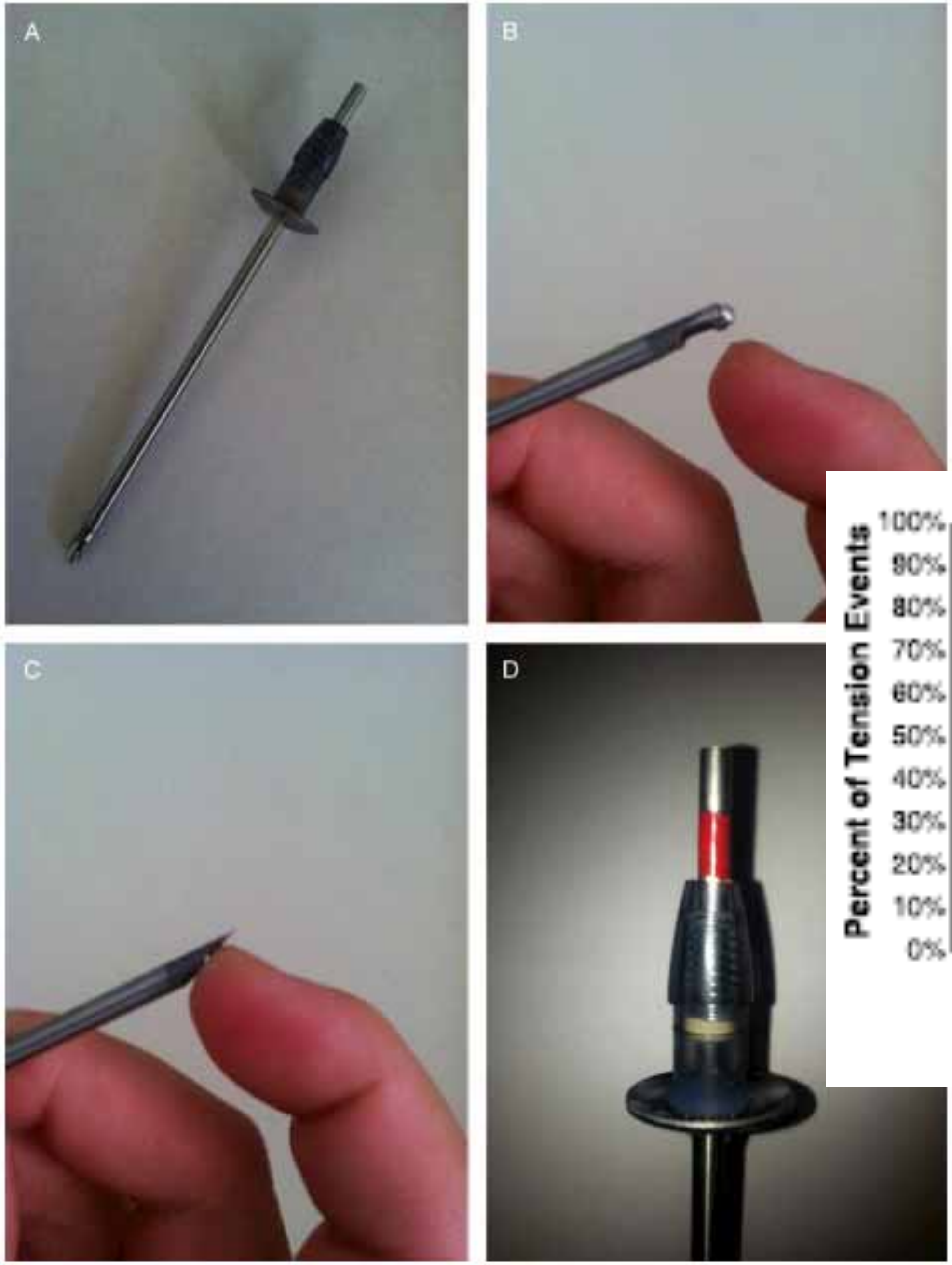
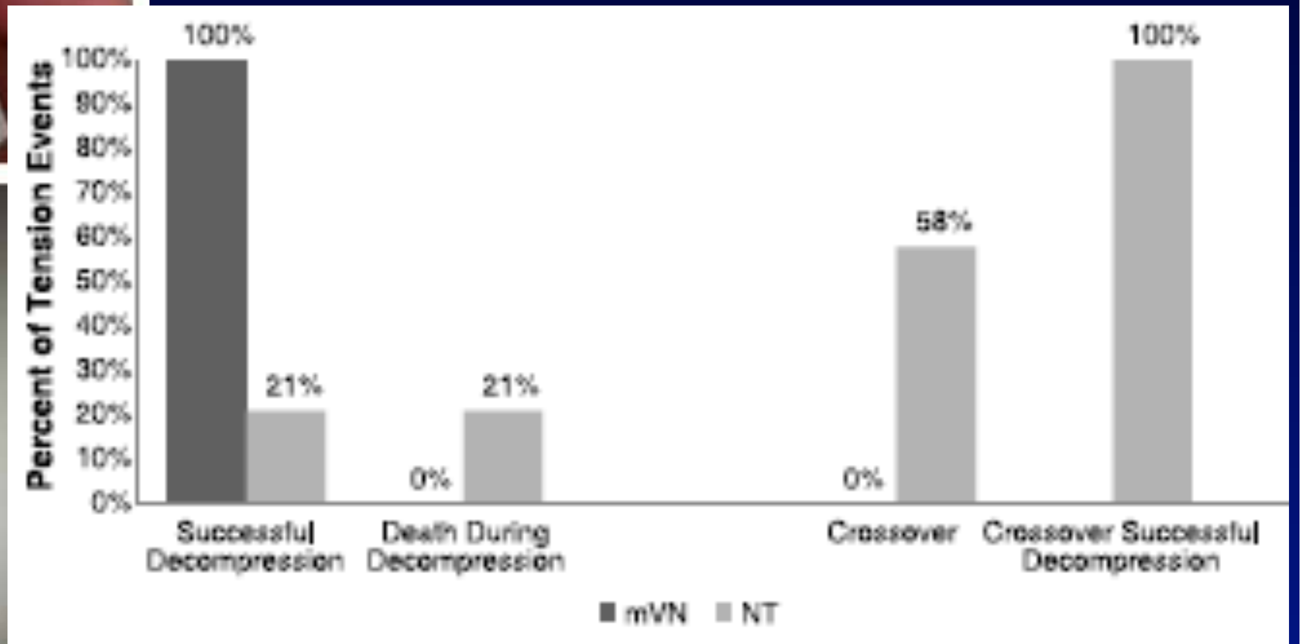




J Trauma Acute Care Surg 2013; 75:1071

OPEN PNEUMOTHORAX

"Sucking Chest Wound"

- Pressure Equilibration; Air Passes through Hole if >2/3 Diameter of Trachea
- Temporary Occlusive Dressing Taped on 3 Sides
- Tube Thoracostomy

PULMONARY CONTUSION / FLAIL CHEST

- Pa
- Pr ion
- Su d
- Ri
- Su

NEXT LECTURE

MASSIVE HEMOTHORAX

- >1500 mL Blood Loss
- Neck Veins Flat vs Distended
- Shock, Absent Breath Sounds, Percussion Dullness
- O.R. if: >1500 mL

  200 mL/hr x 2-4 hr

  Continued Transfusion
- Correct Coagulopathy, Consider Angioembolization

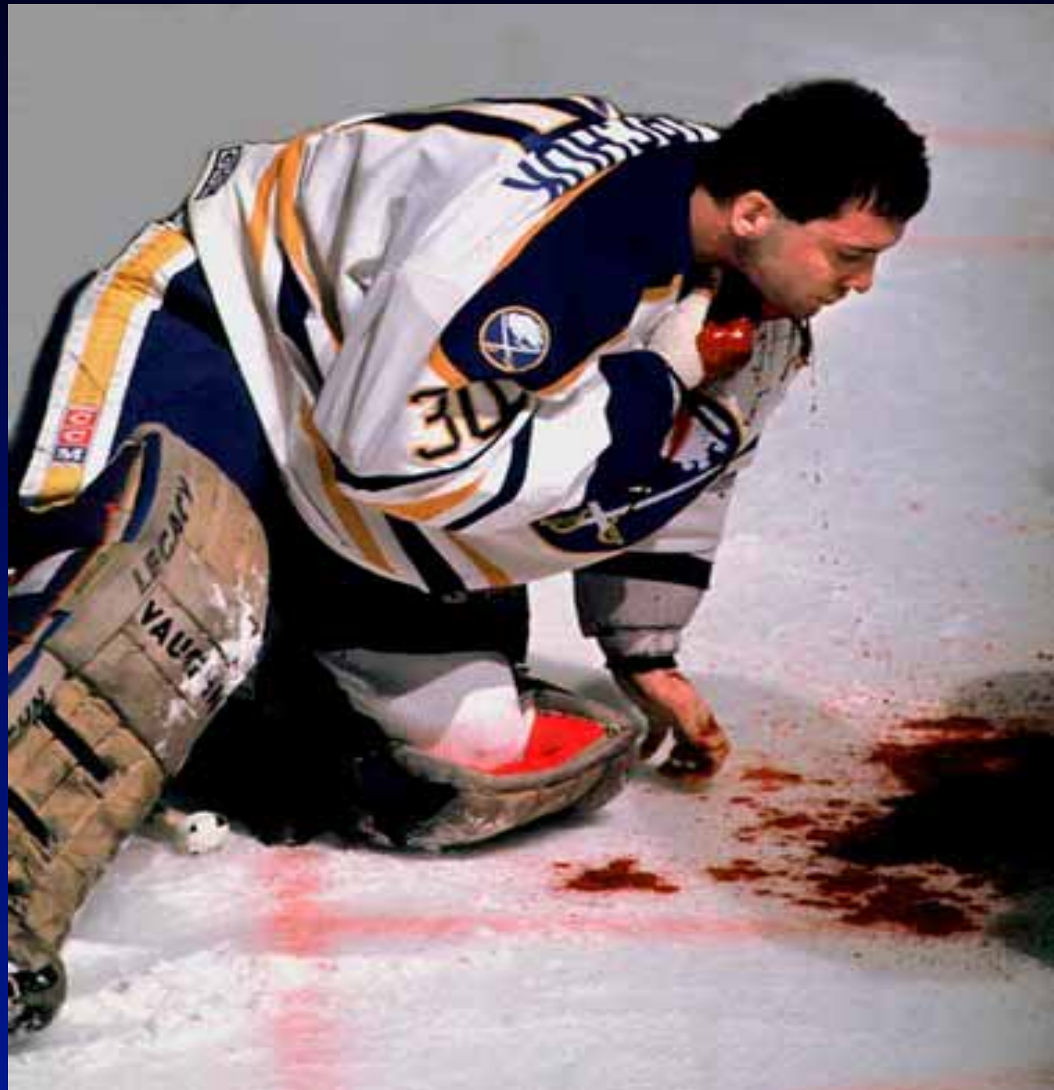
Pitfall: High Volume Output, Abruptly Stops → ?Caked Hemothorax

"C" - ETIOLOGIES OF SHOCK

- Hemorrhagic
- Cardiac Compressive
- Cardiogenic
- Neurogenic
- Septic

WHERE DOES BLOOD GO?

- Street / Wounds
- Fractures
- Chest
- Pelvis
- Abdomen



CIRCULATION- BLOOD LOSS

	Class of Hemorrhage			
	I	II	III	IV
Blood Loss (%)	15	15-30	30-40	>40
HR	<100	>100	>120	>140
SBP	Nl	Nl	Dec	Dec
Pulse P	Nl / Inc	Dec	Dec	Dec
RR	14-20	20-30	30-40	>35
UO (ml/hr)	>30	20-30	5-15	Nil

Blood Vol = 7 ml/kg

"C" - ETIOLOGIES OF SHOCK

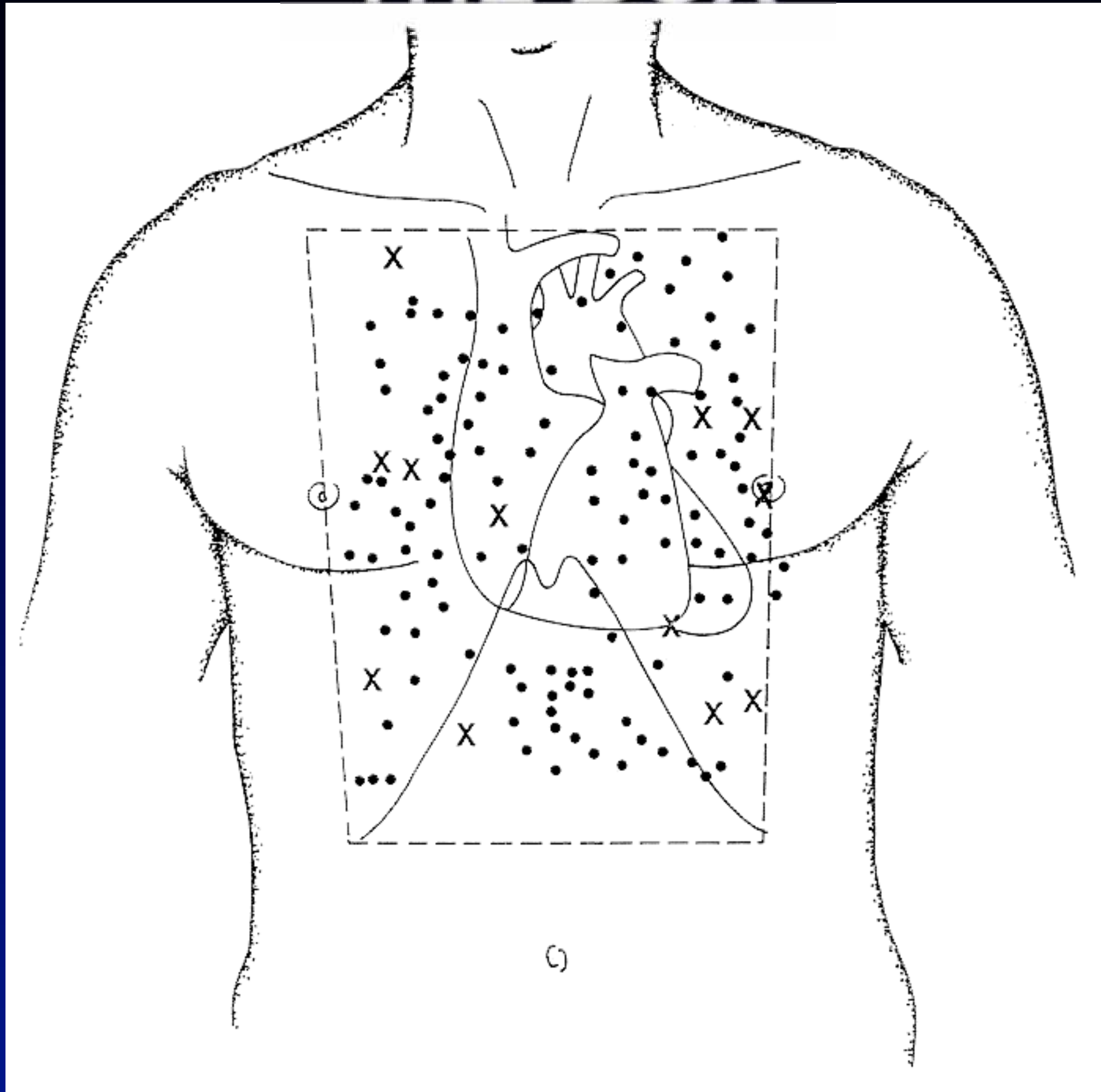
- Hemorrhagic
- Cardiac Compressive
- Cardiogenic
- Neurogenic
- Septic

CARDIAC COMPRESSIVE SHOCK

Tension Pneumothorax

Rx: Tube Thoracostomy

"THE BOX"



Nagy KK et al. J Trauma 1995; 38:859

PHYSICAL EXAMINATION

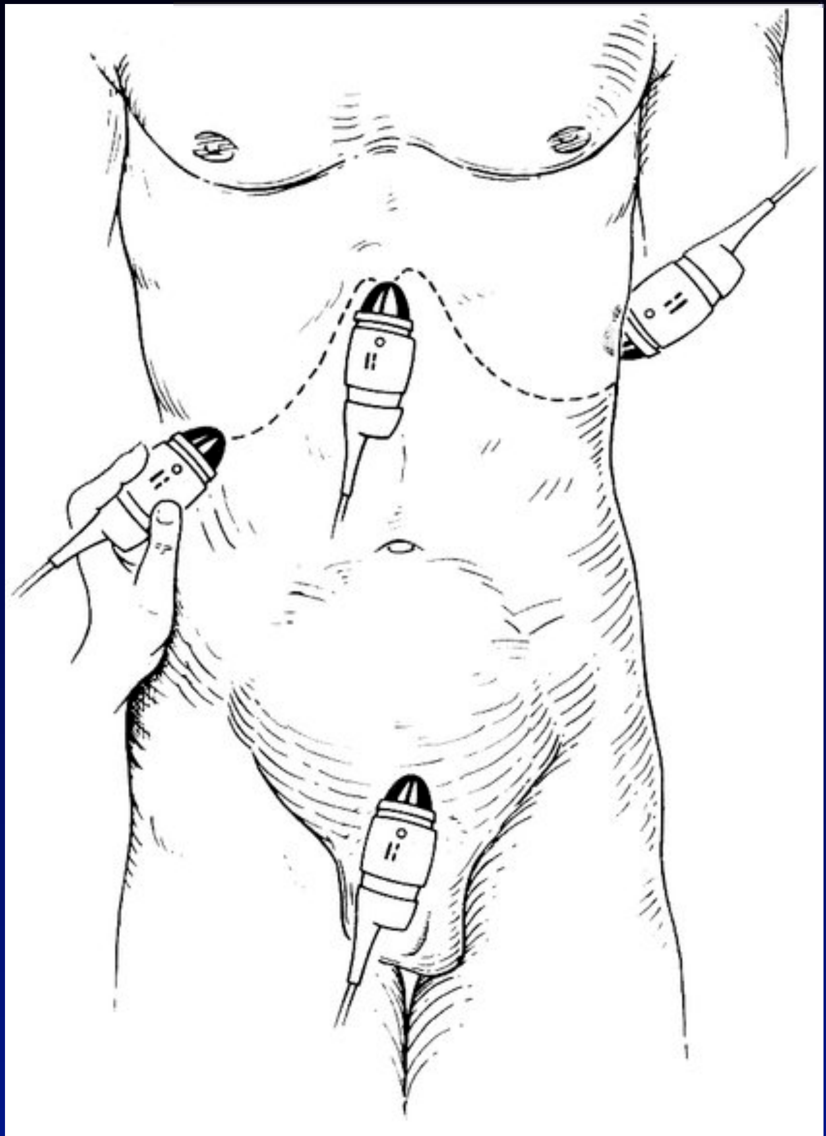
Vital Signs, Neck Veins, Auscultation

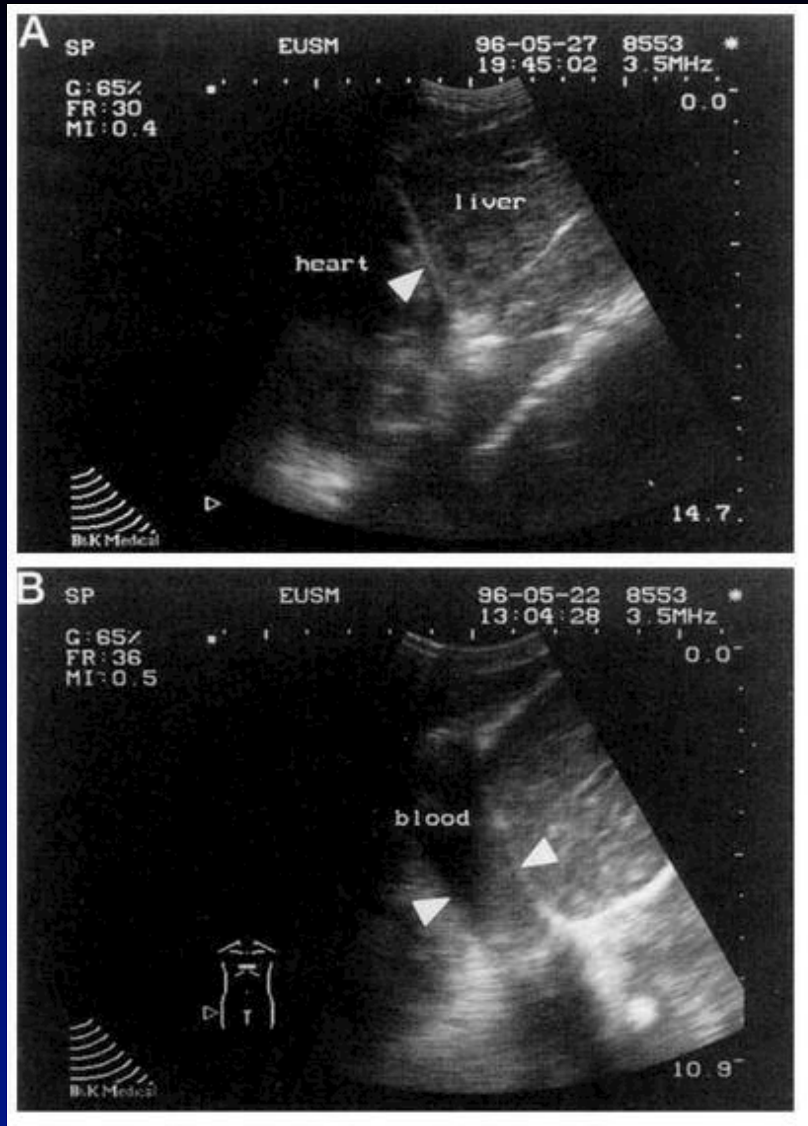
Beck's Triad (Hypotension, JVD, Muffled Heart Tones)

Tachycardia, Narrow Pulse Pressure

Pulsus Paradoxus (SBP Drop > 10 mm Hg with Inspiration)

ULTRASONOGRAPHY – FAST



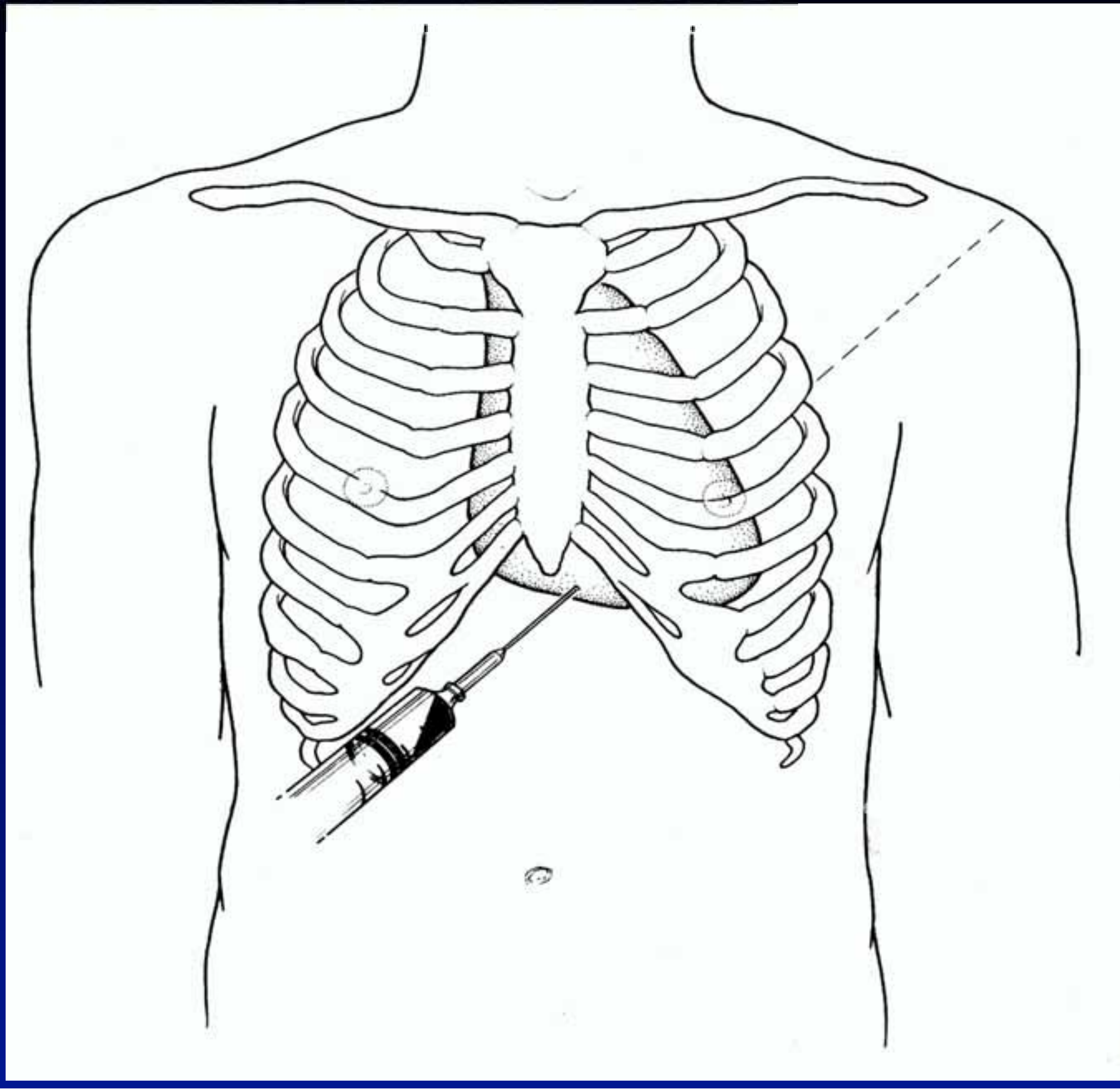


Rozycki et al. J Trauma 1995; 39:492

PERICARDIOCENTESIS

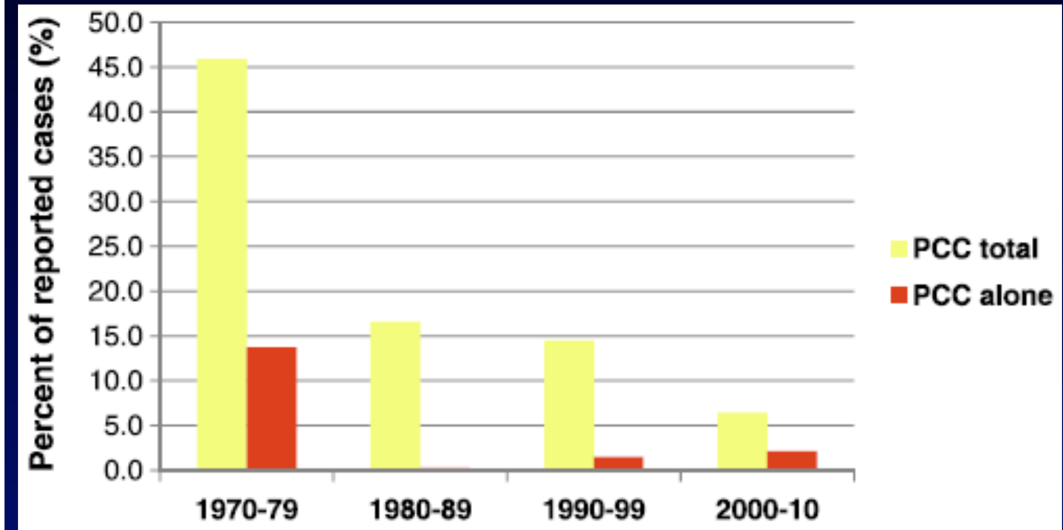
50% False (+):
Enter Chamber.
Coronary Artery
Puncture;
Dysrhythmia.

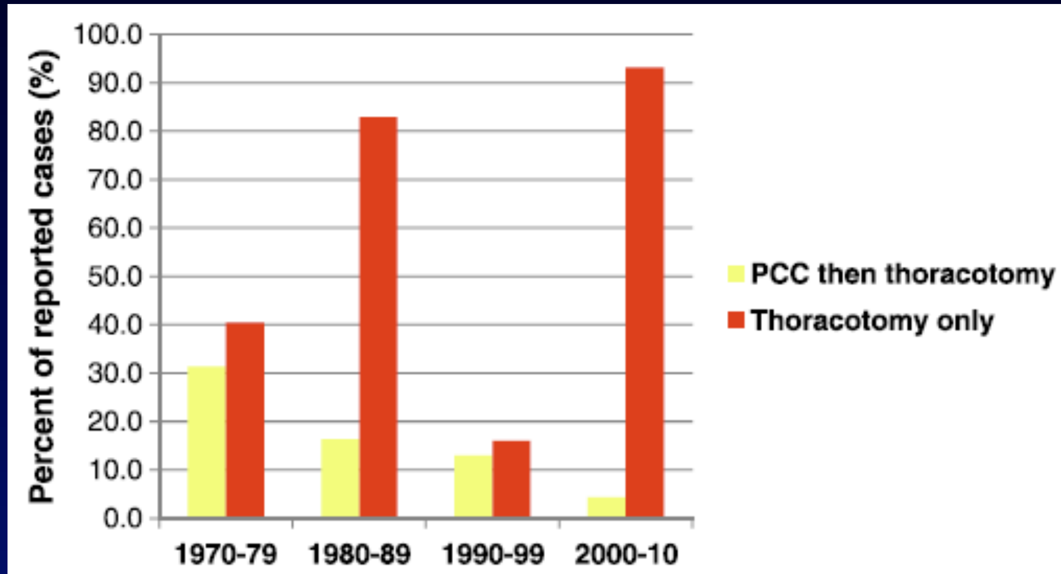
37% False (-):
Clot



Pericardiocentesis in trauma: A systematic review

Tim H. Lee, MD, Jean-Francois Ouellet, MD, Mackenzie Cook, MD, Martin A. Schreiber, MD, *and* John B. Kortbeek, MD

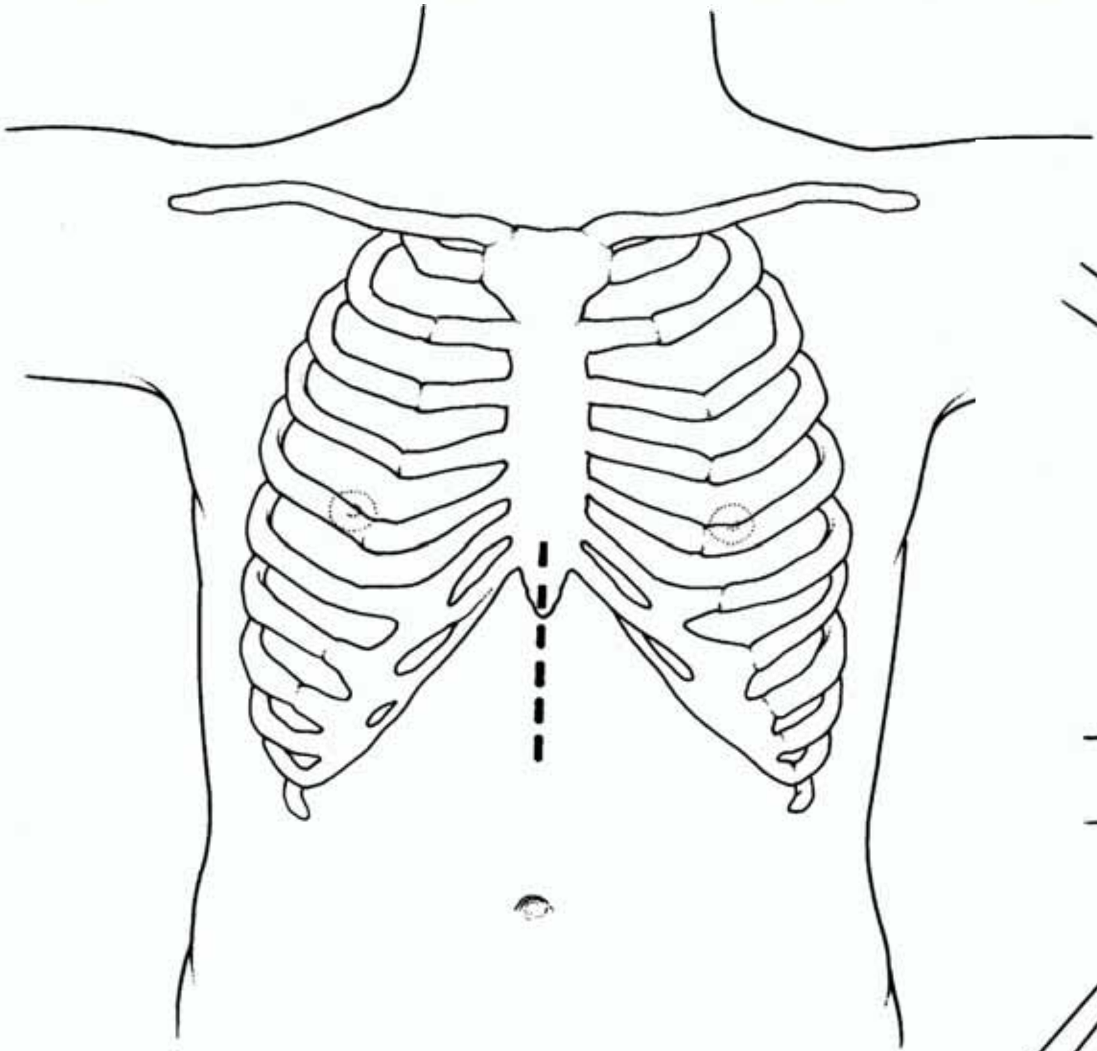


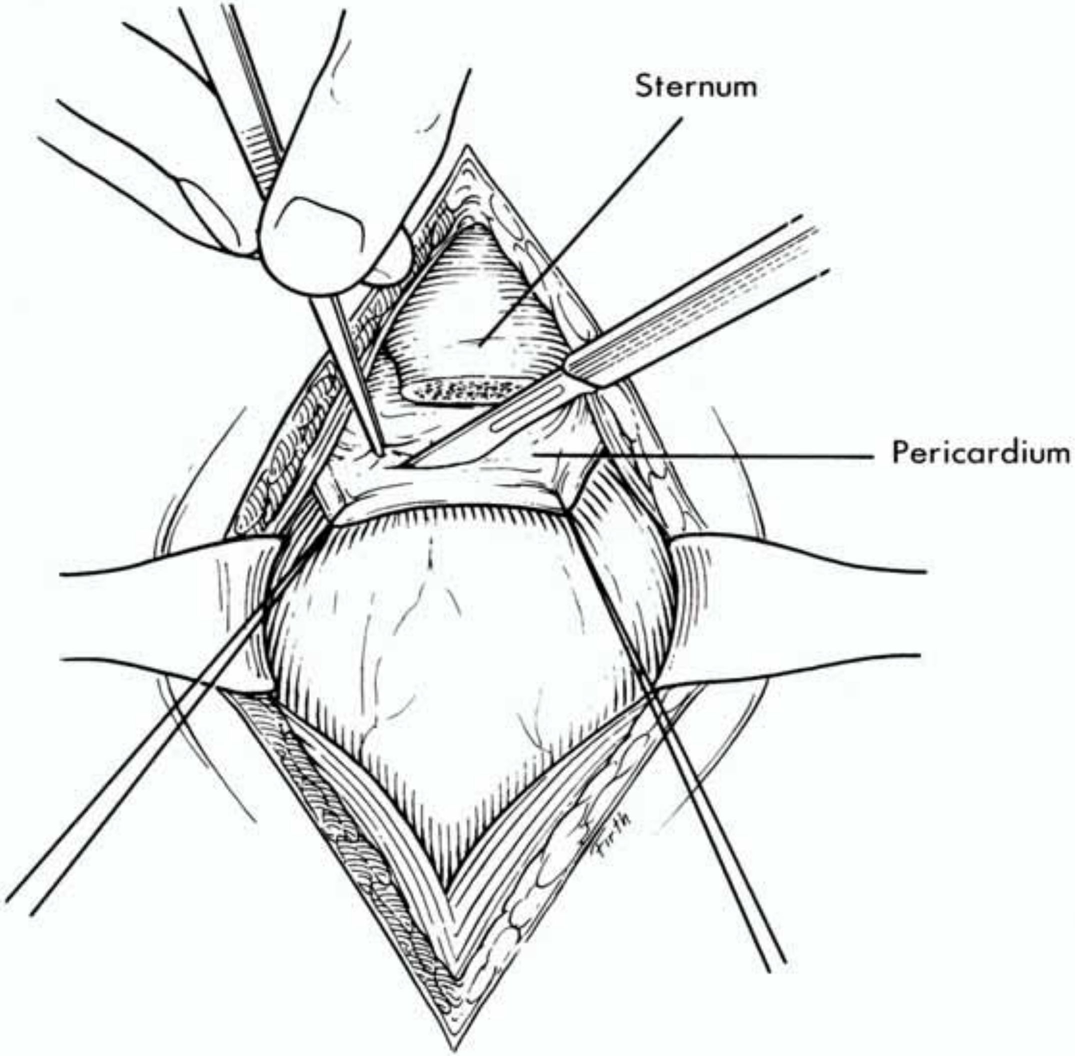


Studies on the use of PCC for trauma are limited and biased toward survivors. The reported survival rate is high. There remains a limited role for PCC in nontrauma centers where definitive surgical management is not immediately available and transport time to a higher level of care facility supports the use of temporary decompression by PCC. (*J Trauma Acute*

J Trauma Acute Care Surg 2013; 75:543

SUBXIPHOID PERICARDIAL WINDOW





Screening for Occult Penetrating Cardiac Injuries

Andrew J. Nicol, PhD, FCS, Pradeep H. Navsaria, MMed, FCS,* Steve Beningfield, FCRad(D)SA,† Martijn Hommes, MD,* and Delawir Kahn, ChM, FCS**

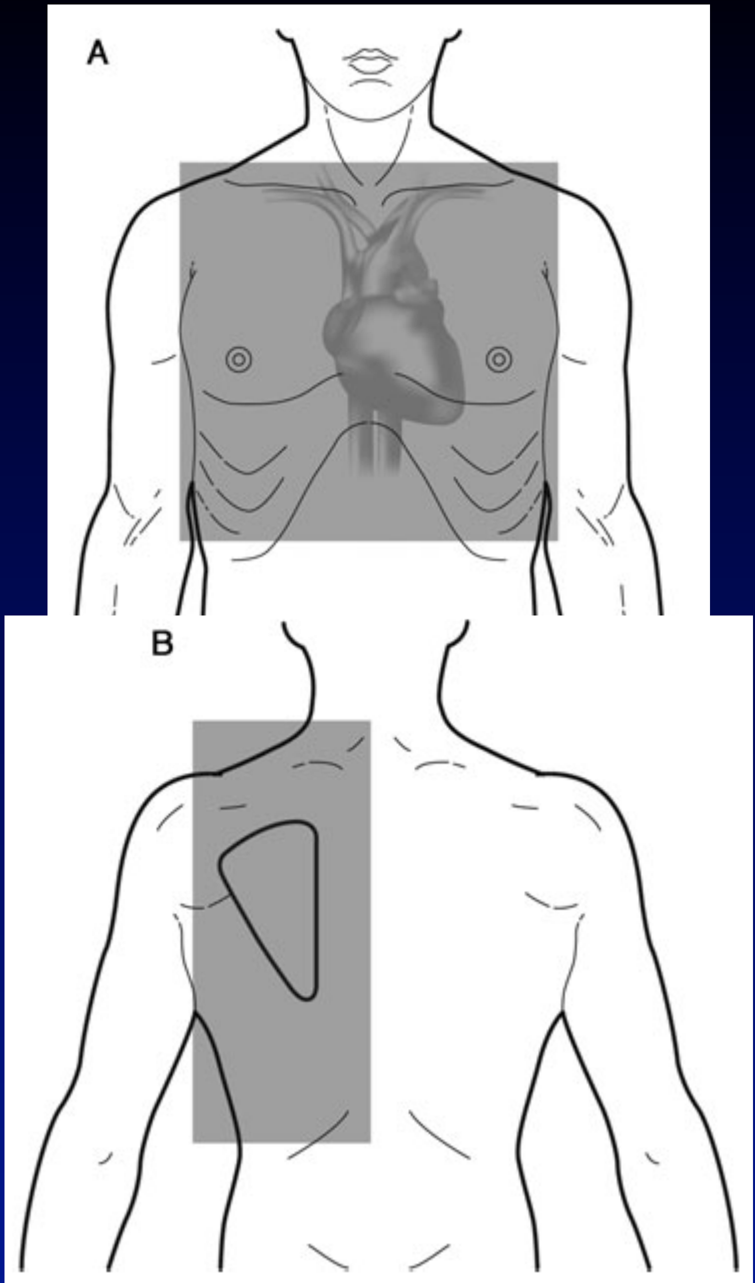
Ann Surg 2015; 261:573

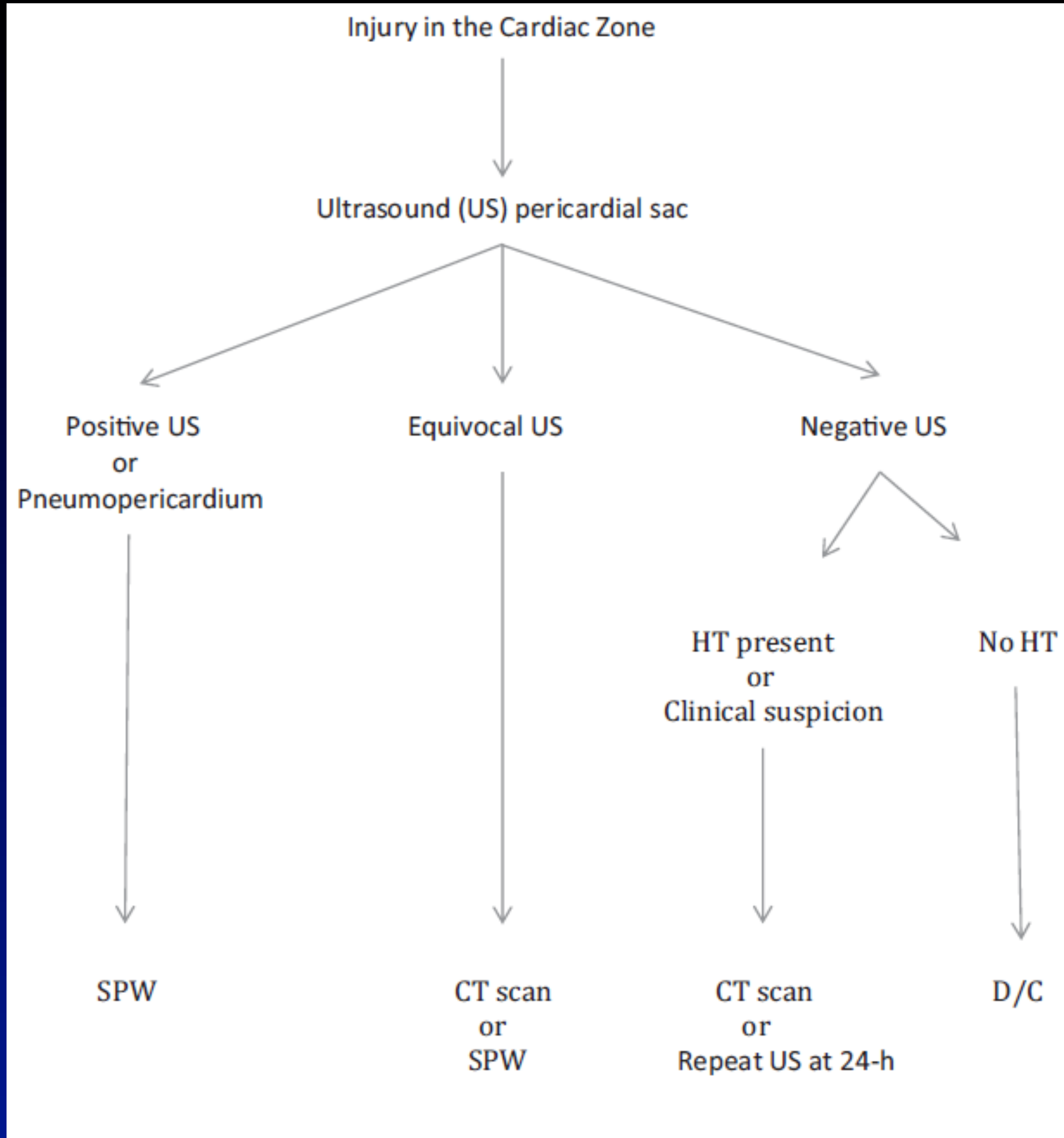
Methods: Patients presenting with a penetrating chest wound and a possible cardiac injury to the Groote Schuur Hospital Trauma Centre between October 2001 and February 2009 were prospectively evaluated. All patients were hemodynamically stable, had no indication for emergency surgery, and had an US scan followed by subxiphoid pericardial window exploration.

TABLE 2. US as a Screen for Potential Cardiac Injuries

	US Positive	US Negative	Total
SPW +ve	117	18	135
SPW –ve	35	2	37
Total	152	20	172

FIGURE 2. **A** and **B**, The "cardiac zone"—the high-risk area for a PCI.





Sternotomy or Drainage for a Hemopericardium After Penetrating Trauma

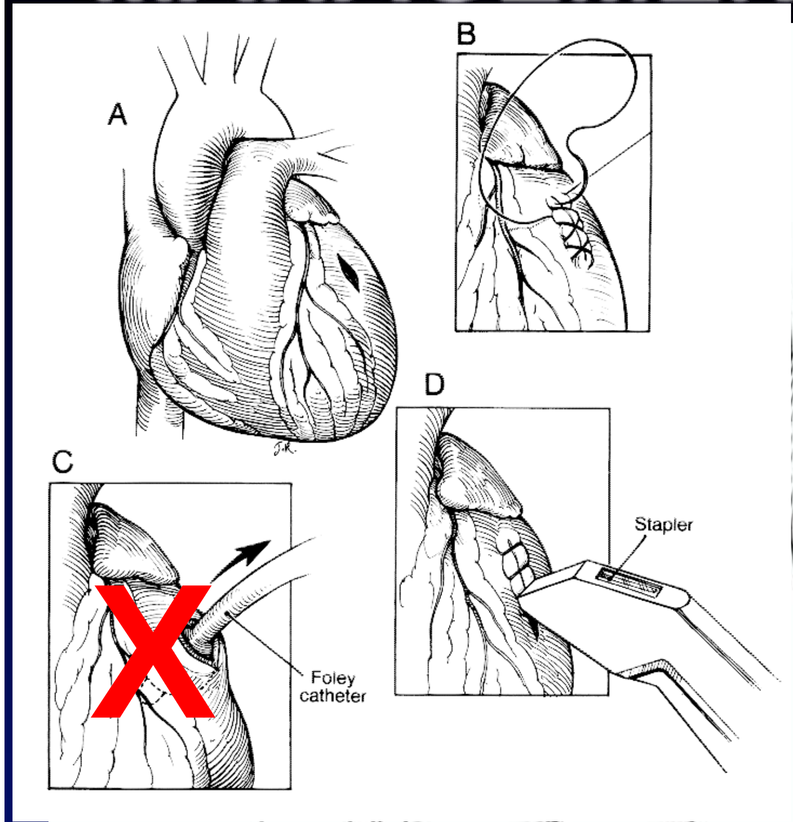
A Randomized Controlled Trial

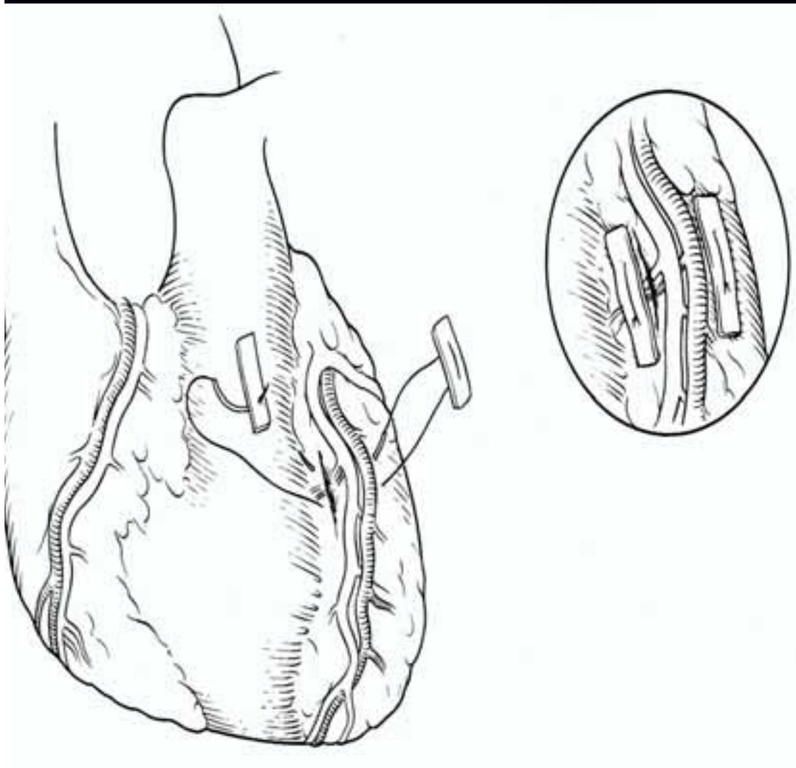
Andrew J. Nicol, FCS, PhD, Pradeep H. Navsaria, FCS, MMed,* Martijn Hommes, MD,* Chad G. Ball, MD,† Sorin Edu, FCS,* and Delawir Kahn, FCS, ChM**

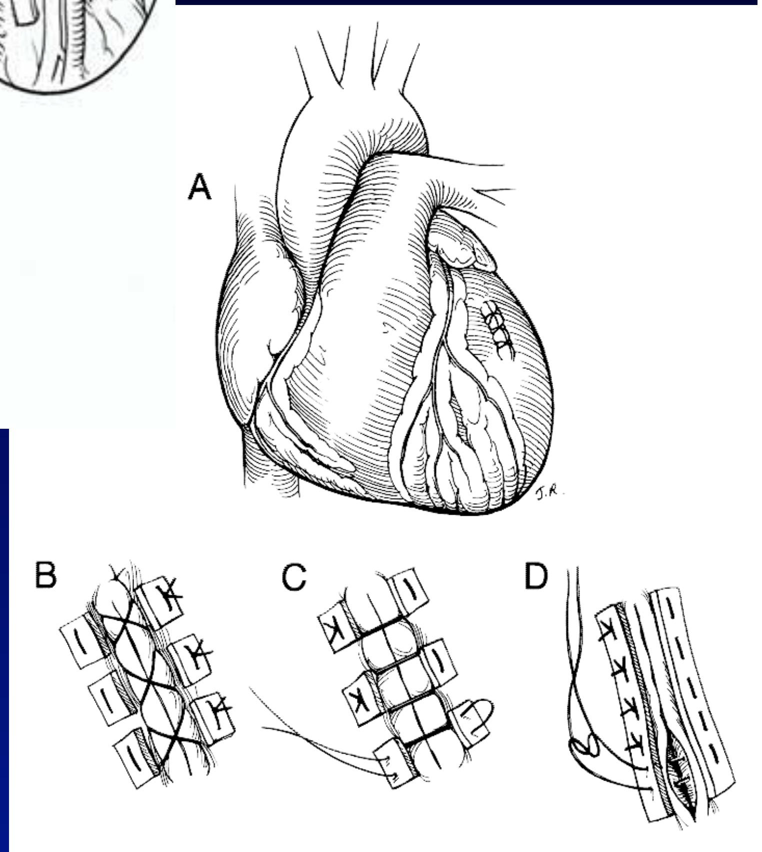
Ann Surg 2014; 259:438

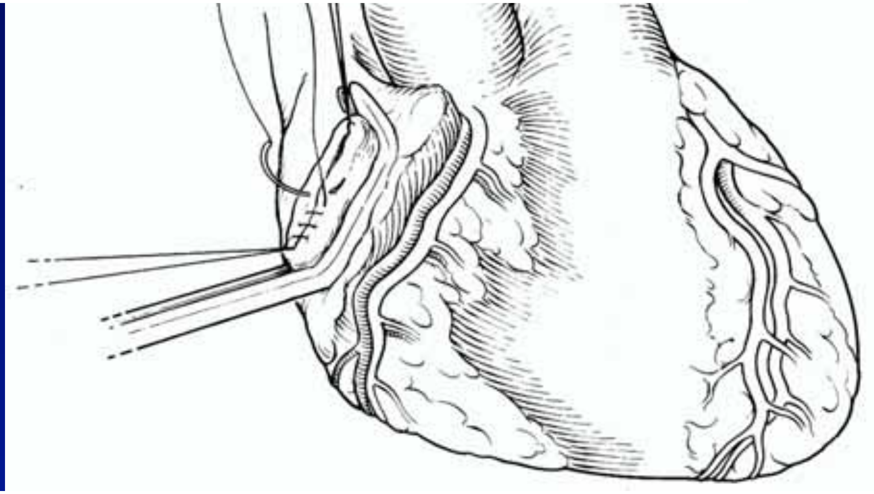
Results: Fifty-five patients were randomized to sternotomy and 56 to pericardial drainage and wash-out only. Fifty-one of the 55 patients (93%) randomized to sternotomy had either no cardiac injury or a tangential injury. There were only 4 patients with penetrating wounds to the endocardium and all had sealed. There was 1 death postoperatively among the 111 patients (0.9%) and this was in the sternotomy group. The mean intensive care unit (ICU) stay for a sternotomy was 2.04 days (range, 0–25 days) compared with 0.25 days (range, 0–2) for the drainage ($P < 0.001$). The estimated mean difference highlighted a stay of 1.8 days shorter in the ICU for the drainage group (95% CI: 0.8–2.7). Total hospital stay was significantly shorter in the SPW group ($P < 0.001$; 95% CI: 1.4–3.3).

MANAGEMENT OF CARDIAC WOUNDS



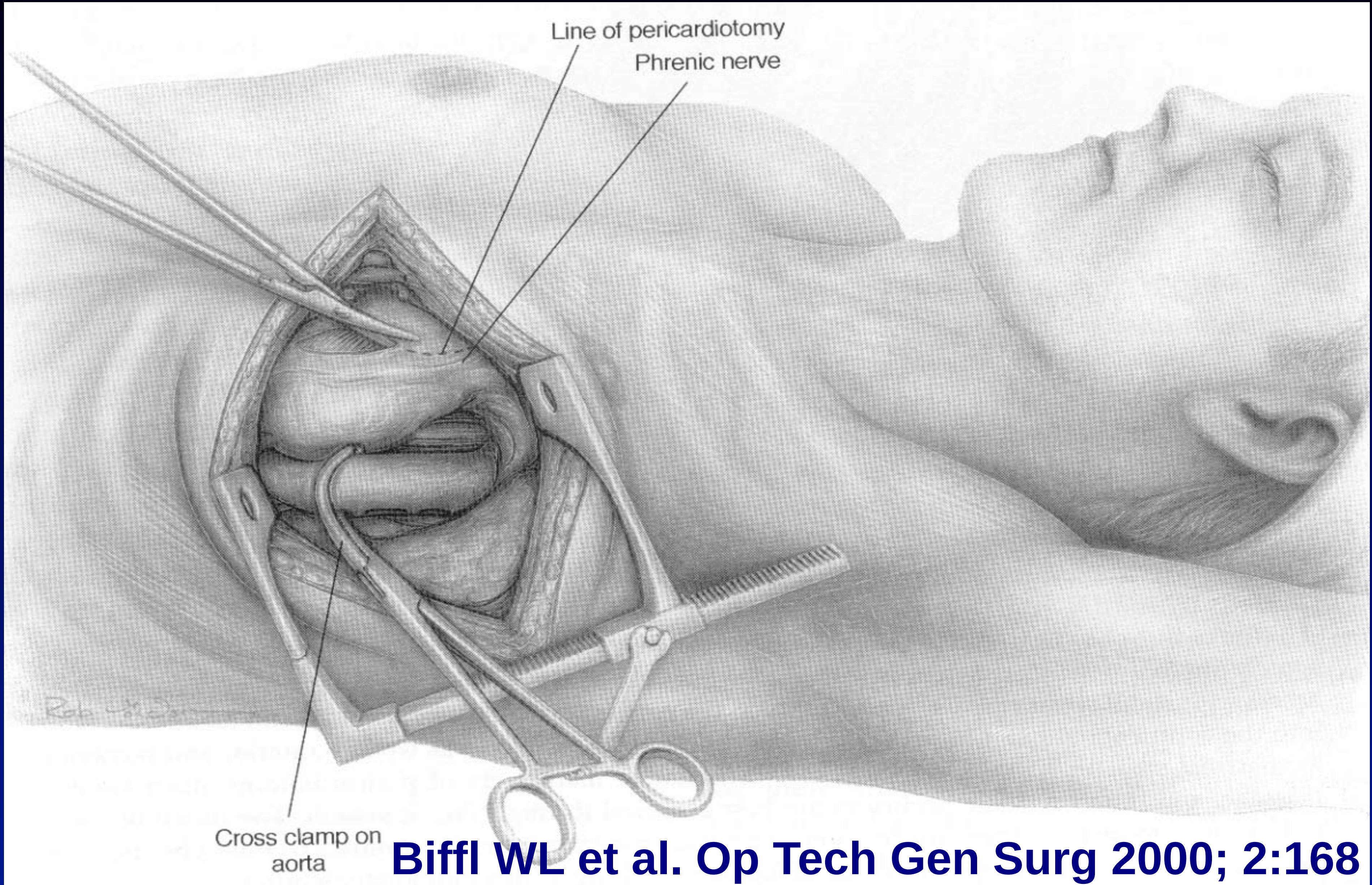






Wall MJ et al. J Trauma 1997; 42:905

RESUSCITATIVE THORACOTOMY



Biffl WL et al. Op Tech Gen Surg 2000; 2:168

RESUSCITATIVE THORACOTOMY

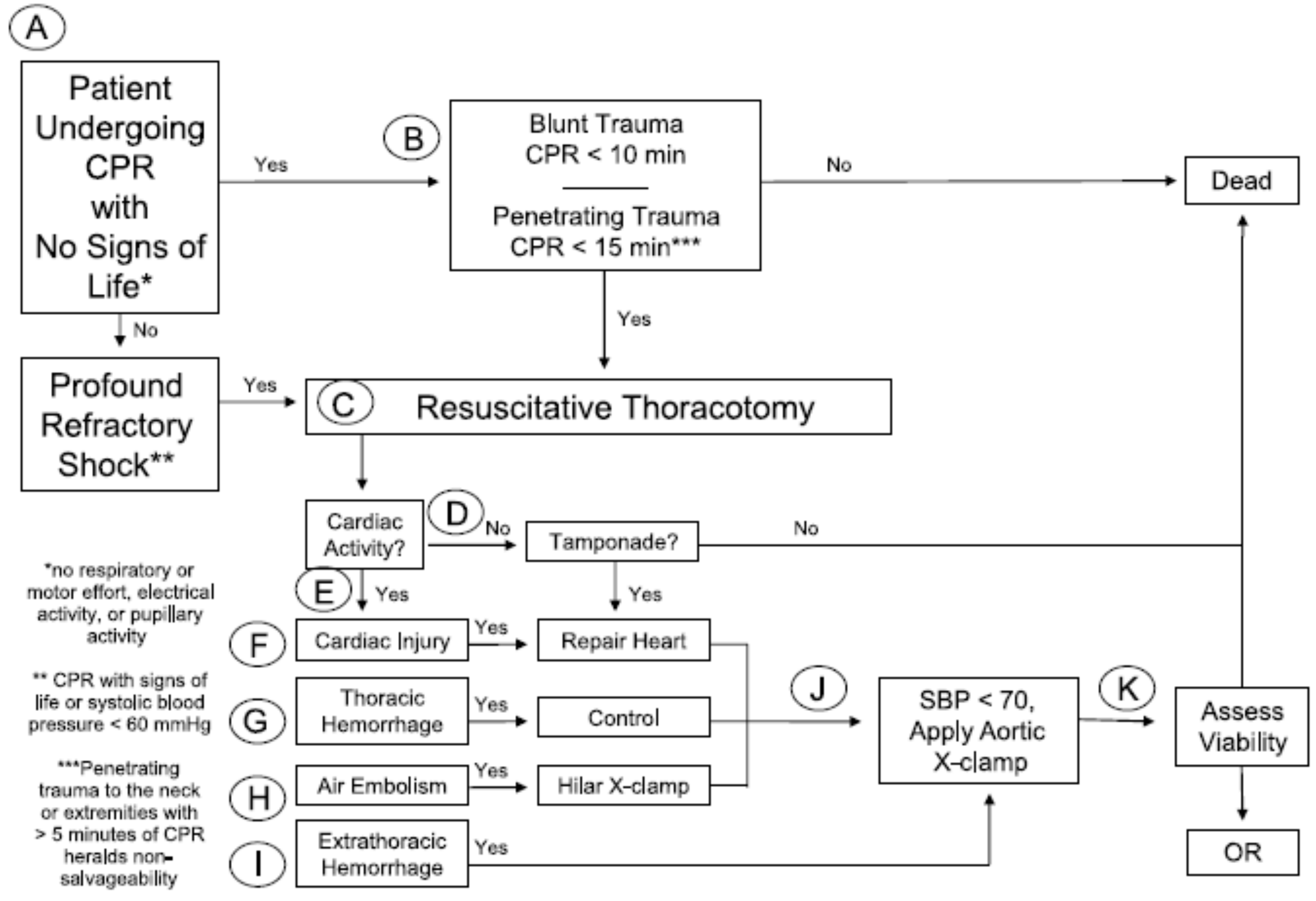
Objectives

- Release Pericardial Tamponade
- Repair Cardiac Wounds
- Perform Open Cardiac Massage
- Cross-Clamp Aorta to Limit Subdiaphragmatic Hemorrhage and Redistribute Blood Flow to Myocardium and Brain
- Control Intrathoracic Hemorrhage
- Control Bronchovenous Air Embolism

Western Trauma Association Critical Decisions in Trauma: Resuscitative thoracotomy

J Trauma Acute Care Surg 2012; 73:1359

Clay Cothren Burlew, MD, Ernest E. Moore, MD, Frederick A. Moore, MD, Raul Coimbra, MD,
Robert C. McIntyre, Jr., MD, James W. Davis, MD, Jason Sperry, MD,
and Walter L. Biffl, MD, *Denver, Colorado*



CARDIOGENIC SHOCK

Myocardial Infarction

Dx: ECG, Enzymes

Bronchovenous Air Embolism

Dx: Shock with Positive Pressure Vent

Rx: Hilar Cross-Clamp, Ventricular / Aortic Root Venting, Vigorous Cardiac Massage

BLUNT CARDIAC INJURY
(Formerly "Cardiac Contusion")

Direct Impact Injury to the Heart

Right Heart (RV) Most Commonly Affected

Clinical Significance: Occult and Inconsequential to Life-Threatening Dysrhythmias or Pump Failure ("Sig BCI")

- No Characteristic Presentation
- No Diagnostic Gold Standard

JACK A. BARNEY RESIDENT AWARD

Cardiac Enzymes Are Irrelevant in the Patient With Suspected Myocardial Contusion

Walter L. Biffl, MD, Frederick A. Moore, MD, Ernest E. Moore, MD, Angela Sauaia, MD, Robert A. Read, MD, Jon M. Burch, MD, *Denver, Colorado*

No Patient with SIG-BCI Had Elevated CK-MB Without Abnormal ECG

CK-MB Levels Were Not Predictive of SIG-BCI

Am J Surg 1994; 169:523

CARDIAC TROPONIN

Low Sensitivity and Predictive Value for SIG-BCI

Fulda GJ et al. J Trauma 1997; 43:304
Bertinchant JP et al. J Trauma 2000; 48:924

Real Value:

Normal Admission ECG + cTnI at 4-8 Hrs Has Negative Predictive Value for SIG-BCI Approaching 100%:

0/46 Salim A et al. J Trauma 2001; 50:237

0/40 Collins JN et al. Am Surg 2001; 67:821

0/131 Velmahos GC et al. J Trauma 2003; 54:45

Screening for blunt cardiac injury: An Eastern Association for the Surgery of Trauma practice management guideline

Keith Clancy, MD, Catherine Velopulos, MD, Jaroslaw W. Bilaniuk, MD, Bryan Collier, DO, William Crowley, MD,† Stanley Kurek, DO, Felix Lui, MD, Donna Nayduch, RN, Ayodele Sangosanya, MD, Brian Tucker, DO, *and* Elliott R. Haut, MD

In patients with a normal ECG result *and* normal troponin I level, BCI is ruled out. The optimal timing of these measurements, however, has yet to be determined. Conversely, patients with normal ECG results but elevated troponin I level should be admitted to a monitored setting (new).

J Trauma Acute Care Surg 2012; 73:S301

OTHER TIDBITS

OCCULT PNEUMOTHORAX

Seen on CT but not CXR

2% Trauma Admissions

30% PTXs DeMoya et al. J Trauma 2007; 63:13

If Asymptomatic, No Rx

?"Prophylactic" Tube Thoracostomy for Positive-Pressure Ventilation

Blunt Traumatic Occult Pneumothorax: Is Observation Safe?—
Results of a Prospective, AAST Multicenter Study

Forrest O. Moore, MD, FACS, Pamela W. Goslar, PhD, Raul Coimbra, MD, PhD, FACS, George Velmahos, MD, PhD, MSEd, FACS, Carlos V. R. Brown, MD, FACS, Thomas B. Coopwood, Jr., MD, Lawrence Lottenberg, MD, FACS, Herb A. Phelan, MD, FACS, Brandon R. Bruns, MD, John P. Sherck, MD, Scott H. Norwood, MD, FACS, Stephen L. Barnes, MD, FACS, Marc R. Matthews, MD, FACS, William S. Hoff, MD, FACS, Marc A. de Moya, MD, FACS, Vishal Bansal, MD, Charles K. C. Hu, MD, FACS, Riyad C. Karmy-Jones, MD, FACS, Fausto Vinces, DO, Karl Pembaur, BS, David M. Notrica, MD, FACS, and James M. Haan, MD, FACS

448 Pts Observed

27 (6%) Chest Tube for PTX Progression, Resp Distress, or Hemothorax

10/73 (14%) Failed on PPV- No Tension

J Trauma 2011; 70:1019

Occult pneumothoraces in critical care: A prospective multicenter randomized controlled trial of pleural drainage for mechanically ventilated trauma patients with occult pneumothoraces

Ma ID,

TABLE 4. OPTX Sizes of Observed Patients Who Subsequently Required Pleural Drainage (obs-TT) or Not Required Drainage (obs-OK) on the Site Randomized to Observation

	Obs-OK	Obs-Fail	*p*
Total population (n = 50)	40	10	
Ball index, median (IQR)	16.8 (2.5–48.0)	20.1 (9.8–33.0)	0.784
de Moya score, median (IQR)	18.7 (15.0–26.5)	17.6 (15.8–23.5)	0.912
AAST (mm) , median (IQR)	8.2 (5.0–15.1)	7.6 (5.8–13.5)	0.808
Wolfman ("miniscule")	15	1	NA
Wolfman ("anterior")	22	9	NA
Wolfman ("anterolateral")	3	0	NA

NA, not applicable.

Kirkpatrick et al. J Trauma Acute Care Surg 2013; 74:747

HEMOTHORAX

Indications for Surgery:

- **>1500 mL Output**
- **200 mL/hr Output x 2-4 hr***
- **Continued Transfusion***

***Correct Coagulopathy, Consider Angioembolization**

Excerpta Medica

The American Journal of Surgery

The American Journal of Surgery 190 (2005) 844–848

Papers presented

Occult traumatic hemothorax: when can sleeping dogs lie?

John F. Bilello, M.D., F.A.C.S.*, James W. Davis, M.D., F.A.C.S., Deborah M. Lemaster, R.N., M.S.N.

Department of Surgery, Trauma/Critical Care, University Medical Center, University of California, San Francisco–Fresno Campus, 445 S. Cedar Ave., Fresno, CA 93702, USA

HTX <1.5 cm (260 mL) Can Be Watched

92% Success

EAST Guideline: ALL HTXs Should be Drained

Mowery NT et al. J Trauma 2011; 70:510

Does size matter? A prospective analysis of 28–32 versus 36–40

TABLE 5. Our Study Outcomes in Comparison With Those of Inaba et al.[3]

	Kulvatunyou et al.		Inaba et al.[3]	
	14F PC (n = 36)	32F–40F CT (n = 191)	28F–32F CT (n = 144)	36F–40F CT (n = 131)
IO, mean ± SD, mL	560 ± 81	426 ± 37	312 ± 314	393 ± 364
Tube days, mean ± SD	5 ± 0.8	6 ± 0.3	6.3 ± 3.9	6.2 ± 3.6
Failure (retained HTX), %	8	24	12	11

CT, chest tube.

Two-Year Experience of Using Pigtail Catheters to Treat Traumatic Pneumothorax: A Changing Trend

Narong Kulvatunyou, MD, Aparna Vijayasekaran, MD, Adam Hansen, MD, Julie L. Wynne, MD, Terrance O'Keeffe, MD, Randall S. Friese, MD, Bellal Joseph, MD, Andy Tang, MD, and Peter Rhee, MD

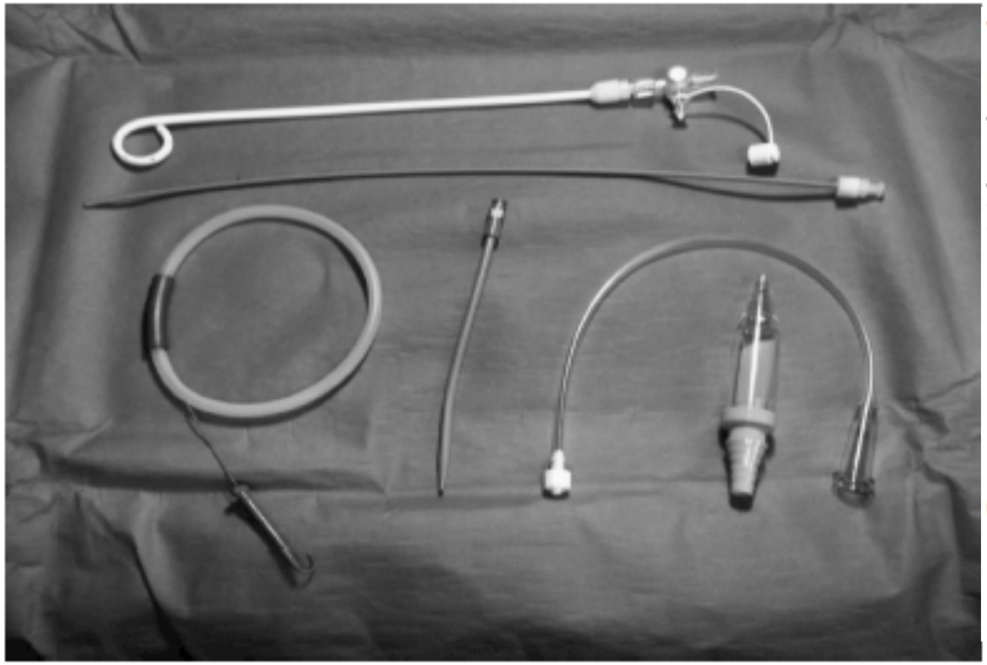


TABLE 3. Insertion-Related Complications for the Pneumothorax Group

	Intervention
Pigtail catheter	
1—Left subclavian vein insertion	Blood transfusion and withdrawal of the catheter
1—Intercostal artery injury	Chest tube placement, bleeding stopped
1—Subcutaneous placement	Tube replacement
Chest tube	
3—Subcutaneous placement	Tube replacement
1—Tube dislodgement	Tube replacement

Failure rate, n (%)	8 (11%)	6 (4%)	0.06

J Trauma 2011; 71:1104

ABX FOR TUBE THORACOSTOMY

Prophylactic Abx do not Reduce Empyema/Pneumonia; Associated with Resistant HAIs

Maxwell et al. J Trauma 2004; 57:742

Presumptive antibiotic use in tube thoracostomy for traumatic hemopneumothorax: An Eastern Association for the Surgery of Trauma practice management guideline

Forrest O. Moore, MD, Therese M. Duane, MD, Charles K.C. Hu, MD, Adam D. Fox, DO, Nathaniel McQuay, Jr., MD, Michael L. Lieber, MS, John J. Como, MD, Elliott R. Haut, MD, Andrew J. Kerwin, MD, Oscar D. Guillamondegui, MD, *and* J. Bracken Burns, DO

Cannot Recommend For or Against Abx

J Trauma Acute Care Surg 2012; 73:S341

RETAINED HEMOTHORAX

Residual HTX on CXR after CT Placement = 33% Risk of Empyema

Karmy-Jones R et al. Can Respir J 2008; 15:255

Development of posttraumatic empyema in patients with retained hemothorax: Results of a prospective, observational AAST study

Joseph DuBose, MD, Kenji Inaba, MD, Obi Okoye, MD, Demetrios Demetriades, MD, PhD, Thomas Scalea, MD, James O'Connor, MD, Jay Menaker, MD, Carlos Morales, MD, Tony Shiflett, MD, Carlos Brown, MD, Ben Copwood, MD, *and* **the AAST Retained Hemothorax Study Group,** *Baltimore, Maryland*

Among patients with trauma and posttraumatic RH, the incidence of empyema was 26.8%. Independent predictors of empyema development after posttraumatic RH included the presence of rib fractures, Injury Severity Score of 25 or higher, and the need for additional interventions to evacuate retained blood from the thorax. Our findings highlight the need to

TABLE 2. Independent Predictors of Empyema in Patients with Posttraumatic Retained Hemothoraces

Step	Variable	Adjusted OR (95% CI)	*p*	Cumulative R^2
1	Rib fractures	2.28 (1.27–4.11)	0.006	0.180
2	ISS ≥ 25	2.40 (1.30–4.43)	0.005	0.217
3	Additional intervention	28.82 (6.62–125.49)	<0.001	0.251

J Trauma Acute Care Surg 2012; 73:752

RETAINED HEMOTHORAX

PRCT 2nd Chest Tube vs VATS

VATS = Dec Duration of CT Drainage, LOS, Cost

10/24 with 2nd CT (42%) Required Surgery

Meyer DM et al. Ann Thoracic Surg 1997; 64:1396

EAST Guidelines 2011

"Persistent retained hemothorax, seen on plain films, after placement of a thoracostomy tube should be treated with early VATS, not a second chest tube (Level 1).

J Trauma 2011; 70:510

RIB FRACTURES

Co[illegible] ns

12%[illegible] 975

Eld[illegible]

22[illegible]

20[illegible]

20% 11% Stawicki, J Am Geriatr Soc 2004; 52:805

NEXT LECTURE

Epidural analgesia improves outcome after multiple rib fractures

Eileen M. Bulger, MD, Thomas Edwards, PhD, MD, Patricia Klotz, RN, and
Gregory J. Jurkovich, MD, *Seattle, Wash*

Table II. Unadjusted outcome parameters

	Epidural (n = 22)	*Opioids (n = 24)*	P value
Pneumonia	4 (18%)	9 (38%)	.15
No. of vent days*	8 ± 16	9 ± 26	.41
ARDS	10 (45%)	6 (25%)	.15
Mortality	2 (9%)	1 (4.2%)	.50
LOS (d)*	18 ± 16	16 ± 13	.60
LICU (d)*	10 ± 15	12 ± 26	.78

Surgery 2004; 136:426

Continuous Intercostal Nerve Blockade for Rib Fractures: Ready for Primetime?

Michael S. Truitt, MD, Jason Murry, MD, Joseph Amos, MD, Manuel Lorenzo, MD, MBA, Alicia Mangram, MD, Ernest Dunn, MD, and Ernest E. Moore, MD

Conclusion: Utilization of CINB significantly improved pulmonary function, pain control, and shortens LOS in patients with rib fractures.

J Trauma 2011; 71:1548

PNEUMOMEDIASTINUM

Sign of Aerodigestive Injury

5% of Chest CTs

10% Have Injuries

If Asymptomatic, Manage Expectantly

Macleod et al. Am Surg 2009; 75:375
Dissanaike et al. J Trauma 2008; 65:1340

TRACHEOBRONCHIAL INJURY

Subcu Emphysema; Pneumomediastinum; PTX w Air Leak

Dx by Bronchoscopy

Karmy-Jones et al. Thorac Surg Clin 2007; 17:35

Western Trauma Association Critical Decisions in Trauma: Diagnosis and management of esophageal injuries

J Trauma Acute Care Surg 2015; 79:1089

Walter L. Biffl, MD, Ernest E. Moore, MD, David V. Feliciano, MD, Roxie A. Albrecht, MD, Martin Croce, MD, Riyad Karmy-Jones, MD, Nicholas Namias, MD, Susan Rowell, MD, Martin Schreiber, MD, David V. Shatz, MD, *and* Karen Brasel, MD, *Denver, Colorado*

CTA Chest

Esophagoscopy / Esophagography

THORACIC GSW

Exam + CXR or E-FAST

- -Hemodynamics, Location of Wound(s); Early repeat CXR

Unilateral GSW – Chest tube

- -Drained vs Retained Htx vs Large Air Leak

Transmediastinal GSW – Chest tube(s), CT scan

- -Add'l W/U based on trajectory

Thoracoabdominal GSW – Chest tube, Laparotomy, ?Pericardial window

DAMAGE CONTROL RESUSCITATION

Damage Control: Keep a Badly Damaged Ship Afloat After Major Penetrating Injury to the Hull

Damage Control: Keep a Badly Damaged Ship Afloat After Major Penetrating Injury to the Hull

Plug Gaping Holes

Extinguish Fires

“Dog Down” Watertight Doors

Keep Ship Afloat

- **Assess Overall Damage**
- **Establish a Plan for Definitive Repair**

DAMAGE CONTROL IN TRAUMA

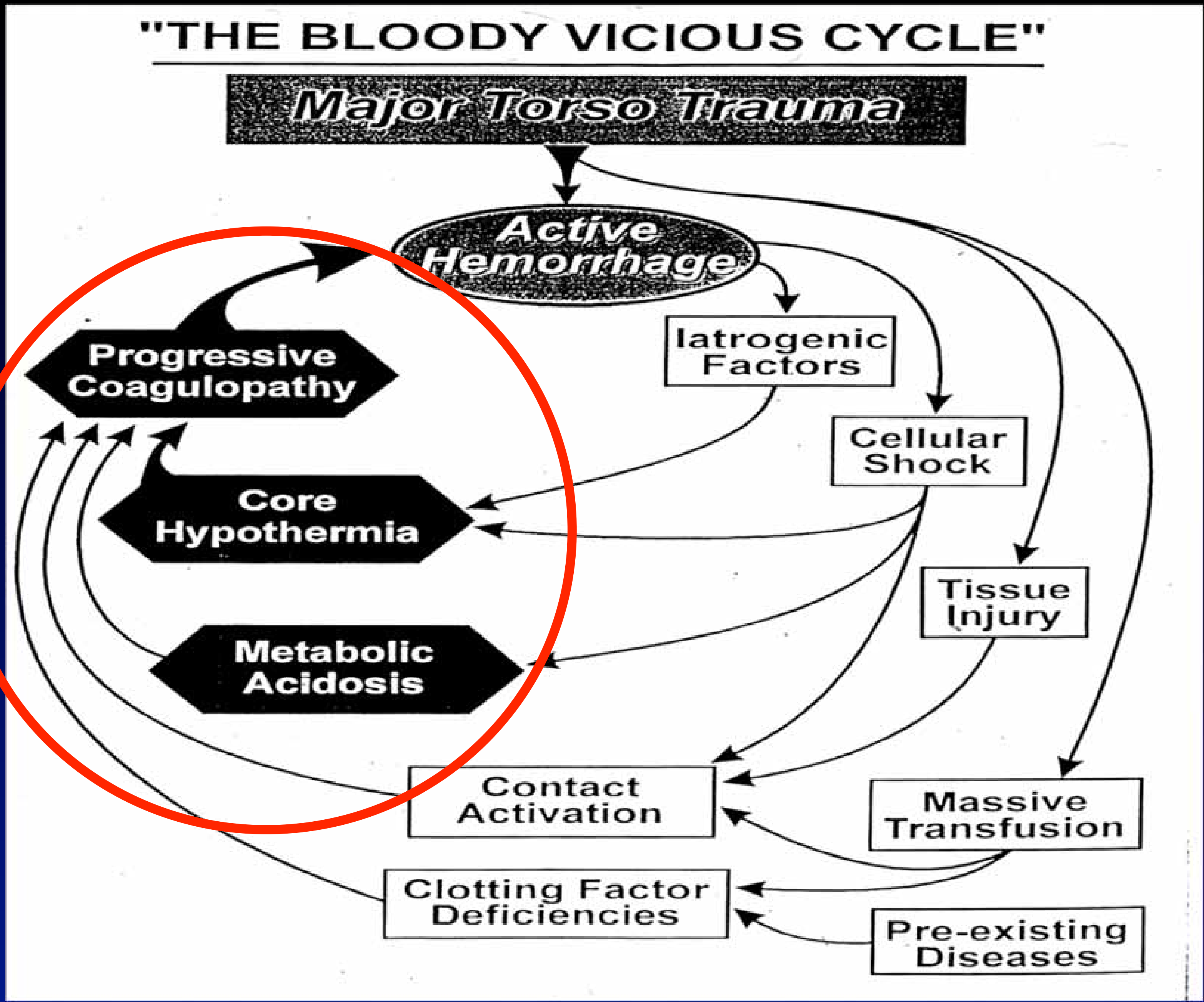
1976- Lucas and Ledgerwood

1979- Calne et al

1981- Feliciano et al

1983- Stone et al

1993- Rotondo et al



Kashuk J, Moore EE et al. J Trauma 1982; 22:261

Damage Control Resuscitation: Directly Addressing the Early Coagulopathy of Trauma

J Trauma 2007; 62:307

John B. Holcomb, MD, FACS, Don Jenkins, MD, FACS, Peter Rhee, MD, FACS, Jay Johannigman, MD, FS, FACS, Peter Mahoney, FRCA, RAMC, Sumeru Mehta, MD, E. Darrin Cox, MD, FACS, Michael J. Gehrke, MD, Greg J. Beilman, MD, FACS, Martin Schreiber, MD, FACS, Stephen F. Flaherty, MD, FACS, Kurt W. Grathwohl, MD, Phillip C. Spinella, MD, Jeremy G. Perkins, MD, Alec C. Beekley, MD, FACS, Neil R. McMullin, MD, Myung S. Park, MD, FACS, Ernest A. Gonzalez, MD, FACS, Charles E. Wade, PhD, Michael A. Dubick, PhD, C. William Schwab, MD, FACS, Fred A. Moore, MD, FACS, Howard R. Champion, FRCS, David B. Hoyt, MD, FACS, and John R. Hess, MD, MPH, FACP

"Damage control resuscitation addresses the entire lethal triad immediately upon admission to a combat hospital"

Anticipate and Attenuate; Reverse

DAMAGE CONTROL RESUSCITATION

- Permissive Hypotension
- Limit Isotonic Crystalloid
- Aggressive Hemostatic Resuscitation
- Bleeding Control
- Rewarming
- Correction of Acidosis, Hypocalcemia

Bogert et al. J Intensve Care Med 2016; 31:177
Giannoudi et al. Eur J Trauma Emerg Surg 2016; 42:273
Chang et al. Crit Care Clin 2017; 33:15

PERMISSIVE HYPOTENSION

- **Premise: Avoid Exacerbating Hemorrhage and Dilutional Coagulopathy**
- **Caveat: Clear Evidence of Benefit and Optimal Perfusion Targets Lacking**
- **Goal: SBP 70-90; MAP >50; Radial Pulse**
- **Caution: Severe TBI; Prolonged Shock**

Bogert et al. J Intensve Care Med 2016; 31:177
Giannoudi et al. Eur J Trauma Emerg Surg 2016; 42:273
Chang et al. Crit Care Clin 2017; 33:15

LIMIT ISOTONIC CRYSTALLOID

- <u>Premise</u>: **Excess Crystalloid** – Dilutional Coagulopathy, ARDS, Cardiac Dysfunction, Compartment Syndromes, Ileus, Anastomotic Leak, Wound Complications, MOF, Death
- <u>Mechanism</u>: **Intracellular Edema** – Disrupt Biochemical Processes (Pancreatic Insulin, Hepatocyte Glucose Metabolism, Cardiac Myocyte Excitability); **Inflammation** – Inflammatory Mediators; Endothelial Glycocalyx Degradation

Bogert et al. J Intensve Care Med 2016; 31:177
Giannoudi et al. Eur J Trauma Emerg Surg 2016; 42:273
Chang et al. Crit Care Clin 2017; 33:15

Goal-directed resuscitation in the prehospital setting: A propensity-adjusted analysis

J Trauma Acute Care Surg 2013; 74:1207

Joshua B. Brown, MD, Mitchell J. Cohen, MD, Joseph P. Minei, MD, Ronald V. Maier, MD, Michael A. West, MD, Timothy R. Billiar, MD, Andrew B. Peitzman, MD, Ernest E. Moore, MD, Joseph Cuschieri, MD, Jason L. Sperry, MD, MPH, *and* The Inflammation and the Host Response to Injury Investigators, *Pittsburgh, Pennsylvania*

If Not Hypotensive, >500 mL Crystalloid Assoc w/ Higher Mortality and Coagulopathy

Aggressive early crystalloid resuscitation adversely affects outcomes in adult blunt trauma patients: An analysis of the Glue Grant database

J Trauma Acute Care Surg 2013; 74:1215

George Kasotakis, MD, Antonis Sideris, MD, Yuchiao Yang, PhD, Marc de Moya, MD, Hasan Alam, MD, David R. King, MD, Ronald Tompkins, MD, ScD, George Velmahos, MD, MsEd, PhD, *and* the Inflammation and Host Response to Injury Investigators, *Boston, Massachusetts*

24 Hr Crystalloid Correlated w/ Vent Days, ICU & Hosp LOS, ARDS, MOF, SSI, Bloodstream Infxn, Compartment Syndromes

OPTIMAL FLUID?

- **Colloid- Discouraged due to Cost, Coagulopathy, Renal Dysfunction**
- **Crystalloid- NS vs LR vs Plasmalyte**

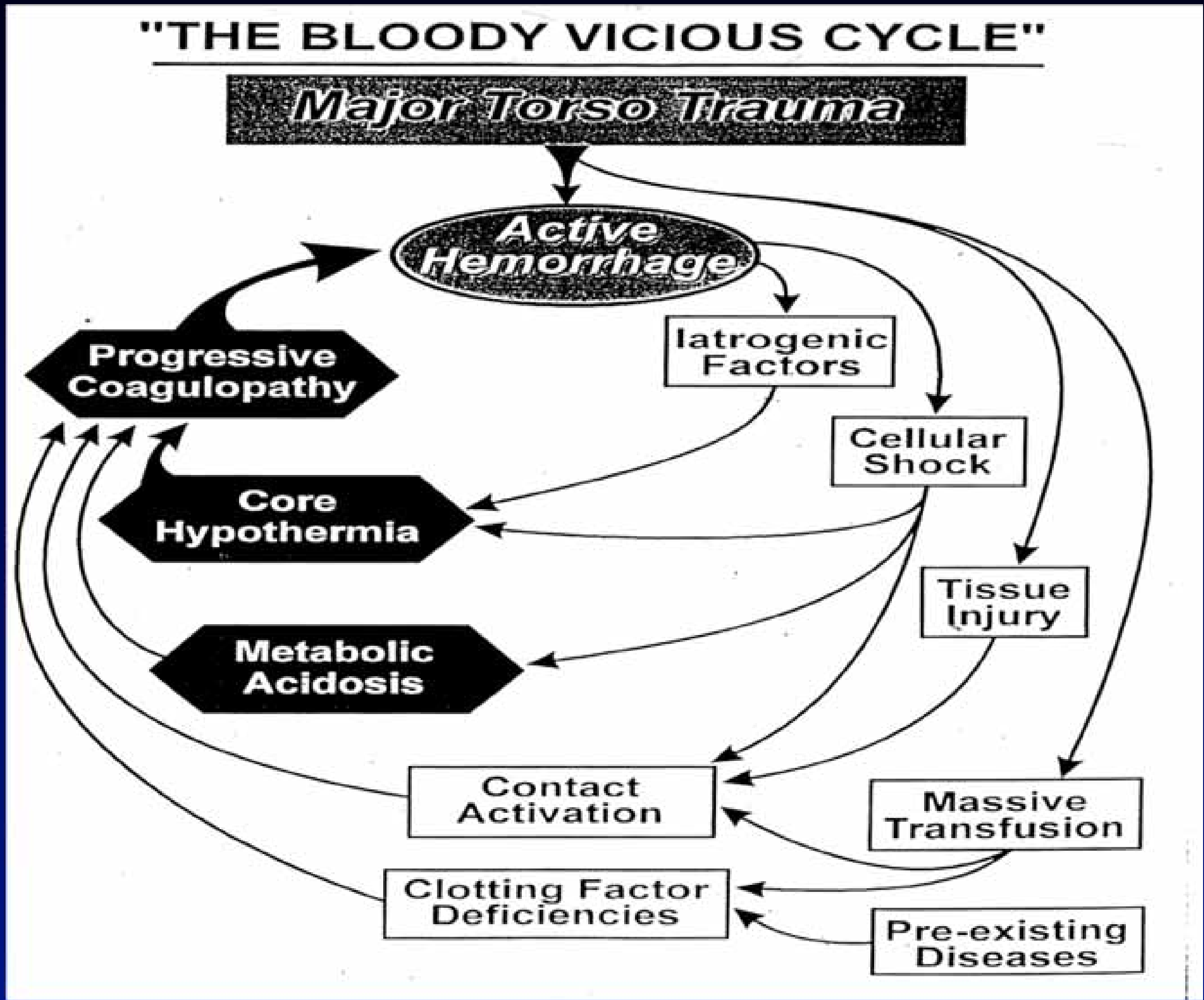
Effects of Plasma-lyte A, lactated Ringer's, and normal saline on acid-base status and intestine injury in the initial treatment of hemorrhagic shock☆

Ying Wang, PhD [a,1], Wei Guo, MD [b,1], Dawei Gao, PhD [b], Guoxing You, MD [a], Bo Wang, PhD [a], Gan Chen, PhD [a], Lian Zhao, PhD [a], Jingxiang Zhao, PhD [a,*], Hong Zhou, PhD [a,**]

Am J Emerg Med 2017; 35:317

Conclusions: Although the 3 crystalloid solutions play different roles, PA is better at correcting the acid-base balance and improving intestine injury during HS than NS and LR.

HEMOSTATIC RESUSCITATION



Kashuk J, Moore EE et al. J Trauma 1982; 22:261

PRESUMPTIVE FFP

0022-5282/82/2208-0672$02.00/0
The Journal of Trauma
Vol. 22, No. 8
Printed in U.S.A.

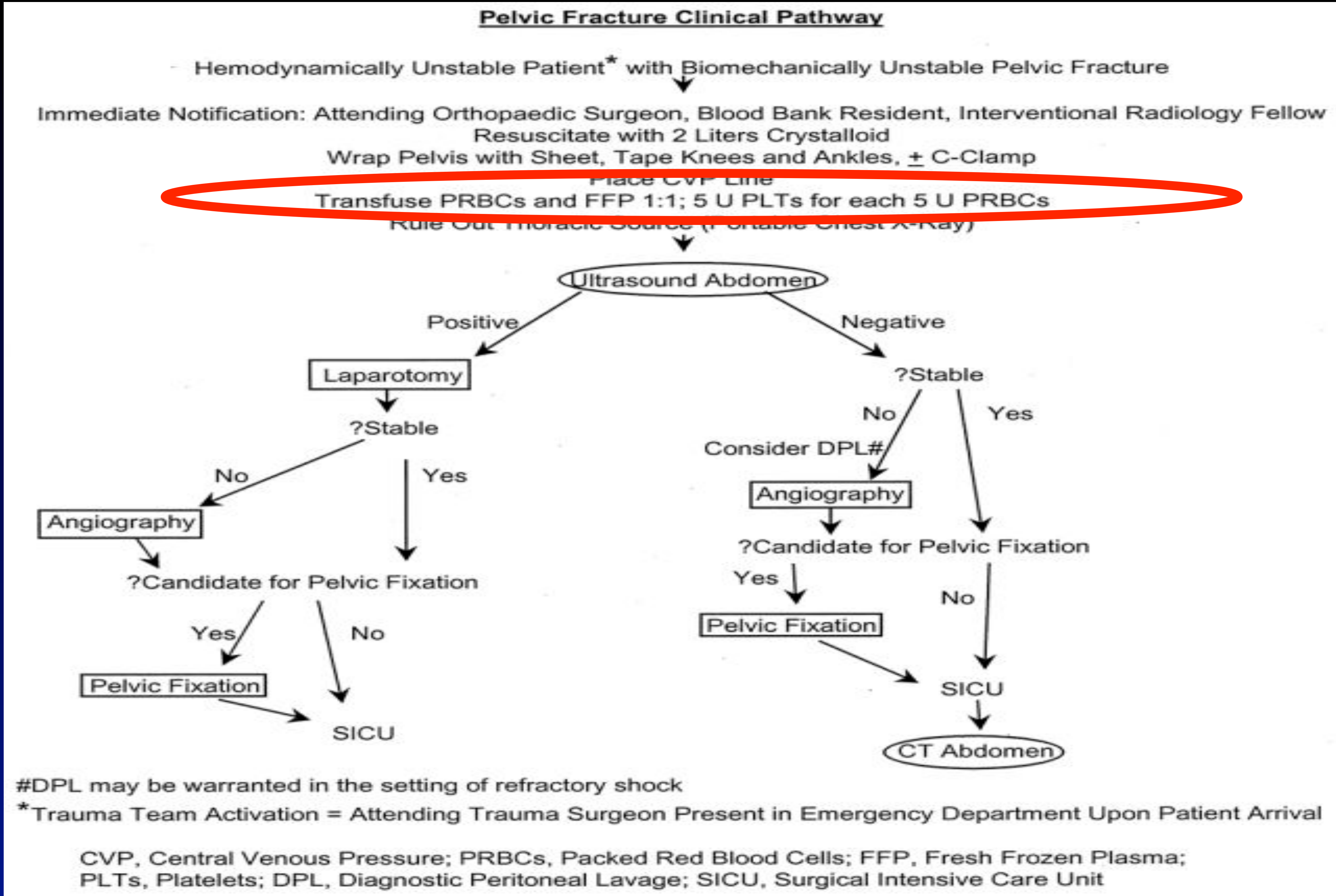
Major Abdominal Vascular Trauma—A Unified Approach

JEFFRY L. KASHUK, M.D., ERNEST E. MOORE, M.D., J. SCOTT MILLIKAN, M.D., and JOHN B. MOORE, M.D.

Although coagulation studies were often poorly documented, indirect evidence of inadequate factor replacement was obtained by calculating the ratio of bank blood to unit of fresh frozen plasma (FFP) given. A consistent deviation from the commonly accepted ratio of 4–5:1 was evident, increasing to 8:1 in nonsurvivors and 9:1 in those where an overt coagulopathy was documented.

factor replacement is certainly involved. We believe fresh frozen plasma should be administered with the first four units of bank blood in the hypotensive patient, as well as

Kashuk J, Moore EE et al. J Trauma 1982; 22:261



Biffl et al, Ann Surg 2001; 233:843

Post-Injury Life Threatening Coagulopathy

1:1:1 FFP:PLT:RBC

Special Commentary

The Journal of TRAUMA® Injury, Infection, and Critical Care

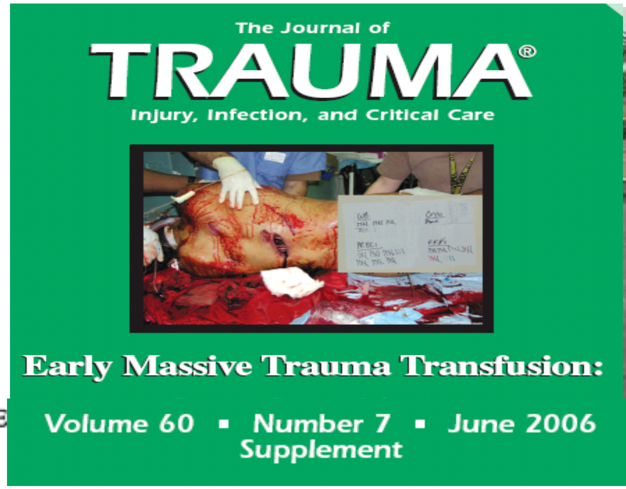
Damage Control Resuscitation: Directly Addressing the Early Coagulopathy of Trauma

John B. Holcomb, MD, FACS, Don Jenkins, MD, FACS, Peter Rhee, MD, FACS, Jay Johannigman, MD, FS, FACS, Peter Mahoney, FRCA, RAMC, Sumeru Mehta, MD, E. Darrin Cox, MD, FACS, Michael J. Gehrke, MD, Greg J. Beilman, MD, FACS, Martin Schreiber, MD, FACS, Stephen F. Flaherty, MD, FACS, Kurt W. Grathwohl, MD, Phillip C. Spinella, MD, Jeremy G. Perkins, MD, Alec C. Beekley, MD, FACS, Neil R. McMullin, MD, Myung S. Park, MD, FACS, Ernest A. Gonzalez, MD, FACS, Charles E. Wade, PhD, Michael A. Dubick, PhD, C. William Schwab, MD, FACS, Fred A. Moore, MD, FACS, Howard R. Champion, FRCS, David B. Hoyt, MD, FACS, and John R. Hess, MD, MPH, FACP

UNCLASS ALARACT
SUBJECT: OPTIMAL RESUSCITATION OF SEVERELY INJURED SOLDIERS

1. COMBAT RESUSCITATION DATA ANALYZED BY THE US ARMY INSTITUTE OF SURGICAL RESEARCH (USAISR) DEMONSTRATE THAT CASUALTIES WHO RECEIVE MORE THAN 10 UNITS OF PACKED RED BLOOD CELLS (PRBCS) IN A 24-HOUR PERIOD (MASSIVE TRANSFUSION) HAVE A PROFOUND SURVIVAL BENEFIT WHEN THE PLASMA (FFP) TO PRBC TRANSFUSION RATIO IS 1:1. CASUALTIES WHO RECEIVE LESS FFP (1 UNIT FFP TO 4 UNITS PRBCS, OR LESS) HAVE AN OVERALL MORTALITY OF 65%, WHILE THOSE WHO RECEIVE A 1:1 RATIO HAVE AN OVERALL MORTALITY OF 20% (P< 0.001).

2. SEVERELY INJURED CASUALTIES SHOULD HAVE THE 1:1 RATIO INITIATED AS EARLY AFTER INJURY AS POSSIBLE. TRANSFUSIONS MUST BE ACCOMPLISHED ACCORDING TO GUIDELINES ESTABLISHED BY THE CENTCOM BLOOD PROGRAM MANAGER. THE CURRENT APPROVED CENTCOM CLINICAL PRACTICE GUIDELINE FOR DAMAGE CONTROL RESUSCITATION AND TRANSFUSION IS POSTED ON THE JOINT PATIENT TRACKING APPLICATION (JPTA) WEBSITE:



HEMOSTATIC RESUSCITATION

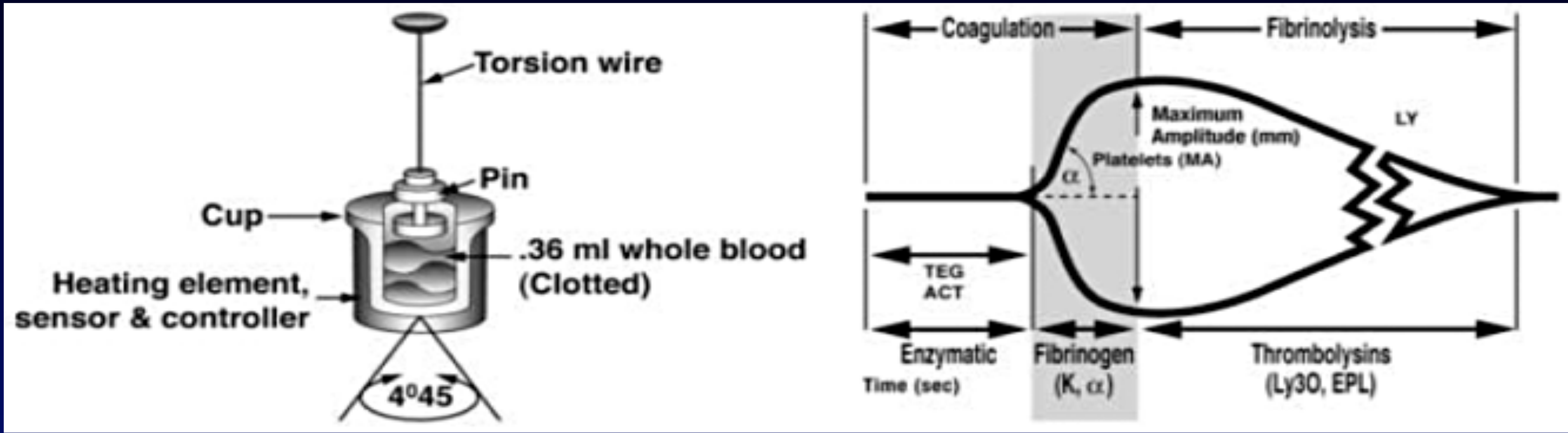
- 2 Lg Bore IVs Upper Ext
- Early MTP
- FFP:PLTs:PRBCs 1:1:1-2

MASSIVE TRANSFUSION

- ABC Score ≥2
  - Penetrating Mechanism
  - SBP <90
  - HR >120
  - (+) FAST
- Persistent hemodynamic instability
- Active bleeding requiring operation or angioembolization
- Blood transfusion in trauma bay

TQIP Best Practices

THROMBELASTOGRAPHY



Goal-Directed Resuscitation

PRBCs, FFP, PLTs

Fibrinogen, Anti-Fibrinolysis

Goal-directed Hemostatic Resuscitation of Trauma-induced Coagulopathy

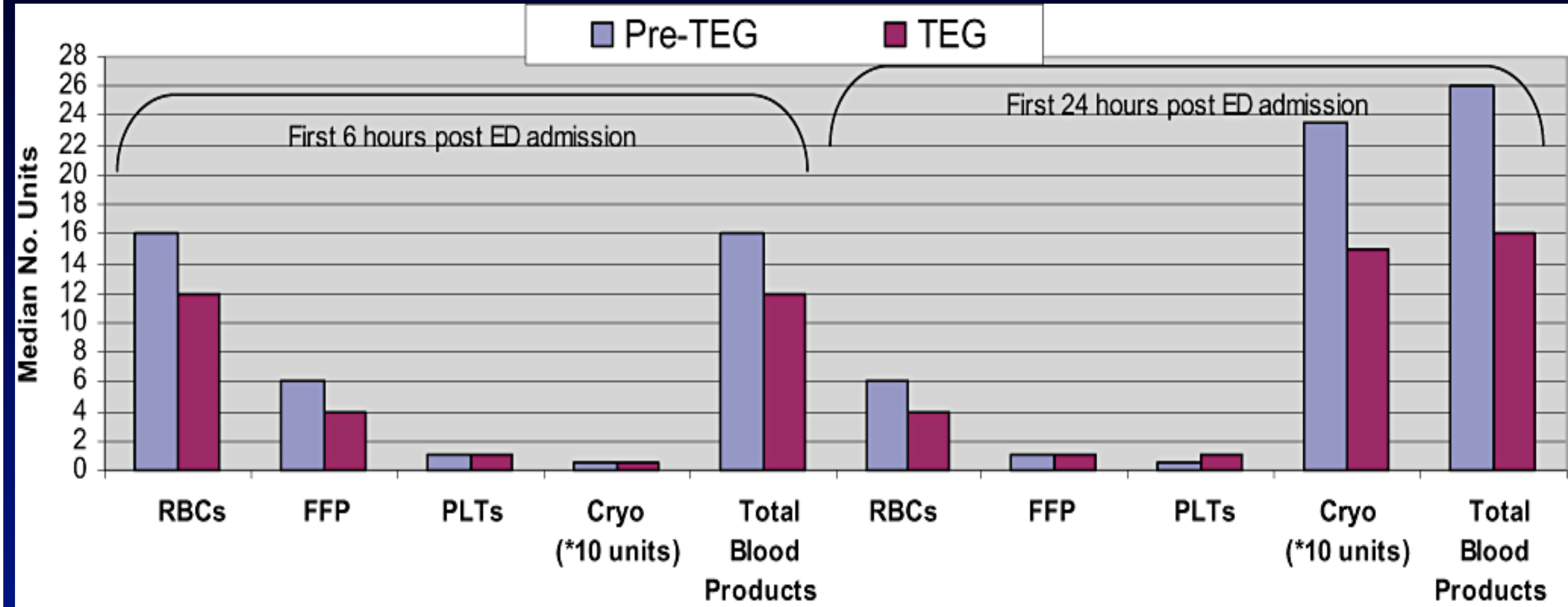
A Pragmatic Randomized Clinical Trial Comparing a Viscoelastic Assay to Conventional Coagulation Assays

Eduardo Gonzalez, MD, Ernest E. Moore, MD,*† Hunter B. Moore, MD,* Michael P. Chapman, MD,* Theresa L. Chin, MD,* Arsen Ghasabyan, MPH,* Max V. Wohlauer, MD,* Carlton C. Barnett, MD,*† Denis D. Bensard, MD,*† Walter L. Biffl, MD,*† Clay C. Burlew, MD,*† Jeffrey L. Johnson, MD,*† Fredric M. Pieracci, MD, MPH,*† Gregory J. Jurkovich, MD,*† Anirban Banerjee, PhD,* Christopher C. Silliman, MD, PhD,*‡§ and Angela Sauaia, MD, PhD*¶*

	As Treated		
	CCA (N = 47)	TEG (N = 64)	*P*
Deaths, no. (% within group)	19 (40.4)	12 (18.7)	0.011
Time to death in hours, median (IQR)	3.5 (2.2–8.3)	11.5 (4.9–211.0)	0.073
Deaths occurring in the first 6 hours from ED arrival, no. (% within group)	11 (23.4)	4 (6.2)	0.010
Deaths occurring >6 h from ED arrival, no. (% within group)	8 (17.0)	8 (12.5)	0.589
Hemorrhagic deaths, no. (% within group)	11 (23.4)	5 (7.8)	0.020
TBI deaths, no. (% within group)	6 (12.8)	4 (6.3)	0.321
Organ failure, no. (% within group)	2 (4.3)	3 (4.7)	1.00

Ann Surg 2016; 263:1051

CONSISTENT TREND TOWARD REDUCED BLOOD PRODUCT UTILIZATION



Kashuk et al, Transfusion 2011

PLASMA FIRST IN THE FIELD FOR POSTINJURY HEMORRHAGIC SHOCK

Ernest E. Moore,*† Theresa L. Chin,† Michael C. Chapman,† Eduardo Gonzalez,*†
Hunter B. Moore,*† Christopher C. Silliman,† Kirk C. Hansen,† Angela Sauaia,*†
and Anirban Banerjee†

Shock 2014; 41(Suppl 1):35

TABLE 1. **Denver massive transfusion activation protocol**

I. Field alert criteria (physiologic)
Resuscitation Outcome Consortium vital signs
(*a*) SBP < 70 mmHg
(*b*) SBP 71–90 mmHg + heart rate >108/min
II. ED activation criteria (anatomic)
Field physiologic criteria + ED anatomic
(*a*) Penetrating torso
(*b*) Abdominal ultrasound positive in >1 region
(*c*) Unstable major pelvic fracture

TRAUMA HEMOSTASIS AND OXYGENATION RESEARCH POSITION PAPER ON REMOTE DAMAGE CONTROL RESUSCITATION: DEFINITIONS, CURRENT PRACTICE, AND KNOWLEDGE GAPS

Donald H. Jenkins,[*] Joseph F. Rappold,[†] John F. Badloe,[‡] Olle Berséus,[§]
COL Lorne Blackbourne,[||] Karim H. Brohi,[¶] Frank K. Butler,[**]
LTC Andrew P. Cap,[††] Mitchell Jay Cohen,[‡‡] Ross Davenport,[§§]
Marc DePasquale,[||||] Heidi Doughty,[¶¶] Elon Glassberg,[***†††] Tor Hervig,[‡‡‡]
Timothy J. Hooper,[§§§] Rosemary Kozar,[||||||] Marc Maegele,[¶¶¶] Ernest E. Moore,[****]
Alan Murdock,[††††] Paul M. Ness,[‡‡‡‡] Shibani Pati,[§§§§] Col Todd Rasmussen,[||||||||]
Anne Sailliol,[¶¶¶¶] Martin A. Schreiber,[*****] Geir Arne Sunde,[†††††]
Leo M. G. van de Watering,[‡‡‡‡‡] Kevin R. Ward,[§§§§§] Richard B. Weiskopf,[||||||||||]
Nathan J. White,[¶¶¶¶¶] Geir Strandenes,[******††††††] and Philip C. Spinella[**||||||‡‡‡‡‡]

KNOWLEDGE GAPS WHERE FUTURE RESEARCH ENDEAVORS ARE NEEDED

- **Prehospital Monitoring Shock/Coagulopathy**
- **Hypotensive Resuscitation; Endpoints of Resuscitation**
- **Whole Blood vs Components; Dried Products**
- **Pathogen Reduced Technology for Products**
- **Role of TBI**

Shock 2014; 41 Suppl 1:3