THORACIC TRAUMA

Arthur Hill, M.D.
Department of Surgery
Division of Cardiothoracic Surgery
University of California, San Francisco

THORACIC TRAUMA

- EPIDEMIOLOGY
  - Blunt Injury
  - Penetrating Injury
- SPECTRUM OF THORACIC TRAUMA
- APPROACHES TO THE TREATMENT
- RESUSCITATIVE THORACOTOMY
- SPECIFIC CHALLENGES IN THORACIC TRAUMA
  - Aortic Trauma
  - Cardiac Trauma

EPIDEMIOLOGIC ISSUES

- BLUNT
  - MVC
  - Falls
  - Airplane Crashes

- PENETRATING
  - Stab wounds
  - Bullet wounds

BLUNT THORACIC TRAUMA

- 45 – 50% of unrestrained drivers have thoracic injuries
- 25% of drivers who die have thoracic injuries

Blunt Thoracic Trauma

- Distribution of Organ Injury:
  - Chest Wall 70%
  - Lung 21%
  - Heart 7%
  - Diaphragm 7%
  - Esophagus 7%
  - Aorta 4.8%
  - Tracheobronchial Injuries 0.8%

Jones KW. Thoracic Trauma. Surg Clin North Am 1980; 60: 957-81.
Hill AB, Fleiszer DM, Brown RA. Chest trauma in a Canadian urban setting - implications for trauma research in Canada. J Trauma 1991; 31: 971-73.
Devitt JH, McLean RF, Koch J-P. Anaesthetic management of blunt thoracic trauma. Can J Anaesth 1991; 38: 506-10.
Shorr RM, Crittenden M, Indeck M, Hartunian SL, Rodriguez A. Blunt thoracic trauma; analysis of 515 patients. Ann Surg 1987; 206: 200-5.

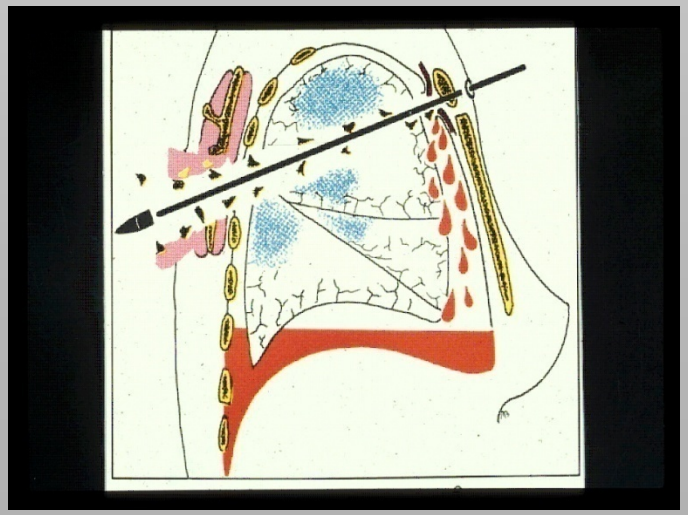
DISTRIBUTION OF THORACIC INJURIES SECONARY TO BLUNT TRAUMA

- Consequences of Chest Wall Injury:
  - Rib Fractures (most common chest wall injury in blunt trauma)
  - Hemothorax (70-80% of penetrating and major blunt injuries)
  - Flail Chest (Incidence 1.2% -- 20-40% mortality)
  - Sternal Fracture (5-8% in blunt trauma; 25-30% mortality)
- Consequences of Chest Wall Injury and Lung Injury
  - Pulmonary Contusion (30-75% of blunt trauma; mortality 14-20%)
  - Pneumothorax (10-30% in blunt injury; 95% in penetrating injury)
    - Simple
    - Open
    - Tension
- Consequences of Cardiac Injury
  - Pericardial Tamponade (usually associate with penetrating trauma)
  - Myocardial Contusion (most common blunt injury to heart)

PENETRATING THORACIC INJURIES

- Low velocity missile

- High velocity missile



PENETRATING THORACIC TRAUMA

- 40% Penetrating Injury Involves the Thorax
- 15-28% of Penetrating Thoracic Injuries Require Thoracotomy

PENETRATING THORACIC TRAUMA

- Distribution of Organ Injury
  - Chest Wall 100%
  - Lung 65-90%
  - Heart 49%
  - Diaphragm 30%
  - Intra-Abdominal Injury
    - Liver 20%
    - Stomach 8%
    - Small intestine 7%
    - Colon 6%
    - Kidney 5%

Mechanisms of Early Death after Thoracic Injury

- Airway Obstruction
- Loss of Oxygenation or Ventilation
- Exsanguination
- Cardiac Failure
- Cardiac Tamponade
- Air Embolism

ATLS Algorithm

- A – Airway (with c-spine protection)
- B – Breathing (pleural drainage)
- C – Circulation (stop the bleeding)
- D – Disability (neuro status, fractures)
- E – Exposure (temperature, pain)

RECOGNITION OF TREATABLE LIFE-THREATING INJURY

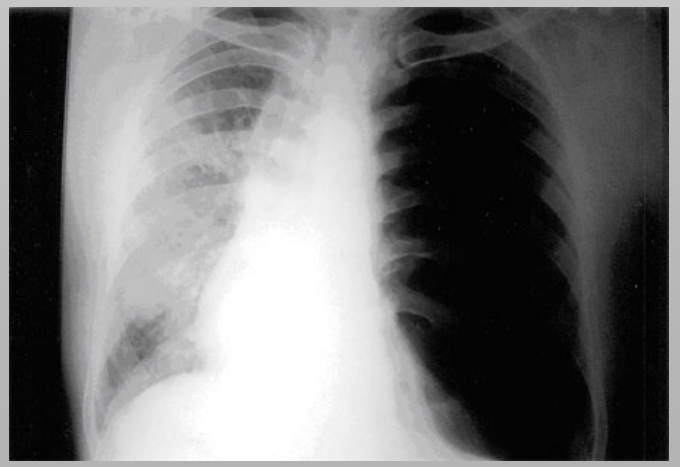
- Tension Pneumothorax
- Cardiac Tamponade

TENSION PNEUMOTHORAX

- Physical Exam

•Unilateral absence of breath sounds
•JVD
•Hypotension
•Tracheal deviation

- CXR

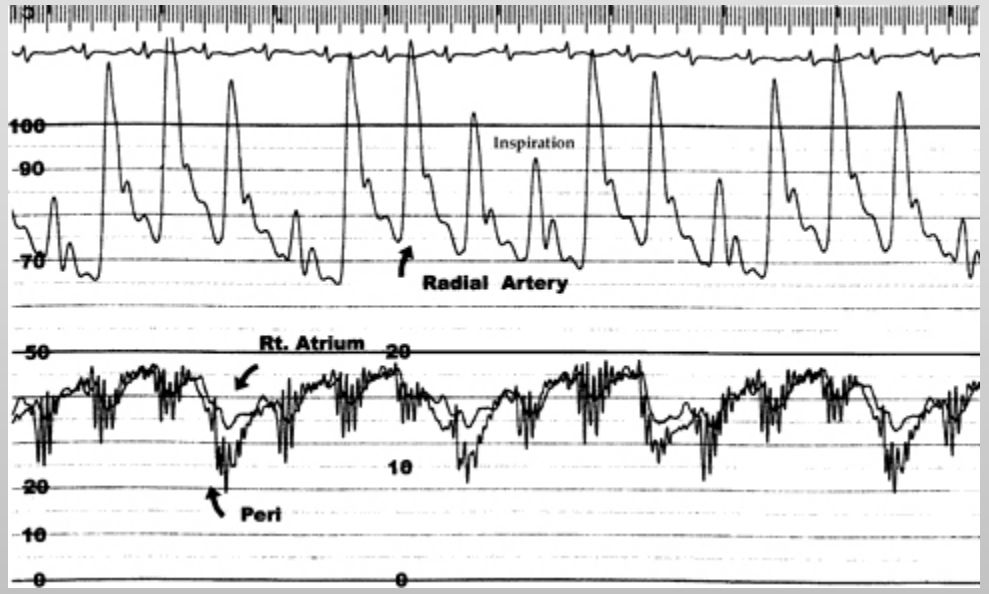


TENSION PNEUMOTHORAX

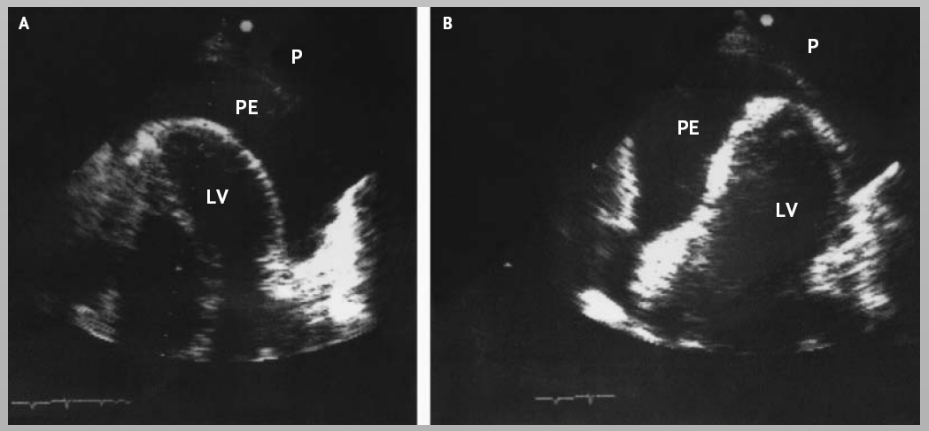
- Treatment:
  - Needle thoracostomy
    - (buy time)
  - Chest-tube
    - (definitive)

CARDICAC TAMPONADE

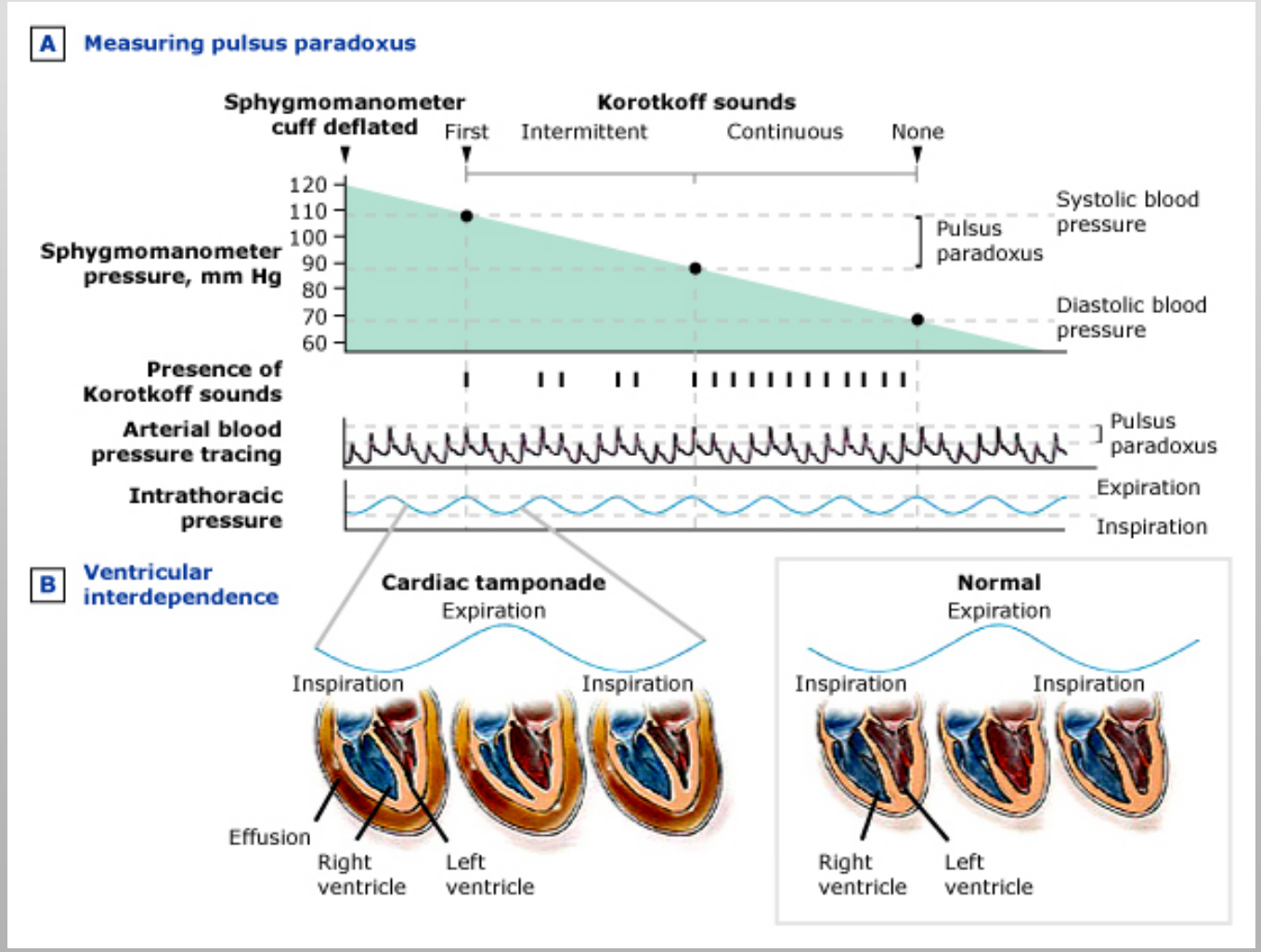
- Physical Exam



- FAST/ECHO

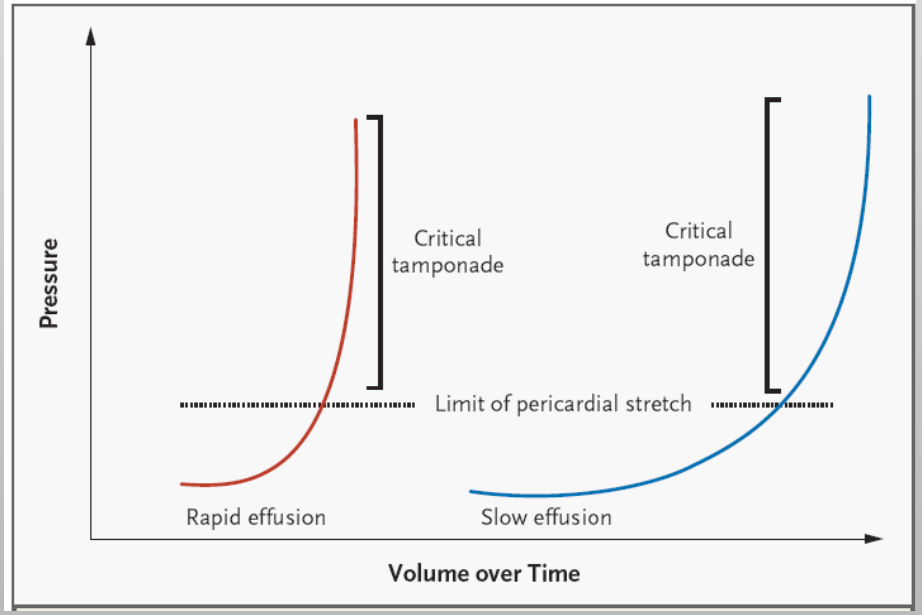


Pulsus Paradoxus



CARDICAC TAMPONADE

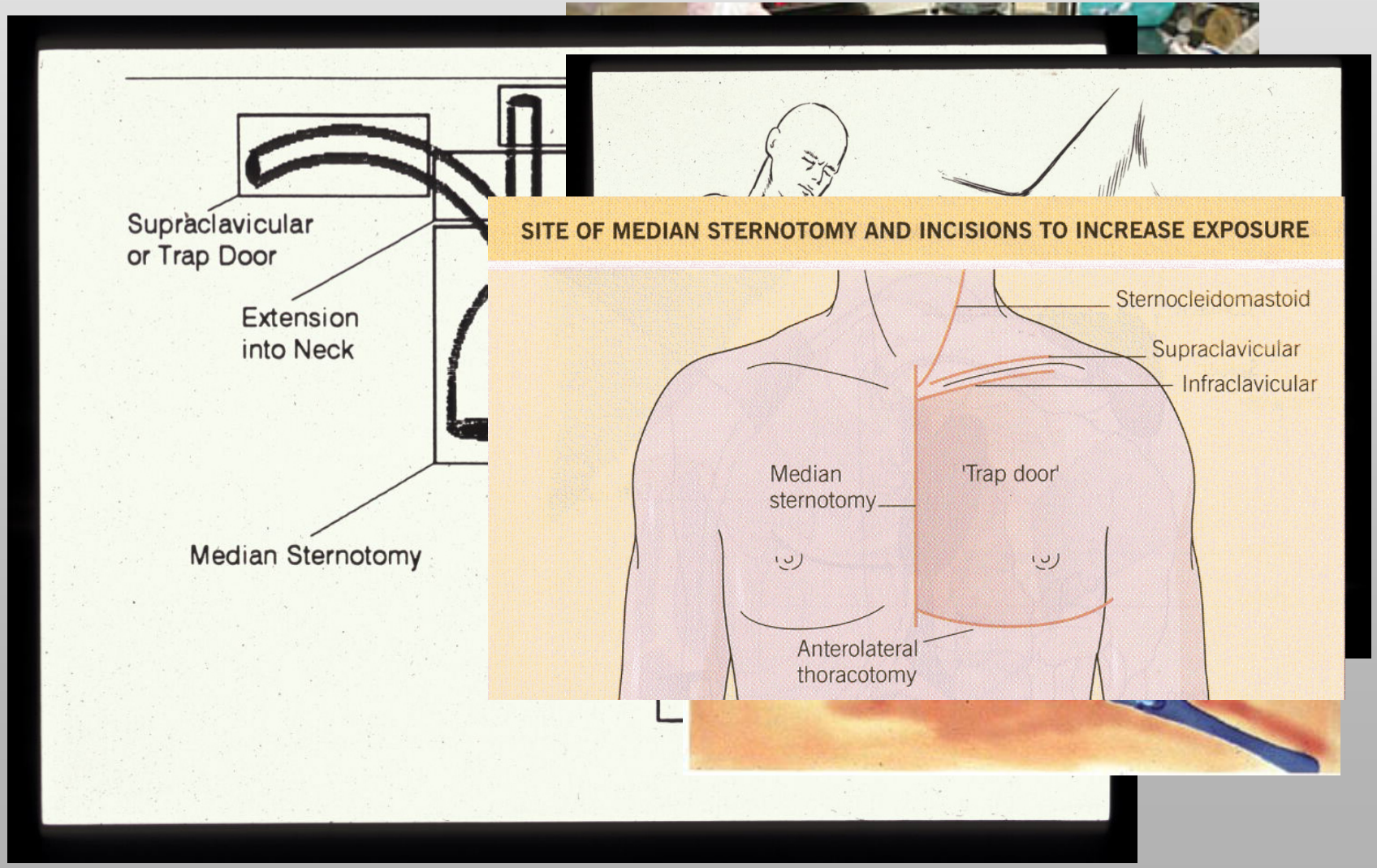
- Treatment
  - Drainage
    - Surgical
      - L thoracotomy
      - Laparotomy
        (with pericardial window)
      - Median Sternotomy
    - Pericardiocentesis



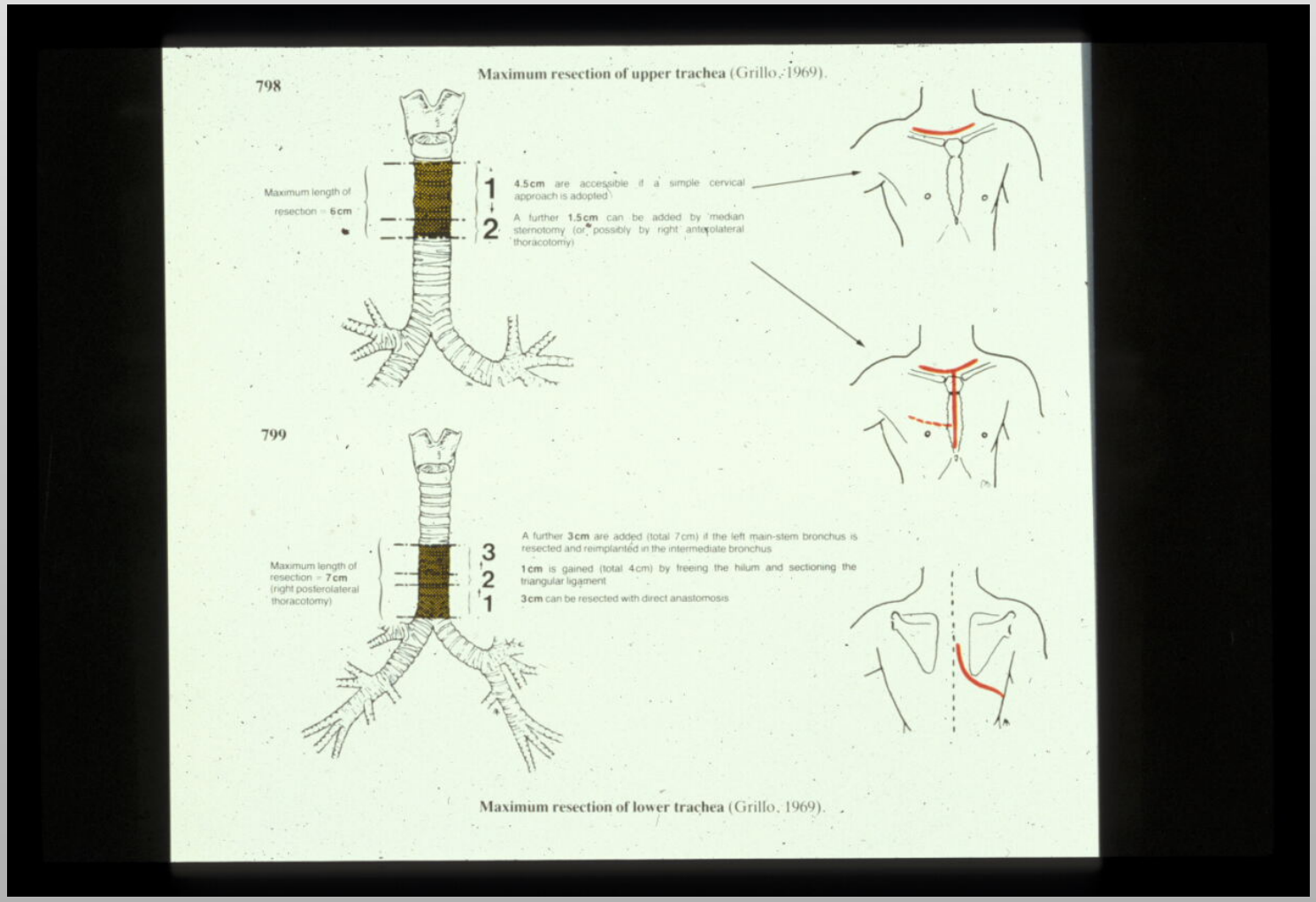
THORACIC TRAUMA

- All major thoracic trauma requires treatment by a surgeon.

Thoracic Incisions Used in Trauma



Incision Choice for Tracheal Injury



RESUSCITATIVE (ER) THORACOTOMY

INDICATIONS

TECHNIQUE

RESUSCITATIVE (ER) THORACOTOMY

10-15% of Thoracic Trauma patients will require Resuscitative Thoracotomy

Indication for ERT

- Penetrating thoracic trauma with
  - Recent loss of signs of life followed by
  - acute hemodynamic deterioration
- Penetrating abdominal trauma with
  - signs of life on admission followed by
  - acute hemodynamic deterioration

- Selected Blunt thoracic trauma with
  - signs of life on admission followed by
  - observed acute hemodynamic deterioration

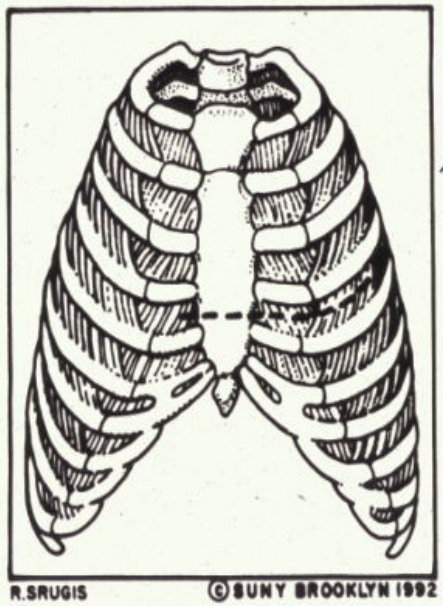
Contraindication to ERT with Presentation to ER

- Blunt trauma without signs of life
- Penetrating torso trauma without signs of life at the scene
- No cardiac activity in the absence of tamponade by FAST Exam

Purpose of ERT

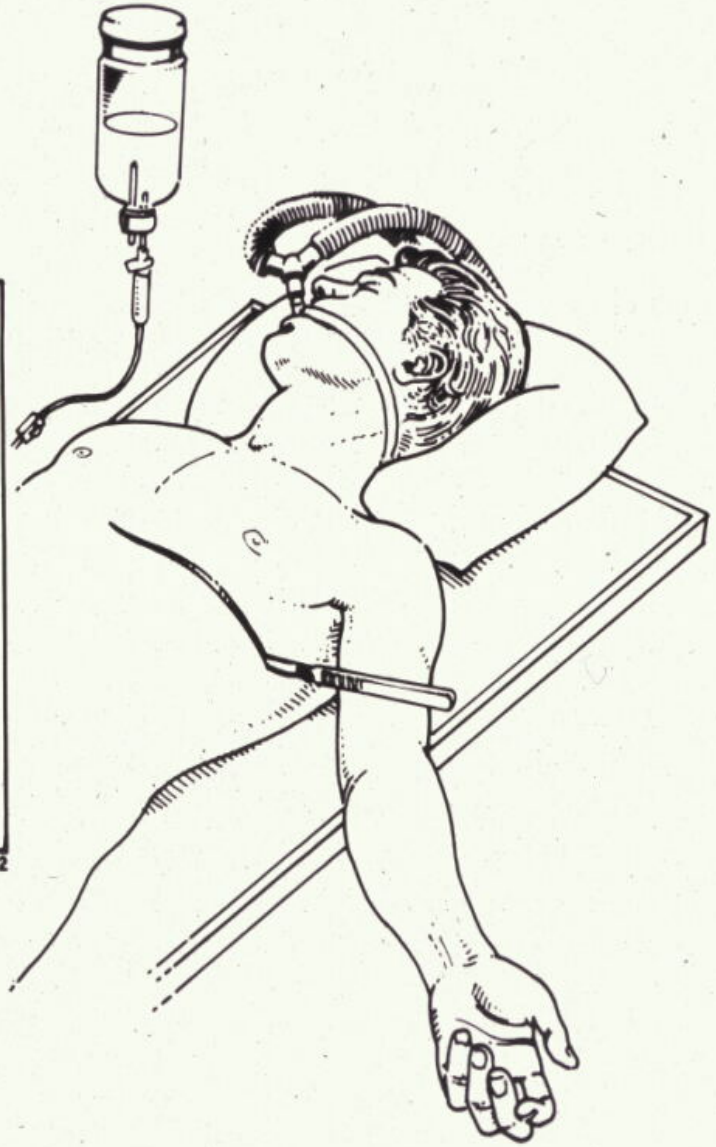
- Terminate exsanguination
  - Cardiac
  - Non-cardiac
- Relieve cardiac tamponade
- Open chest CPR
- Treatment of Massive air embolism
- Thoracic aortic cross-clamping

Technique of ERT

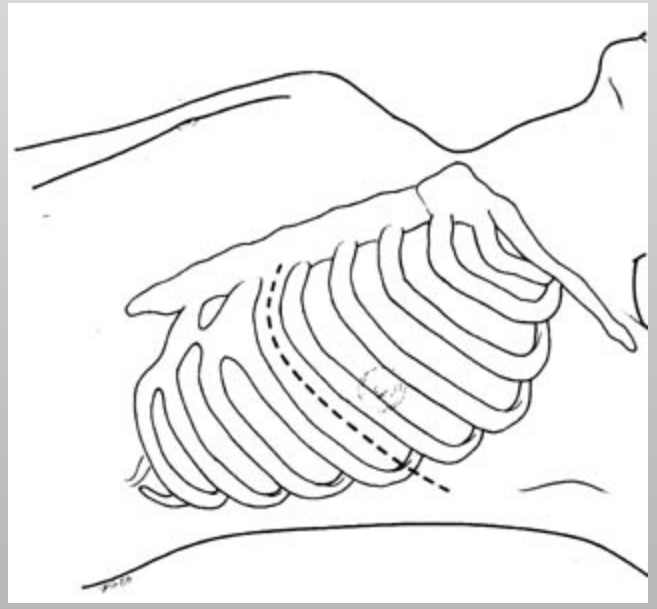


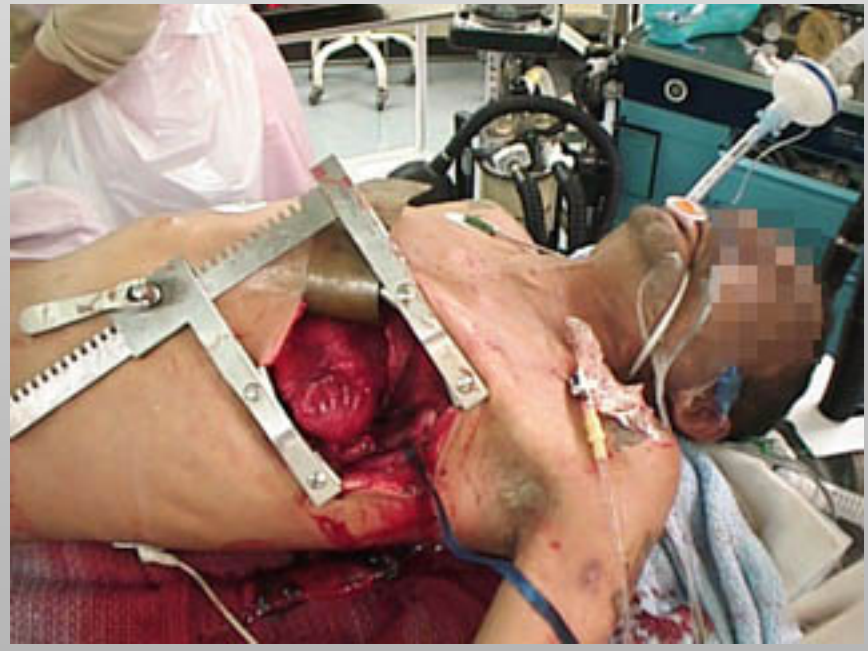
R.SRUGIS

©SUNY BROOKLYN 1992



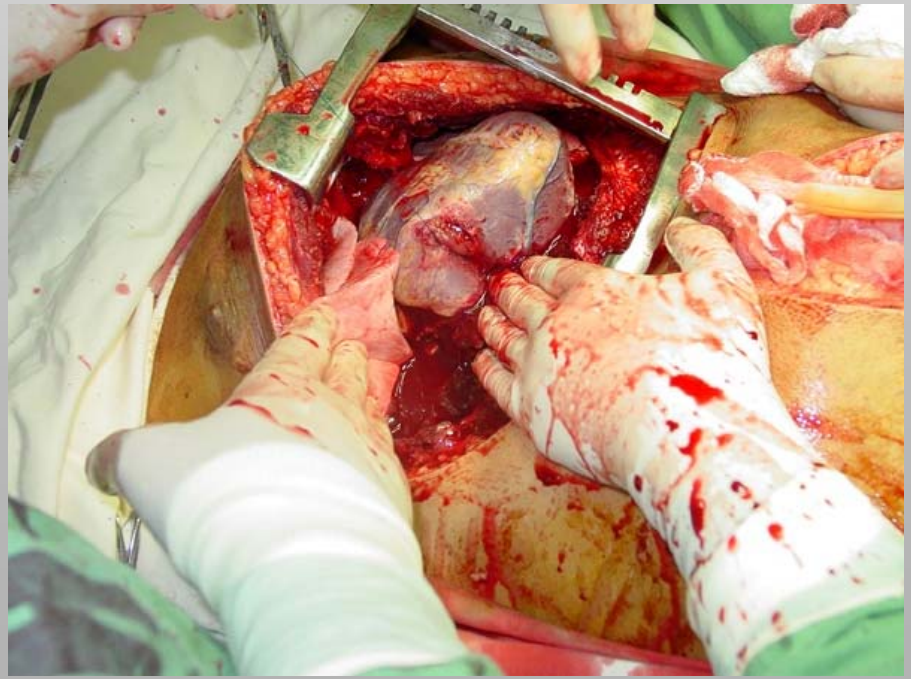
Resuscitative (ER) Thoracotomy

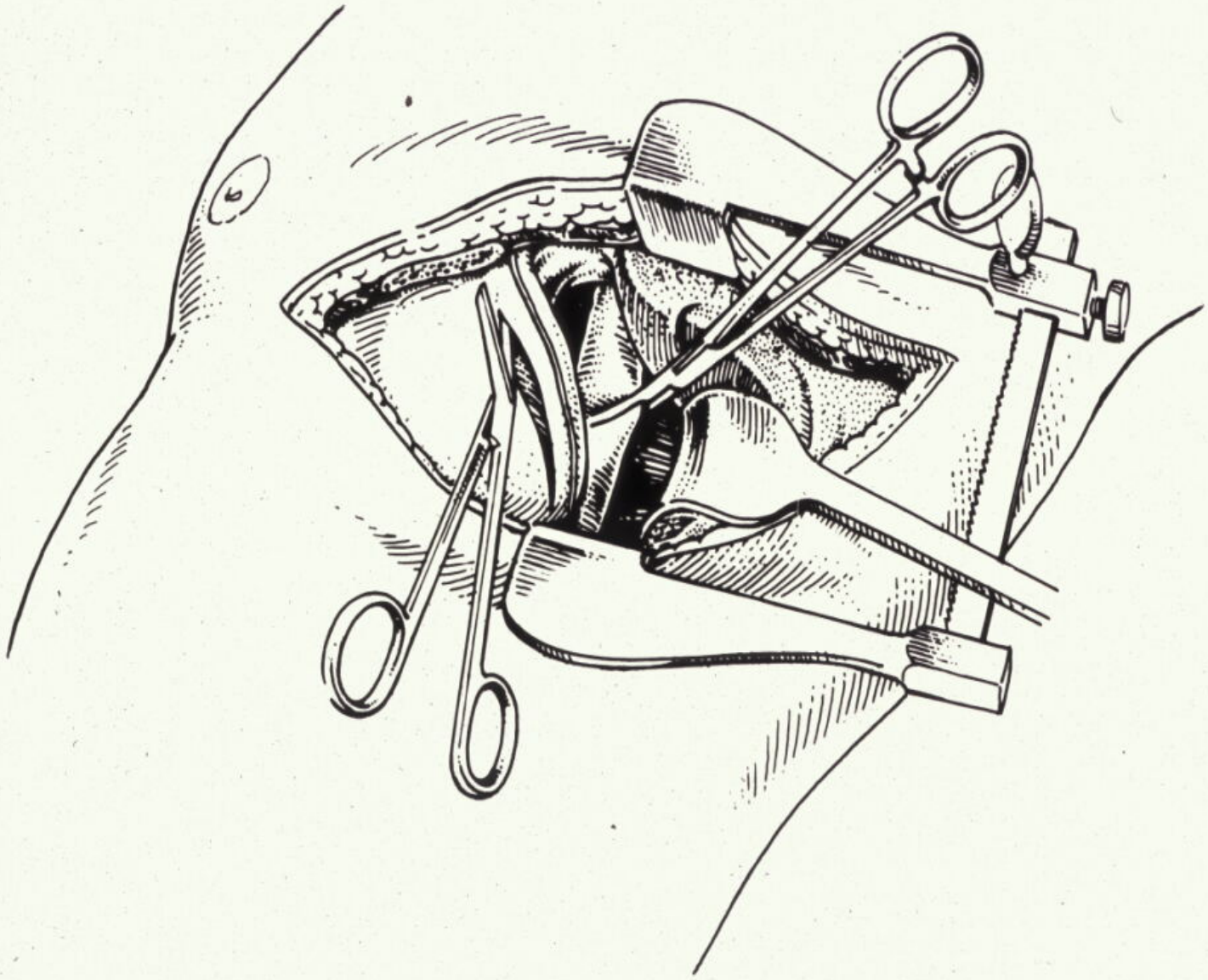


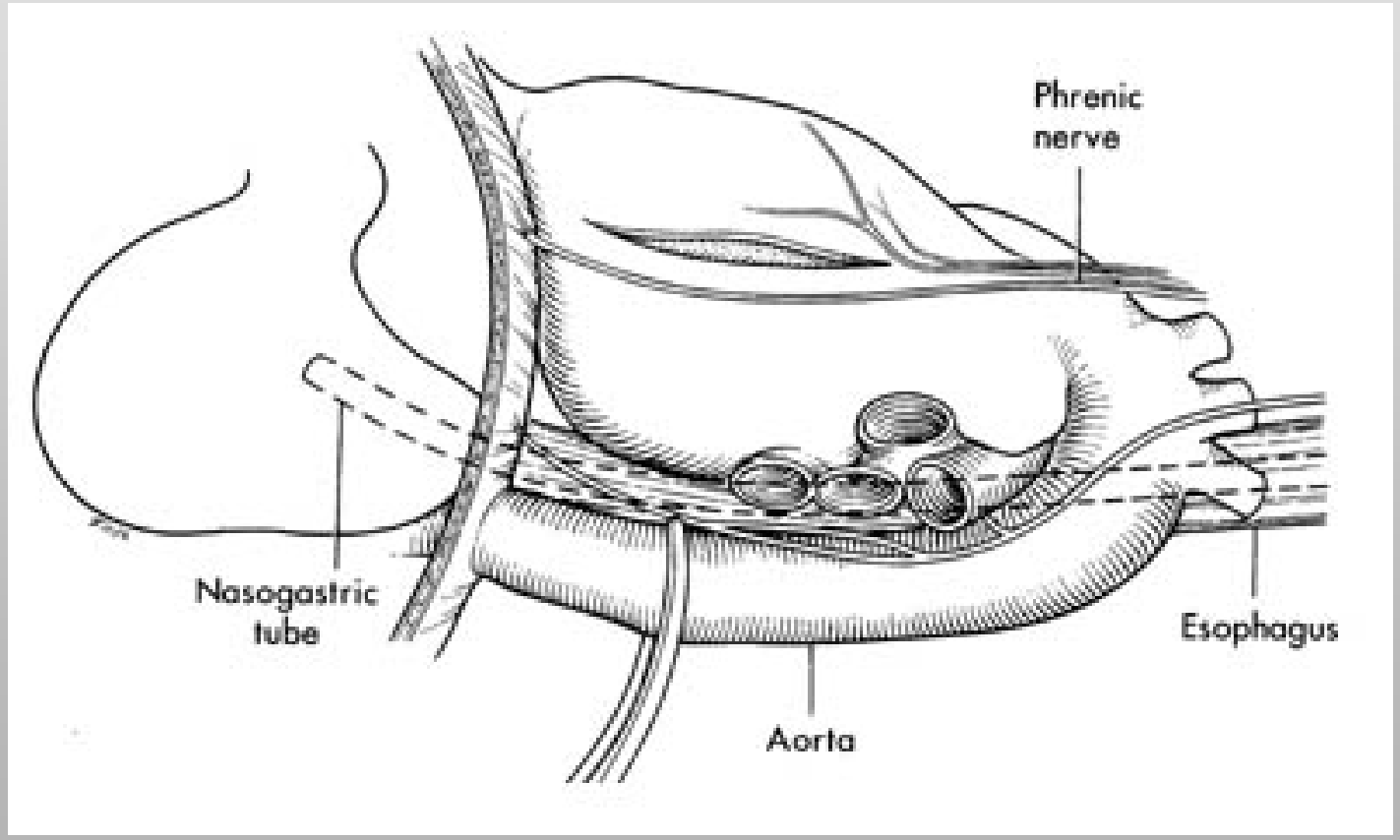


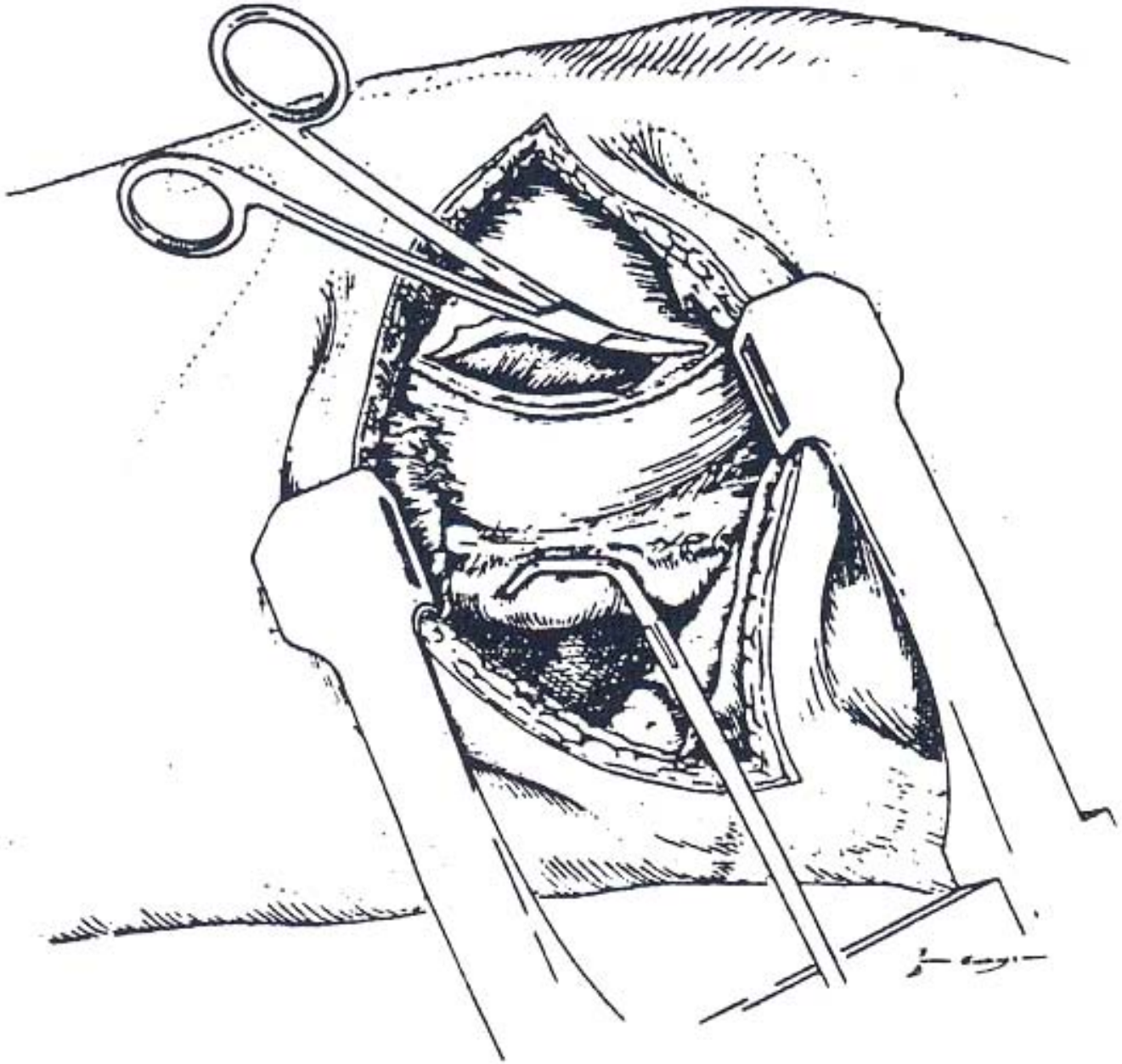
Anterio-lateral Thoracotomy

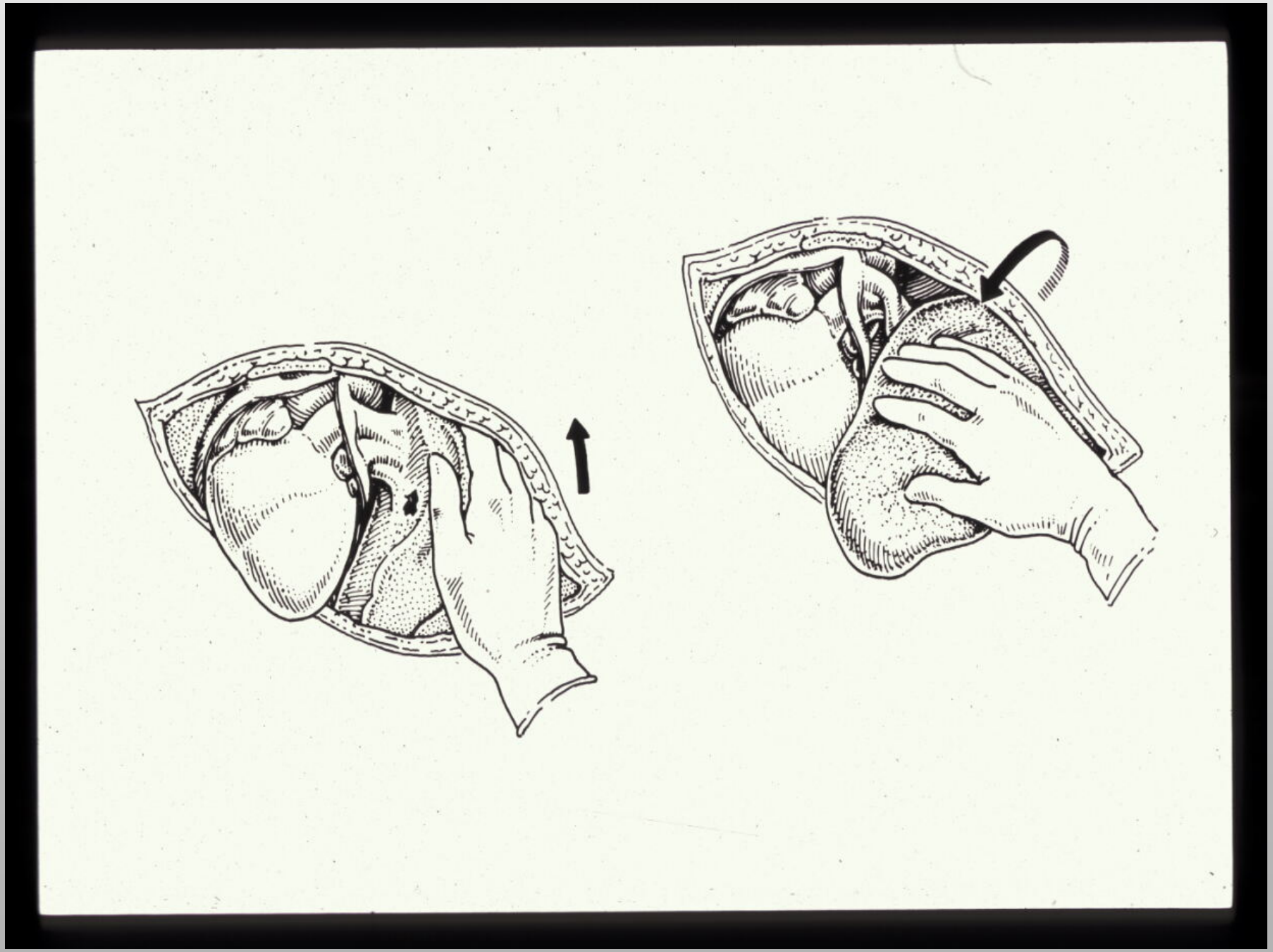
- Rapid, versatile incision
- Can expose left subclavian veins if made higher than usual
- Can be extended into clam shell or trap door

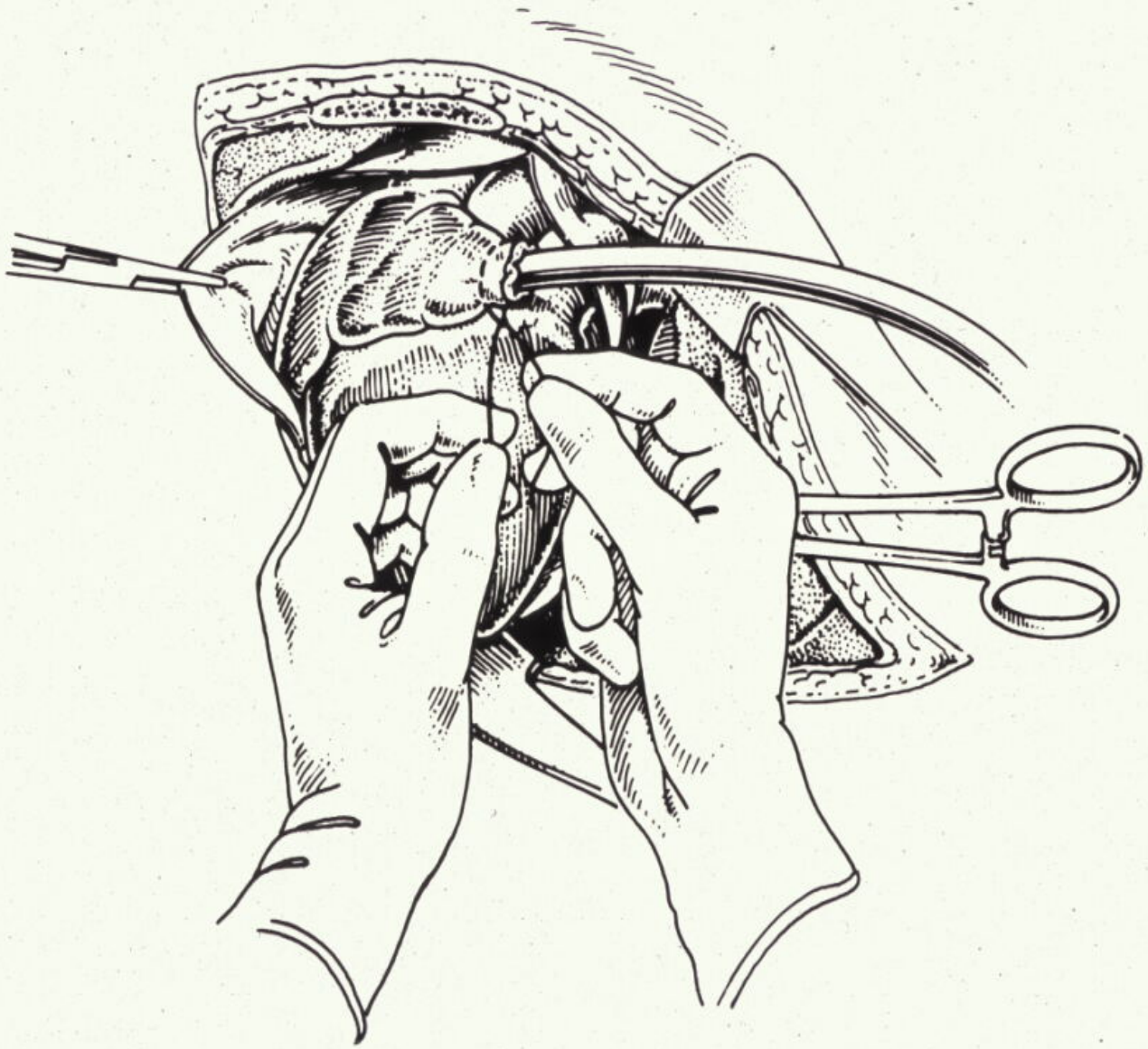


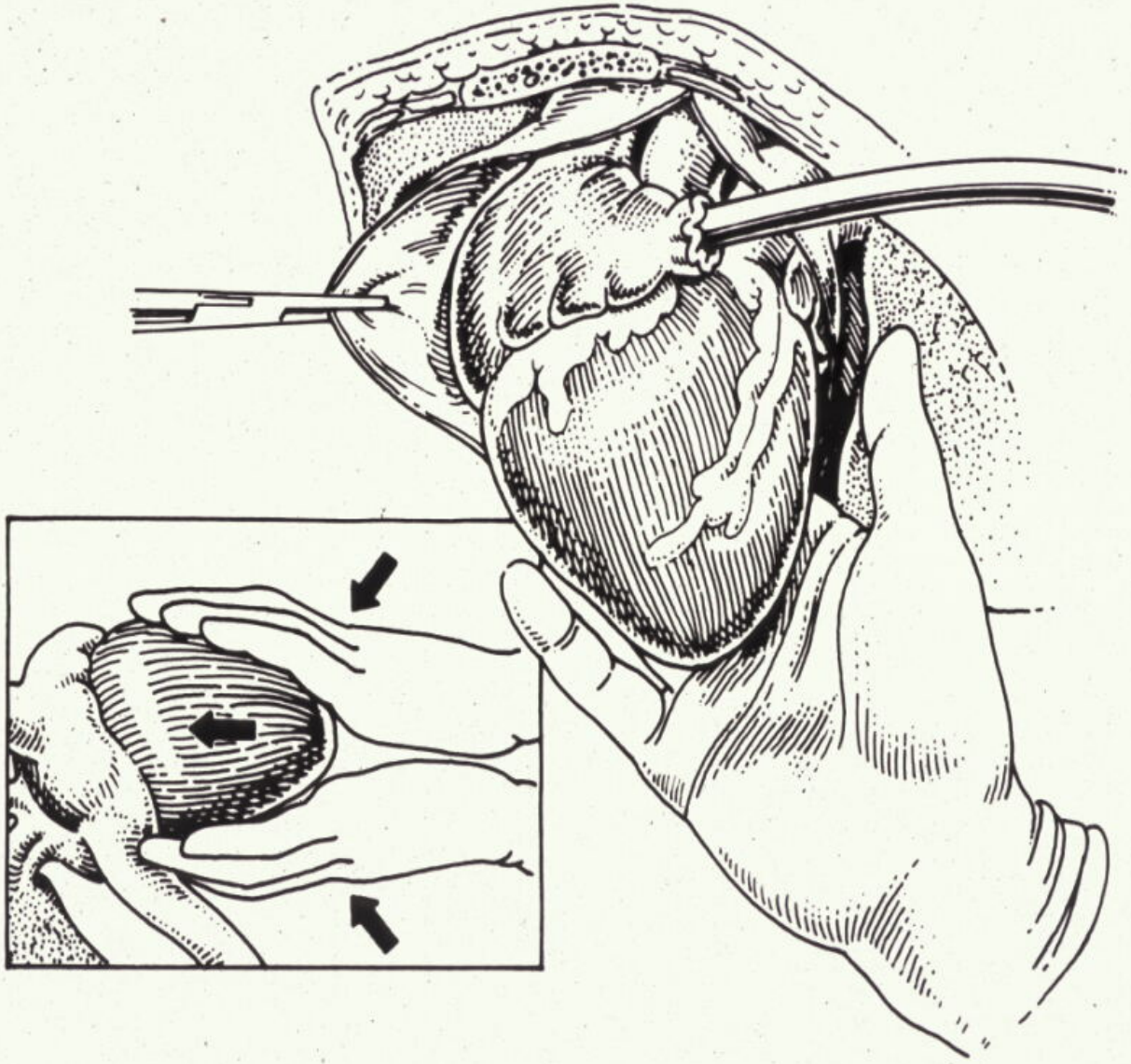


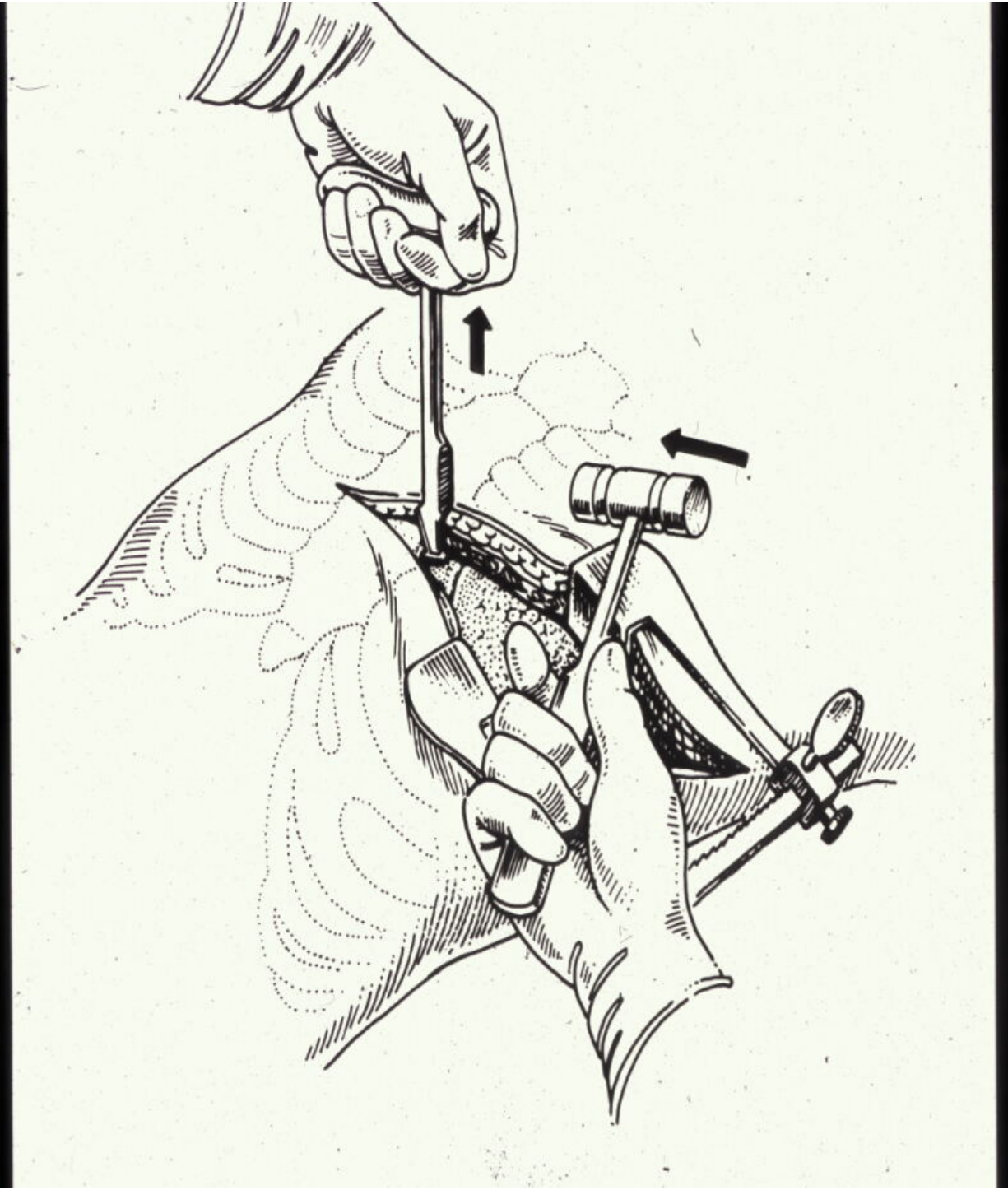

Phrenic
nerve
Nasogastric
tube
Esophagus
Aorta

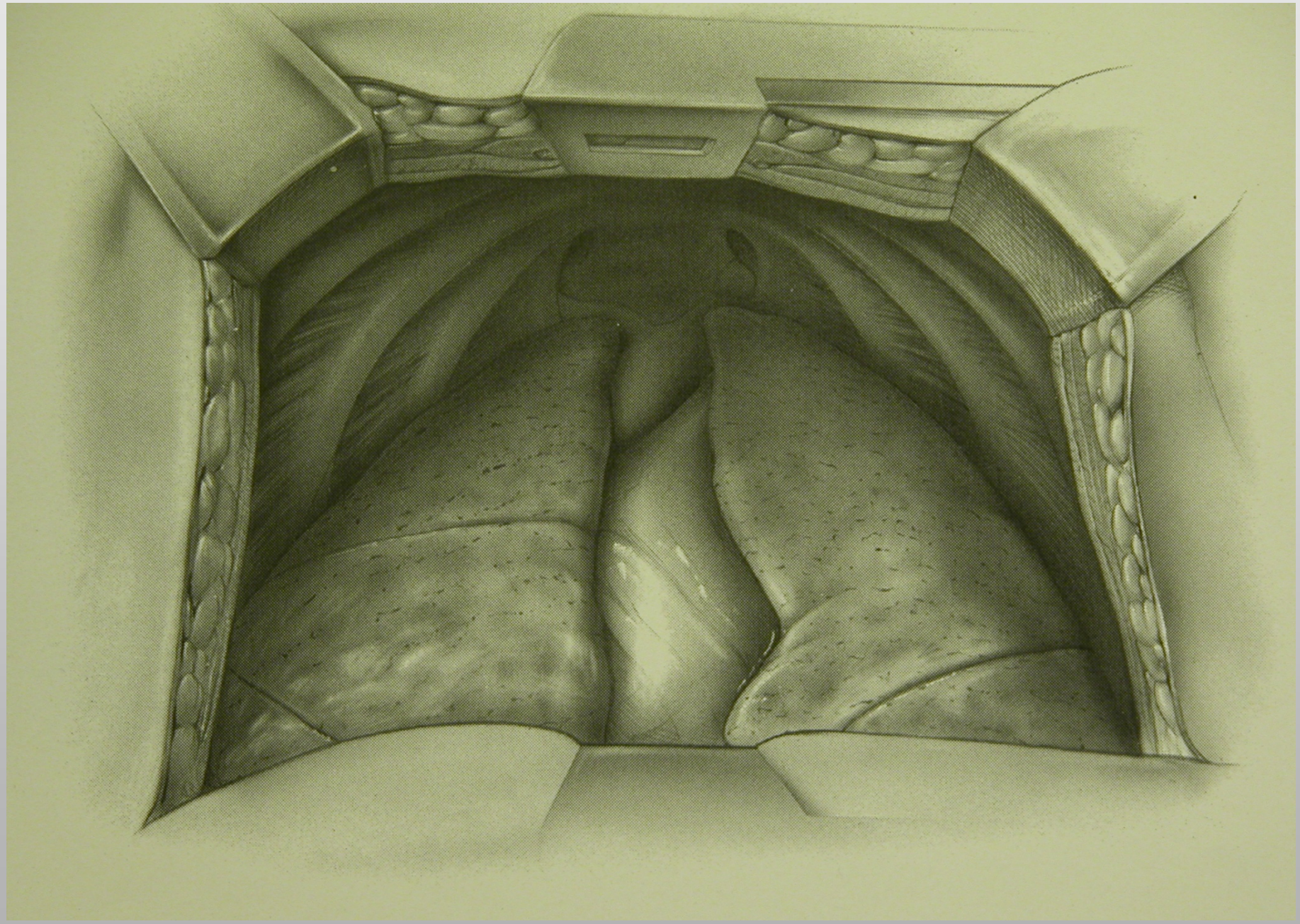


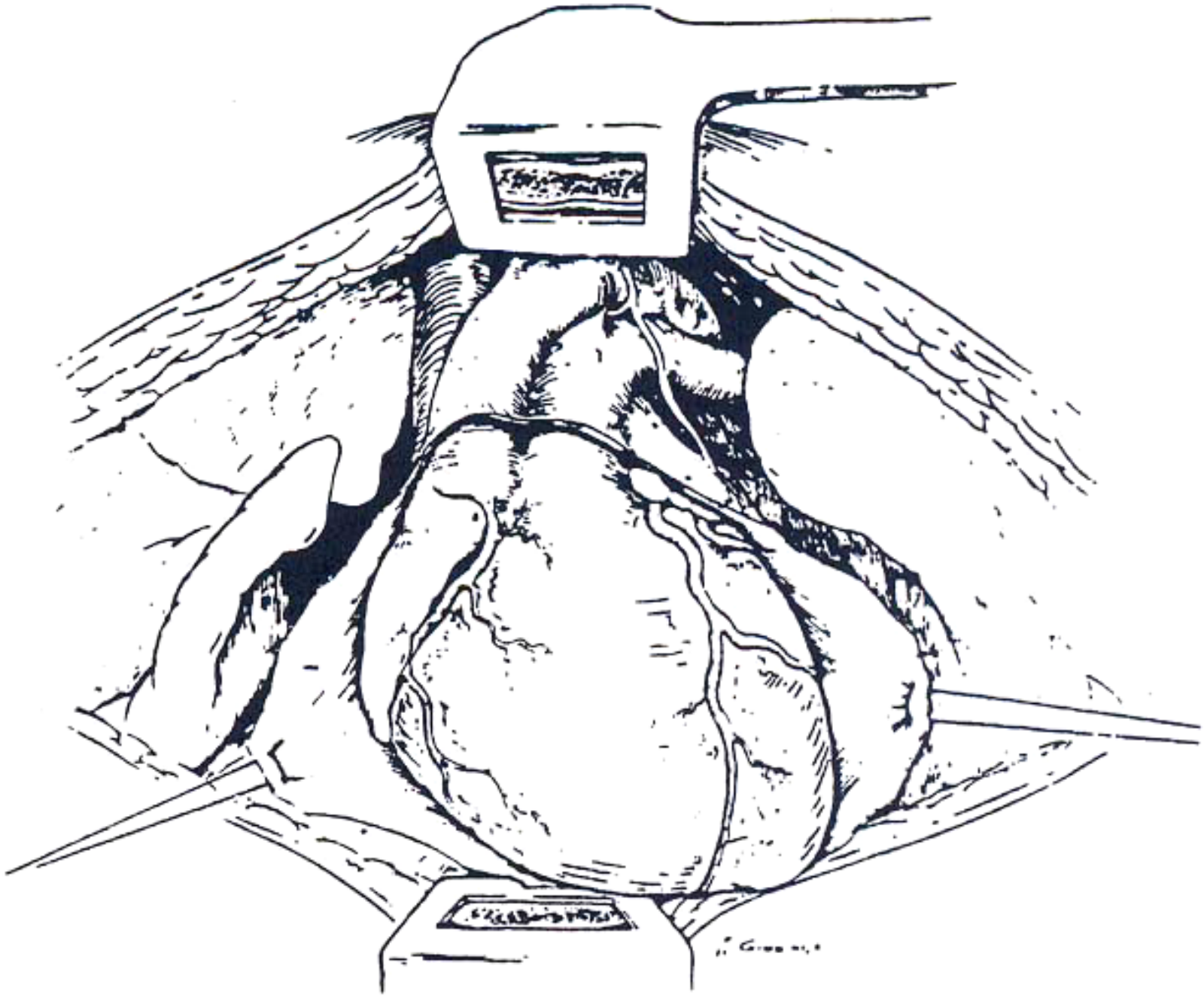










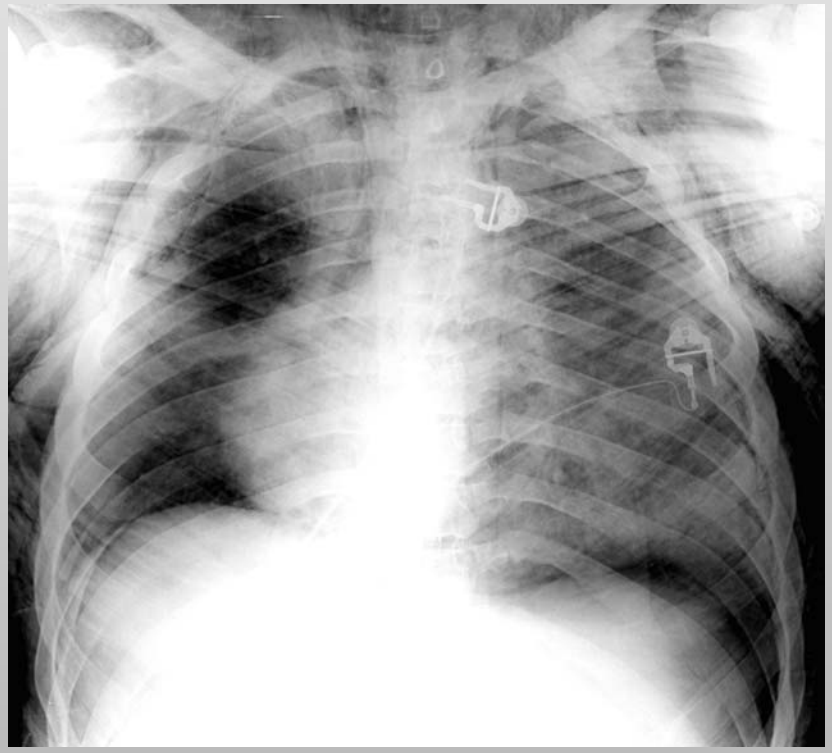


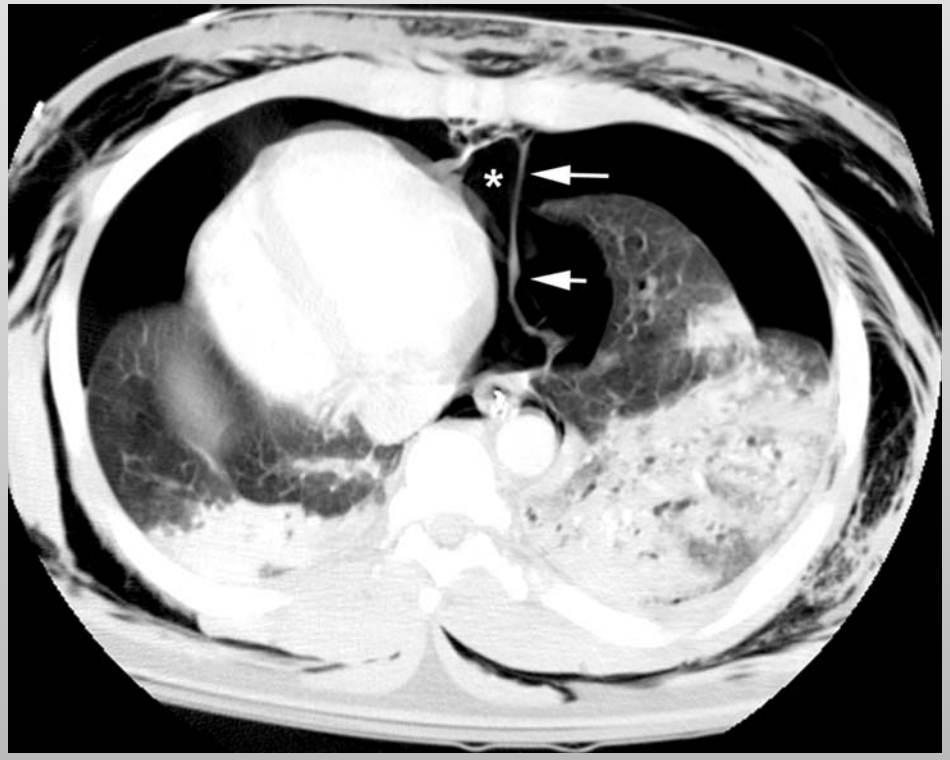
Resuscitative Thoracotomy OVERALL SURVIVAL

– Overall	0-70%
– Penetrating	9-70%
• Stab wounds	70%
• GSW	9-33%
– Blunt	0-2.5 %

Asensio JA, Berne JD, Demetriades D et al. 'One hundred five penetrating cardiac injuries: A 2-year prospective evaluation'. J Trauma 1998;44:1073-108
Karmy-Jones R, Jurkovich GJ, Nathens AB et al. 'Timing of Urgent Thoracotomy for Hemorrhage After Trauma: A Multicenter Study.' Arch Surg 2001;136:513-518
Tyburski JG, Astra L, Wilson RF et al. 'Factors affecting prognosis with penetrating wounds of the heart'. J Trauma 2000;48:587-590
Rhee PM, Acosta J, Bridgeman A et al. 'Survival after emergency department thoracotomy: review of published data from the past 25 years.' J Am Coll Surg 2000;190:288-298
Branney SW, Moore EE, Feldhaus KM et al. ' Critical analysis of two decades of experience with postinjury emergency department thoracotomy in a regional trauma center'. J Trauma 1998;45:87-95
Campbell NC, Thomson SR, Muckart DJJ.' Review of 1198 cases of penetrating cardiac trauma'. Br J Surg 1997;84:1737-1740

--25-year-old man with cardiac herniation after motorcycle accident





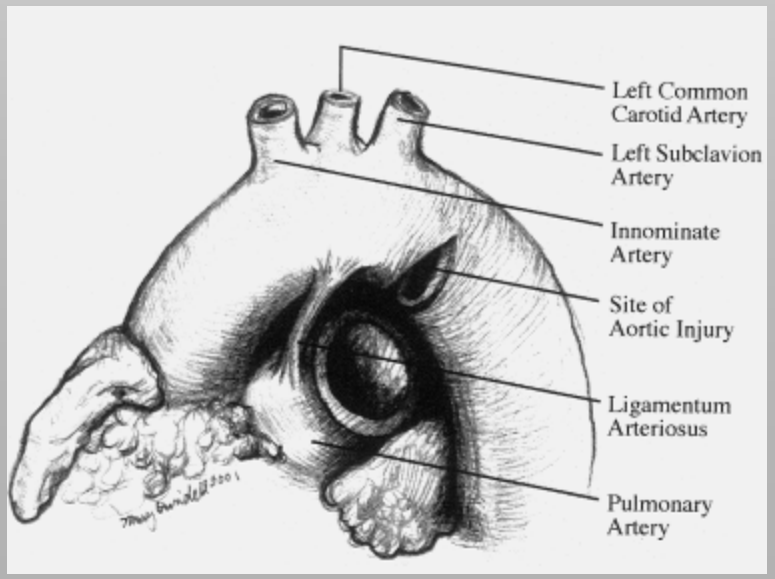
Wielenberg, A. J. et al. Am. J. Roentgenol. 2006;187:W239-W240

Specific Challenges in Thoracic Trauma

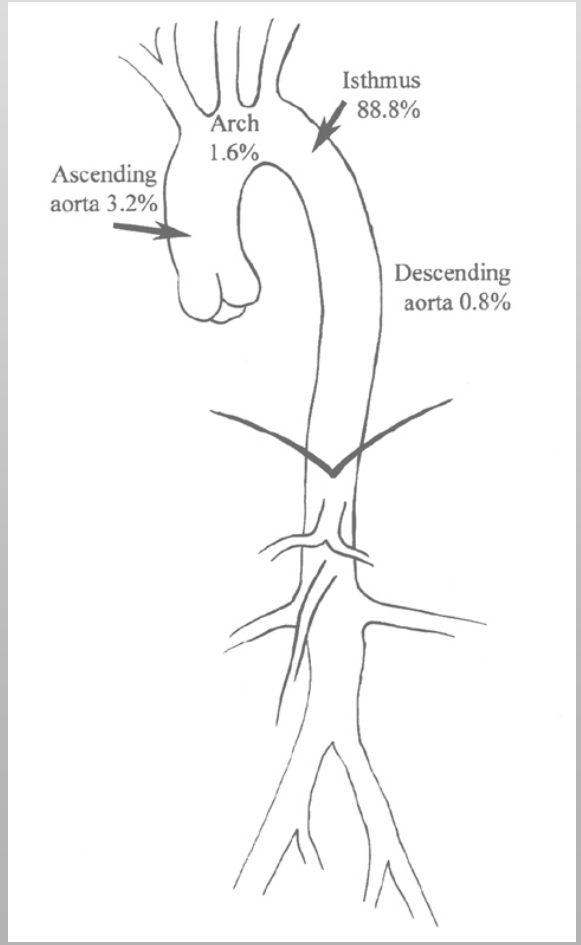
- Thoracic Aortic Injury
- Cardiac Injury

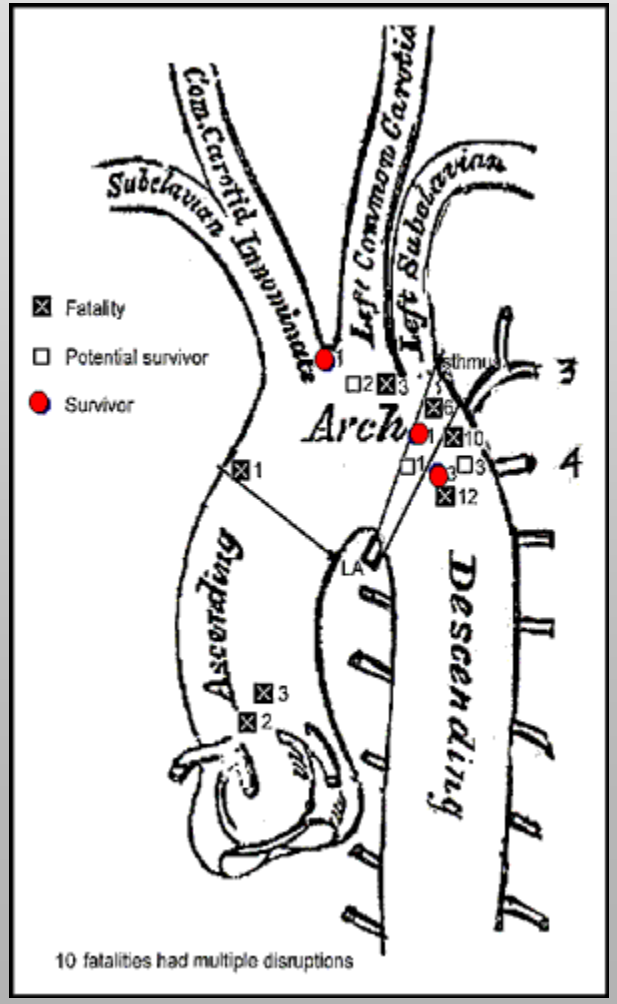
THORACIC AORTIC INJURY

- Mechanism: rapid deceleration produces shearing injury between fixed and mobile portions of the aorta.



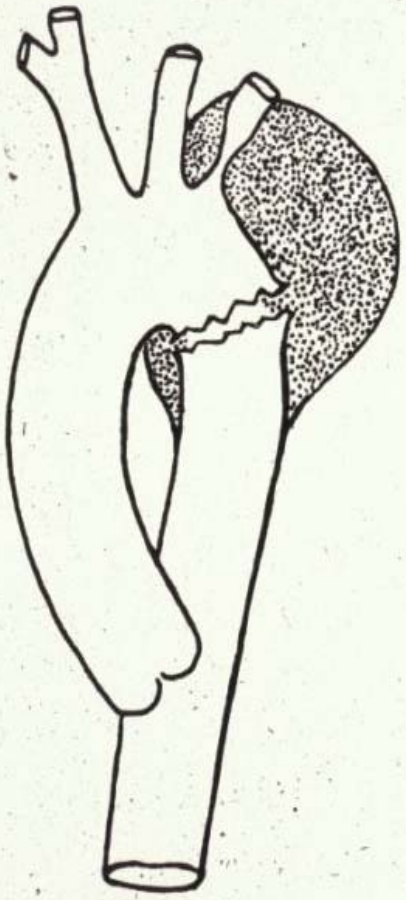
DISTRIBUTION OF AORTIC INJURIES



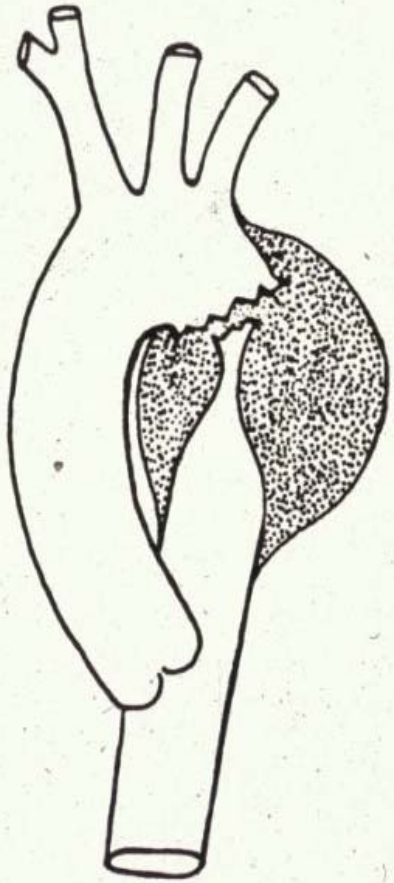


943 Effect of isthmic rupture on **peripheral arterial pressure**.

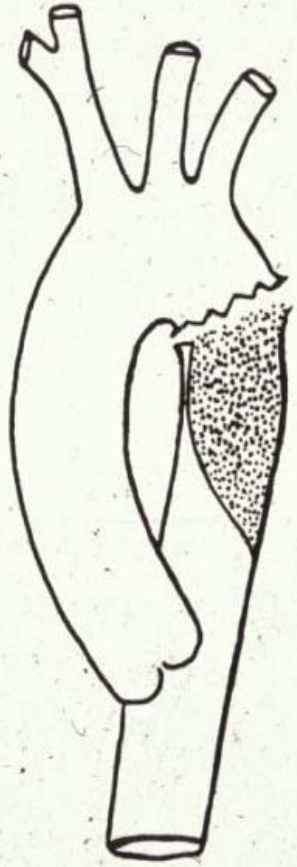
Reduced pressure in **left arm**
(N.B. *reduced pressure in right arm usually signifies avulsion of innominate artery*).



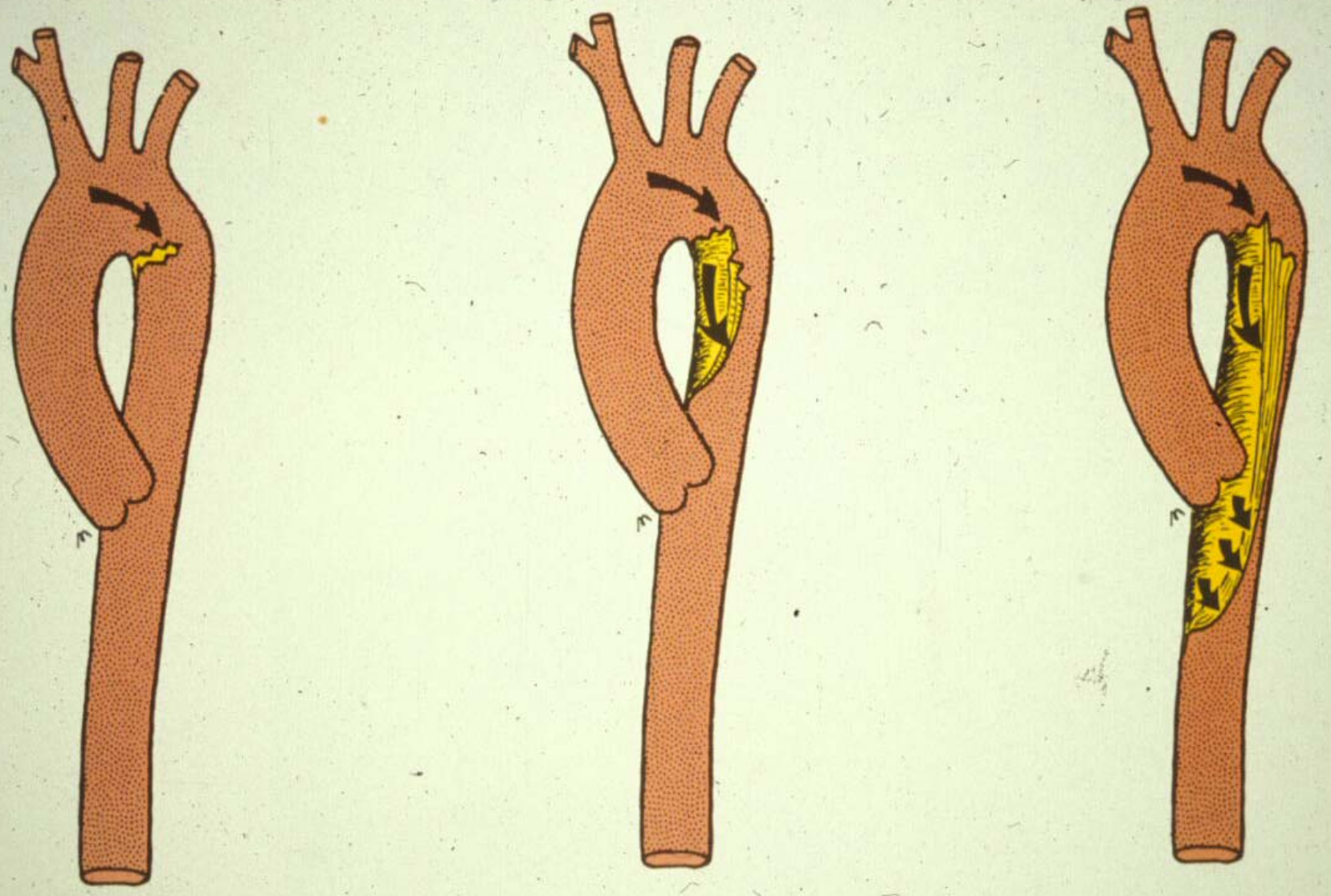
Reduced pressure in **lower limbs** (see **944**).



Pressure reduced virtually to nil in **distal aorta**
(intimal flap, see **972, 975**).



Incomplete isthmic rupture with increasingly extensive and obstructive intimal flap (**pseudo-coarctation**).



Traumatic Aortic Dissection/Rupture

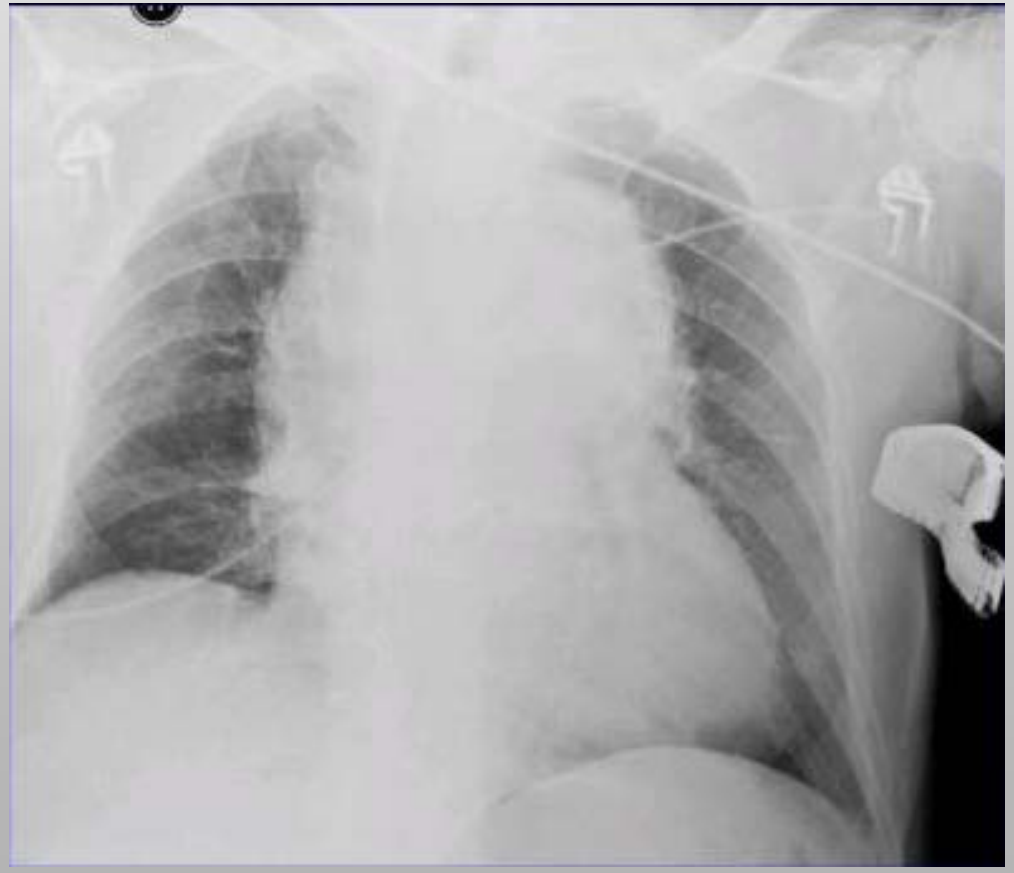
- 15% of fatal MVC victims have aortic rupture
- 85% die instantaneously
- 10-15% survive to hospital
- 21% die within six hours
- 31% die within 24 hours
- 84% die within 4 months
- Must have high index of suspicion

Parmly et al (Circulation 1958)

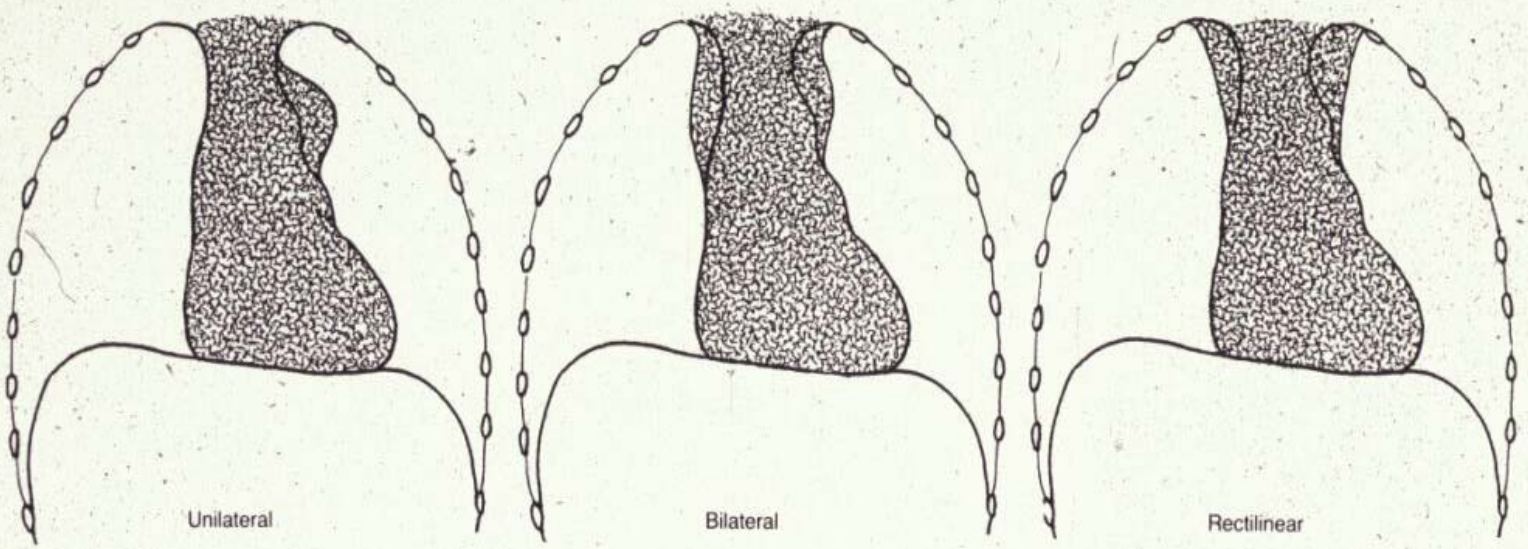
DIAGNOSIS OF BAI

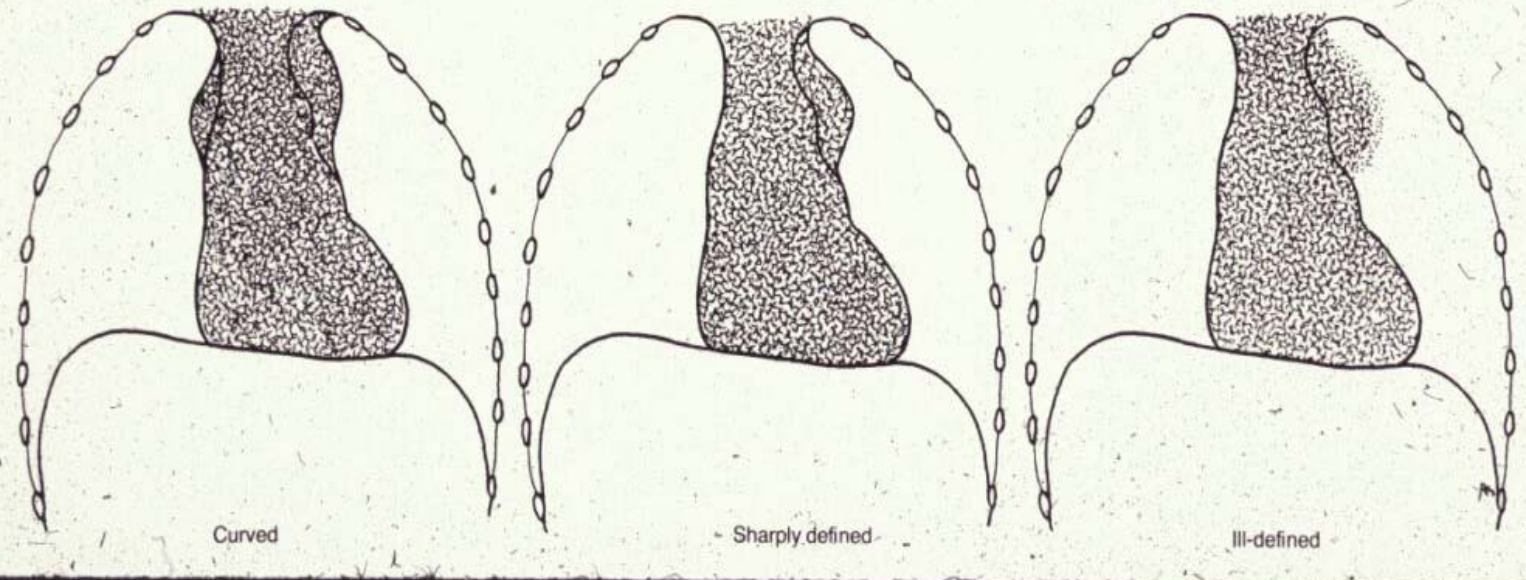
- Chest X-ray
- Aortography
- Thoracic CT SCAN
- Thoracic MRI
- Cardiac Echo (TEE)

MEDIASTINAL WIDENING



945 If it is the result of a ruptured aorta, the mediastinal widening can be:





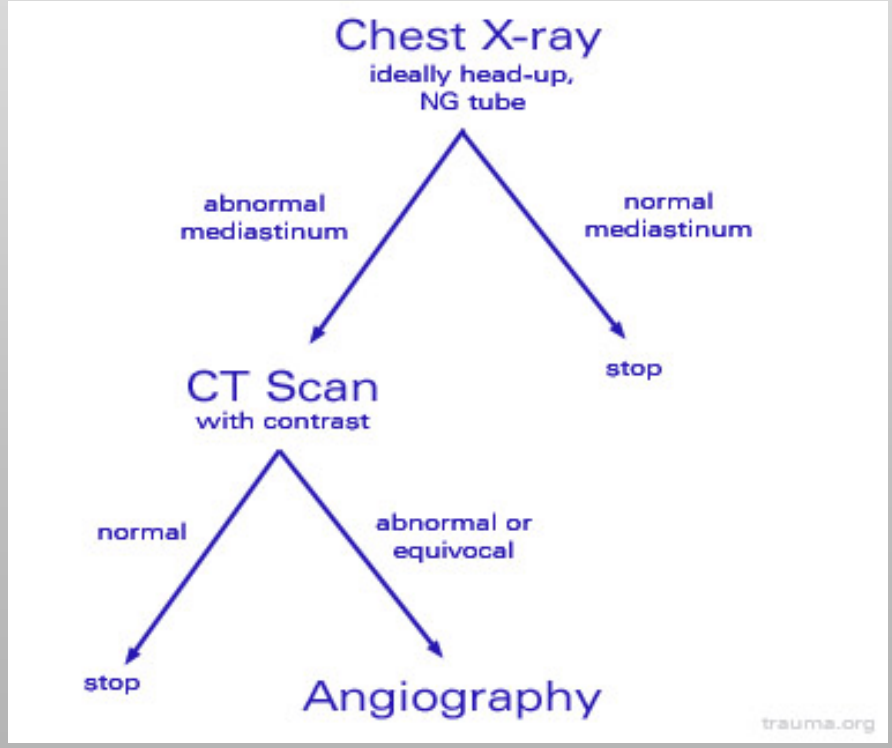
CXR FINDINGS

in 259 patients with blunt aortic injury.

Wide mediastinum	221 (85)
Indistinct aortic knob	63 (24)
Left pleural effusion	49 (19)
Apical cap	49 (19)
First and/or second rib fracture	33 (13)
Tracheal deviation	32 (12)
Depressed left bronchus	12 (5)
NG tube deviation	29 (11)
Negative x-ray	19 (7)

[a] Numbers in parentheses are percentage of x-ray films with the particular finding.

Thoracic Aortic Injury

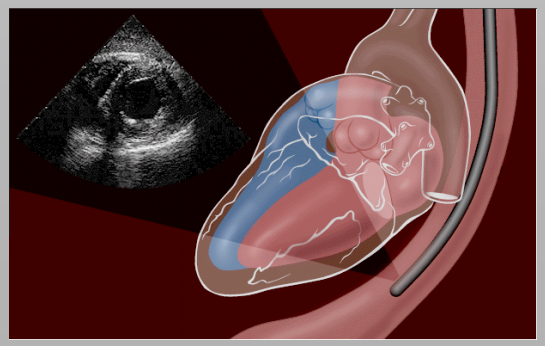


BAI: DEFINITIVE DIAGNOSIS

- Thoracic CT

- Angiography

- TEE (operator dependent)



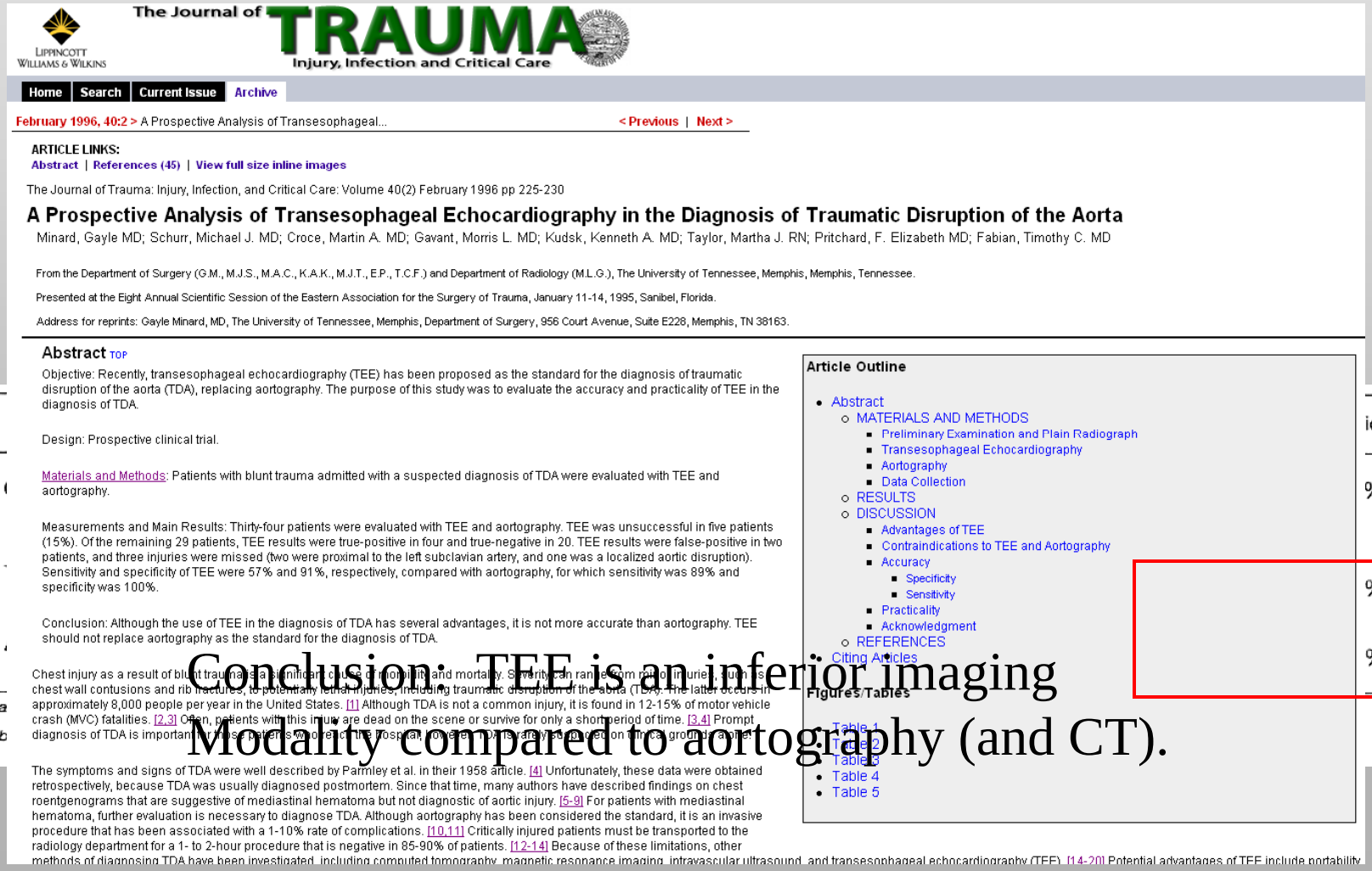
BAI: DEFINITIVE DIAGNOSIS Helical CT vs. Angiography

Conclusion: CT comparable to Aortography

	HCTT		Aortography
True positive	71		56
True negative	353		201
False positive	70		2
Indeterminate		65	
''Aortic injury''		5	
False negative	0		5
Sensivity	100%		92%
Specificity	83%		99%
Accuracy	86%		97%
Positive predictive value	50%		97%
Negative predictive value	100%		97%

HCTT = helical computed tomography of the thorax.

BAI: DEFINITIVE DIAGNOSIS
TEE vs. Angiography



The Journal of TRAUMA Injury, Infection and Critical Care

Lippincott Williams & Wilkins

Home | Search | Current Issue | Archive

February 1996, 40:2 > A Prospective Analysis of Transesophageal... < Previous | Next >

ARTICLE LINKS:
Abstract | References (45) | View full size inline images

The Journal of Trauma: Injury, Infection, and Critical Care: Volume 40(2) February 1996 pp 225-230

A Prospective Analysis of Transesophageal Echocardiography in the Diagnosis of Traumatic Disruption of the Aorta

Minard, Gayle MD; Schurr, Michael J. MD; Croce, Martin A. MD; Gavant, Morris L. MD; Kudsk, Kenneth A. MD; Taylor, Martha J. RN; Pritchard, F. Elizabeth MD; Fabian, Timothy C. MD

From the Department of Surgery (G.M., M.J.S., M.A.C., K.A.K., M.J.T., E.P., T.C.F.) and Department of Radiology (M.L.G.), The University of Tennessee, Memphis, Memphis, Tennessee.

Presented at the Eight Annual Scientific Session of the Eastern Association for the Surgery of Trauma, January 11-14, 1995, Sanibel, Florida.

Address for reprints: Gayle Minard, MD, The University of Tennessee, Memphis, Department of Surgery, 956 Court Avenue, Suite E228, Memphis, TN 38163.

Abstract TOP

Objective: Recently, transesophageal echocardiography (TEE) has been proposed as the standard for the diagnosis of traumatic disruption of the aorta (TDA), replacing aortography. The purpose of this study was to evaluate the accuracy and practicality of TEE in the diagnosis of TDA.

Design: Prospective clinical trial.

Materials and Methods: Patients with blunt trauma admitted with a suspected diagnosis of TDA were evaluated with TEE and aortography.

Measurements and Main Results: Thirty-four patients were evaluated with TEE and aortography. TEE was unsuccessful in five patients (15%). Of the remaining 29 patients, TEE results were true-positive in four and true-negative in 20. TEE results were false-positive in two patients, and three injuries were missed (two were proximal to the left subclavian artery, and one was a localized aortic disruption). Sensitivity and specificity of TEE were 57% and 91%, respectively, compared with aortography, for which sensitivity was 89% and specificity was 100%.

Conclusion: Although the use of TEE in the diagnosis of TDA has several advantages, it is not more accurate than aortography. TEE should not replace aortography as the standard for the diagnosis of TDA.

Article Outline

- Abstract
  - MATERIALS AND METHODS
    - Preliminary Examination and Plain Radiograph
    - Transesophageal Echocardiography
    - Aortography
    - Data Collection
  - RESULTS
  - DISCUSSION
    - Advantages of TEE
    - Contraindications to TEE and Aortography
    - Accuracy
      - Specificity
      - Sensitivity
    - Practicality
    - Acknowledgment
  - REFERENCES
- Citing Articles

Figures/Tables

- Table 1
- Table 2
- Table 3
- Table 4
- Table 5

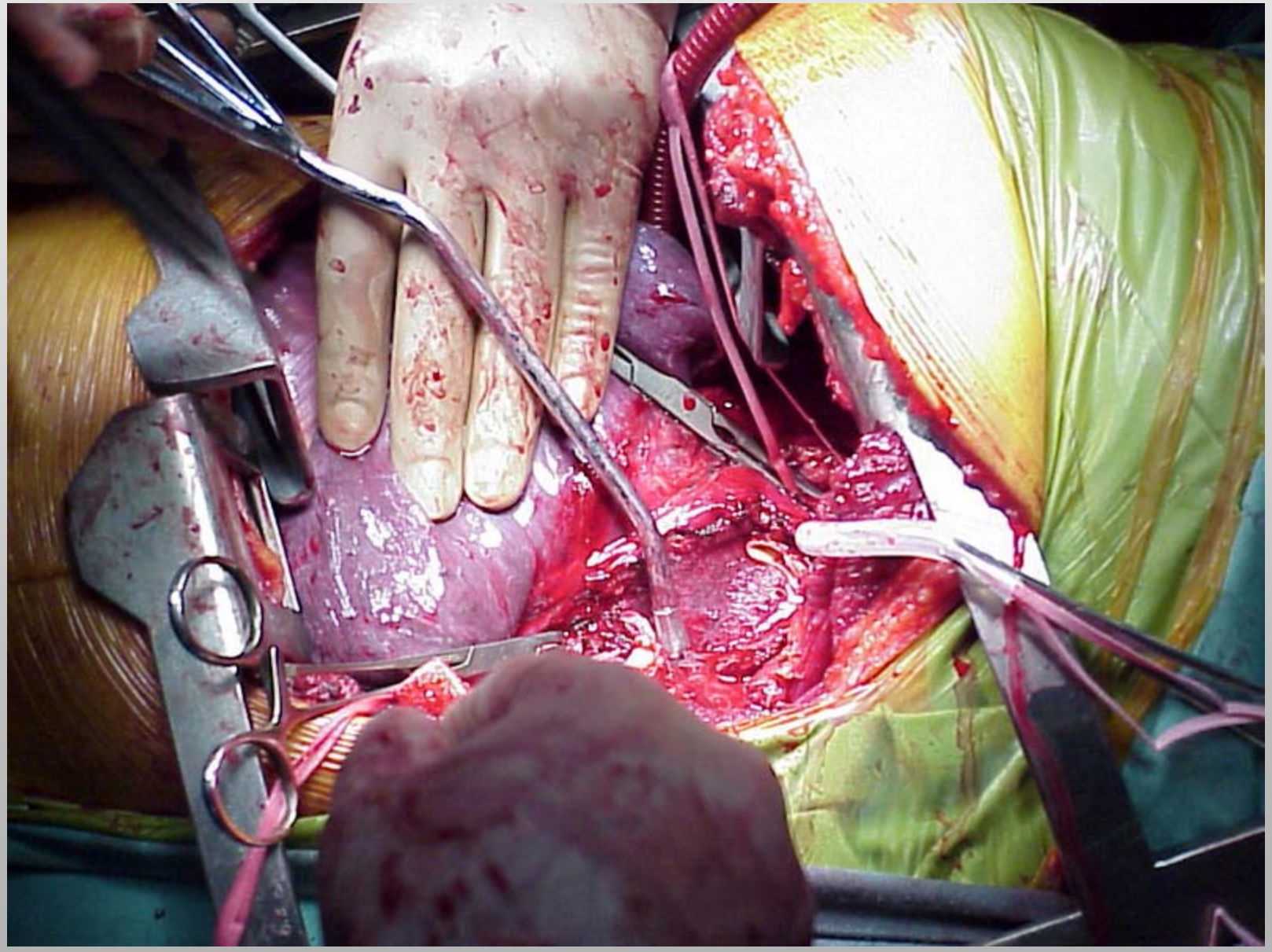
Chest injury as a result of blunt trauma is a significant cause of morbidity and mortality. Severity can range from minor injuries, such as chest wall contusions and rib fractures, to potentially lethal injuries, including traumatic disruption of the aorta (TDA). The latter occurs in approximately 8,000 people per year in the United States. [1] Although TDA is not a common injury, it is found in 12-15% of motor vehicle crash (MVC) fatalities. [2,3] Often, patients with this injury are dead on the scene or survive for only a short period of time. [3,4] Prompt diagnosis of TDA is important, as [illegible] the hospital course. Consequently, emphasis on this [illegible]

The symptoms and signs of TDA were well described by Parmley et al. in their 1958 article. [4] Unfortunately, these data were obtained retrospectively, because TDA was usually diagnosed postmortem. Since that time, many authors have described findings on chest roentgenograms that are suggestive of mediastinal hematoma but not diagnostic of aortic injury. [5-9] For patients with mediastinal hematoma, further evaluation is necessary to diagnose TDA. Although aortography has been considered the standard, it is an invasive procedure that has been associated with a 1-10% rate of complications. [10,11] Critically injured patients must be transported to the radiology department for a 1- to 2-hour procedure that is negative in 85-90% of patients. [12-14] Because of these limitations, other methods of diagnosing TDA have been investigated, including computed tomography, magnetic resonance imaging, intravascular ultrasound, and transesophageal echocardiography (TEE). [14-20] Potential advantages of TEE include portability

Conclusion: TEE is an inferior imaging Modality compared to aortography (and CT).

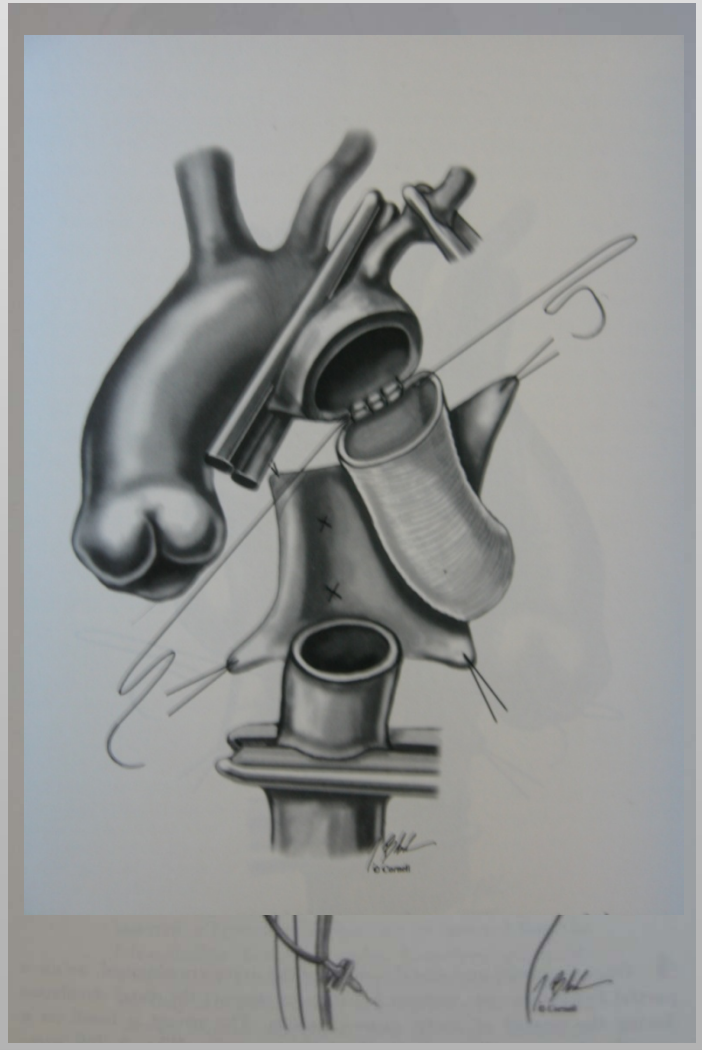
TREATMENT OPTIONS IN BAI

- Surgical therapy
  - Clamp-and-sew
  - Bypass
- Endovascular Stent Therapy



PARTIAL BYPASS

- Decrease upper body hypertension
- Perfusion to lower body (gut/kidney/liver)
- Prevent spinal cord ischemia/infarction



DATA SUPPORTING THE USE OF BYPASS FOR SURGICAL TREATMENT OF BAI

LIPPINCOTT WILLIAMS & WILKINS

The Journal of TRAUMA Injury, Infection and Critical Care

ARTICLE LINKS:
Abstract | References (28) | View thumbnail images

The Journal of Trauma: Injury, Infection, and Critical Care: Volume 42(3) March 1997 pp 374-383

Prospective Study of Blunt Aortic Injury: Multicenter Trial of the American Association for the Surgery of Trauma

Fabian, Timothy C. MD; Richardson, J. David MD; Croce, Martin A. MD; Smith, J. Stanley Jr., MD; Rodman, George Jr., MD; Kearney, Paul A. MD; Flynn, William MD; Ney, Arthur L. MD; Cone, John B. MD; Luchette, Fred A. MD; Wisner, David H. MD; Scholten, Donald J. MD; Beaver, Bonnie L. MD; Conn, Alasdair K. MD; Coscia, Robert MD; Hoyt, David B. MD; Morris, John A. Jr., MD; Harviel, J. Duncan MD; Peitzman, Andrew B. MD; Bynoe, Raymond P. MD; Diamond, Daniel L. MD; Wall, Matthew MD; Gates, Jonathan D. MD; Asensio, Juan A. MD; McCarthy, Mary C. MD; Girotti, Murray J. MD; VanWijngaarden, Mary MD; Cogbill, Thomas H. MD; Levison, Marc A. MD; Aprahamian, Charles MD; Sutton, John E. Jr., MD; Allen, C. F. MD; Hirsch, Erwin F. MD; Nagy, Kimberly MD; Bachulis, Ben L. MD; Bales, Charles R. MD; Shapiro, Marc J. MD; Metzler, Michael H. MD; Conti, Vincent R. MD; Baker, Christopher C. MD; Bannon, Michael P. MD; Ochsner, M. Gage MD; Thomason, Michael H. MD; Hiatt, Jonathan R. MD; O'Malley, Keith MD; Obeid, Farouck N. MD; Gray, Perry MD; Bankey, Paul E. MD; Knudson, M. Margaret MD; Dyess, Donna Lynn MD; Enderson, Blaine L. MD

From the University of Tennessee (T.C.F., M.A.C.), Memphis Tennessee, University of Louisville (J.D.R.), Louisville, Kentucky, The Pennsylvania State University (J.S.S.Jr.), Hershey, Pennsylvania, Methodist Hospital of Indiana, Inc. (G.R.Jr.), Indianapolis, Indiana, University of Kentucky Chandler Medical Center (P.A.K.), Lexington, Kentucky, Erie County Medical Center (W.F.), Buffalo, New York, Hennopin County Medical Center (A.L.N.), Minneapolis, Minnesota, University of Arkansas (J.B.C.), Little Rock, Arkansas, University of Cincinnati Medical Center (F.A.L.), Cincinnati, Ohio, University of California at Davis (D.H.W.), Sacramento, California, Butterworth Regional Trauma Center (D.J.S.), Grand Rapids, Michigan, Ohio State University (B.L.B.), Columbus, Ohio, Massachusetts General Hospital (A.K.C.), Boston, Massachusetts, St. John's Regional Health Center (R.C.), Springfield, Missouri, University of California (D.B.H.), San Diego, California, Vanderbilt University (J.A.M.Jr.), Nashville, Tennessee, Washington Hospital Center (J.D.H.), Washington, DC, University Medical Center (A.B.P.), Pittsburgh, Pennsylvania, University of South Carolina (R.P.B.), Columbia, South Carolina, Allegheny General Hospital (D.L.D.), Pittsburgh, Pennsylvania, Baylor College of Medicine (M.W.), Houston, Texas, Brigham and Women's Hospital (J.D.G.), Boston, Massachusetts, University of Southern California (J.A.A.), Los Angeles, California, Wright State University (M.C.M.), Dayton, Ohio, Victoria Hospital (M.J.G.), London, Ontario, University of Alberta (M.V.), Edmonton, Alberta, Gundersen Clinic, Ltd. (T.H.C.), LaCross, Wisconsin, John C. Lincoln Hospital & Health Center (M.A.L.), Phoenix, Arizona, Medical College of Wisconsin (C.A.), Milwaukee, Wisconsin, Dartmouth-Hitchcock Medical Center (J.E.S.Jr.), Lebanon, New Hampshire, Good Samaritan Regional Medical Center (C.F.A.), Phoenix, Arizona, Boston University Medical Center (E.F.H.), Boston, Massachusetts, Cook County Hospital (K.N.), Chicago, Illinois, Sparrow Hospital (B.L.B.), Lansing, Michigan, State University of New York (C.R.B.), Syracuse, New York, St. Louis University (M.J.S.), St. Louis, Missouri, University of Missouri (M.H.M.), Columbia, Missouri, University of Texas Medical Branch (V.R.C.), Galveston, Texas, University of North Carolina (C.C.B.), Chapel Hill, North Carolina, Mayo Clinic (M.P.B.), Rochester, Minnesota, Memorial Medical Center (M.G.O.), Savannah, Georgia, Carolinas Medical Center (M.H.T.), Charlotte, North Carolina, Cedars-Sinai Medical Center (J.R.H.), Los Angeles, California, UMDNJ (K.O.), Camden, New Jersey, Henry Ford Hospital (F.N.O.), Detroit, Michigan, Health Sciences Centre (P.G.), Winnipeg, Manitoba, University of Texas Southwestern Medical Center (P.E.B.), Dallas, Texas, University of California (M.M.K.), San Francisco, California, University of South Alabama (D.L.D.), Mobile, Alabama, and University of Tennessee (B.L.E.), Knoxville, Tennessee.

Presented at the 56th Annual Meeting of the American Association for the Surgery of Trauma, September 19-21, 1996, Houston, Texas.

Address for reprints: Timothy C. Fabian, MD, 956 Court Avenue, Room G210, Memphis, TN 38163.

Abstract TOP

Background: Blunt aortic injury is a major cause of death from blunt trauma. Evolution of diagnostic techniques and methods of operative repair have altered the management and posed new questions in recent years.

Methods: This study was a prospectively conducted multicenter trial involving 50 trauma centers in North America under the direction of the Multi-institutional Trial Committee of the American Association for the Surgery of Trauma.

Results: There were 274 blunt aortic injury cases studied over 2.5 years, of which 81% were caused by automobile crashes. Chest computed tomography and transesophageal echocardiography were applied in 88 and 30 cases, respectively, and were 75 and 80% diagnostic, respectively. Two hundred seven stable patients underwent planned thoracotomy and repair. Clamp and sew technique was used in 73 (35%) and bypass techniques in 134 (65%). Overall mortality was 31%, with 63% of deaths being attributable to aortic rupture; mortality was not affected by method of repair. Paraplegia occurred postoperatively in 8.7%. Logistic regression analysis demonstrated clamp and sew (p = 0.002) and aortic cross clamp time of > or = to30 minutes (p=0.01) to be associated with development of postoperative paraplegia.

Article Outline

- Abstract
  - METHODS
  - RESULTS
    - Diagnostics
    - Operative Repair and Outcome
  - DISCUSSION
  - Acknowledgments
  - PAPER DISCUSSION
  - REFERENCES
- Citing Articles

Figures/Tables

USE OF CENTRIFUGAL PUMP FOR BAI

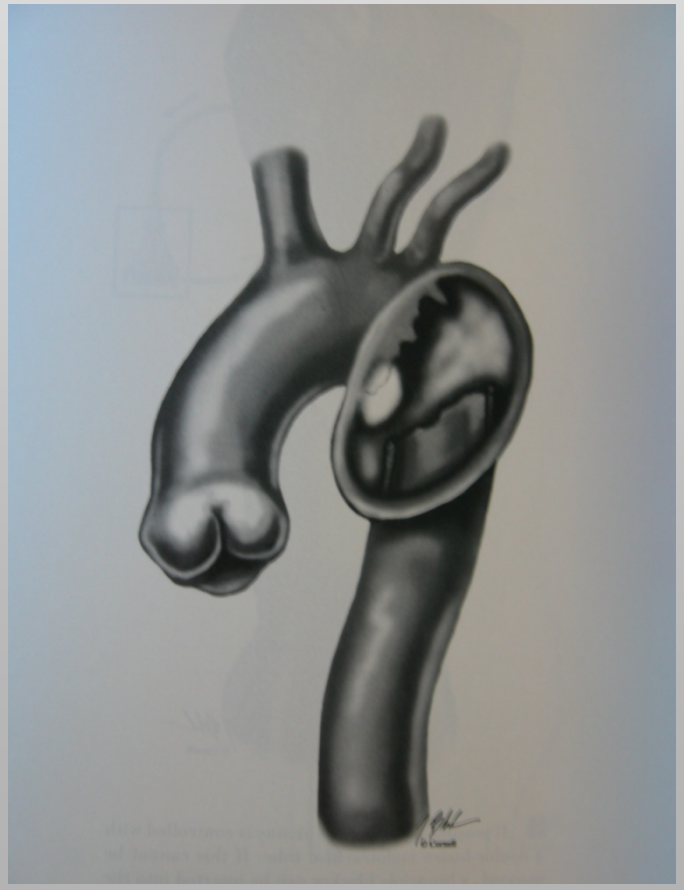
Multicenter Trial: 207 patients; 1997

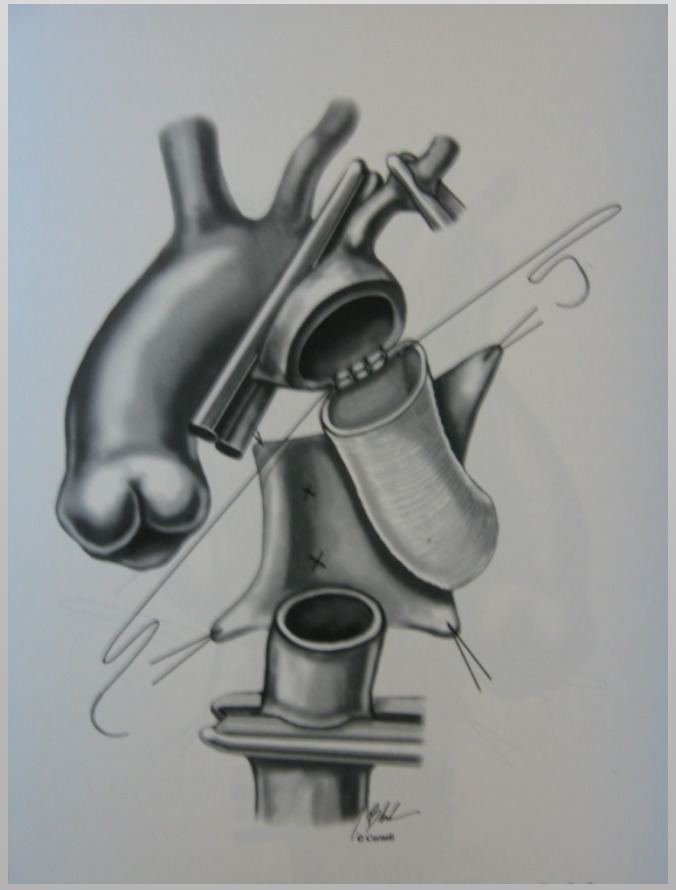
Operative Technique	n	Paraplegia (%)	Mortality (%)
Bypass	134	6 (4.5)[a]	20 (14.9)
Gott shunt	4	0	0
Full bypass	22	1 (4.5)	5 (22.7)
Partial bypass	39	3 (7.7)	5 (12.8)
Centrifugal pump	69	2 (2.9)[b]	10 (14.5)
Clamp and sew	73	12 (16.4)[a,b]	11 (15.1)

[a] $p < 0.004$ bypass versus clamp and sew.
[b] $p < 0.01$, centrifugal pump versus clamp and sew.

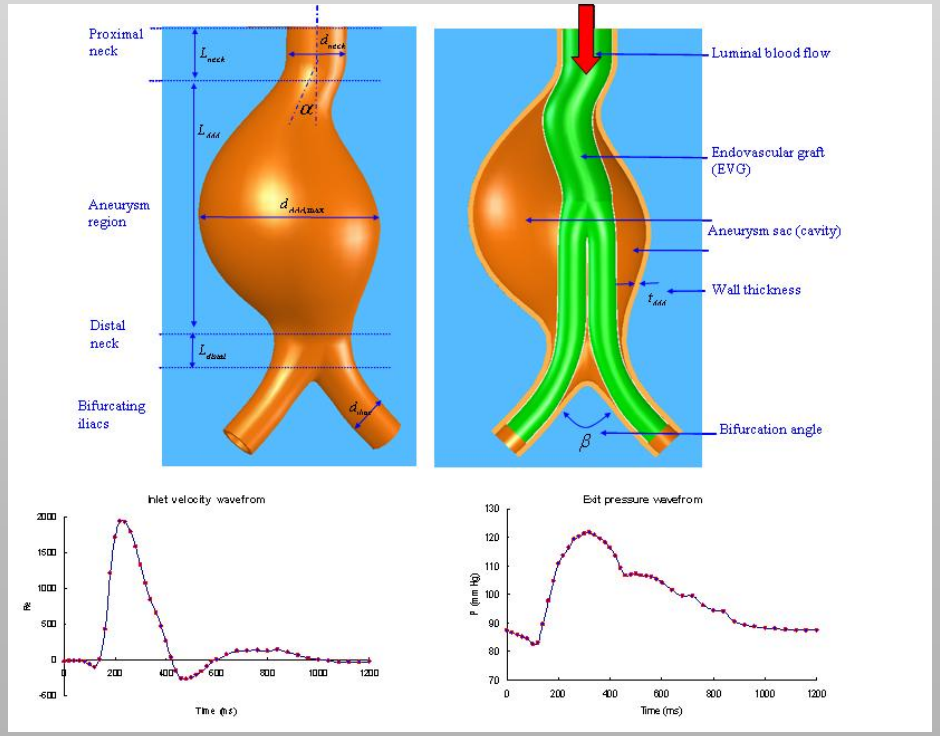
Conclusion: Bypass is associated with a decreased paraplegia rate when used in BAI → Standard of Care.

SURGICAL REPAIR OF BAI

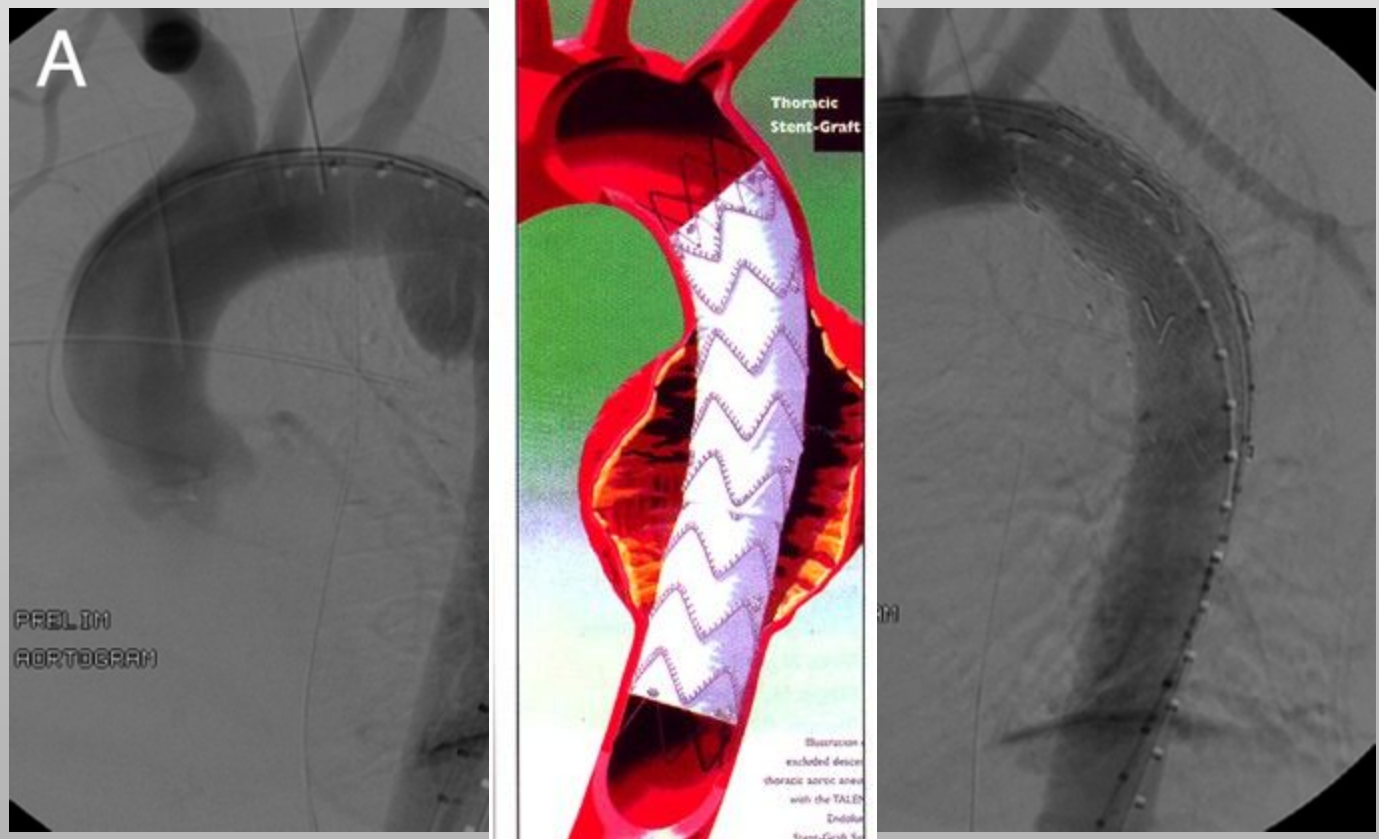




ENDOVASCULAR THERAPIES



ENDOVASCULAR STENT GRAFTS FOR ACUTE BLUNT AORTIC INJURY



Exklusion eines thorakalen Aneurysmas durch Stent graft device (TSG, Schema Medtronic AVE)

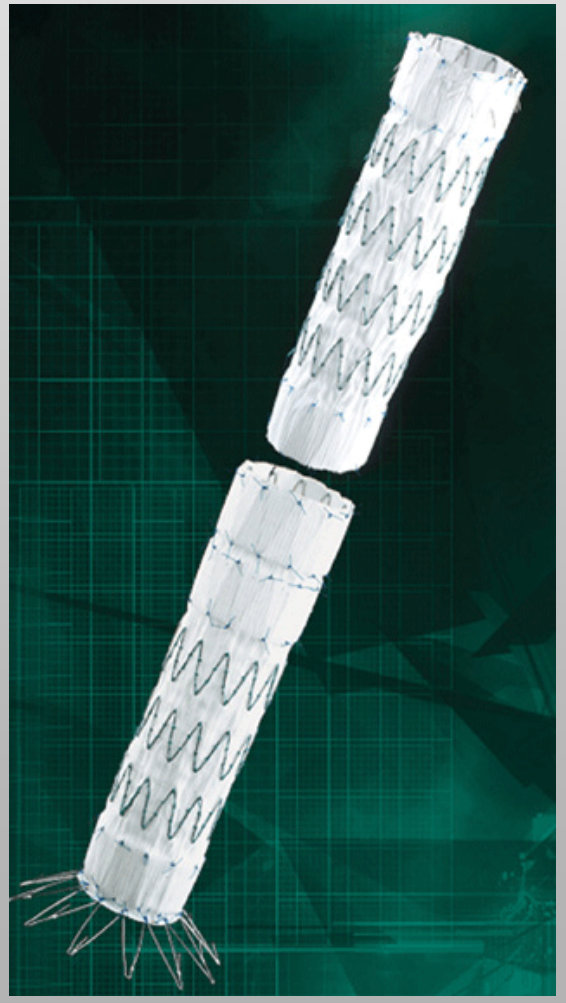
ENDOVASCULAR STENT GRAFTS FOR ACUTE BLUNT AORTIC INJURY

Where do we stand?

ENDOVASCULAR STENT GRAFTS FOR ACUTE BLUNT AORTIC INJURY

Available Devices

- GORE TAG
  - FDA approved
- Medtronic Talent™
  - FDA approved
  - VALOR Study (non-traumatic thoracic aortic aneurysms)
  - 99.5 successful deployment
  - All cause death rate: 16.1 vs. 29.8 ($p<0.01$)
- COOK Zenith® TX2
  - FDA approved
  - 2-piece modular thoracic endograft



ENDOVASCULAR STENT GRAFTS FOR ACUTE BLUNT AORTIC INJURY

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

Endovascular Stent Grafts for Acute Blunt Aortic Injury

Center	Patient	Age (yr)	Sex	ISS	Total LOS (days)	ICU LOS (days)	Mortality	F/U (mo)
CHR	1	45	M	16	4	1	No	30
	2	22	M	45	14	4	No	24
	3	25	F	45	37	23	No	10
	4	26	M	24	7	0	No	6
	5	22	F	42	27	12	No	6
	6	51	M	34	22	13	No	6
	7	43	M	57	103	1	No	5
	8	28	M	33	28	17	No	5
	9	18	F	29	12	0	No	4
	10	19	M	34	6	1	No	3
HMC	1	35	M	41	41	22	No	12
	2	27	M	58	140	120	No	12
	3	12	M	25	14	4	No	12
	4	81	F	36	5	5	Yes	n/a
	5	46	F	48	30	15	No	12
	6	39	M	24	50	10	No	3

CHR, Calgary Health Region; HMC, Harborview Medical Center; ISS, Injury Severity Score; LOS, length of stay; ICU, intensive care unit; F/U, follow-up.

10% of patients who initially survive the injury die before operative intervention.[3] Typically, these patients are young, with severe comorbid head, chest, abdominal, and orthopedic injuries. The surgical standard of care has been early operative repair with thoracotomy and graft interposition, with a mortality rate of 5% to 28%[4–7] and a cord infarction-related paraplegia risk of 9% to 19%.[3,5,8] Recent data suggest that delaying the repair to treat comorbidities in stable patients decreases morbidity and mortality without a concurrent increase in rupture risk.[9–11]

these techniques to the repair of blunt aortic injury (BAI).[4,14–19] The objective of this study was to determine the outcome of EVSG for acute BAI at two tertiary (Level I) trauma centers, the Calgary Health Region (CHR), in Calgary, Alberta, Canada, and Harborview Medical Center (HMC) in Seattle, Washington.

PATIENTS AND METHODS

A retrospective review from the CHR and HMC was

- Retrospective
- 1999-2003
- 16 patients
- Review of Literature

GRAFTS FOR
IC INJURY

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

Management of Blunt Thoracic Aortic Injuries: Endovascular Stents versus Open Repair

Michael C. Ott, MD, Tanya Charyk Stewart, MSc, D. Kirk Lawlor, MD, Daryl K. Gray, MD, and Thomas L. Forbes, MD

Background: Endovascular stent graft (EV) technology has been successfully adapted to the repair of blunt traumatic aortic injuries. The purpose of this study was to compare the outcomes of patients treated with EV repair and open repair after blu

Methods: trauma center's try identified a blunt traumati over an 11-yea erative interve then compared.

Results: Over an 11-year period, 18 patients underwent repair of a blunt thoracic aortic injury (EV, 6; open, 12). There were no significant differences in demographics, injury, or crash statistics between groups. The open group had a

morbidity, mortality, intensive care unit length of stay, and number of ventilator-dependent days was seen with EV repair.

Conclusion: We observed a clear trend toward improved outcomes after EV repair of thoracic aortic injuries com-

Table 5 Transfusion Requirements

Blood product	Stent Group (n = 6), Count	Open Group (n = 12), Count	Fisher's Exact Test *p* Value
Mean total PRBCs	2.33	7.33	0.16
Mean total PLT	0.50	5.60	0.28
Mean total FFP	1.00	6.75	0.34

PRBC, packed red blood cells; PLT, platelets; FFP, fresh frozen plasma.

Table 7 Hospital Stay

Variable	Stent Group (n = 6)	Open Group (n = 12)	*p* Value
ICU days			
Median	6.5	6.5	0.63
Range	3–28	3–85	
Ventilator days			
Median			0.14
Range	0–16	1–85	

B lunt inju lethal, w ing the h ical attention, prognosis is still poor, with a 30% mortality rate within the first 6 hours and a 40% to 50% mortality rate within the first 24 hours after injury.[3] This high mortality rate has previously prompted traditional management of BAI to emphasize rapid diagnosis and immediate primary or inter- position graft

Several ac traditional mar adaptations of comes and dec The addition c pulmonary by creased spinal mortality.[3–5] P associated inju thoracotomy, c

crease intraoperative and postoperative complications in properly monitored patients.[7,8] Despite these advances, a recent meta-analysis and systematic review have demonstrated that the risk of mortality (8–33%) and paraplegia (2–26%) remains significant[5,9] after open repair of BAI.

Table 6 Mortality and Morbidity

Variable	Stent Group (n = 6)		Open Group (n = 12)		Fisher's Exact Test *p* Value
	Count	%	Count	%	
Deaths	0	0.00	2	16.67	0.53
Paraplegia	0	0.00	2	16.67	0.53
Recur laryngeal nerve injury	0	0.00	1	8.33	1.00
Major adverse outcome (death, paraplegia, recurrent laryngeal)	0	0.00	5	41.67	0.25
Perioperative complications					
ARDS	0	0.00	1	8.33	1.00
Sepsis	0	0.00	5	41.67	0.11
MI	0	0.00	2	16.67	0.53
Tracheostomy postoperatively	1	16.67	4	33.33	1.00
Arrhythmia	2	33.33	2	16.67	0.57
PE	1	16.67	1	8.33	1.00

ARDS, acute respiratory distress syndrome; MI, myocardial infarction; PE, pulmonary embolism.

Submitted fo
Accepted for
Copyright ©
From the Tra Sciences Centre, a Canada.
Presented at t 2003, Banff, Albe
Address for Surgery, London Health Sciences Centre, 375 South Street, Room N380, London, Ontario N6A 4G5, Canada; email: tom.forbes@lhsc.on.ca.

DOI: 10.1097/01.TA.0000114061.69699.A3

reviewing these charts only, one third (n = 18) had injuries that truly required surgical repair and were included in the study. The remaining 37 patients not accounted for in the data

- Retrospective Review
- University of Western Ontario
- 2004
- 18 patients
- 6 Stent
- 12 Open

Journal of Surgical Research 138, 181–188 (2007)
doi:10.1016/j.jss.2006.09.039

Association for Academic Surgery, 2006

The Midterm Results of Stent Graft Treatment of Thoracic Aortic Injuries[1]

James T. McPhee, M.D.,[2] Emad H. Asham, M.D., Michael J. Rohrer, M.D., Michael J. Singh, M.D., Geoffrey Wong, M.D., Robert W. Vorhies, M.D., Peter R. Nelson, M.D., and Bruce S. Cutler, M.D.

Division of Vascular Surgery, University of Massachusetts Medical Center, Worcester, Massachusetts

Submitted for publication January 9, 2006

Introduction and objectives. **Several publications document the technical feasibility of stent graft repair of aortic transection. We report our mid-term results of endovascular repair of thoracic aortic transections using covered stent grafts and compare this to a cohort undergoing open repair during the same time period to demonstrate the shift in practice pattern at our institution.**

Materials and methods. **A retrospective review of patients who sustained blunt thoracic transection was undertaken. Medical records were examined to identify the clinical outcome of the procedure, and follow-up CT scans were reviewed to document adequate treatment of the transection. Outcome measures include procedure-related mortality, neurological morbidity, and successful immediate and mid-term coverage of the thoracic false aneurysm and absence of graft migration or endoleak.**

Results. **From July, 2000 to October, 2004, 27 patients were identified with descending thoracic aortic transection at our level I trauma center. Fourteen patients were managed nonoperatively, five patients underwent thoracotomy and direct aortic repair, and eight patients underwent endoluminal stent graft repair. Of the endovascular group ($n = 8$), repairs were performed with stacked AneuRx aortic cuffs (Medtronic, Inc., Minneapolis, MN) ($n = 6$), a Gore thoracic aortic stent graft (Thoracic EXCLUDER; W.L. Gore, Flagstaff, AZ) ($n = 1$), or a Medtronic Talent thoracic endograft (Medtronic, Inc.) ($n = 1$). Access for stent graft deployment was the common femoral artery ($n = 2$), iliac artery ($n = 4$), or distal abdominal aorta ($n = 2$). Completion arch aortography and postoperative CT scanning confirmed successful management of the aortic transection in each patient. There were no procedure-related deaths, paraplegia, or stroke. Postoperative complications included a brachial artery thrombosis in one patient as well as an external iliac artery dissection and acute renal failure in a second patient for a complication rate of 37.5%. Two patients died as a result of their injuries unrelated to the stent graft repair. Mean follow-up of 16.6 mo has shown no evidence of endoleak or stent graft migration. Of the open repair group ($n = 5$), one patient died in the operating room during attempted aortic repair, and one patient had a postoperative stroke.**

Conclusions. **Due to technical success and absence of delayed complications including endoleak and graft migration, stent graft repair of traumatic aortic transection has replaced open aortic repair as the primary treatment modality in the multiply injured trauma patient at our institution. The postoperative complication rate observed in this small series tempers the success to some degree, but the severity of the complications compares favorably with those observed in the open repair group.** © 2007 Elsevier Inc. All rights reserved.

Key Words: **Endovascular; Endograft; Aortic transection; Aortic injury; Stent-graft; Endoluminal.**

INTRODUCTION

Aortic transection related to rapid deceleration is a highly lethal injury with pre-hospital mortality greater than 80% [1–3]. Those individuals who survive do so because of the preserved integrity of the aortic adventitia, parietal pleura, and mediastinal structures. The traditional management of such patients has been direct surgical repair of the aortic transection with an interposition graft, which is a formidable operation with substantial associated morbidity and mortality [2].

[1] Poster presentation at the 1st Academic Surgical Congress, February 7-11, 2006, San Diego, CA.

[2] To whom correspondence and reprint requests should be addressed at Division of Vascular Surgery, University of Massachusetts Medical Center, 55 Lake Ave. North, Worcester, MA 01655. E-mail: mcphej02@ummhc.org.

- Retrospective Study
- 2006
- 27 patients
  - 14 Non-operative
  - 8 Endovascular
    - 0% prm
    - 25% mortality
    - 37% complication rate
  - 5 Thoracotomy
    - 20% prm
    - 60% mortality
- Grafts used:
  - AneuRx 8
  - Talent 1
  - Gore 1

Comparison of Endovascular and Open Repair Patients

	Endovascular patients	Thoracotomy patients	*P*
N	8	5	>0.05
Mean age (years)	30.8	40.6	>0.05
Mean ISS	46	39	>0.05
Mean OR time (minutes)	253	262	>0.05
Mean ICU LOS (days)	14	23	>0.05
Mean total LOS (days)	28.8	29.3	>0.05
Mean Blood transfusion (# units)	9.0	16.8	>0.05
Procedure-related mortality (%)	n/a	20	n/a
Paralysis (%)	n/a	n/a	n/a
Stroke (%)	n/a	20	n/a
Mean follow-up (months)	16.6	33.3	>0.05

ISS = injury severity score; LOS = length of stay.

Eur J Vasc Endovasc Surg (2008) xx, 1–6

ELSEVIER

Improved Outcomes with Endovascular Stent Grafts for Thoracic Aorta Transections

I.V. Mohan [a,b,*], K. Hitos [b], G.H. White [a], J.P. Harris [a], M.S. Stephen [a], J. May [a], J. Swinnen [b], J.P. Fletcher [b]

[a] Royal Prince Alfred Hospital, Missenden Road, Camperdown, Sydney, NSW, Australia
[b] Westmead Hospital, Hawkesbury Road, Wentworthville, Sydney, NSW, Australia

Submitted 29 August 2007; accepted 28 March 2008

KEYWORDS
Thoracic aortic transection;
Multiple trauma;
Stent-grafts

Abstract *Objective:* To retrospectively assess the outcome of endovascular stent-graft implantation for thoracic aortic transections (ETAT).
Design: Retrospective review.
Methods: 16 patients median age 30 years, treated between May 2000 and April 2007. Median injury severity score was 33 (range 29 to 66) in 14 acute patients; 2 patients had thoracic pseudoaneurysms. The Cook-Zenith endograft was used in eight patients, Medtronic-Talent (6) and Gore-Excluder (2). Average procedure time was 90 minutes, blood loss 100 (range 40 to 3000) mls, screening time 10.8 (range 5.9 to 22.6) minutes, and contrast dose was 195 (range 60 to 400) mls.
Results: Graft deployment was successful in all cases. There was one death within 30 days. The left subclavian artery was completely covered in one case, and partially in three. Two patients had Type I endoleak, and one delayed Type II endoleak. One patient had iatrogenic right coronary artery dissection. Two patients developed difficult to treat hypertension, and one acute renal failure.
Conclusion: Endovascular intervention is a safe and effective treatment for aortic transection in multiple trauma patients. ETAT reduces the major morbidity and mortality associated with open repair in multiple trauma patients. The majority of these patients are young and long-term follow up is necessary to assess graft durability.
© 2008 European Society for Vascular Surgery. Published by Elsevier Ltd. All rights reserved.

Introduction

Thoracic aortic rupture or transection (TAT) is an acute and commonly fatal, deceleration or blunt injury, associated with multiple trauma. Rupture of the thoracic aorta is the second most common cause of death from motor vehicle

* Corresponding author. Dr I.V. Mohan, MBBS, MD, FRCS, FRACS, P.O. Box 653, Westmead, Sydney, NSW 2145, Australia. Tel.: +61 2 9845 6821; fax: +61 2 9893 7440.
E-mail address: irwin.mohan@doctors.org.uk (I.V. Mohan).

1078-5884/$34 © 2008 European Society for Vascular Surgery. Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.ejvs.2008.03.012

- Retrospective Comparison
- 2008
- 30 patients
  - 14 Stented
  - 12 Open

Table 3 Complications in patients treated acutely with open surgical and endoluminal procedures

Complication	Stented group ($n = 14$)	Open Surgical group ($n = 12$)
Death	1 (7%)	2 (17%)
Paraplegia	0	1 (8%)
Endoleak	3 (21%)	—
Renal Failure	1 (7%)	1 (8%)
Acute Limb Ischaemia	0	1 (8%)
Vascular Access Injury	2 (14%)	2 (14%)
Wound Complications	0	4 (28%)
DVT/PE	0	1 (8%)

Conclusion: Endovascular therapy is safer and as effective and open repair for BAI

META-ANALYSIS

REVIEW ARTICLE

From the Southern Association for Vascular Surgery

Meta-analysis of endovascular vs open repair for traumatic descending thoracic aortic rupture

Eleftherios S. Xenos, MD, PhD, Nicholas N. Abedi, MD, Daniel L. Davenport, PhD, David J. Minion, MD, Omar Hamdallah, MD, Ehab E. Sorial, MD, and Eric D. Endean, MD, *Lexington, Ky*

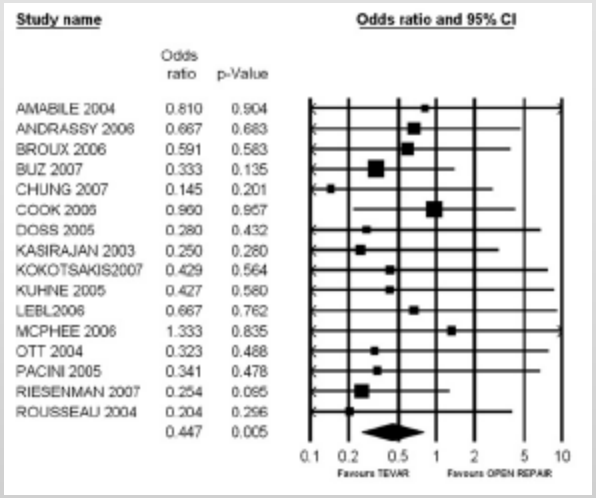
Objectives: Traumatic thoracic aortic injuries are associated with high mortality and morbidity. These patients often have multiple injuries, and delayed aortic repair is frequently used. Endoluminal grafts offer an alternative to open surgical repair. We performed a meta-analysis of comparative studies evaluating endovascular vs open repair of these injuries.
Methods: A systematic search of studies reporting treatment of traumatic aortic injury was performed using the following databases: Medline/PubMed, CINAHL, Proquest, Up to Date, Database of Abstracts of Reviews of Effects (DARE), ClinicalTrials.gov, the Cochrane Central Register of Controlled Trials and the Cochrane Database of Systematic Reviews. Search terms were thoracic aortic trauma, traumatic thoracic aortic injury, traumatic aortic rupture, stent graft repair, and endovascular repair. Outcomes analyzed were procedure-related mortality, overall 30-day mortality, and paraplegia/paraparesis rate using odds ratios (OR) and 95% confidence intervals (CI). Publication bias was investigated using funnel plots. Assessment of homogeneity was performed using the Q test; statistical heterogeneity was considered present at $P < .05$. Weighted averages of age, interval to repair, and injury severity score were compared with the Welch t test; $P < .05$ was considered statistically significant.
Results: Seventeen retrospective cohort studies from 2003 to 2007 were included. All were nonrandomized; no prospective randomized trials were found. These studies reported on 589 patients; 369 were treated with open repair, and 220 underwent thoracic stent graft placement. There was no significant difference in age (mean 38.8 years for both) or interval to repair (mean 1.5 days for endoluminal repair; 1 day for open repair). Injury severity score was higher for patients undergoing endoluminal repair (mean, 42.4 vs 37.4 for open repair, $P < .001$). Procedure-related mortality was significantly lower with endoluminal repair (OR, 0.31; 95% CI, 0.15-0.66; $P = .002$). Overall 30-day mortality was also lower after endoluminal repair (OR, 0.44; 95% CI, 0.25-0.78; $P = .005$). Sixteen studies reported data for postoperative paraplegia; 215 patients were treated with endograft placement and 333 with open repair. The risk of postoperative paraplegia was significantly less with endoluminal repair (OR, 0.32; 95% CI, 0.1-0.93; $P = .037$). The Q test did not indicate significant heterogeneity for the outcomes of interest; publication bias was limited.
Conclusions: Meta-analysis of retrospective cohort studies indicates that endovascular treatment of descending thoracic aortic trauma is an alternative to open repair and is associated with lower postoperative mortality and ischemic spinal cord complication rates. (J Vasc Surg 2008;48:1343-51.)

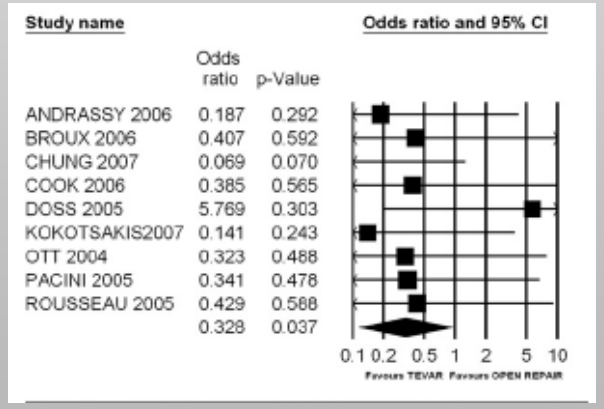
Blunt rupture of the thoracic aorta is devastating, and most patients die at the time of injury.[1] In order of frequency, rupture occurs at the aortic isthmus, the ascending aorta, the aortic arch, the distal descending aorta, and the abdominal aorta.[2,3] The force from rapid deceleration necessary to tear the aorta often leads to other organ injuries. Pate et al[4] found that associated injuries were present in >90% of patients with aortic transection, and 24% of them required a major operation before aortic repair. More than 85% of motor vehicle occupants who sustain a thoracic aortic laceration exsanguinate at the scene.[5-7]

From the Department of Surgery, University of Kentucky.
Competition of interest: none.
Presented at the Thirty-second Annual Meeting of the Southern Association for Vascular Surgery, Naples, Fla, Jan 16-19, 2007.
Reprint requests: Eleftherios S. Xenos, MD, PhD, Assistant Professor of Surgery, University of Kentucky, 800 Rose St, Lexington, KY 40536-0293 (e-mail: esxeno2@email.uky.edu).
0741-5214/$34.00
Copyright © 2008 by The Society for Vascular Surgery.
doi:10.1016/j.jvs.2008.04.060

Traditional treatment of blunt traumatic aortic rupture has been early open surgical repair with graft interposition,[8-10] β-Blockers control the blood pressure and modify the left ventricle systolic ejection dynamics, allowing stabilization of other injuries and delayed repair.[4] Despite reported success in delaying repair, patients remain at risk of rupture. Owing to associated injuries such as pulmonary contusion, solid organ injury, and head injury, open repair with anticoagulation is associated with a significant mortality risk ranging from 24% to 42%.[11] Because of these considerations, interest in less invasive, less traumatic methods of repair has developed.

Dake et al[12] in 1994 reported preliminary results indicating that endovascular stent graft repair is safe in highly selected patients with descending thoracic aortic aneurysms, and Semba et al[13] in 1997 demonstrated that stent graft repair is technically feasible in acute rupture of the descending thoracic aorta. Results of several other clinical studies[14-17] have shown successful emergency repair of acute thoracic aortic disease by endovascular stent grafting.

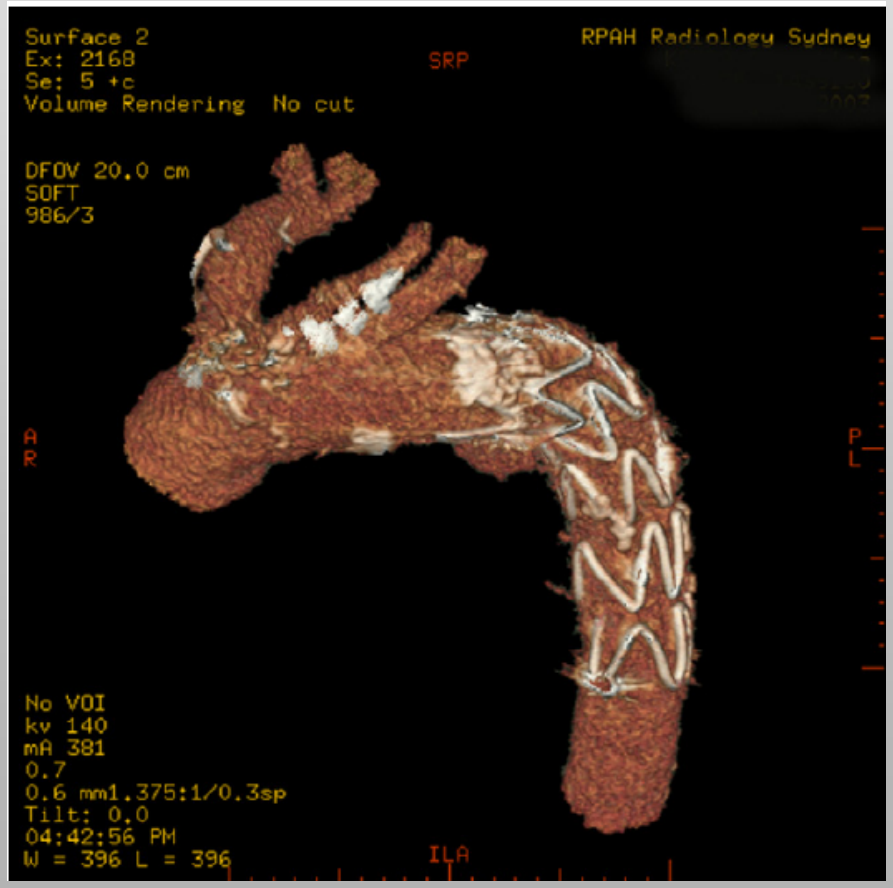




- Tx
- LOS
- Paraplegia
- Mortality

ENDOVASCULAR STENT GRAFTS FOR ACUTE BLUNT AORTIC INJURY

- Evolving Technology
- No Level I data
- No Clinical Equipoise
- The Gold Standard within the next 2-5 years
- Standard of Care



OPERATIVE REPAIR OF THE INJURED HEART

Technique

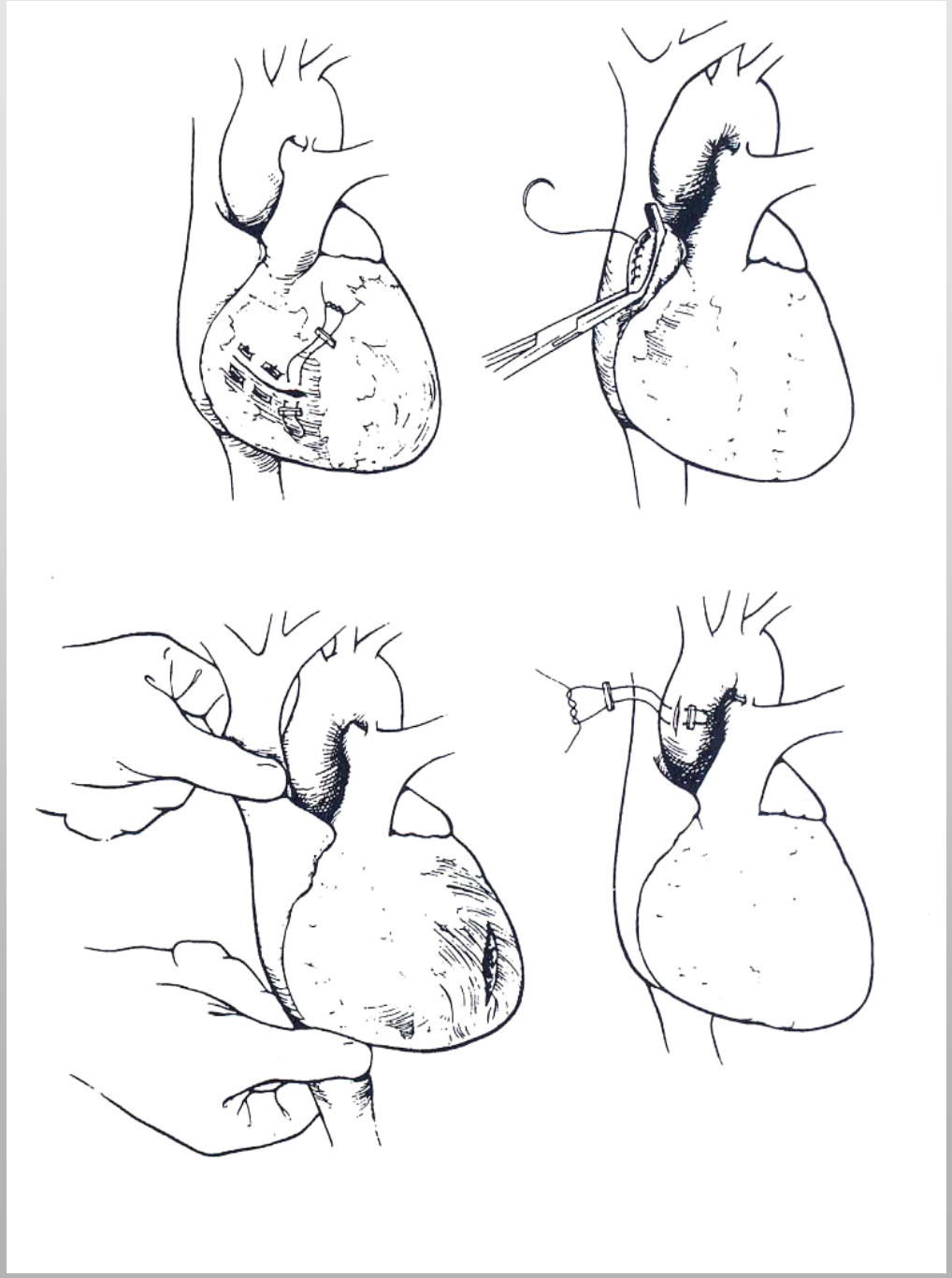
LOCATION OF CARDIAC INJURY FROM PENETRATING TRAUMA

- Frequency of injury dependents on the location of penetration.
- 20 year study with 711 cardiac injuries
  - Right Ventricle- 40%
  - Left Ventricle- 40%
  - Right Atrium 24%
  - Left Atrium- 3%
  - Coronary arteries- 5%

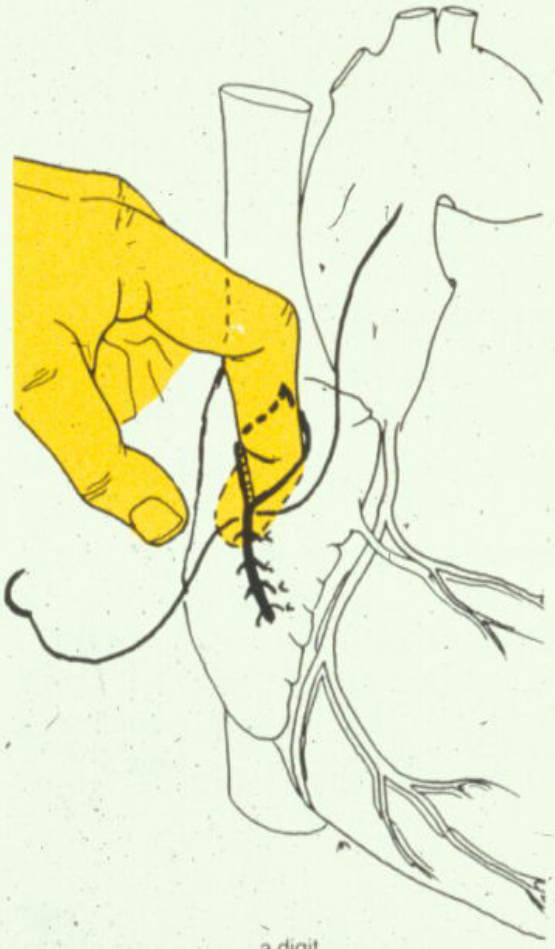
Wall et al., J Trauma 42:905,1997

Maneuvers to control bleeding:

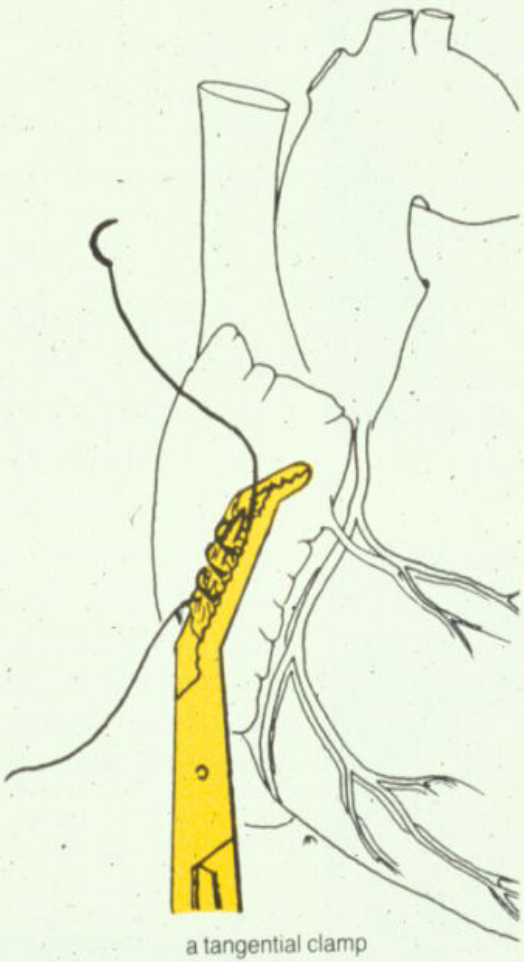
MANUAL COMPRESSION



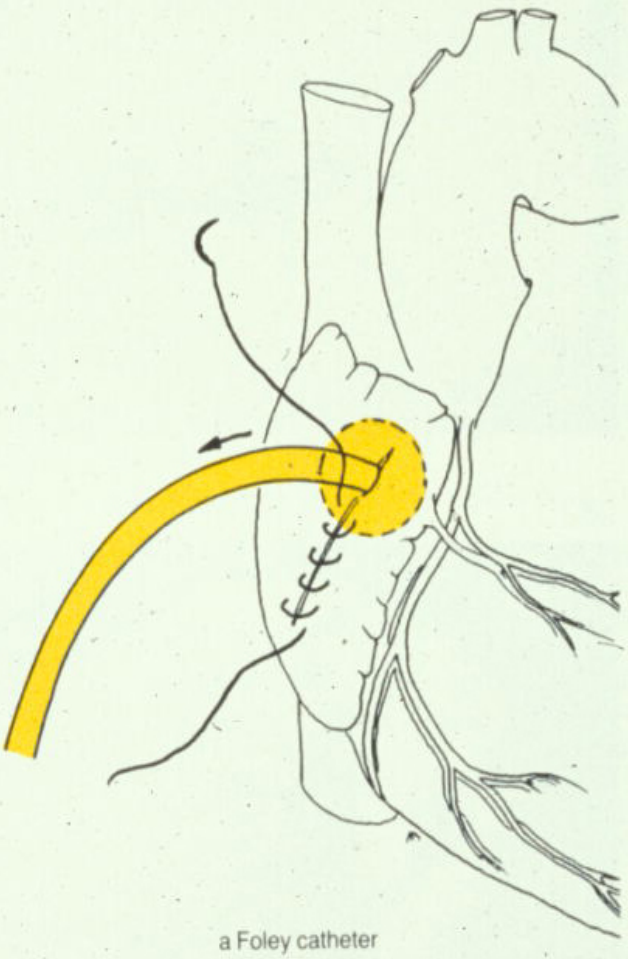
Haemostasis by means of:



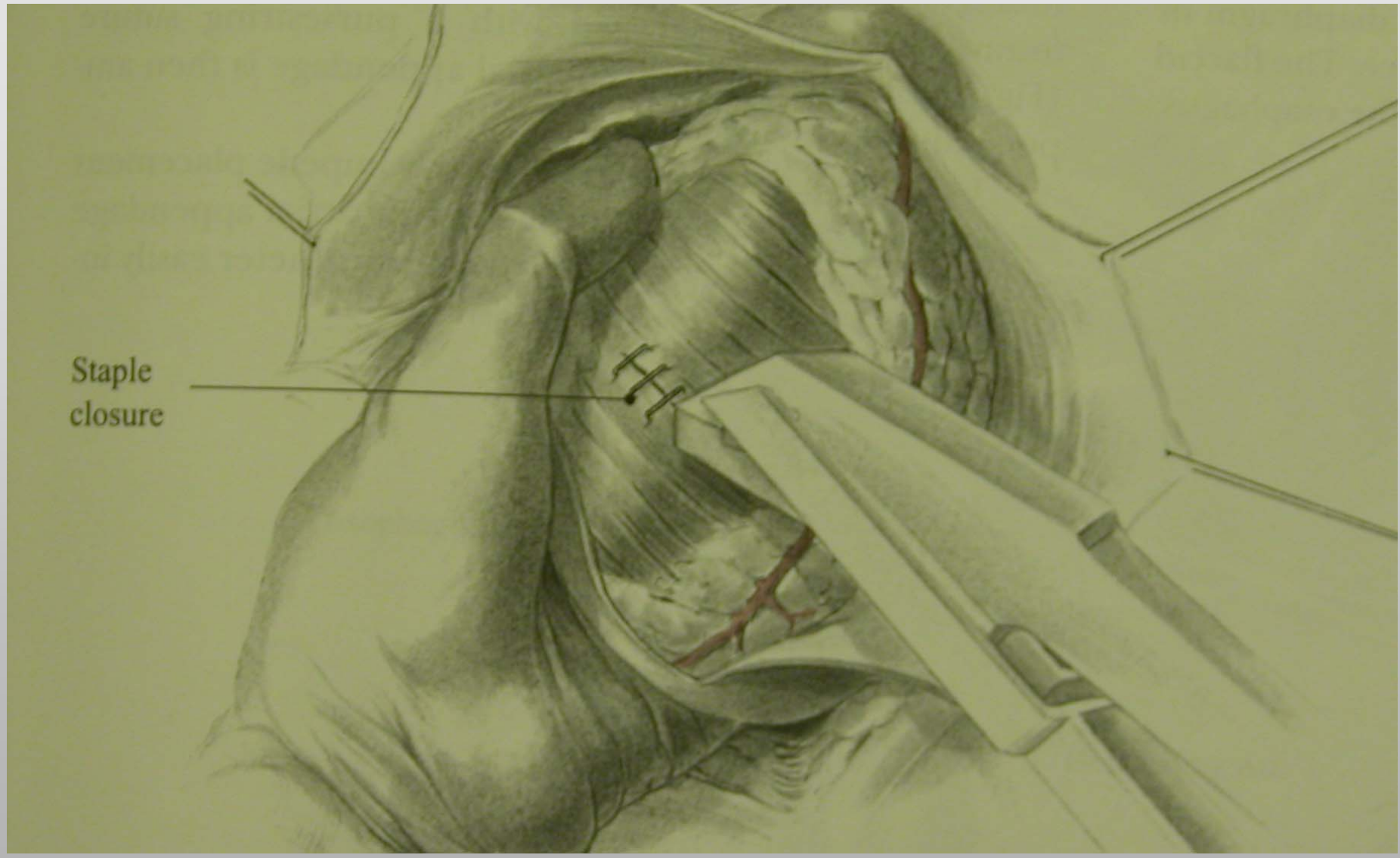
a digit

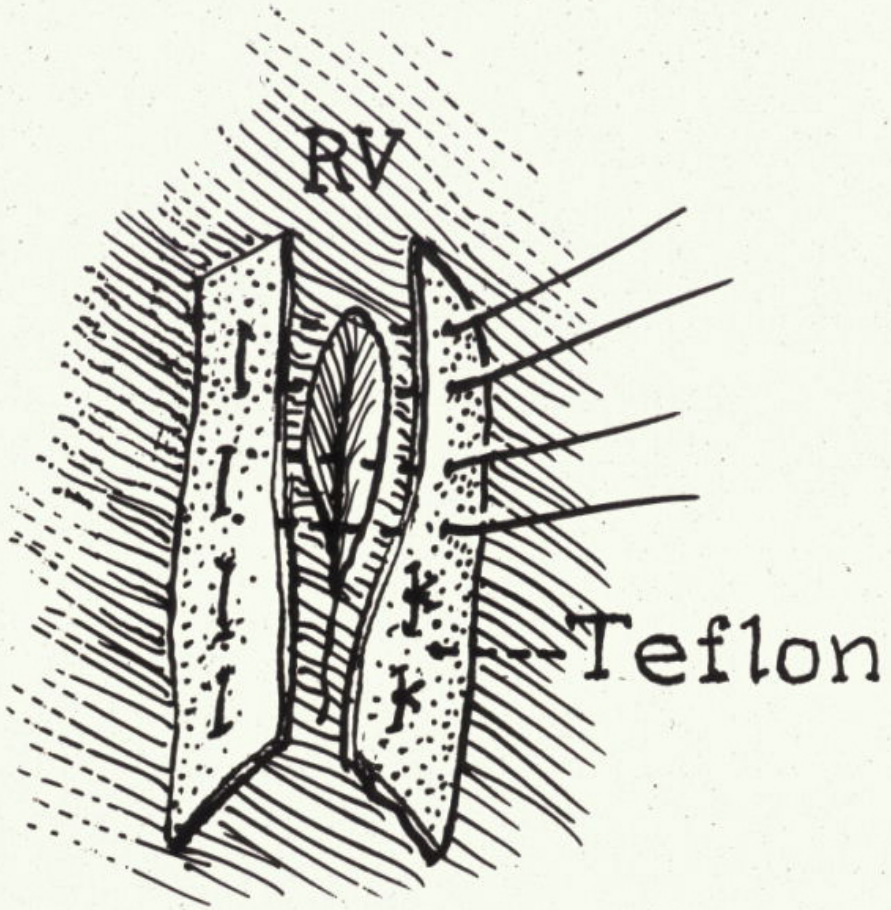


a tangential clamp

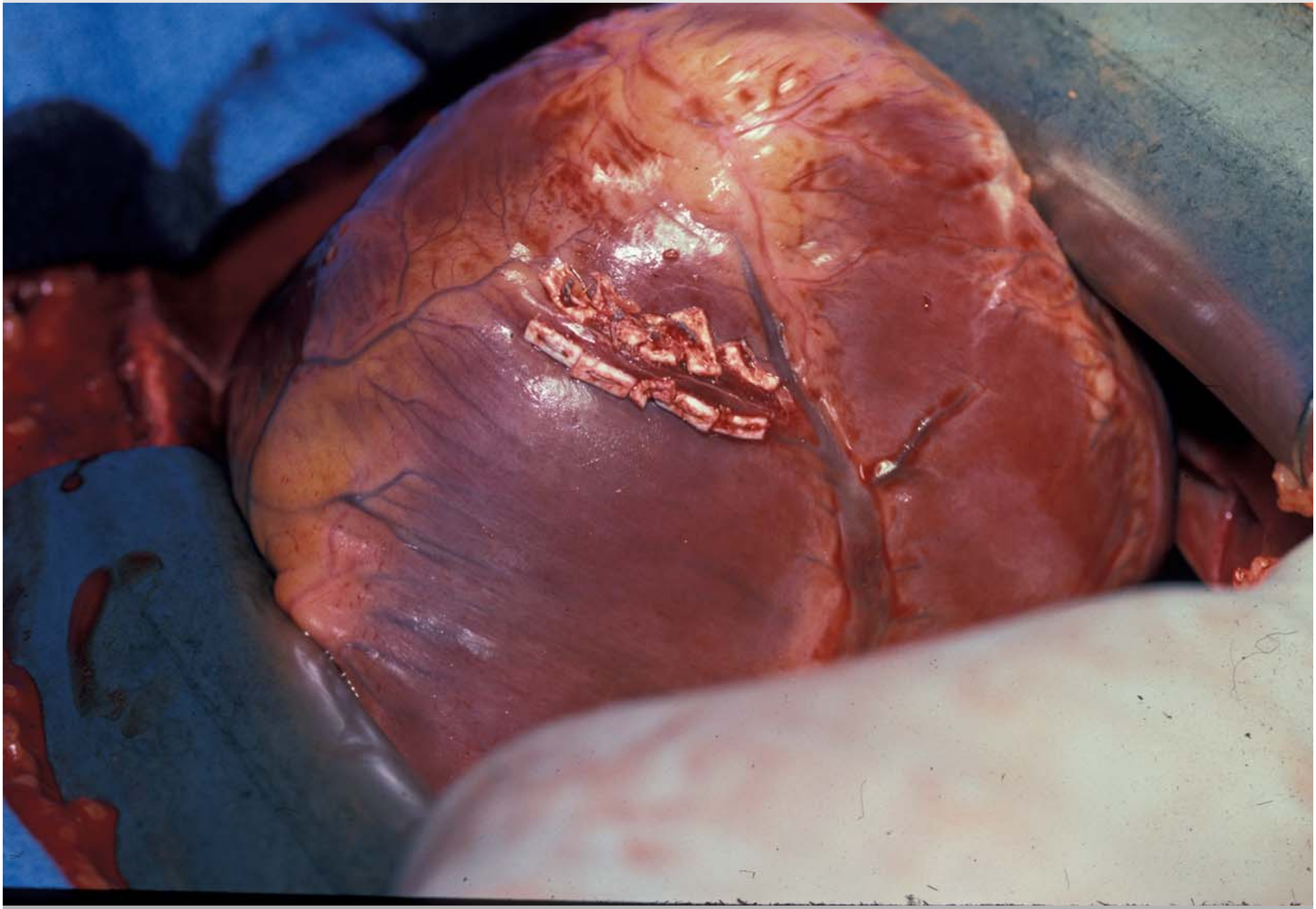


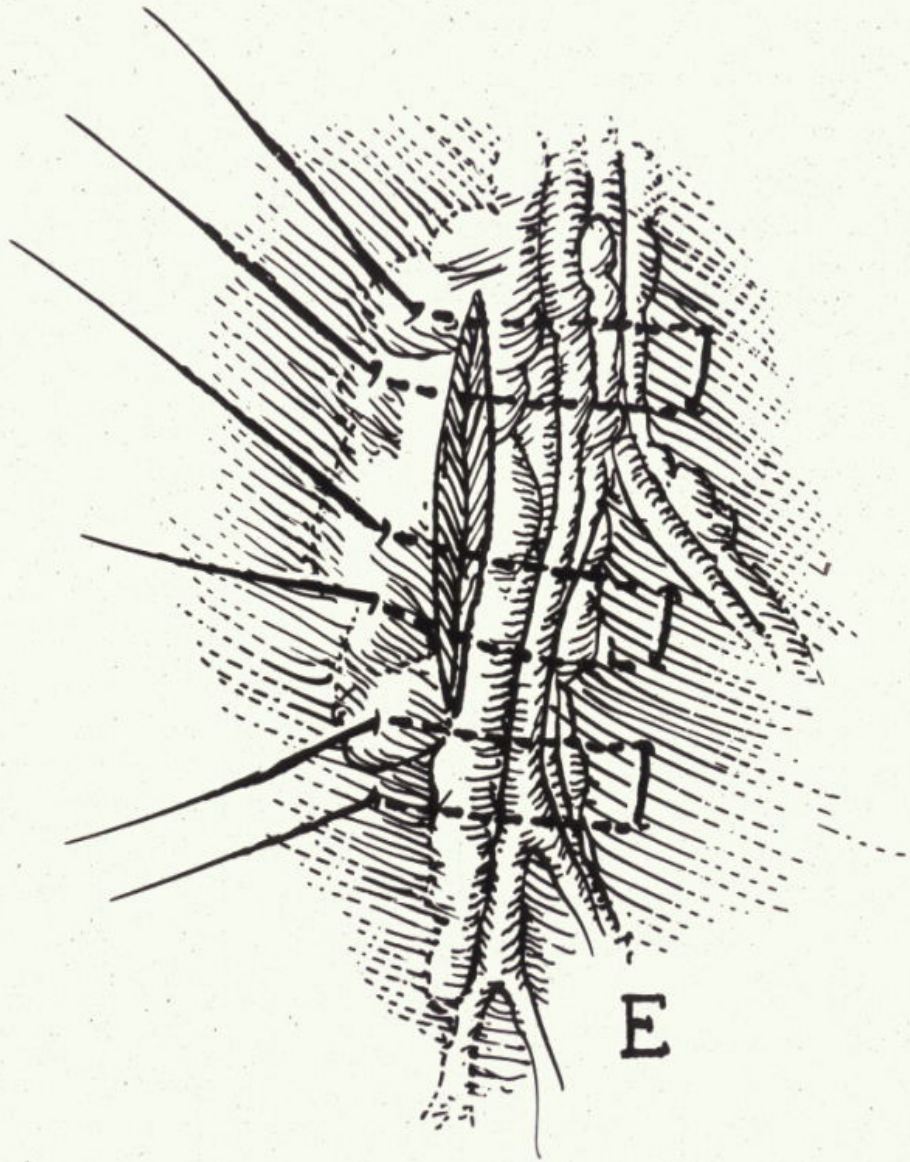
a Foley catheter

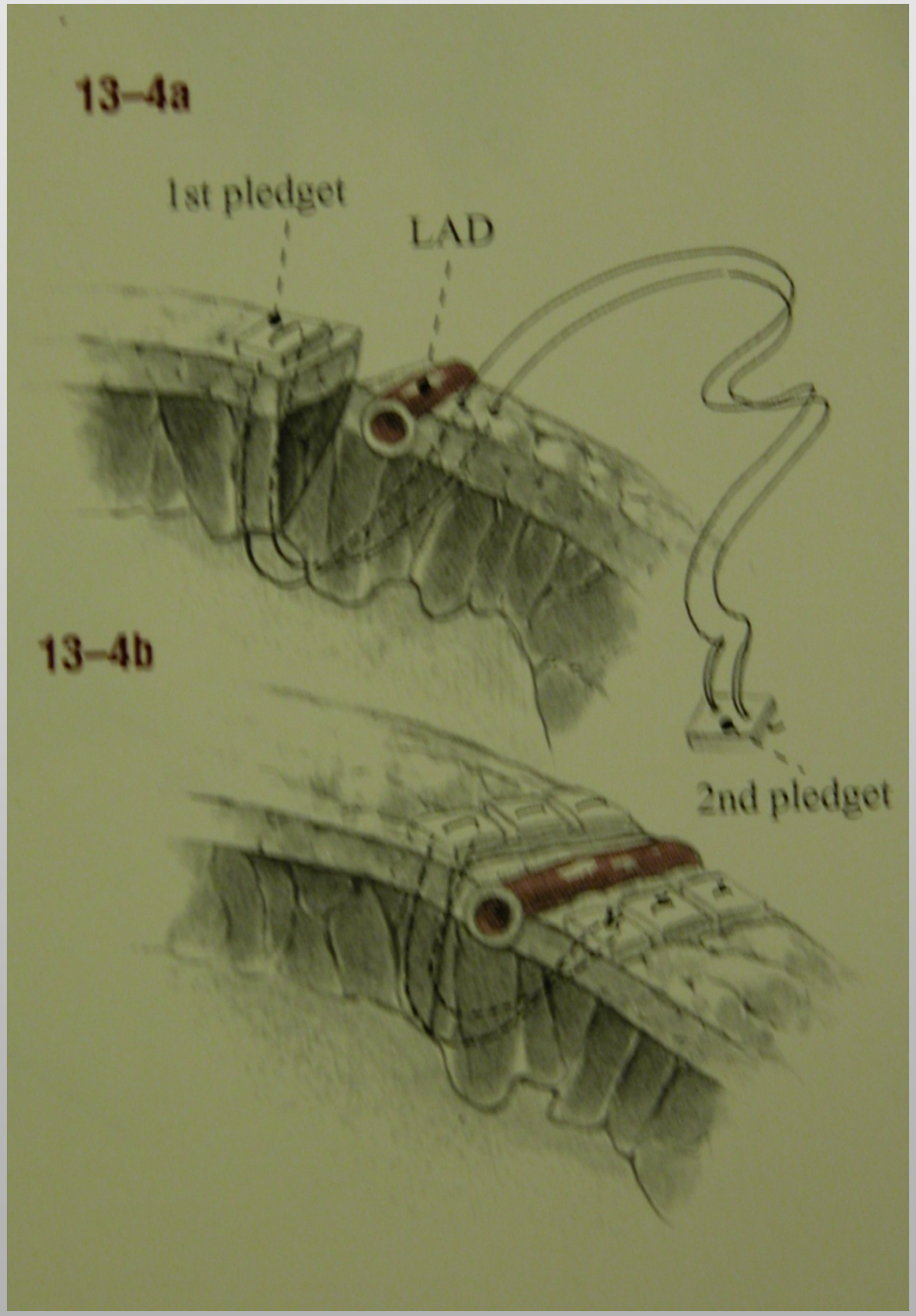

Staple
closure

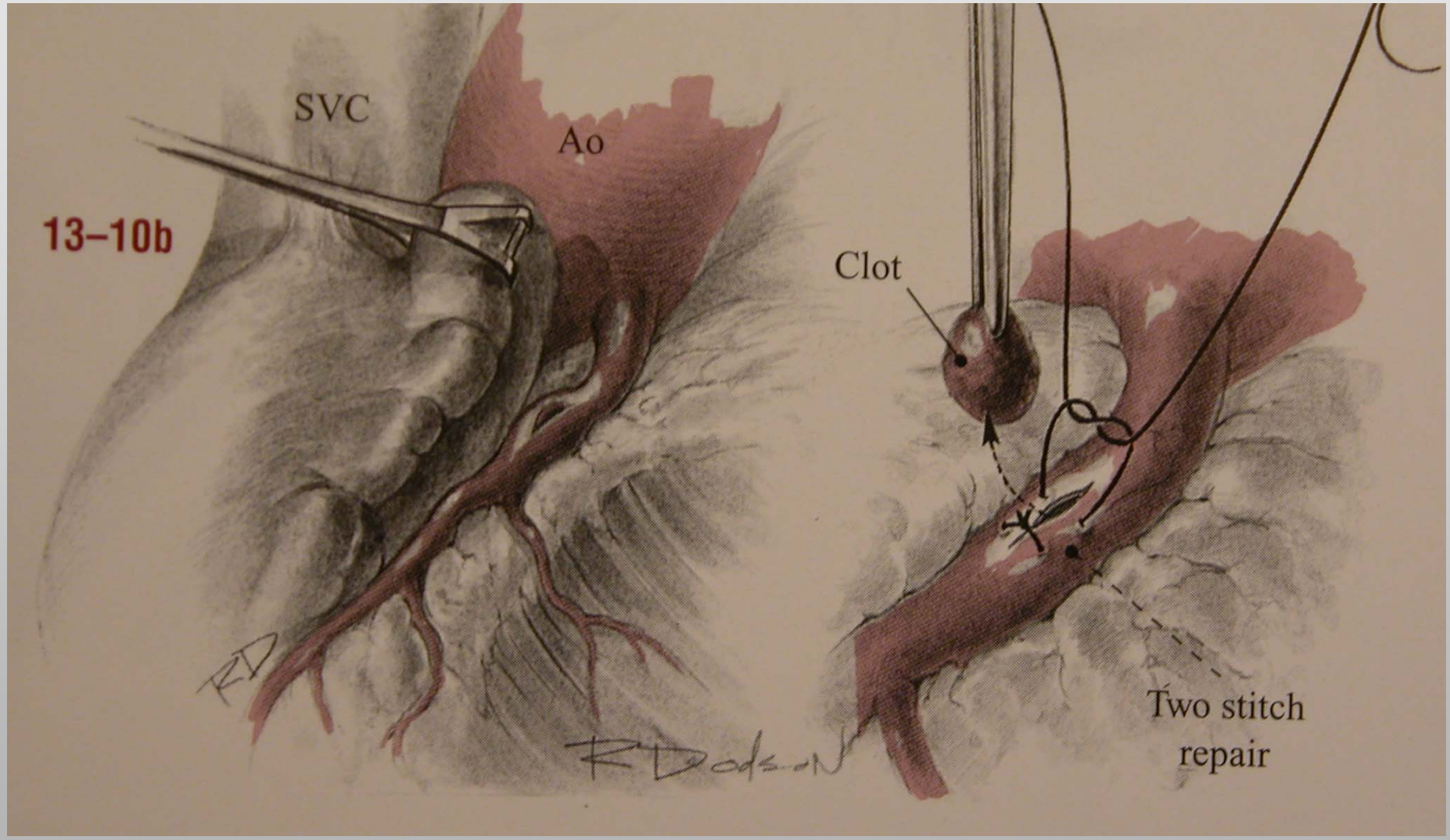


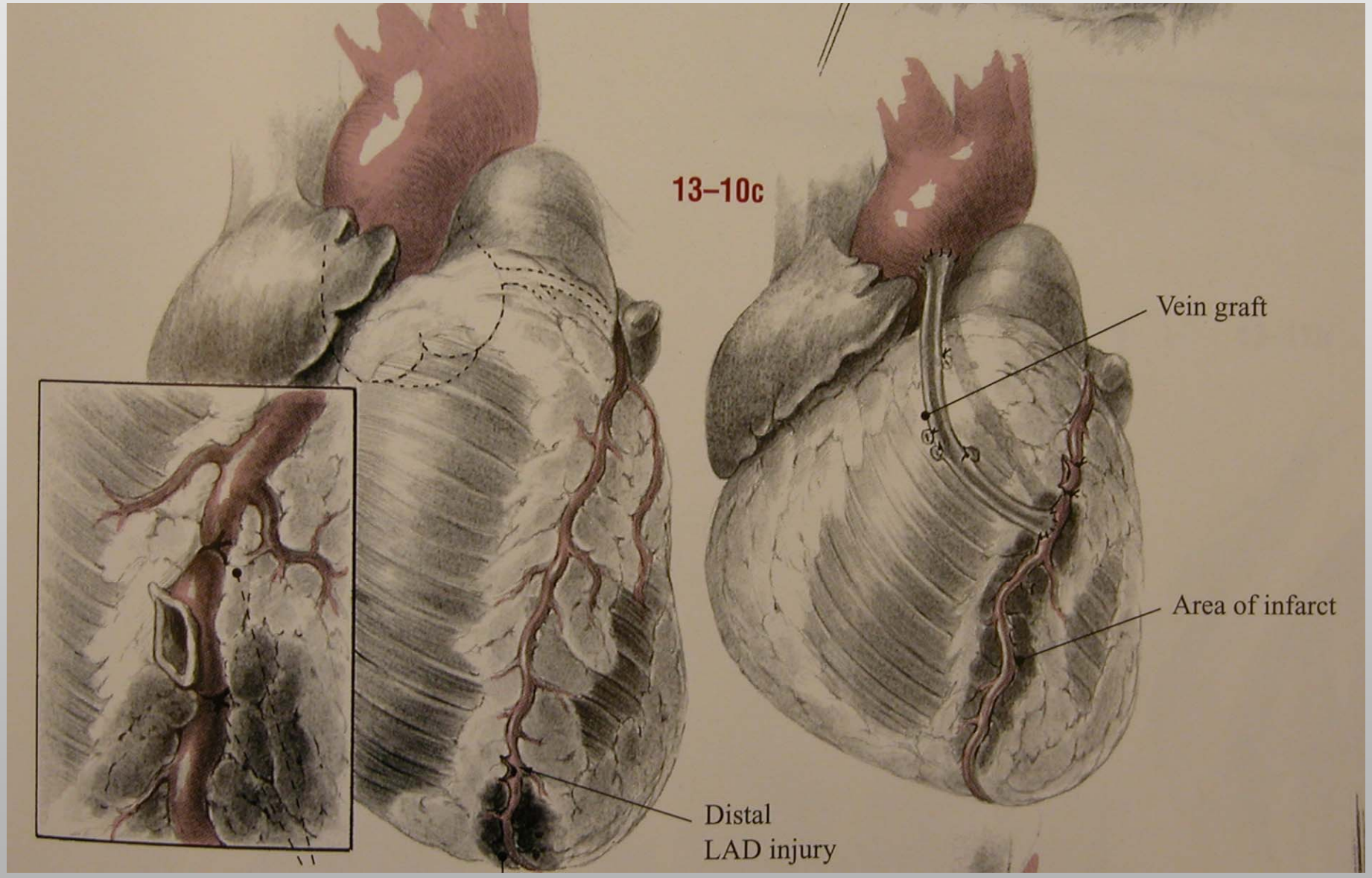
D




E


13–4a
1st pledget
LAD
13–4b
2nd pledget


13–10b
SVC
Ao
Clot
Two stitch
repair


13–10c
Vein graft
Area of infarct
Distal
LAD injury

CARDIAC INJURY EXHAUSTIVE EVALUATION

- Cardiac Echo
- Cardiac Catheterization
- Definitive Repair

PREDICTORS OF SURVIVAL IN CARDIAC TRAUMA

Penetrating Cardiac Injuries: A Prospective Study of Variables Predicting Outcomes

Juan A. Asensio, MD, FACS, James Murray, MD, Demetrios Demetriades, MD, PhD, FACS, John Berne, MD, Edward Cornwell, MD, FACS, George Velmahos, MD, PhD, Hugo Gomez, MD, Thomas V. Berne, MD, FACS

Background: Penetrating cardiac injuries are one of the leading causes of death from urban violence.

Study Design: This is a prospective, 1-year study in a Level I Trauma Center with the objective of analyzing: (1) the parameters measuring the physiologic condition of patients sustaining penetrating cardiac injuries in the field during transport and on arrival, (2) the cardiovascular-respiratory score (CVRS) component of the trauma score, (3) the mechanism and anatomic site of injury, (4) the presence or absence of tamponade, and (5) the cardiac rhythm as a predictor of outcomes. We attempted to correlate cardiac injury grade (AAST-OIS) with mortality. Our main intervention was thoracotomy for resuscitation and definitive repair of cardiac injury. Main outcomes measures were all parameters measuring the physiologic condition of patients, CVRS, mechanism and anatomic site of injury, operative findings and maneuvers, mortality, and grade of injury.

Results: The study consisted of 60 patients sustaining penetrating cardiac injuries, 35 gunshot wound (58%) and 25 stab wounds (42%). The injury severity score (ISS) was > 30 in 22 patients; overall survival was 22 of 60 (36.6%); gunshot wound (GSW) survival, 5 of 35 (14%); and stab wound (SW) survival, 17 of 25 (68%). An emergency department thoracotomy was performed in 37 of 60 (61.7%) with 6 of 37 survivors (16%).

CVRS: 96% mortality (25 of 26) when CVRS = 0; 67% mortality (6 of 9) when CVRS = 1–3; and 25% mortality (7 of 25) when CVRS > 4 ($p < 0.001$).

Mechanism of injury, and presence of sinus rhythm when pericardium opened predict outcomes ($p < 0.001$). Anatomic site of injury and tamponade do not predict outcomes (not significant).

AAST-OIS injury grade and mortality: grade IV, 31 of 60 (52%); grade V, 20 of 60 (75%), and grade VI, 6 of 60 (100%).

Conclusions: Parameters measuring physiologic condition, CVRS, and mechanism of injury plus initial rhythm are significant predictors of outcomes in penetrating cardiac injuries. The need for aortic crossclamping and the inability to restore an organized rhythm or blood pressure after thoracotomy were also predictors of outcomes. The presence of pericardial tamponade was not. (J Am Coll Surg 1998;186:24–34. © 1998 by the American College of Surgeons)

Penetrating injuries of the heart are one of the leading causes of death from urban violence. Improvements in emergency medical services (EMS) systems during the past few years, along with the applied principle of "Scoop and Run," are responsible for many more cardiac injury patients arriving alive, but "in extremis."

During the past two decades, more than 30 series of patients with penetrating cardiac injuries have been reported in the English-language literature.[1–32] Close scrutiny of these series reveals several flaws. Most if not all have been retrospective reviews, originating from institutions treating fewer than 15 cases of cardiac

Received July 30, 1997; Revised September 17, 1997; Accepted October 7, 1997.
From the Division of Trauma and Critical Care, Department of Surgery, University of Southern California and the Los Angeles County/University of Southern California Medical Center, Los Angeles, CA.
Presented at the 1996 Annual Scientific Session of the Western Surgical Association, Portland, OR, November 20, 1996.
Correspondence address: Juan A. Asensio, MD, FACS, Division of Trauma and Critical Care, Department of Surgery, University of Southern California School of Medicine and the Los Angeles County/USC Medical Center, 1200 N. State Street, Room 10-750, Los Angeles, CA 90033-4525.

© 1998 by the American College of Surgeons
Published by Elsevier Science Inc.

ISSN 1072-7515/98/$19.00
PII S1072-7515(97)00144-0

- Prospective Study
- 60 patients (USC 1998)
- Parameters predictive of Survival:
  - Mechanism of injury
  - CVRS
  - Need for Ao x-clamping
  - Inability to restore original rhythm

Thoracic Trauma

- Recognition
  - Diagnosis
  - Severity/Lethality
- Early Treatment

THORACIC TRAUMA

- EPIDEMIOLOGY
  - Blunt Injury
  - Penetrating Injury
- SPECTRUM OF THORACIC TRAUMA
- APPROACHES TO THE TREATMENT
- RESUSCITATIVE THORACOTOMY
- SPECIFIC CHALLENGES IN THORACIC TRAUMA
  - Aortic Trauma
  - Cardiac Trauma