Handbook of Trauma

Kristopher R. Maday, MS, PA-C, CNSC

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Trauma Bay 101

Advanced Trauma Life Support

- Primary Survey
  - A,B,C,D,E
- Secondary Survey
  - PE, labs, scans
- Resuscitation

Primary Survey

- Airway
- Breathing
- Circulation
- Disability
- Exposure

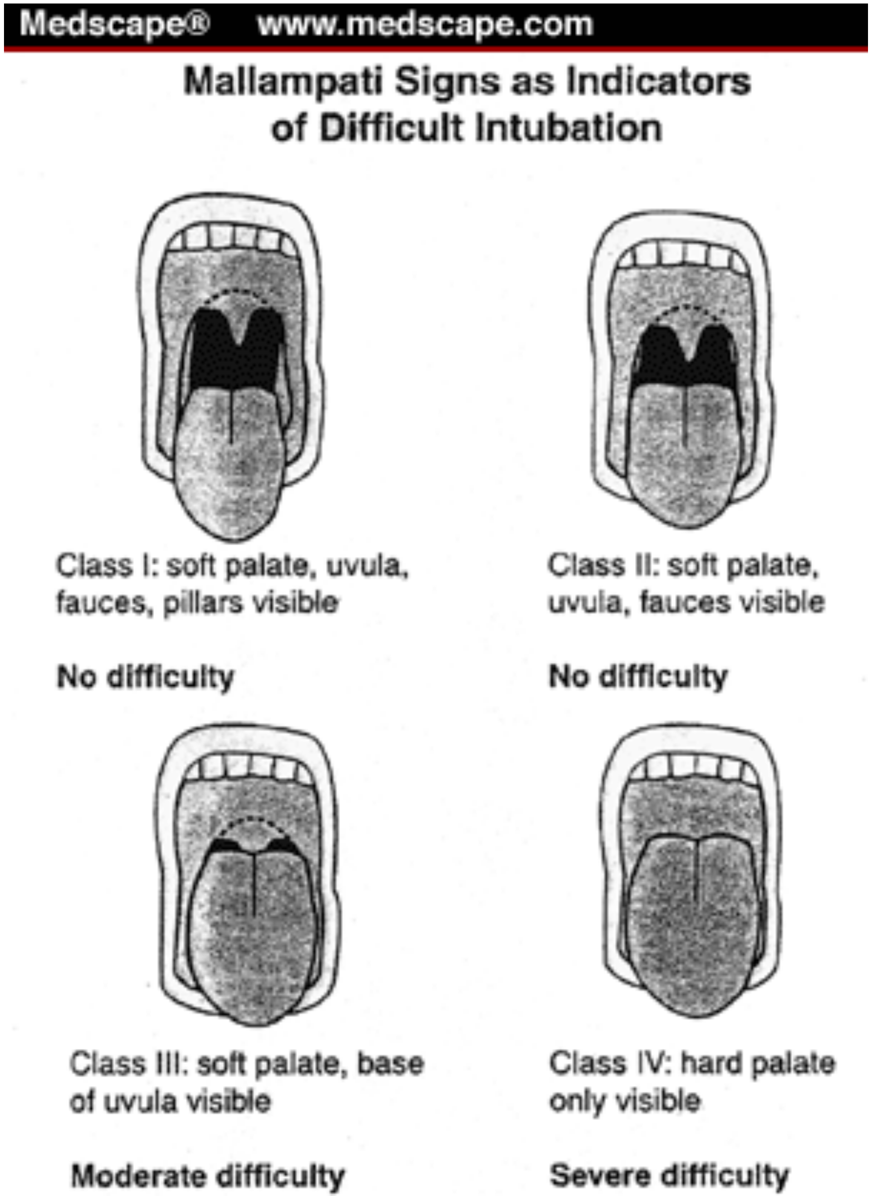
Primary Survey

- Airway
  - Ensure an intact airway
  - Ask patient their name
  - Call out findings

Airway

- Reasons for intubation
  - GCS < 8
  - Signs of Inhalation Burn
    - Carbonaceous sputum, singed nasal hair
  - Neck trauma
  - Weak voice, hoarse
  - Combative
    - F-U intubation
- 6-D’s of difficult Intubation
  - Disproportion, Distortion, Decreased thyromental distance, Decreased interincisor gap, Decreased ROM, Dental overbite
- Mallampati Score

Mallampati Score



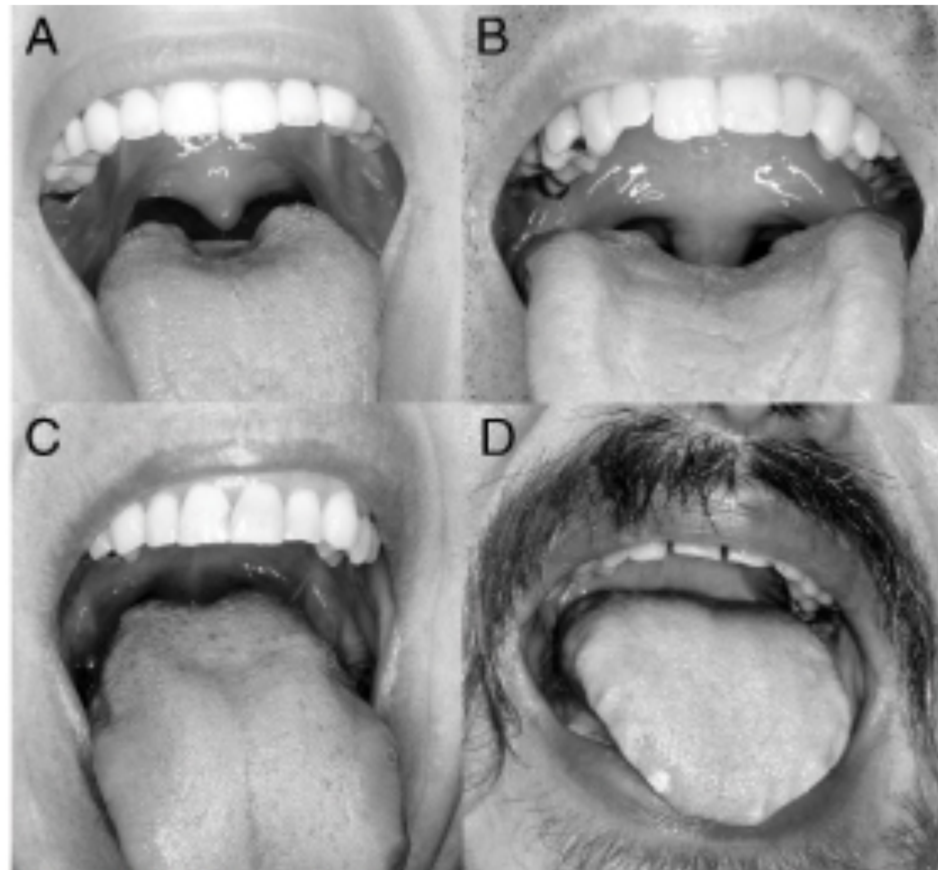


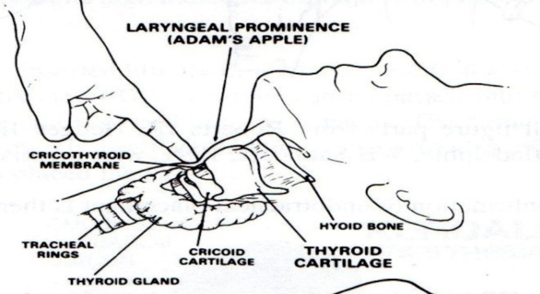
Figure 2: Mallampati views

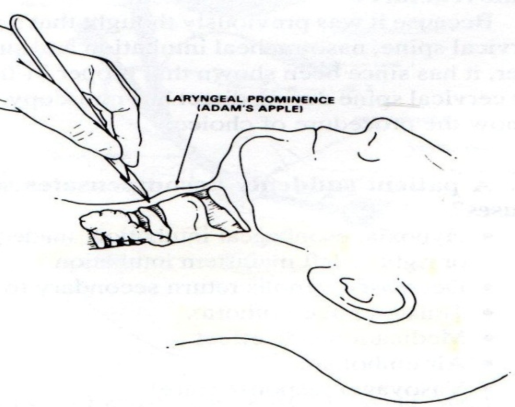
Types of Intubation

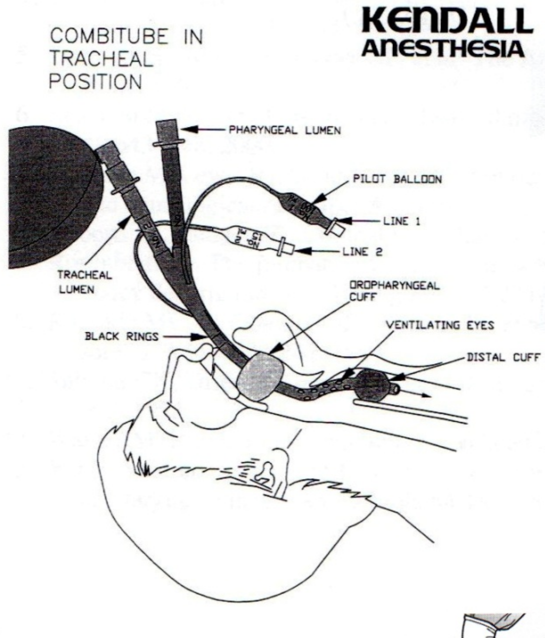
- Standard Rapid Sequence Intubation
  - Sedative
    - Etomidate
      - Less hemodynamic compromise than BZDPs
      - Can cause adrenal insufficiency
  - Neuromuscular Blocker
    - Succinylcholine, Rocuronium
  - 6 P's
    - Prepare
      - all equipment out and ready
    - Preoxygenate
      - 100% NRB for 3 min
    - Pretreat
      - NDNMB to decrease fasiculations
      - Lidocaine to decrease intracranial pressure
      - sedative
    - Paralyze
    - Pass the Tube
    - Post intubation assessment

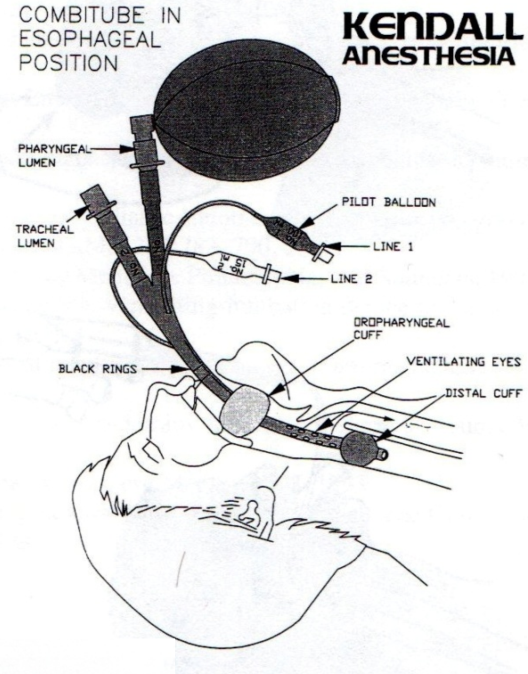
Difficult Intubations

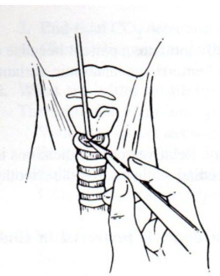
- Fiberoptic Intubation
- Retrograde wire intubation
- Jet ventilation with needle cricothyroidotomy
- Cricothyroidotomy
- LMA
- Combitube



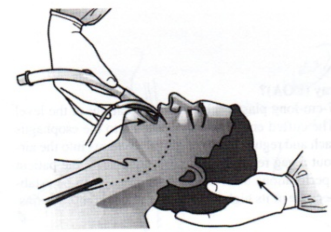


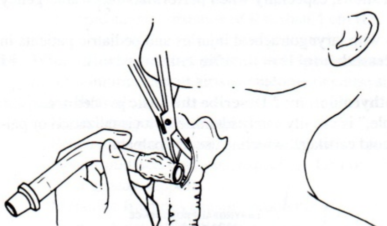




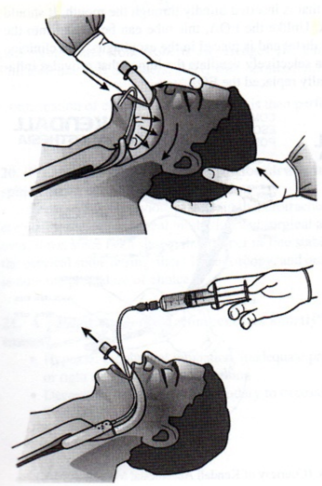


The cricothyroid membrane is identified, and a horizontal incision is made.





A small endotracheal tube (5.0 mm) or tracheostomy tube (Shiley no. 4) is then placed into the trachea.



Confirming ETT Placement

- Gold Standard
  - Direct visualization of vocal cords when placed
- ETCO2 Monitor
  - False Negative
    - During CPR when pulmonary has exchange is limited
  - False positive
    - Ingestion of large quantity of carbonated beverage
- Aspiration
  - If no negative resistance felt on aspiration with 60cc syringe, then in trachea
  - If resistance is felt, then in esophagus

Breathing

- Inspection
  - Asymmetry, flail segment, sucking chest wound, use of accessory muscles, contusions, distended neck veins, tracheal deviation, SQ emphysema
- Auscultation
  - Auscultate grossly laterally (not centrally/anteriorly) one time on each side.
- Call out findings

Life Threatening Thoracic Injuries

- Flail Chest
  - 3 or more ribs fractured in 2 or more places
- Tension Pneumothorax
  - Can be caused by mechanical ventilation
- Massive Hemothorax
  - >1500cc
- Cardiac Tamponade
- Open Pneumothorax
  - Defect in chest wall > 2/3 diameter of trachea

Treatment

- Tension Pneumothorax
  - Needle decompression in 2nd intercostal space, midclavicular line
- Cardiac Tamponade
  - Pericardiocentesis, Subxiphoid window in OR
- Open Pneumothorax
  - Seal with 3 sided bandage
- Massive Hemothorax
  - Thoracostomy tube
    - What output do you need to be concerned with?
      - 1500ml out initially or 300ml/hr

Circulation

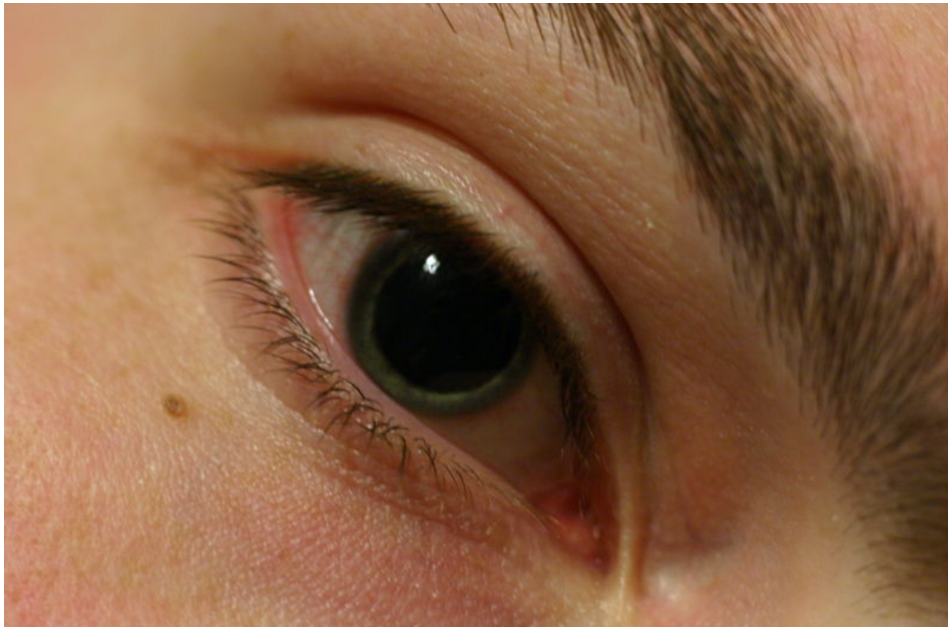
- Palpate bilateral femoral pulses
  - What BP does this represent??
    - 60-70-80-100 rule
- IV access
  - CVL or PIV??
  - UE or LE??
  - Cutdown access
  - IO IV
- Start IVF
  - What should we use??

Disability

- Assess neuro status
  - "Squeeze my hand, move your toes"
  - AVPU Score
    - Alert
    - Voice elicits response
    - Pain elicits response
    - Unresponsive
  - GCS score, pupils
    - If blown, what is the concern?
      - Herniation
    - What do you do?
      - Mannitol, Hyperventilate, hypertonic saline
  - If unconscious what cocktail can you give??
    - Glucose, Thiamine, Narcan
  - If patient is lucid and becomes unresponsive following head trauma, what is the concern?
    - Epidural Hematoma

Table 9-1. Glasgow Coma Scale

Category	Points for a Given Response
Motor	**6:** Obeys verbal command to move
	5: Localizes to pain
	4: Withdraws from pain
	3: Stimulus causes flexure posturing
	2: Stimulus causes extensor posturing
	1: No response to stimulus
Verbal	**5:** Fully oriented
	4: Not fully oriented
	3: Intelligible but not organized
	2: Unintelligible sounds
	1: No vocalization
Eye opening	**4:** Spontaneous
	3: Opens to speech
	2: Opens to pain
	1: No eye opening



Exposure

Figure 3–1

- Cut off all clothes
- Check for gross deformities
- Tuck and Roll
  - Feel for step-offs, bony tenderness, posterior scalp lacs
  - Rectal exam
- Warm blankets to prevent hypothermia
- Call out findings

Adjuncts to Primary Survey

- AMPLE History
  - Allergies. Medications, PMH, Last meal, Events of accident
- Monitoring Vitals
  - HR, BP, EKG
- Foley catheter
  - What do we need to be concerned with?
    - Pelvic fractures, GU injury
- NGT if vomiting, or intubated
- Labs??
  - ABG, UA, Tox screen, BMP, Coags, LA, CBC, Amylase, Lipase, CE
- Two X-rays??
  - CXR and PXR

Secondary Survey

- Performed after primary survey
- ONLY IF PATIENT IS STABLE
- More in depth PE
- Scans

Physical Exam for Trauma

- Head and Face
  - Look for scalp lacs
  - Check bony tenderness of face
  - Check vision
  - Basilar skull fracture
    - Classic PE signs?
      - Mastoid ecchymosis, Periorbital ecchymosis, Hemotypanum
- Neck
  - Look for expanding hematoma, tracheal deviation
  - Keep in c-collar until radiographically cleared

Physical Exam for Trauma

- Neuro
  - Check sensation and motor for deficits
  - Serial exams important for expanding intraspinal or epidural hematoma
    - Any change in exam is significant!!!
- Abdomen
  - Inspection
    - Contusions, penetrating injuries
  - Guarding, peritoneal signs

Physical Exam for Trauma

- Musculoskeletal/Peripheral Vascular
  - Check pelvic stability, if x-ray negative
  - Compartment syndrome
  - Check pulses distally
  - ABI
    - What value is concerning?
      - ABI < 1

Pan-Scan

- If patient stable, its off to CT
  - What must you check first??
    - Creatinine
- CT Chest, Abdomen, Pelvis
- CT C-Spine if neck injury
- CT Head if AMS or patient obtunded
- CT T-Spine, L-Spine if step-offs or boney tenderness
- CT Angio if vascular injury is suspected
- CT Max/Face if facial fractures

What if patient is unstable??

- Quick diagnostic procedures
  - FAST exam
  - Diagnostic Peritoneal Lavage
- Go straight to OR
  - Exploratory Laparotomy

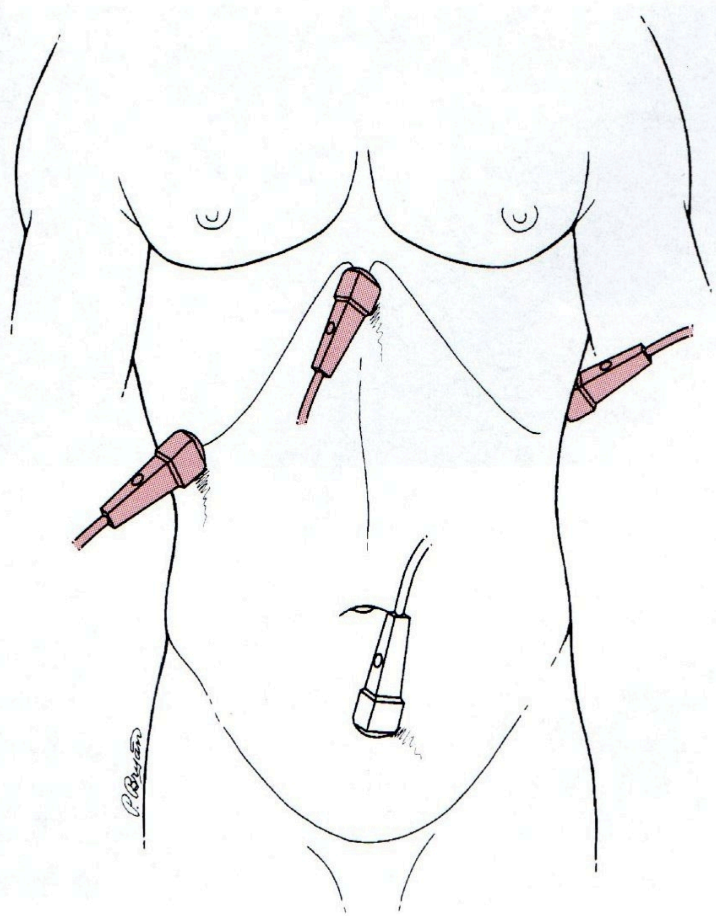


FIGURE 17-3. Schematic diagram of transducer positions for FAST: pericardial, right upper quadrant, left upper quadrant, and pelvis.

End Points of Resuscitation

- Lactic Acid
  - Indicator of anaerobic metabolism and inadequate microcirculatory oxygen delivery
  - Increased mortality with sustained increase in LA
    - 0-10% Mortality if LA < 2.0 within 24hr
    - 25% if LA < 2.0 within 24-48hr
    - 80% if LA > 2.0 after 48hr

End Points of Resuscitation

- Base Deficit
  - Amount of base required to raise 1L of blood to normal pH
  - 2-5 mild, 6-14 mod, >15 severe
  - Need to correlate with HCO_3^-
    - Respiratory status can confound value
  - Hyperchloremic Metabolic Acidosis
- UOP
  - 0.5-1.0 cc/kg/hr

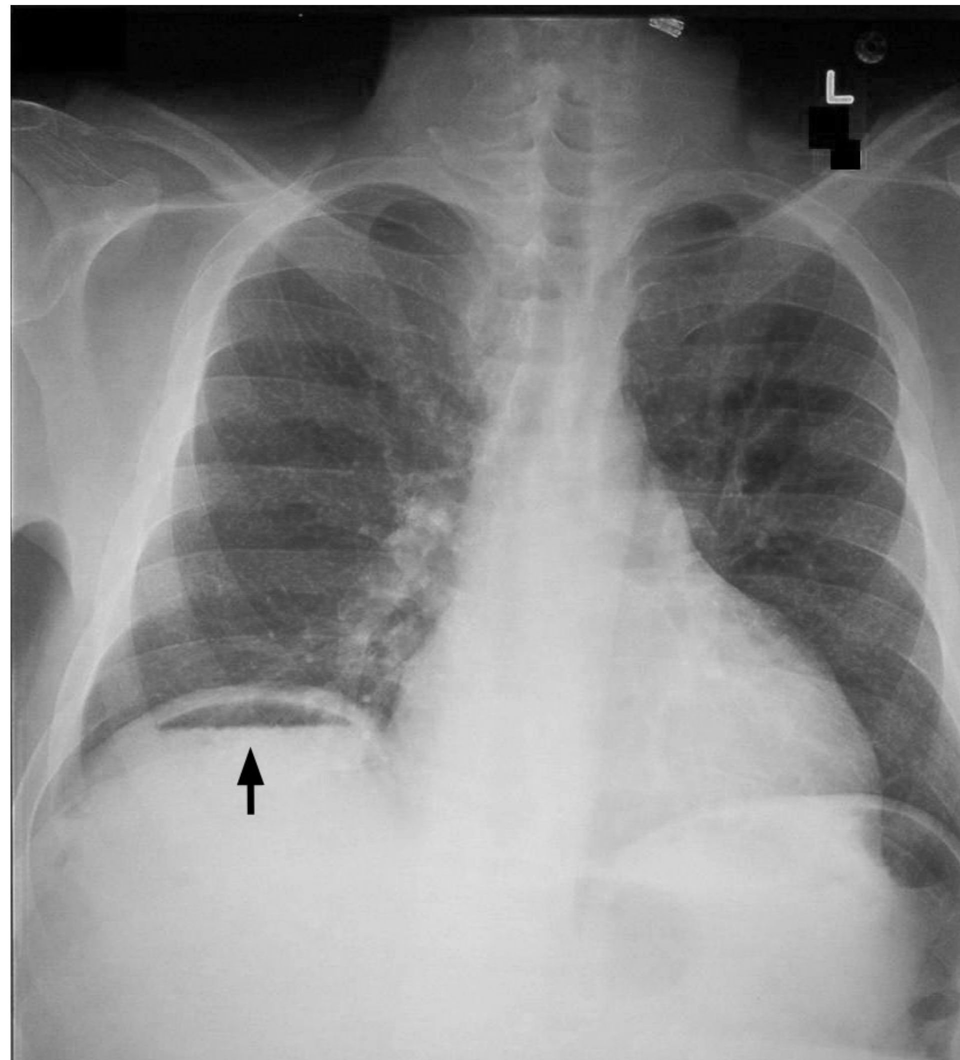
Penetrating Abdominal Trauma

GSW vs. KSW

- If object is still in, leave it be!!
- Check distal pulses for symmetry and strength
- Rectal exam to check for gross blood
- Abdominal exam is insensitive for peritoneal penetration
- FAST exam to determine intraabdominal blood

X-rays

- Mark wound with radiopaque object
- Obtain 2 planes to determine depth and trajectory
- CXR
  - Can show PTX and pneumoperitoneum
- AXR
  - Exclude retained FB



Stab wounds

- LUQ most common injury
  - Most stabbers are right handed
- 60% of anterior stab wounds violate peritoneum
  - 50% of these require repair of abdominal organs
- Risk of abdominal injury vary with location
  - 30% - anterior or flank
  - 15% - thoracoabdominal
  - 10% back

Retained Knife Blade

Local Wound Exploration

- Indicated only if there is a single anterior abdominal wound
  - Defined as area below costal margins, above inguinal creases, and between anterior axillary lines
- Need to determine if peritoneum has been violated
  - NEVER PROBE WOUND
    - May disrupt homeostasis or worsen injury
  - Gently separate skin edges to see if base of wound can be visualized
  - If no peritoneal violation → discharge
  - If inconclusive → CT or DPL
  - If positive → OR
- Contraindication
  - Any clinical need for laparotomy
  - Obese patients

Gunshot Wounds

- Low velocity injury
  - < 1200 ft/s
  - Damage is confined to missile tract
- High velocity injury
- > 2000 ft/s
  - Blast effect and cavitation occur
- 85% of anterior GSW violate peritoneum
  - 95% require repair of abdominal injury

Wound Ballistics

Table 1: Factors Involved in Wound Ballistics

Bullet Design
Caliber (diameter)
Mass
Shape (profile)
Jacket
Pellets
Powder (amount and type)
Weapon Design
Barrel length
Rifling
Single shot
Automatic
Semi-automatic
Portability (weight and size)
Victim
Position
Distance from weapon
Location of wound
Tissue characteristics (bone, muscle, vessel, organ)

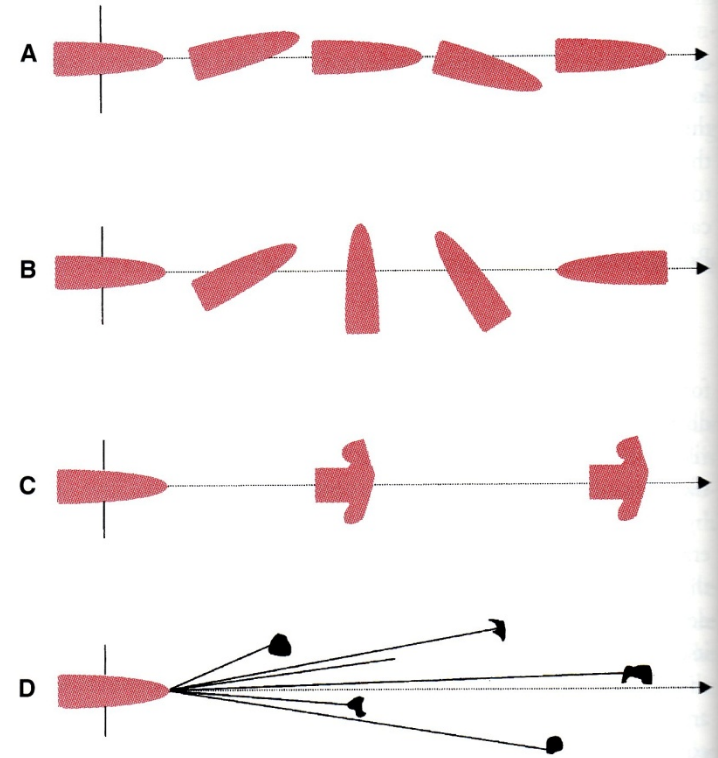
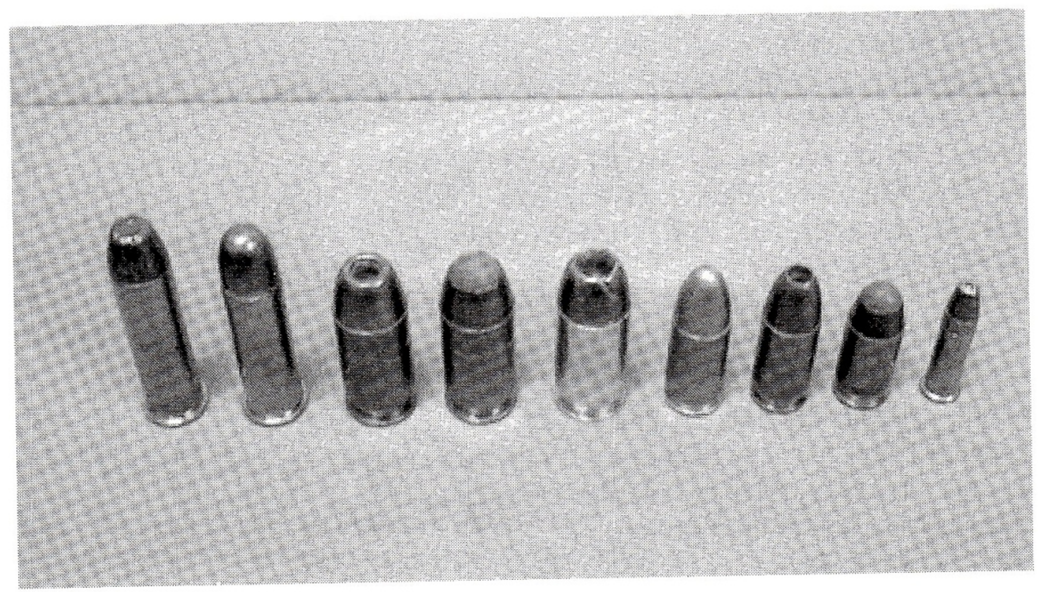


FIGURE 7-4. Yaw, tumble, deformation, and fragmentation. **(A)** Yaw describes deviation from flight path along the longitudinal axis. **(B)** Tumble is deviation in a "head over heels" manner. **(C)** Deformation occurs on impact and increases the actual surface area of the projectile. **(D)** Fragmentation involves the bullet scattering. All of these increase surface area of the projectile and tissue interface.

- 3 principles in wound ballistics
  - Dissipation of kinetic energy
  - Damage from secondary missiles → Fragmentation
  - Damage from cavitation

Handguns

- Lower velocity
- Less deformation, fragmentation
- Less cavitation
- Hollow-point ammunition



Handgun missiles are depicted from left to right: 38 Special, 357 Magnum, 45-caliber soft hollow point, 45-caliber soft hollow point grooved, 9 mm, 9 mm soft hollow point, 380 plastic covered copper-jacketed hollow point, 22 caliber

Rifles

- High velocity
  - Longer barrel = higher acceleration
  - Can maintain 90% of velocity at 100m
- Less tumble and yaw
- Higher fragmentation on impact

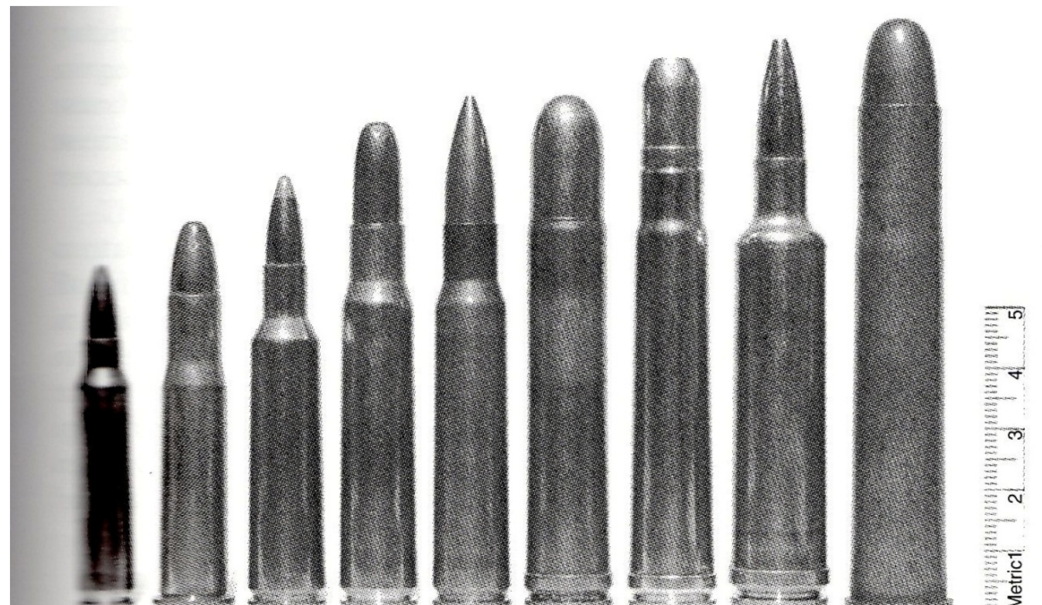


Figure 5 Various rifle bullets compared. Left to right: .223 caliber FMJ (M-16 assault rifle), 30-30 soft point, 6-mm soft point, 30-06 soft point, .308 caliber military-style FMJ (7.62 mm NATO), .458 caliber FMJ magnum, .375 caliber FMJ magnum, .378 caliber FMJ hollow tip, World War II–era .47 caliber FMJ. FMJ, full metal jacket. *(Bullets courtesy of Bruce Ham, MD, and Gerald Warnock, MD, Portland, OR.)*

Shotgun

- Type I
  - > 7 yards
  - Superficial damage
- Type II
  - 3-7 yards
  - Deep structure damage
- Type III
  - < 3 yards
  - 85% fatal
- Pellet embolism
- Searching for plastic casing on close range wounds

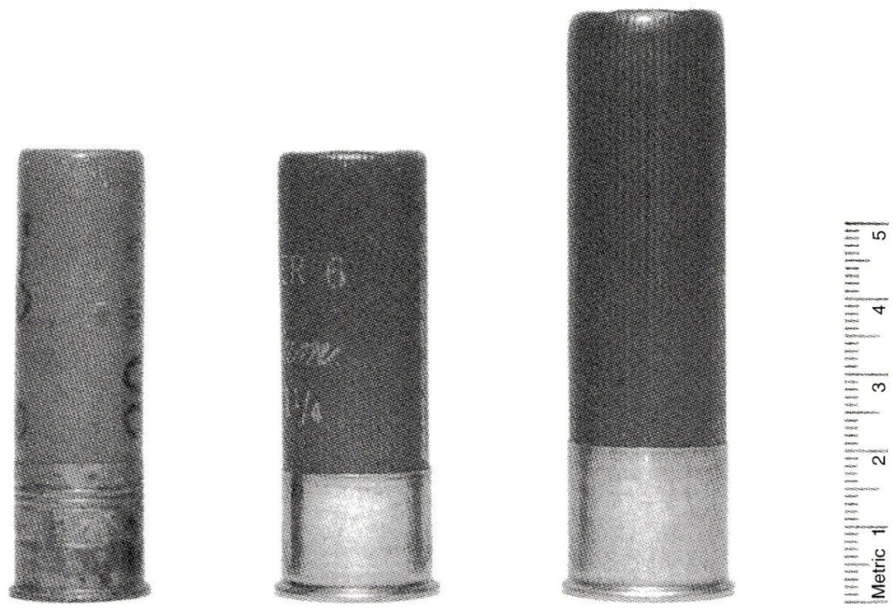


Figure 6 20-gauge, 12-gauge, and 10-gauge shotgun shells compared (left to right). *(Bullets courtesy of Gerald Warnock, MD, Portland, OR.)*

Velocity

TABLE 7-1

Velocity and Kinetic Energy Characteristics of Various Guns

CALIBER	VELOCITY (ft/s)	MUZZLE ENERGY (ft-lb)
Handguns		
0.25 in.	810	73
0.32 in.	745	140
0.357 in.	1410	540
0.38 in.	855	255
0.40 in.	985	390
0.44 in.	1470	1150
0.45 in.	850	370
9 mm	935	345
10 mm	1340	425
Long guns/military weapons		
0.243 Winchester	3500	1725
M-16	3650	1185
7.62 NATO	2830	1535
Uzi	1500	440
AK47	3770	1735

Table 2: Muzzle Velocity by Gun and Bullet Type

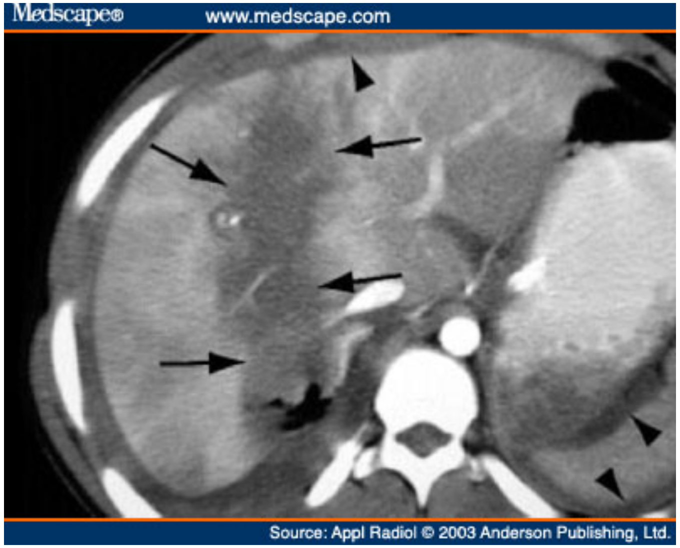
Handguns	M/sec
.38 special	290
.44	305
9 mm	315
.44 magnum	420
Rifles	
.22 long	380
30.06	890
.308 (7.62 mm)	860
Military	
.223 (M-16)	950
.30 (AK-47)	720
.50 (Browning)	850

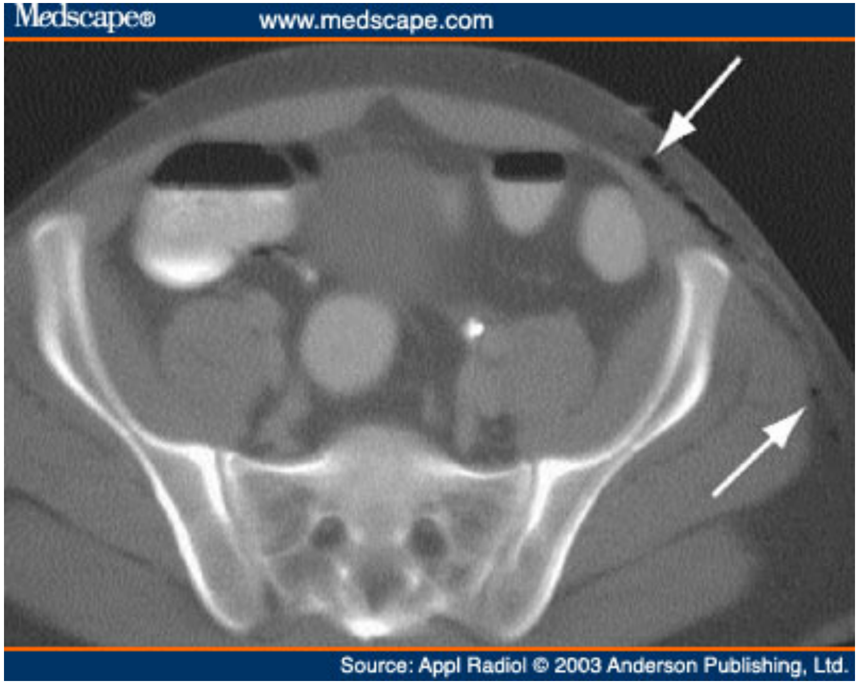
GSW Injuries

- Organs occupying the most space are more often injured
  - Liver
  - Small bowel
  - Stomach
  - Colon
  - Spleen
  - Kidney
  - Pancreas

GSW

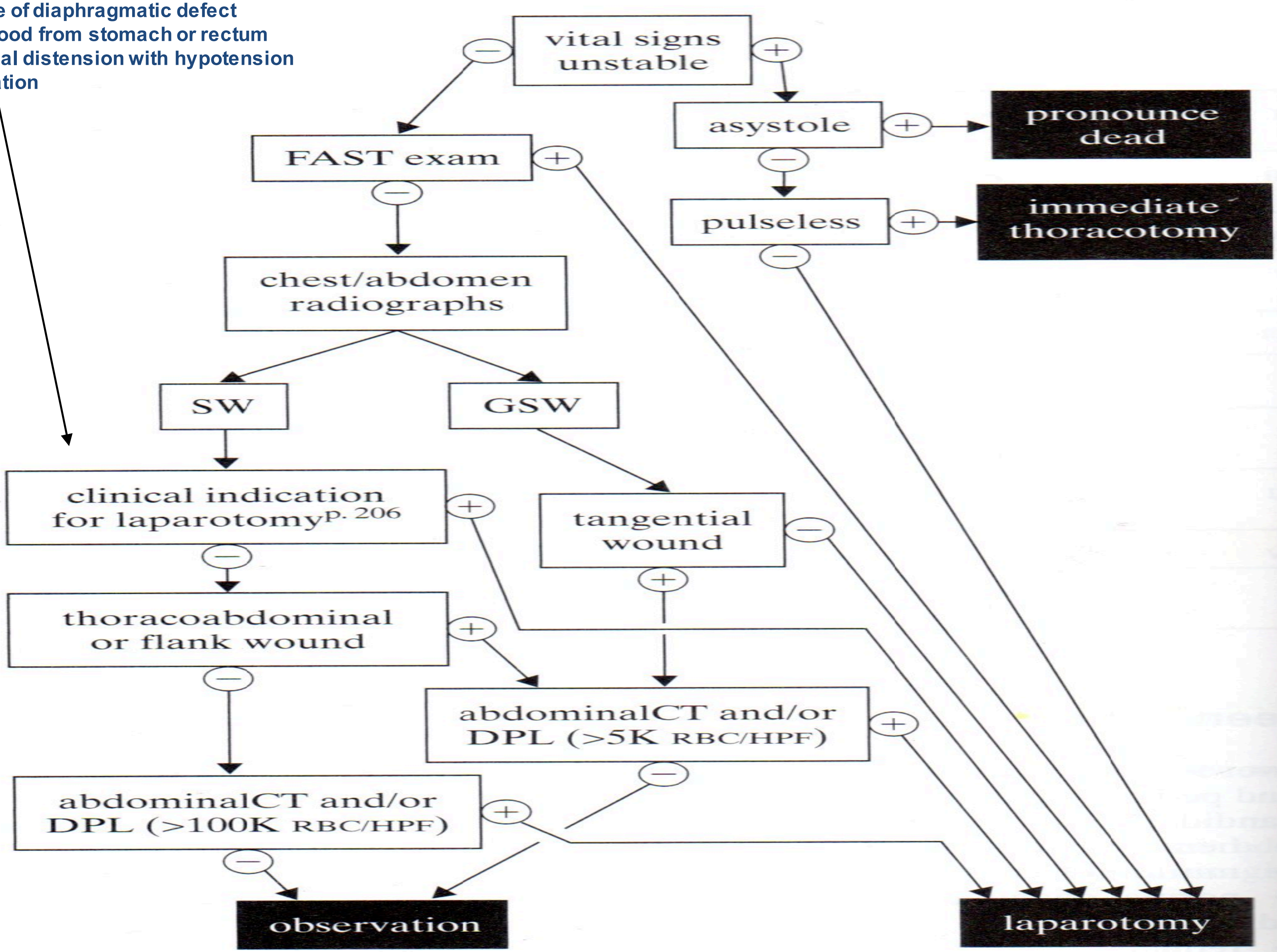
- If stable → CT to determine path of missile
- If unstable → OR





Peritonitis
Retained stabbing implement
Evidence of diaphragmatic defect
Gross blood from stomach or rectum
Abdominal distension with hypotension
Evisceration

Penetrating Abdominal Trauma



Blunt Abdominal Trauma

Mechanism of Injury

- Sudden direct force can cause laceration of solid organs
- Sudden rise in intraabdominal pressure can cause rupture of hollow organs
- Sudden deceleration/acceleration can cause shearing of structures at points of attachment

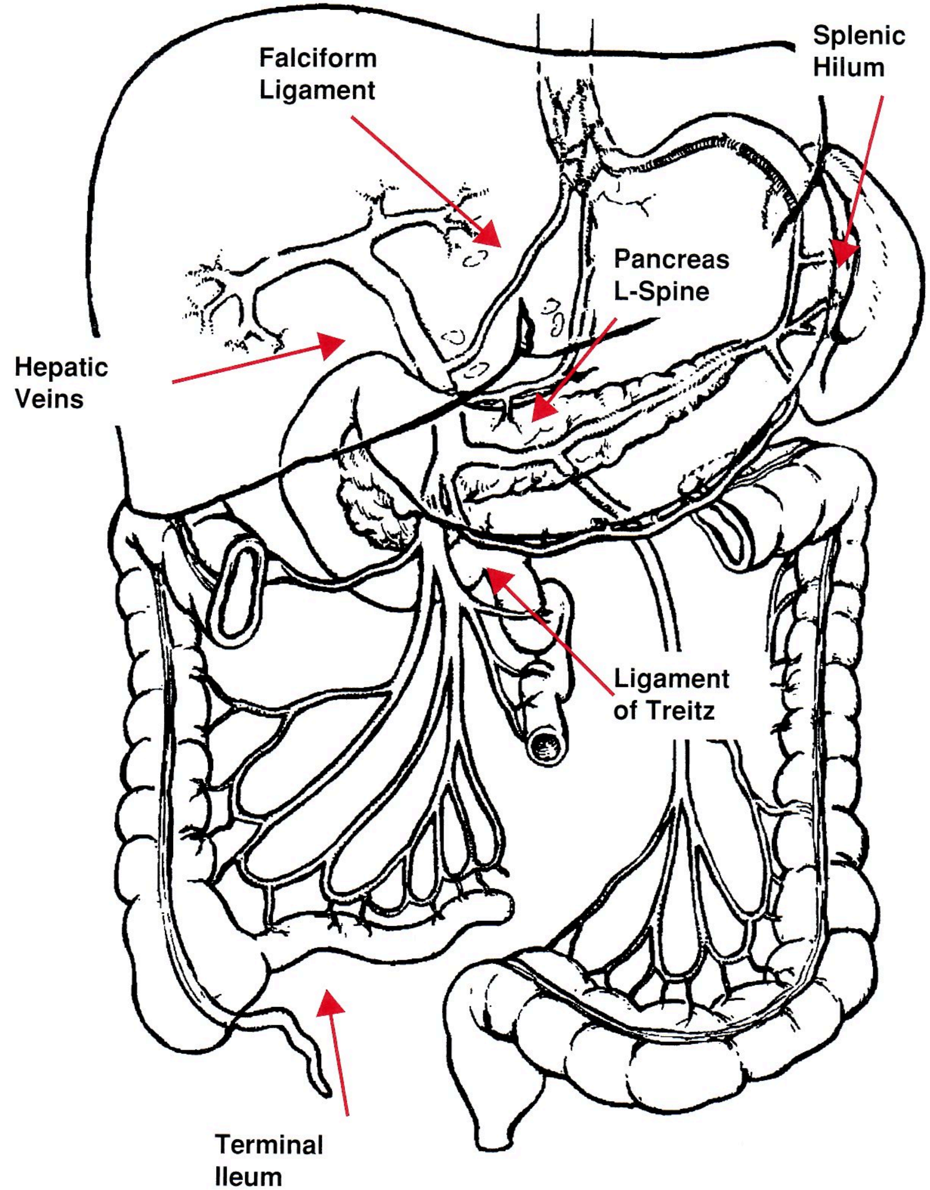


FIGURE 7-7. Points of shear strain in blunt abdominal trauma. All of these points occur where a relatively fixed structure is adjacent to a mobile structure.

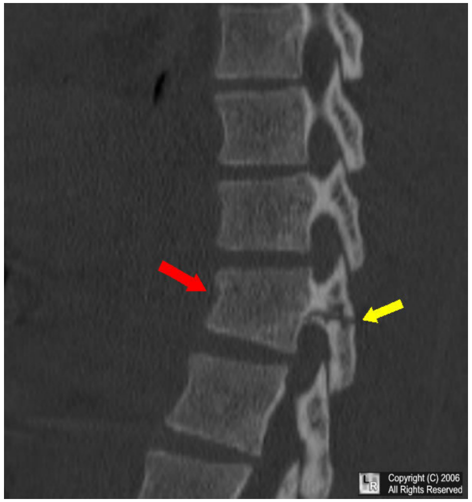
Incidence of organs injured

- Spleen
- Liver
- Kidney
- Small bowel
- Bladder
- Colon
- Diaphragm
- Pancreas
- Retroperitoneal duodenum

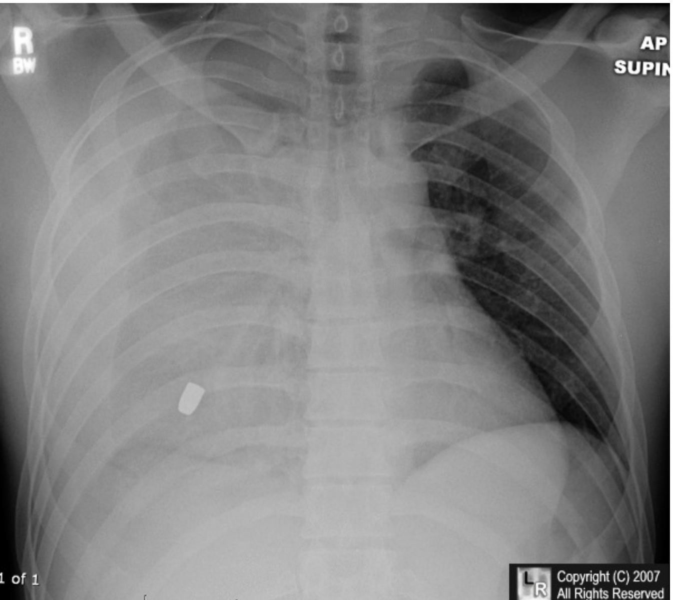
Physical Exam

- Inspect skin for evidence of blunt force trauma
  - Contusions, abrasion
  - Seatbelt sign
    - Injury to mesentery, bowel, and lumbar spine
      - What is this called?
  - Periumbilical and flank ecchymosis occur late in retroperitoneal hematoma
- Abdominal exam
  - Palpate for tenderness, guarding, rigidity
    - 40% of patients with hemoperitoneum have a negative exam
  - Distension
    - Hemoperitoneum
      - Less likely if vital signs are stable
- Rectal Exam
- Distal Pulses
  - Absence or assymetry

Figure 5-2 Lap Belt Injury. Injuries can result when a restraint device, such as a lap-type seat belt or shoulder harness component, is worn improperly.



Unstable Patients



- Decreasing BP, increasing HR, change in neuro status
- What can you do to check for bleeding?
  - Can they survive a trip to CT??
    - No…..
      - CXR to r/o HTX, PTX
      - PXR to r/o open book pelvis
      - AXR unhelpful
- What else can you do??

FAST Exam

- Blood will accumulate in the dependant regions of the abdomen
- Takes < 2min with experienced operator
- Looks at 4 areas for blood
  - In a specific order

FAST Exam

- 1^{st} – Pericardium
  - So blood in heart can be used to set gain
- 2^{nd} – Morrison's pouch
  - Most common place where blood can accumulate
- 3^{rd} – Spleno-renal Recess
- 4^{th} – Pouch of Douglas

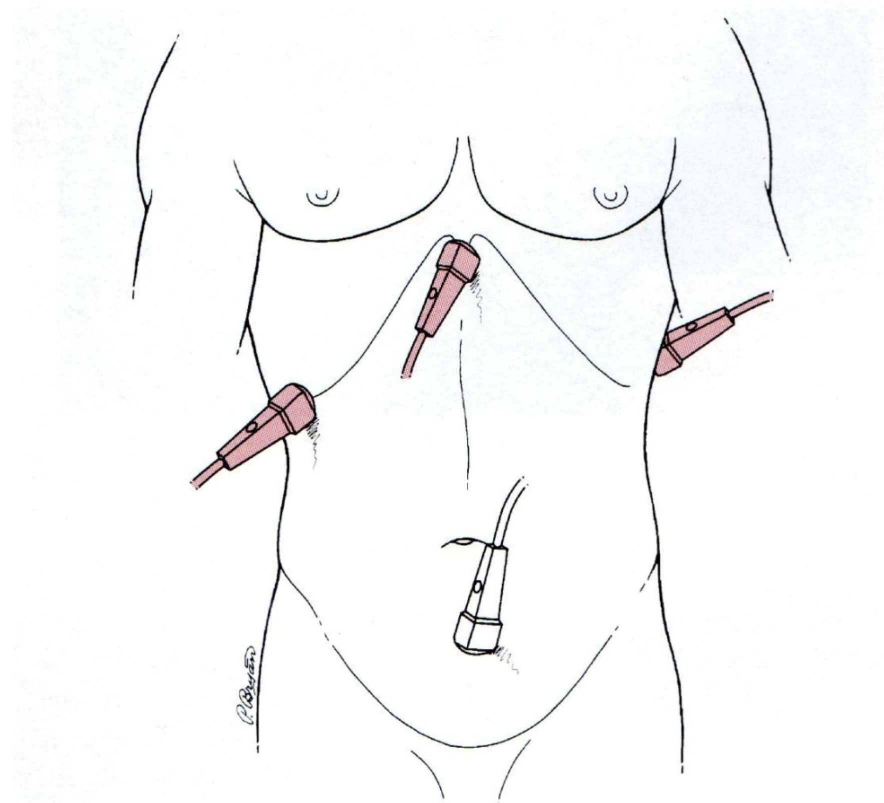
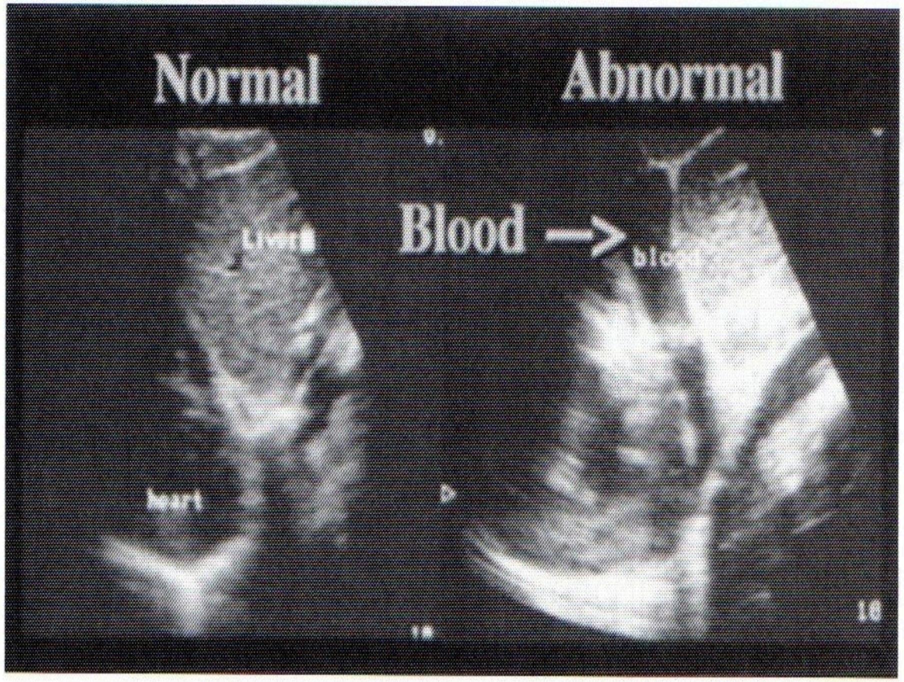
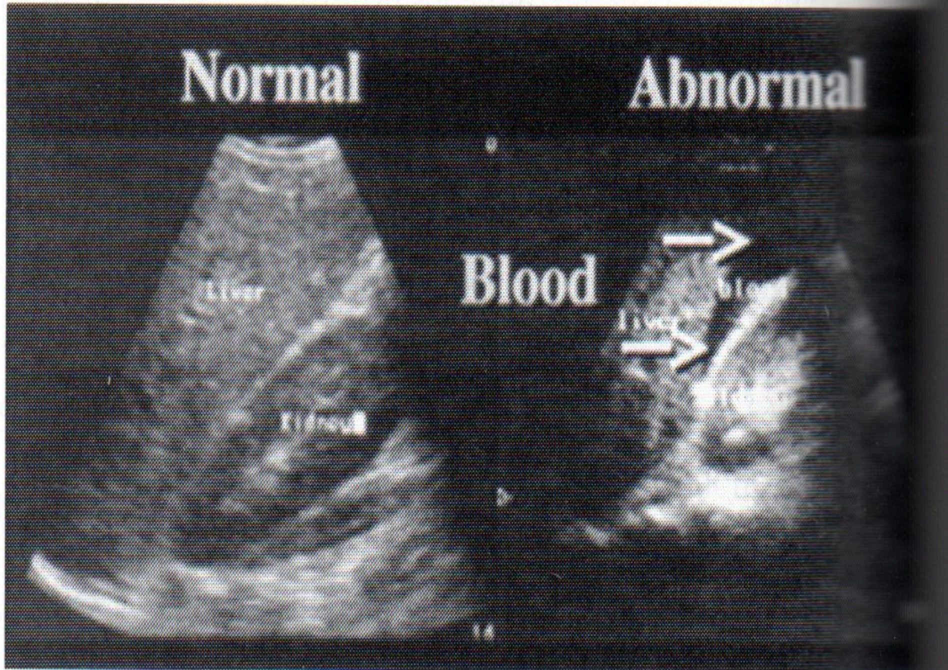
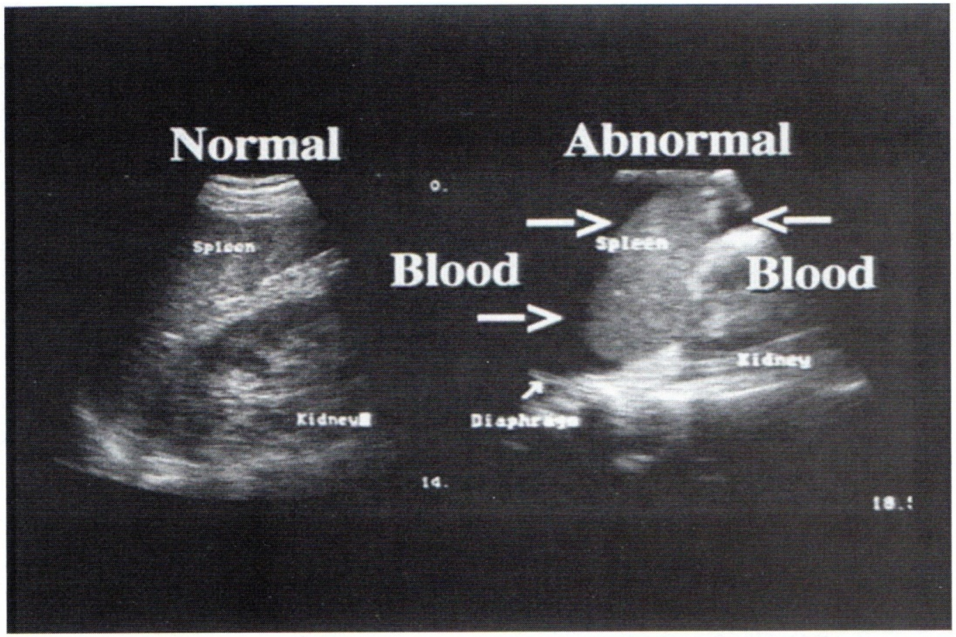
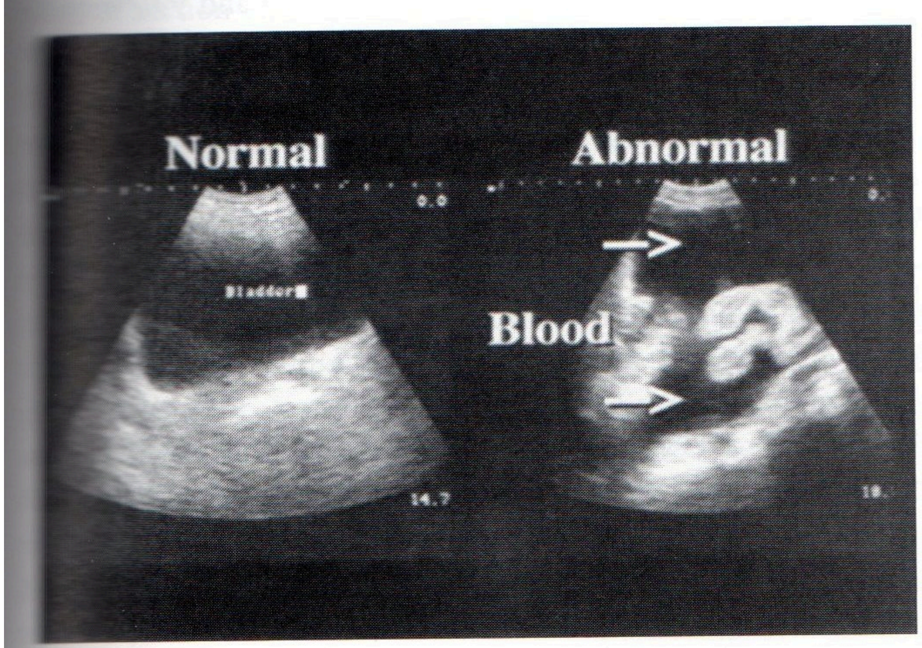


FIGURE 17-3. Schematic diagram of transducer positions for FAST: pericardial, right upper quadrant, left upper quadrant, and pelvis.


Normal
Abnormal
Blood
Liver
blood
heart


Normal
Abnormal
Blood
Liver
Kidney


Normal
Abnormal
Blood
Blood
Spleen
Spleen
Kidney
Kidney
Diaphragm


Normal
Abnormal
Blood
Bladder

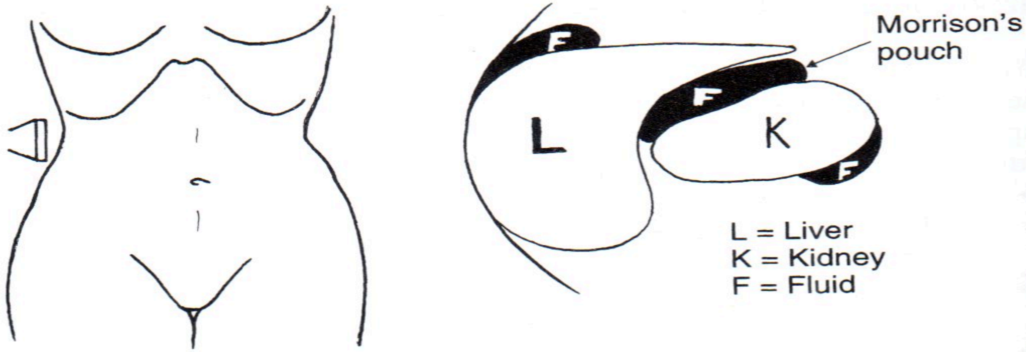


Figure 14–2

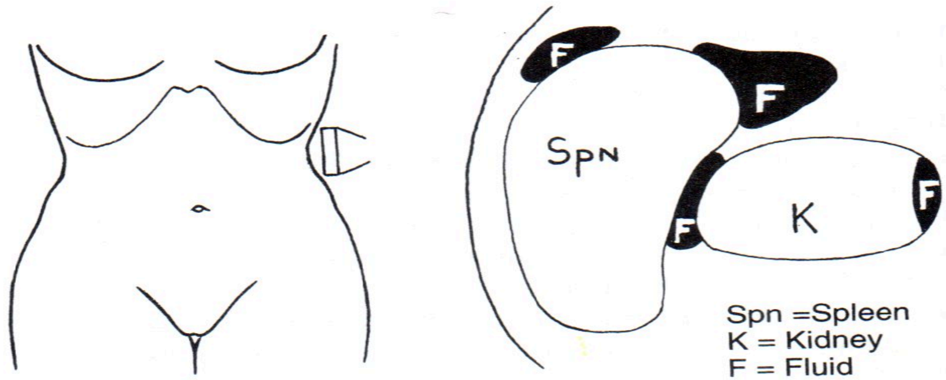


Figure 14–3

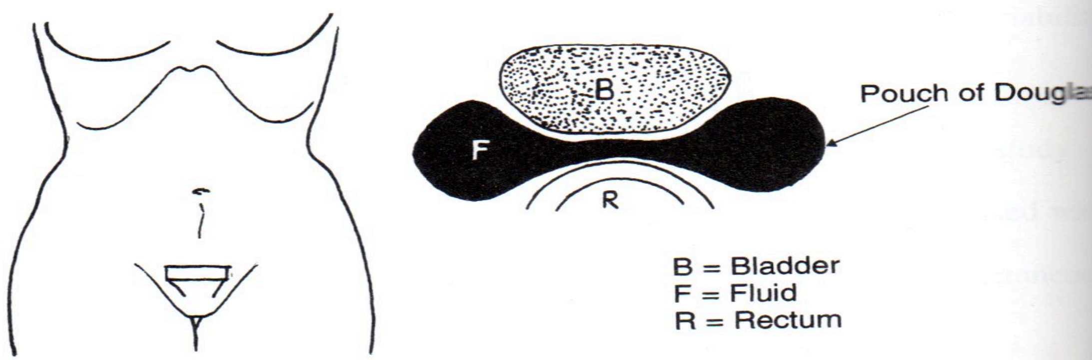
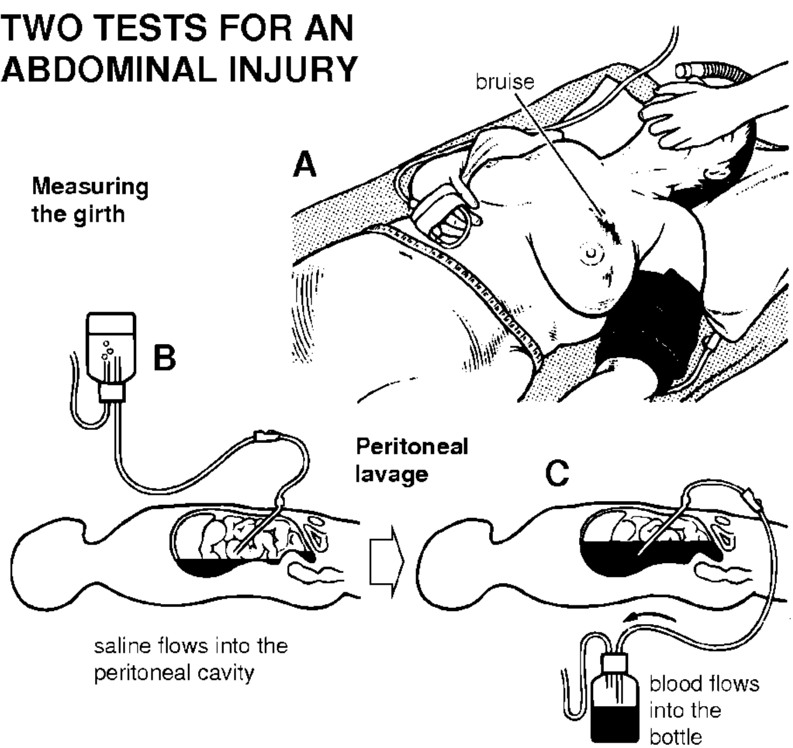


Figure 14–4

FAST Exam

- Advantages
  - Fast, inexpensive, noninvasive, portable
  - Allows for serial exams
  - Confirm placement of DPL fluid
- Disadvantages
  - Requires 70ml of fluid for positive result
  - Operator dependant
  - Does not give cause of bleeding, just that there is blood

Diagnostic Peritoneal Lavage



- Small infraumbilical incision and dissect to peritoneum
  - What are the 2 contraindications to this?
- Place catheter into opening and direct towards the pelvis
- Check for gross blood aspirate
  - If none, instill 1L NS into cavity, drop bag to floor and siphon back into the bag
- Positive if :
  - 10ml of gross blood
  - 100k RBC in fluid
  - 500 WBC in fluid
  - 20 IU/L of amylase in fluid
  - 3 IU/L of ALP in fluid

DPL

- Advantages
  - Accurate detection of hemoperitoneum
  - Low incidence of complications
- Disadvantages
  - Insensitive for diaphagmatic, bowel, and subcapsular injuries
  - Misses retroperitoneal injuries
  - Pelvic fractures can yield false positive
- Contraindications
  - Morbid obesity
  - Previous abdominal surgery
  - Pelvic fractures
  - Pregnancy

What now?

- If FAST exam or DPL is positive
  - Proceed directly to OR
- If FAST exam and DPL is negative and patient still unstable
  - Proceed directly to OR
- If FAST exam and DPL negative and patient is stable
  - CT scan

Abdominal CT

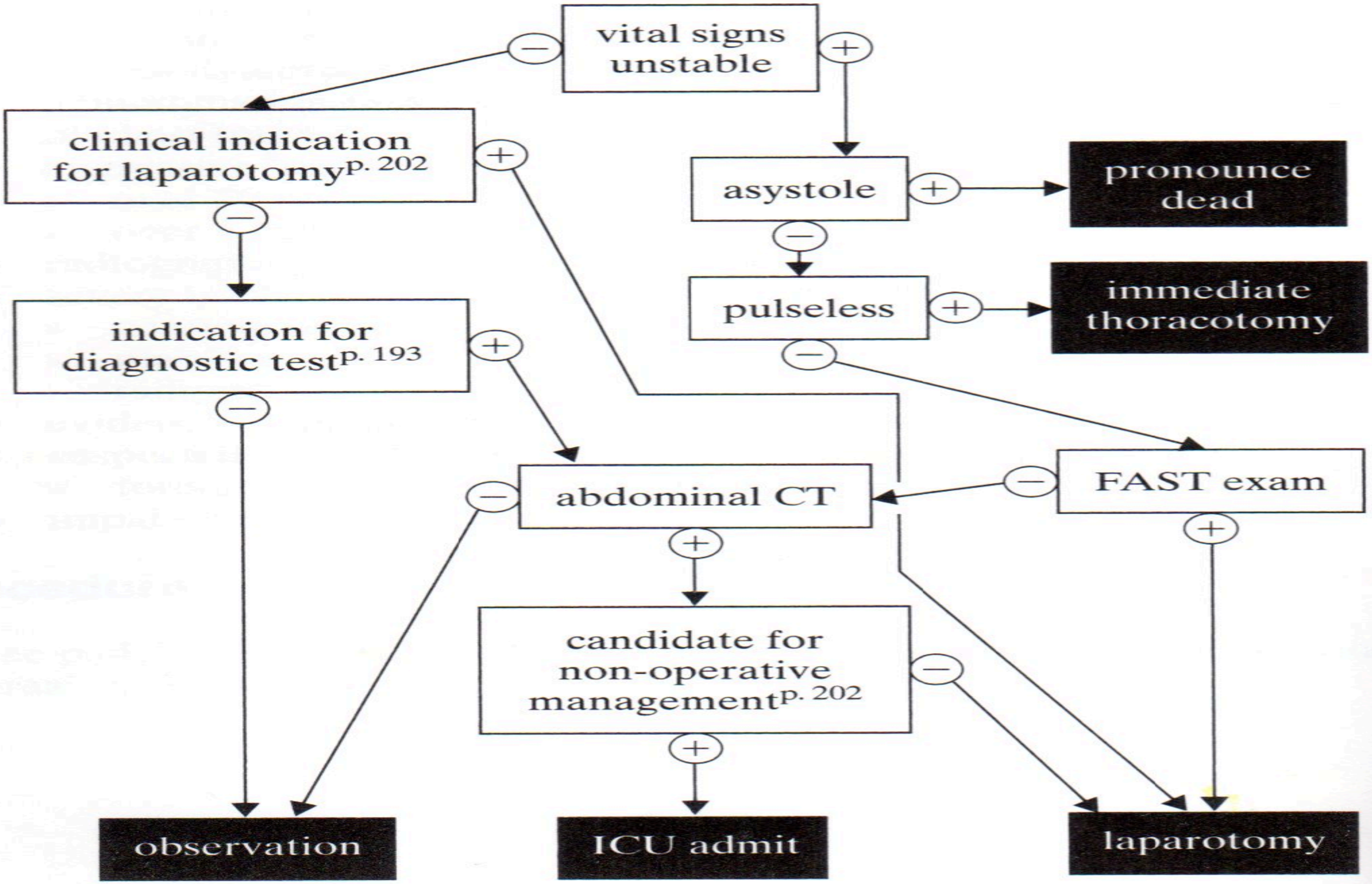
- Only if patient stable enough for trip
- Needs oral and IV contrast
- Advantages
  - Quantifies hemoperitoneum
  - Demonstrates specific organ injury
    - Allows classification of solid organ injuries
  - Identifies retroperitoneal injuries
  - Reveals HTX or PTX too small for CXR
  - Permits a one position study

Abdominal CT

- Disadvantages
  - Interpreter dependant
  - Can not identify hollow viscous injury
  - Increased time need for study
  - Patient can become unstable in scanner
  - Contrast adverse effects
    - Allergic
    - Renal

Abdominal CT

Blunt Abdominal Trauma

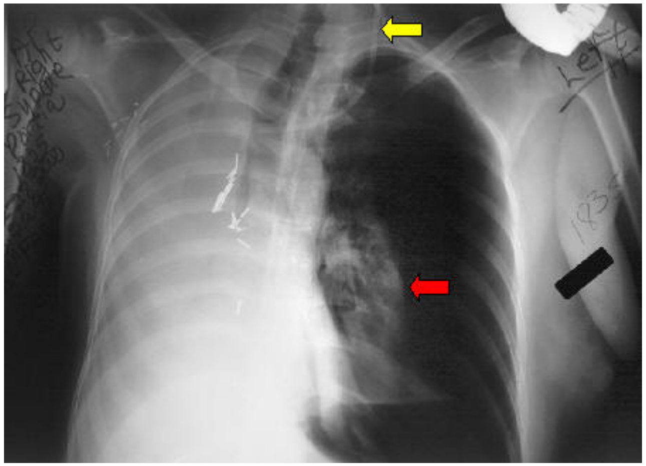


Blunt Chest Injuries

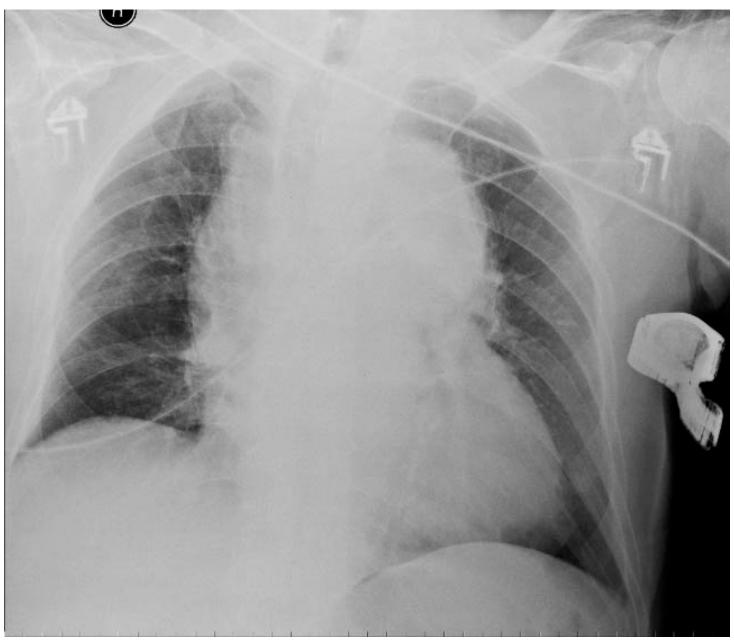
What you need to know from EMS

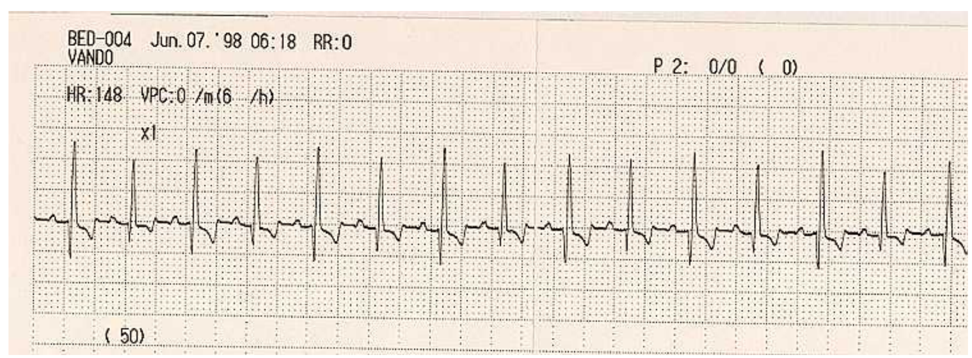
- Vital signs trends
  - BP, HR
- MVC
  - Seatbelt
  - Airbag deployment
  - Bent steering wheel
- Assault
  - If implements used

What you need ASAP



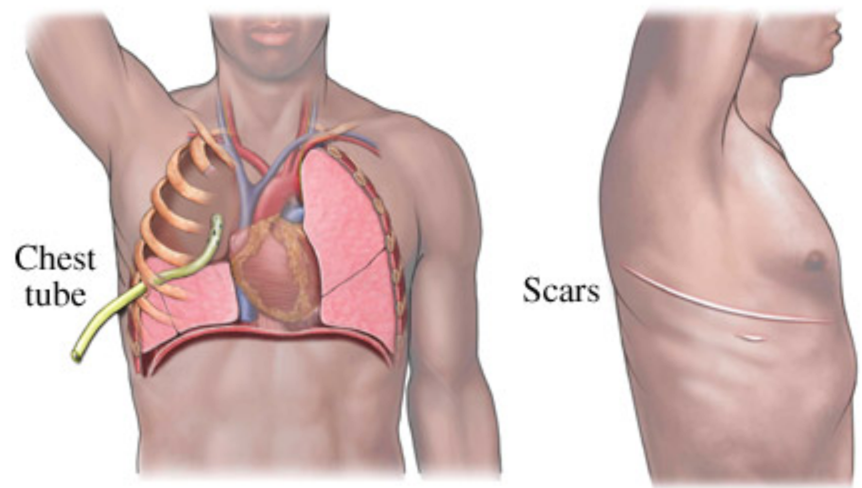
- CXR
  - HTX, PTX, pericardial effusion, widened mediastinum
- ECG
  - Electrical alternans
- Labs
  - CBC, CE, lactic acid



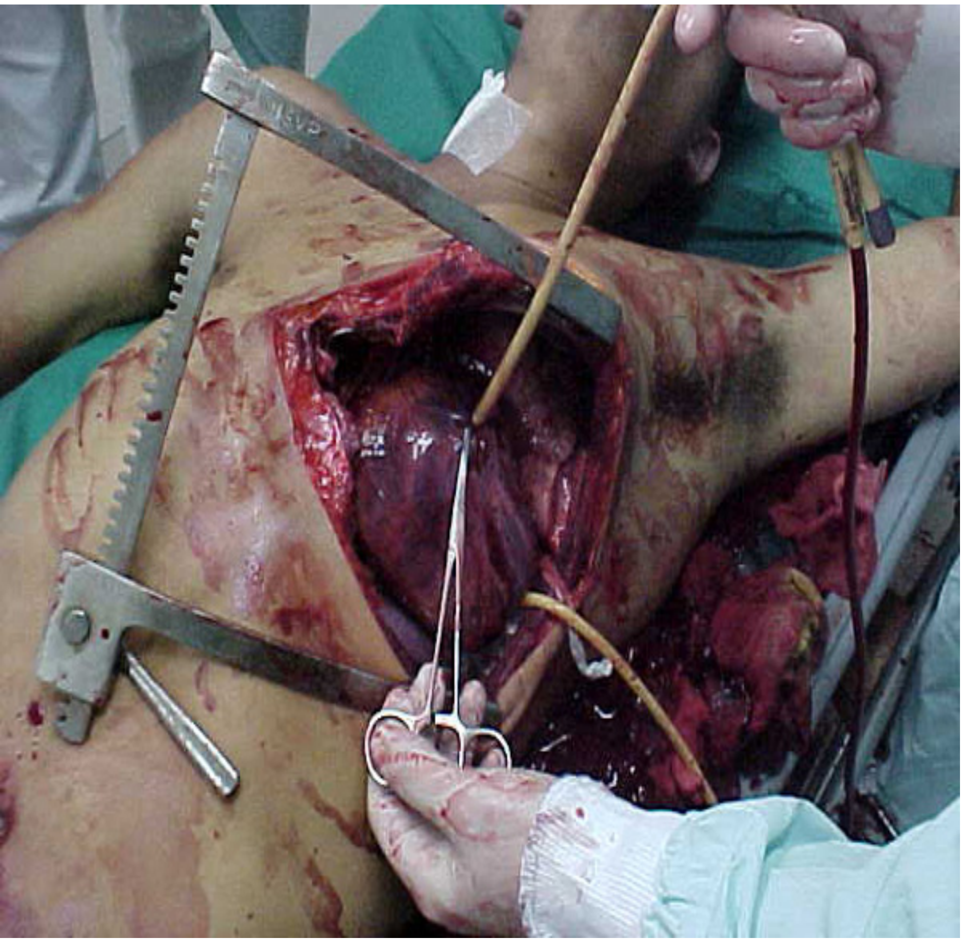


Unstable Patient

- Needle decompress
- Intubate
- Resuscitate
- Chest tube
- FAST exam with thoracic views



Unstable Patient



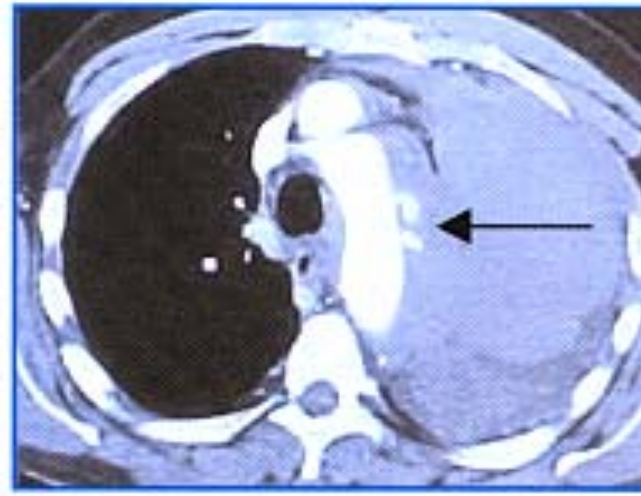
- Indications for thoracotomy
  - Witnessed event with < 5min prehospital CPR
  - Persistant severe hypotension (SBP<60)
    - Intrathoracic hemorrhage
      - CT output of 1500cc or 300cc/hr
    - Cardiac tamponade
    - Air embolism
  - Asystole after signs of life

Unstable Patient

- If patient becomes stable after inventions, proceed directly to OR for formal surgery and repair of structures

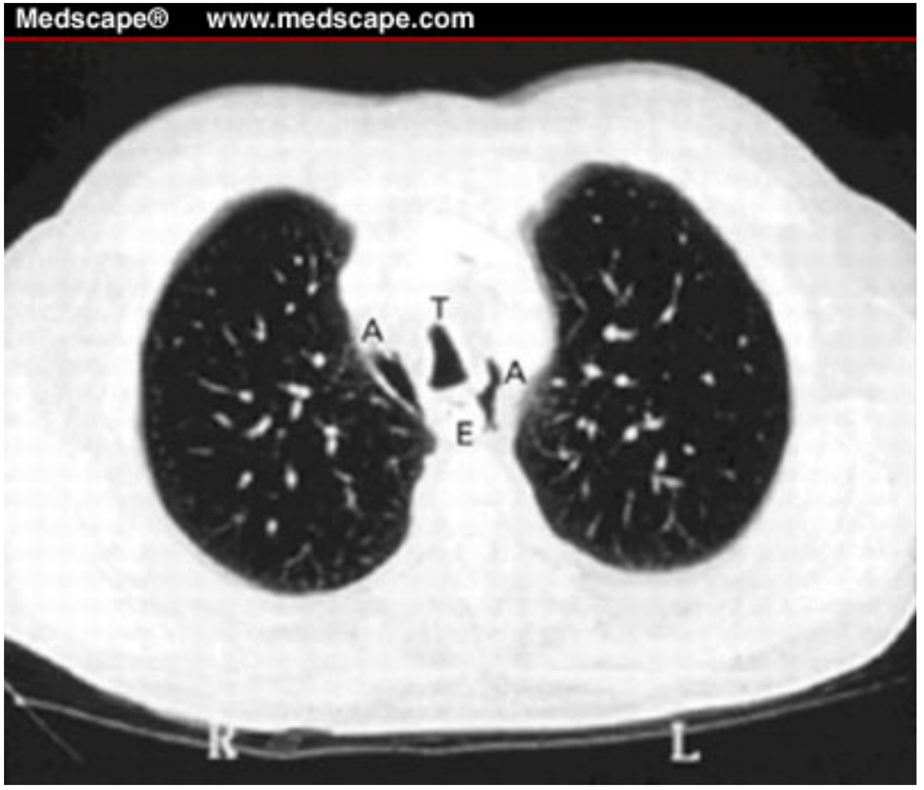
Stable Patient

- Chest CT with contrast
  - HTX, PTX, aortic injuries
- If positive seatbelt sign on neck
  - CT Angio for vasculature of neck
    - More pressing if patient has AMS

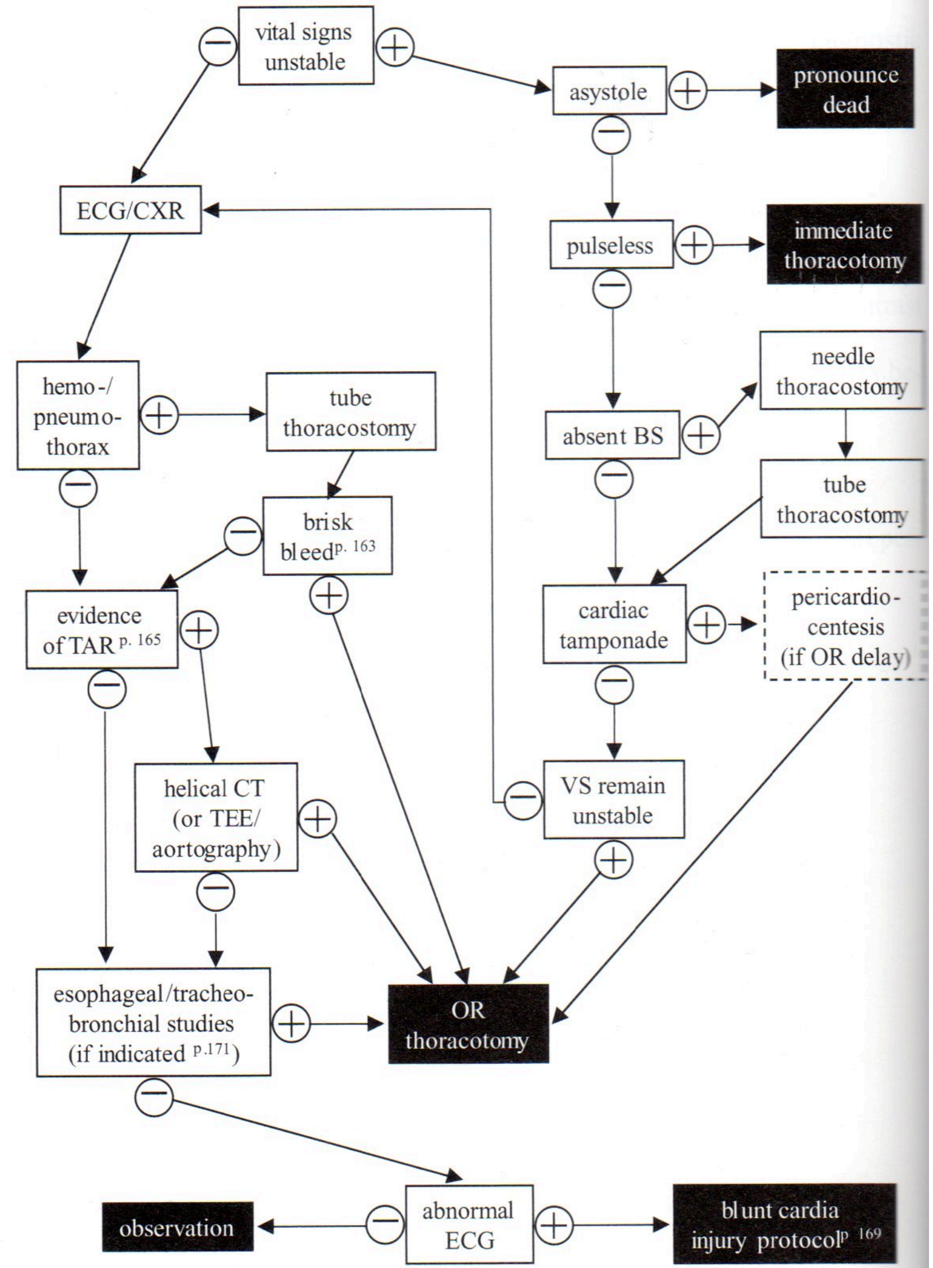


Stable Patient

- SQ emphysema, pneumomediastinum, pneumopericardium
  - Increase suspicion of esophageal injury
  - Proceed with esophagram, rigid endoscopy



Blunt Chest Trauma



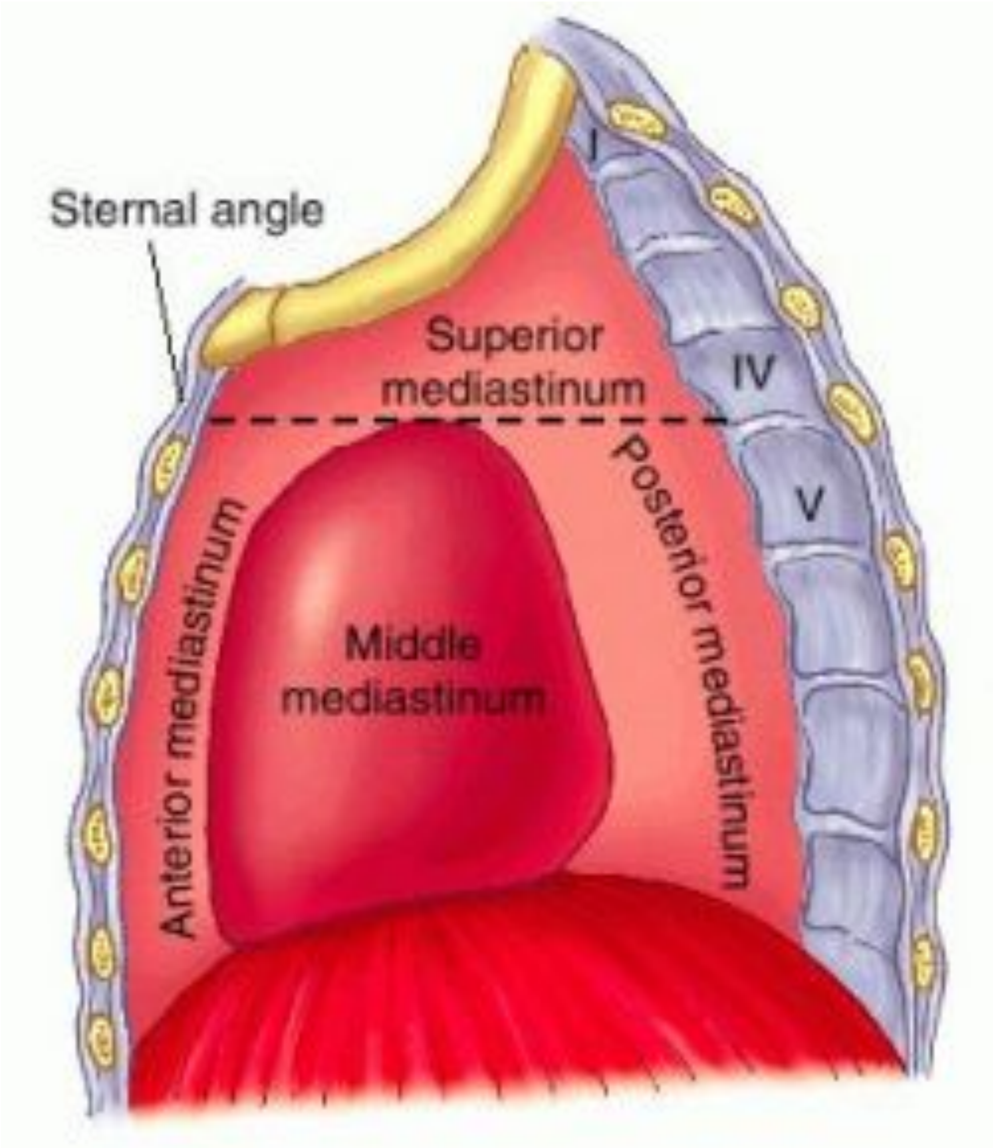
Penetrating Chest

Management

- Best guided by classifying anatomic areas of injury
  - Transmediastinal
  - Central
  - Thoracoabdominal
  - Peripheral
- Immediate CXR
  - Define associated injuries
  - Determine missile tract
- FAST exam with thoracic views
  - Significant HTX
  - Pericardial effusion
- Unstable patient :
  - Needle decompression
  - Intubation
  - Resuscitation
  - Thoracotomy

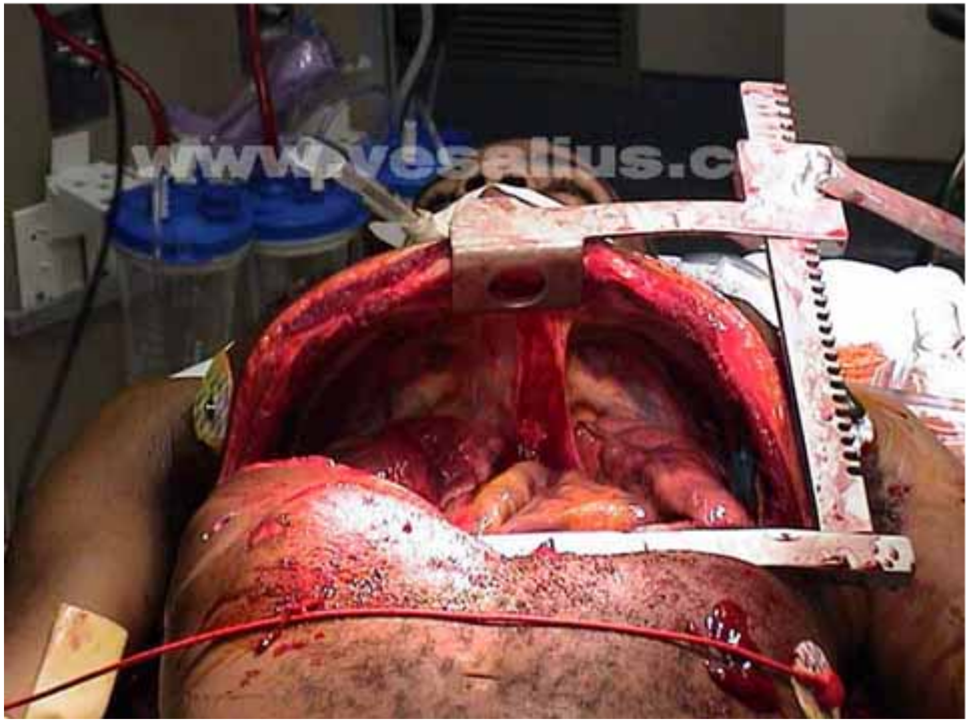
Transmediastinal

- Wounds that traverse the mediastinum
- 4 parts of mediastinum
  - Superior
    - Aortic arch, innominate artery, left carotid artery, subclavian artery, upper half of SVC, innominate veins, trachea, esophagus, thoracic duct
  - Anterior
    - Thymus, small branches of IMA, random lyphatic branches
  - Middle
    - Heart, ascending aorta, lower half of SVC, bifurcation of trachea, pulmonary artery, pulmonary veins,
  - Posterior
    - Descending thoracic aorta, greater and less azygos veins, esophagus, thoracic duct



Transmediastinal

- 2/3 are lethal injuries
- Management
  - Be prepared for thoracotomy is patient becomes pulseless
    - Clamshell might be necessary to control right sided bleeding
  - Echocardiography
    - Reveals cardiac injuries
  - Aortography
    - Aorta and great vessels
  - Esophagram
  - Bronchoscopy



Central

- "The Box"
  - Superior border
    - Suprasternal notch and clavicles anteriorly
    - Superior aspect of scapulae posteriorly
  - Inferior border
    - Subxiphoid anteriorly
    - Costal margins posteriorly
  - Lateral borders
    - Medial to nipples anteriorly
    - Medial to the medial scapular boders posteriorly

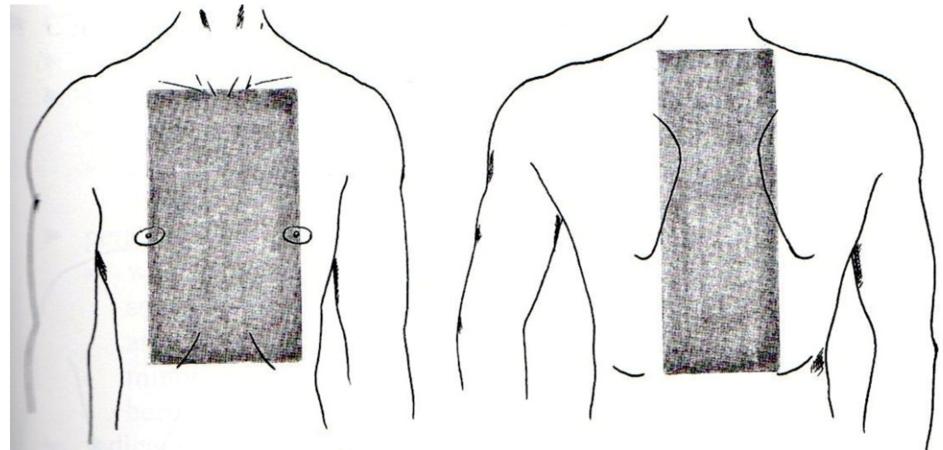
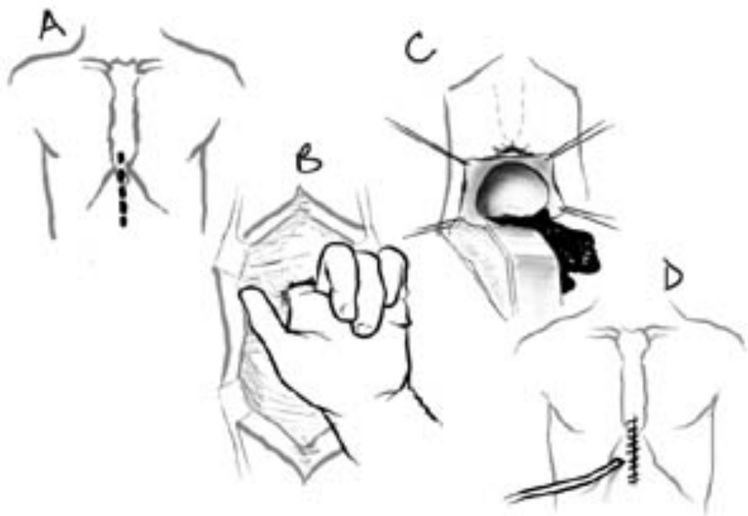
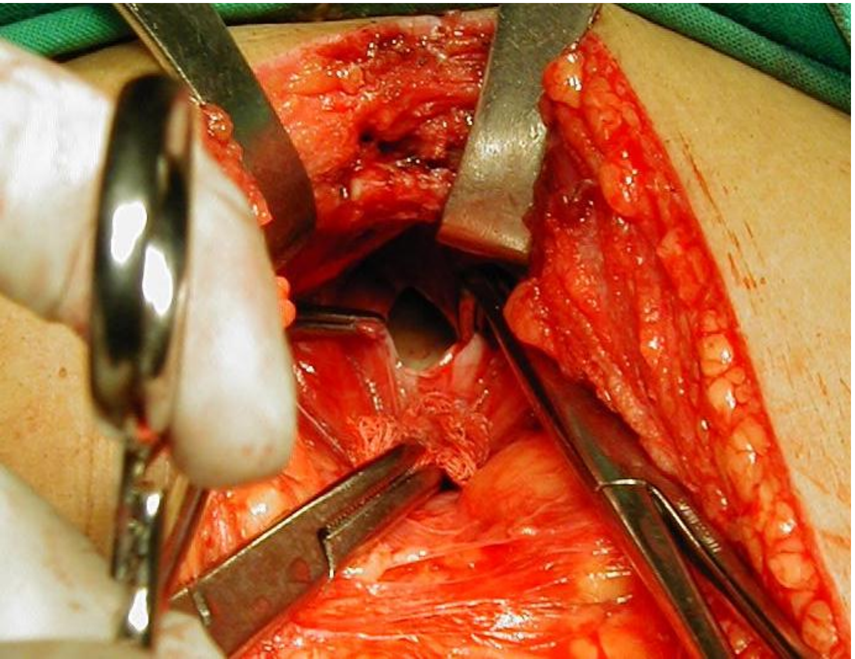


Figure 13–1

Central

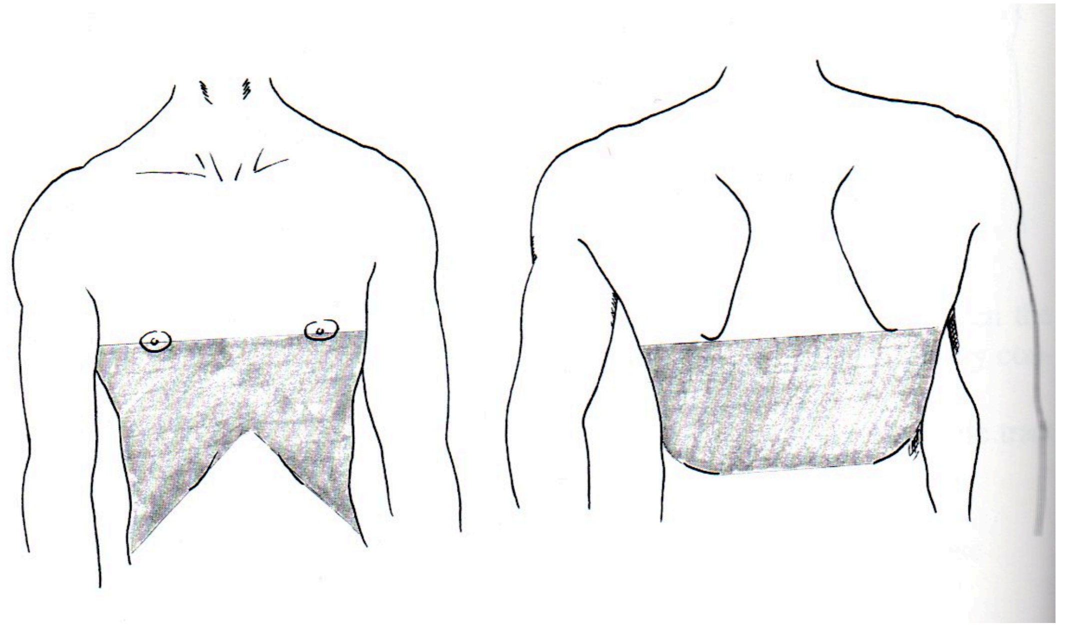


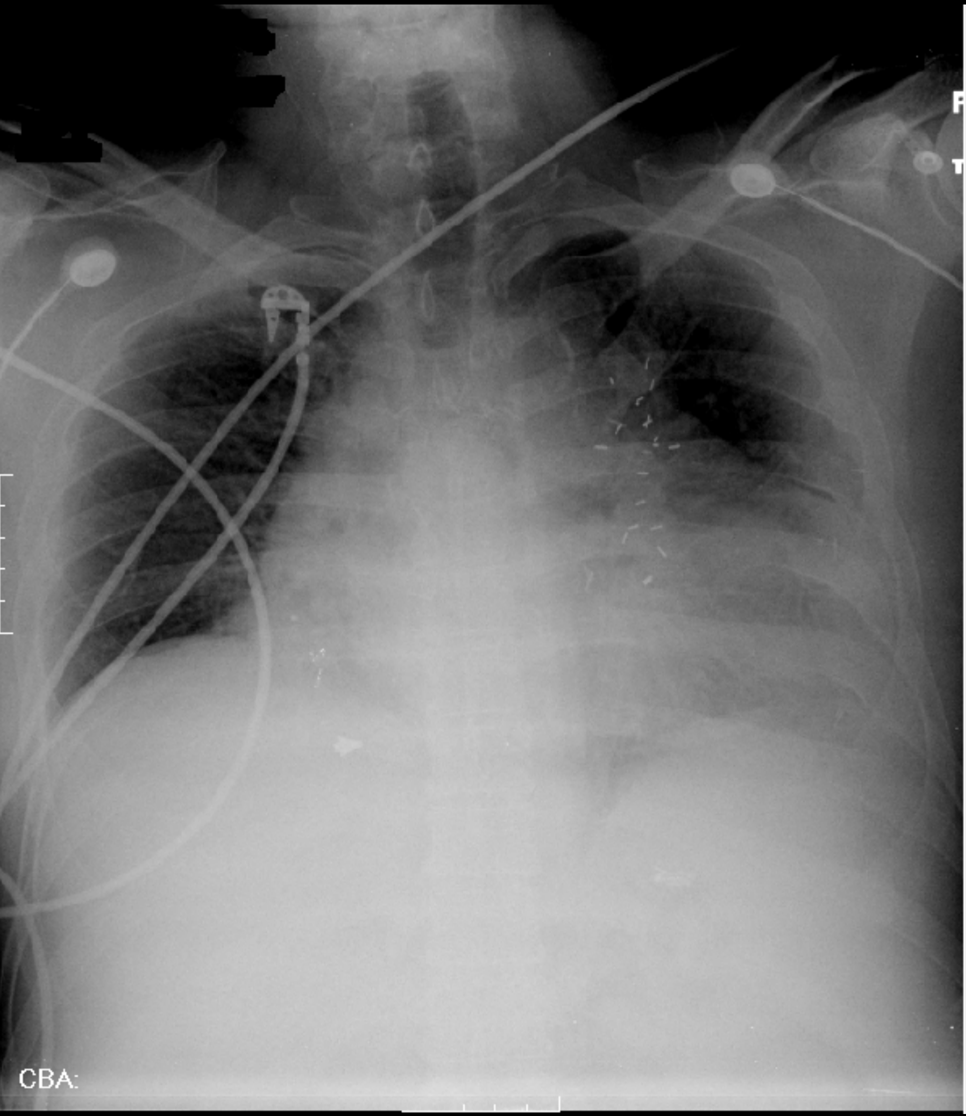


- Anterior central wounds
  - ECHO to exclude hemopericardium
    - Repeat after 6hr
    - If unavailable, Chest CT
    - Pericardial window if positive
- Posterior central wounds
  - ECHO if :
    - Missile tracts approach mediastinum
    - Deep stab wound
  - Arch aortogram if :
    - Wound tract near aorta
    - Clinical suspicion for aortic injury
  - Esophagram/esophagoscopy if:
    - Wound trach near esophagus
    - Clinical suspicion of esophageal injury

Thoracoabdominal

- Location
  - Below niples and above costal margin anteriorly
  - Below scapulae and above costal margin posteriorly

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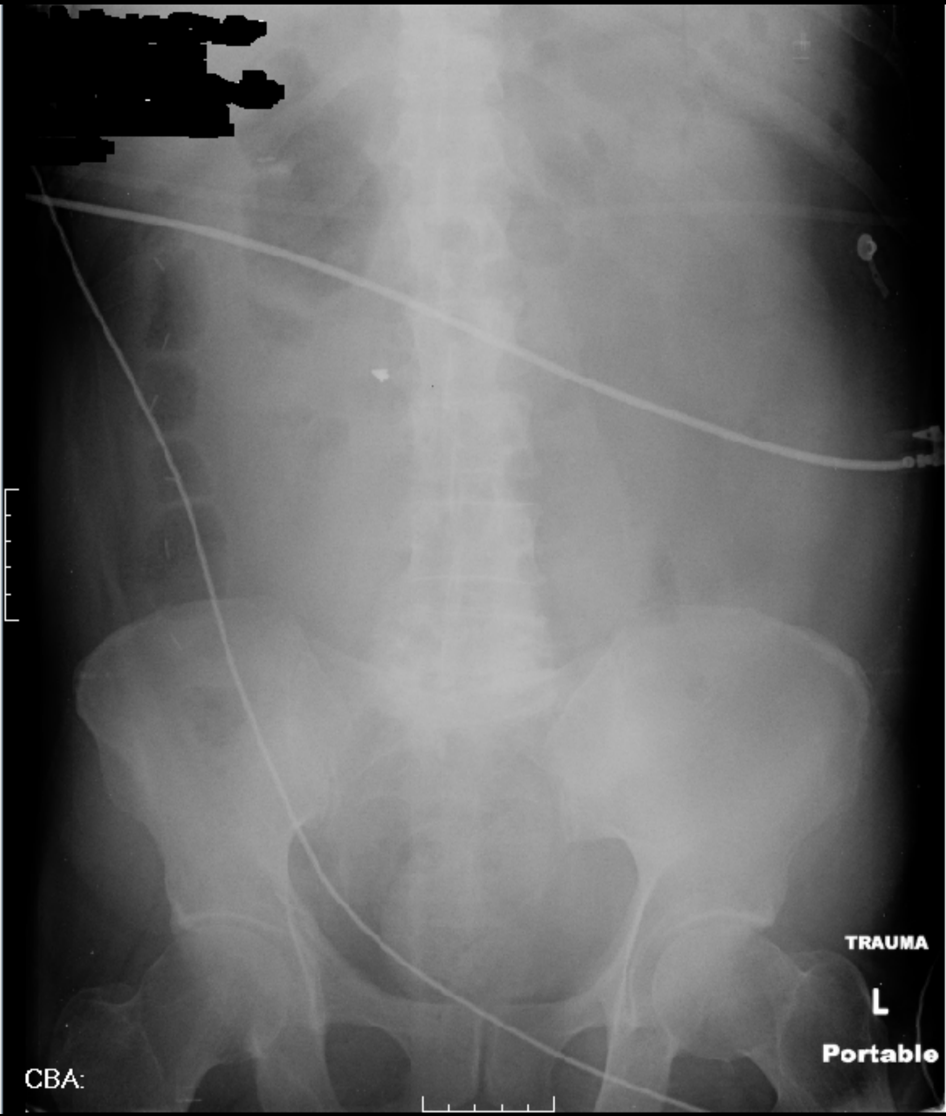
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TRAUMA
L
Portable
CBA:

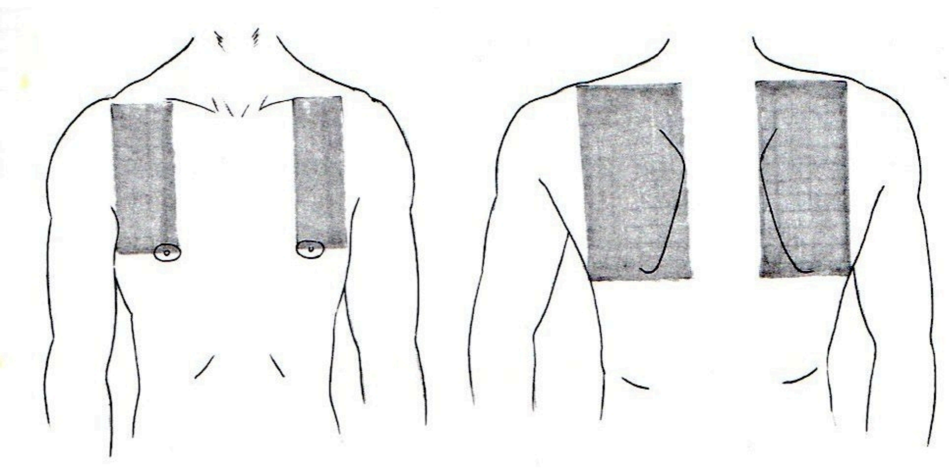
Thoracoabdominal

- Diaphragm can position can change as much as 3-5 cm during normal respirations
  - Diaphragm penetration occurs:
    - 45% of thoracoabdominal GSW
    - 15% of thoracoabdominal stab wounds
- Missed diaphragmatic injure can result in herniation of abdominal contents, strangulated small bowel or stomach
  - Most commonly on left due to protective nature of liver on the right

Thoracoabdominal

- DPL
- CT
  - Low sensitivity for diaphragm injuries
    - 60%
  - Used with DPL to incease accuracy
  - Used in posterior thoracoabdominal wounds
    - Wth triple contrast for retroperitoneal injury.
- Ultrasound
  - Determine fascial penetration
    - Negative = no injury
- FAST exam

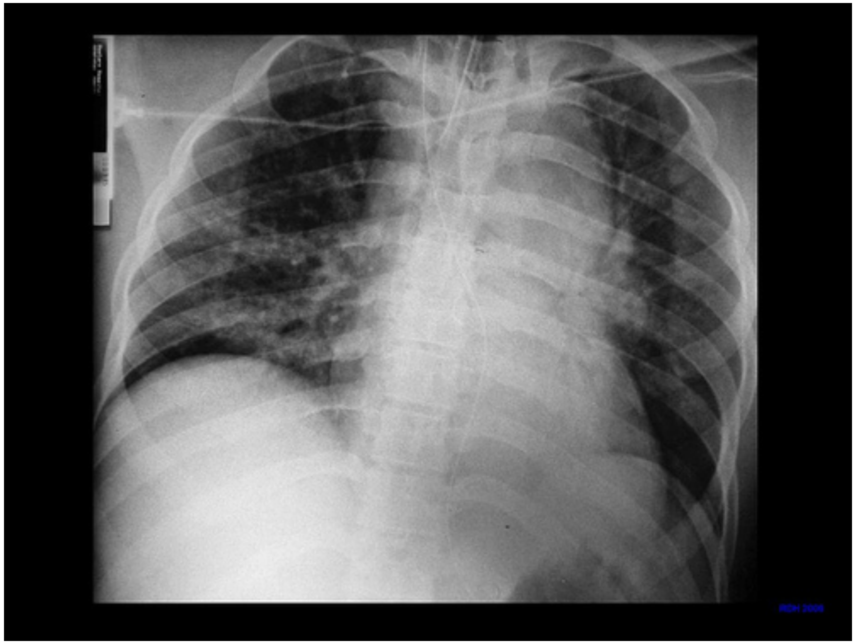
Peripheral



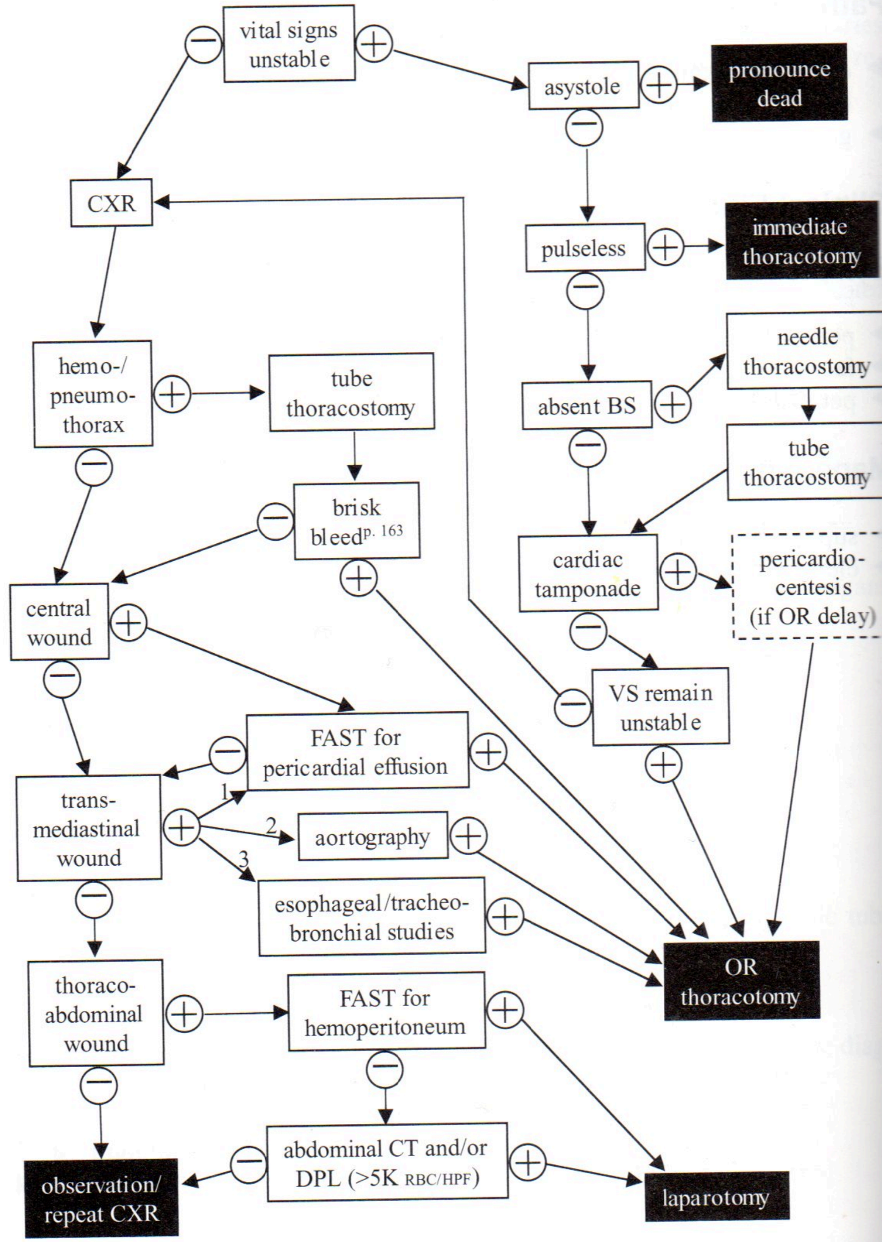
- Location
  - Anterior
    - Lateral to nipples
    - Above the nipple line
  - Posterior
    - Lateral to the medial scapular borders
    - Above the tips of the scapulae

Peripheral

- Patients with peripheral injuries with negative CXR x2 can be discharged home
  - 2nd CXR 6h later
- Angiography indications
  - Enlarging supraclavicular or axillary hematoma
  - Ongoing bleeding from CT
  - Apical hematoma on CXR
    - Suspicious for brachiocephalic or subclavian artery injury
  - Upper extremity pulse deficit
  - Near a major artery or brachial plexus



Penetrating Chest Trauma



Damage Control Surgery

Definition

- Limited operation for control of hemorrhage and contamination and temporary closure
- Resuscitation in ICU
- Planned reoperation when stable

Factors to consider

- Time consuming operation
- Non-operative management of extraabdominal injuries
- Inaccessible vascular injury
- Planned second look
- Metabolic failure during operation

TABLE 41-1

Patients Likely To Need Damage Control Operations
Thoracic Trauma
• Penetrating thoracic wound and systolic blood pressure <90 mmHg
• Pericardial fluid on surgeon-performed ultrasound after blunt or penetrating thoracic trauma
• S/p emergency department thoracotomy for penetrating thoracic wound
Abdominal or Pelvic Trauma
• Penetrating abdominal wound and systolic blood pressure <90 mmHg
• Blunt abdominal trauma, systolic blood pressure <90 mmHg, and peritoneal fluid on surgeon-performed ultrasound or gross blood on diagnostic peritoneal tap
• Closed pelvic fracture, systolic blood pressure <90 mmHg, and peritoneal fluid on surgeon-performed ultrasound or gross blood on diagnostic peritoneal tap
• Open pelvic fracture
Trauma to an Extremity
• Shotgun wound to femoral triangle of thigh
• Mangled extremity from blunt trauma
General
• Emergency laparotomy to be followed by emergent craniotomy for compressive lesion, emergent thoracotomy for repair of ruptured descending thoracic aorta, or therapeutic embolization of pelvic bleeder related to fracture

Metabolic Failure

- Hypothermia (< 35°C or 95° F)
  - 66% of severely injured trauma patients had temps < 36° C
    - 23% < 34° C
  - Causes
    - Hypovolemia
      - Loss of warm blood and decreases oxygen consumption, which decreases heat production
    - Exposure in field, trauma bay, OR
  - Complications
    - Promotes platelet sequestration and dysfunction
    - Increases fibrinolytic activity

Metabolic Failure

- Acidemia (pH < 7.2)
  - Manifestation of anaerobic metabolism occuring during hypoperfusion
  - Can lead to irreversible decrease in CO, hypotension, and ventricular arrythmias
  - Can cause uncoupling of β-andrenergic receptors
    - Decrease response to catecholamines

Metabolic Failure

- Coagulopathy (PT/PTT > 50% normal)
  - Resuscitation can precipitate coagulopathy secondary to dilution, deficiency of clotting factors, hypothermia
    - 4U PRBC = 1U FFP
  - Factor VII has promise in trauma patients
    - Helps generate a thrombin peak
    - Decrease transfusion requirements
    - 8U PRBC = 1U Factor VII

Deadly Triad

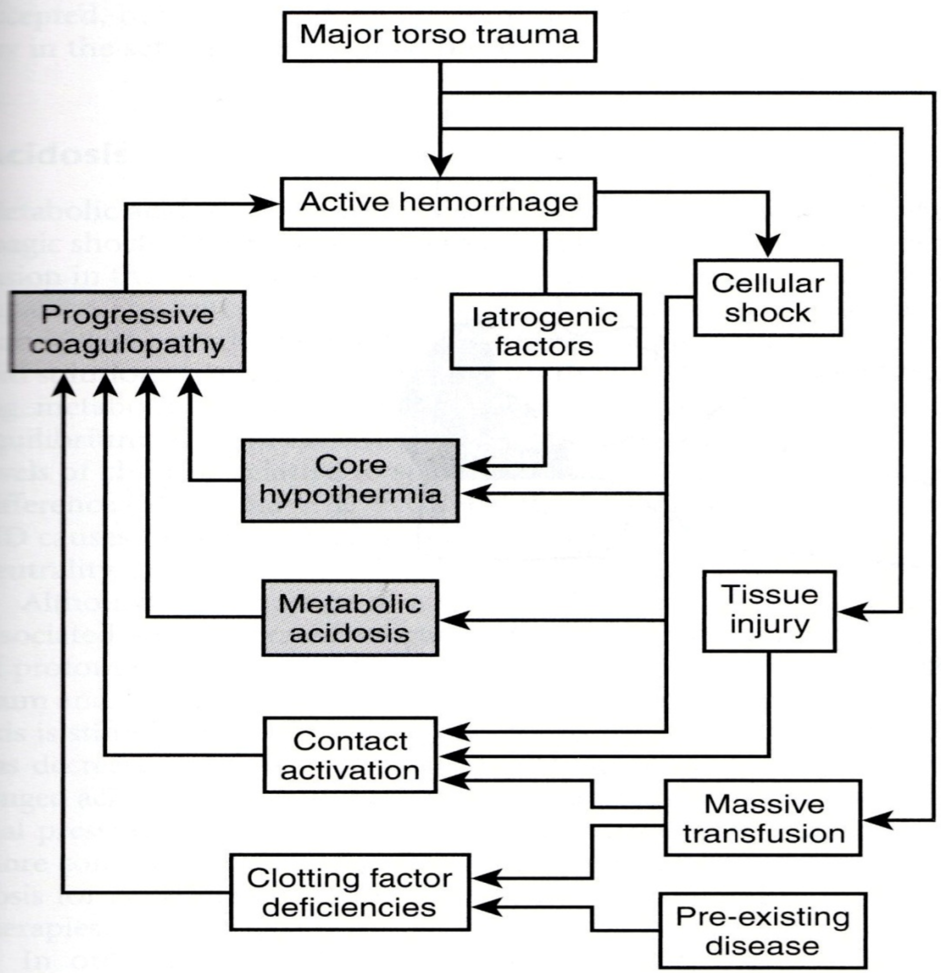


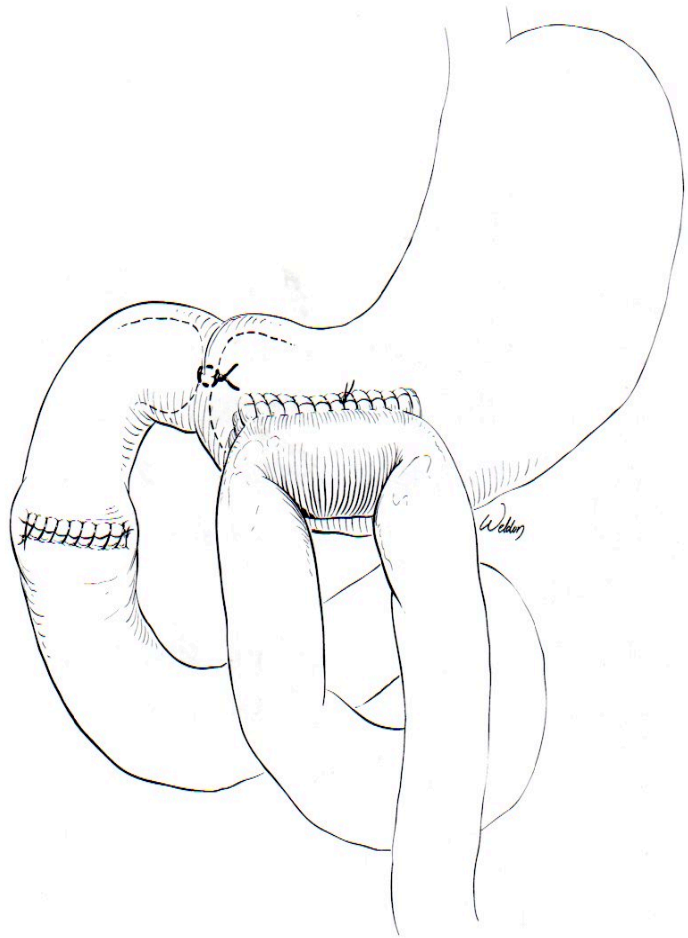
Figure 4 **The lethal triad.** *(Adapted from Moore EE: Staged laparotomy for the hypothermia, acidosis, coagulopathy syndrome. Am J Surg 172:405–410, 1996, with permission of publisher.)*

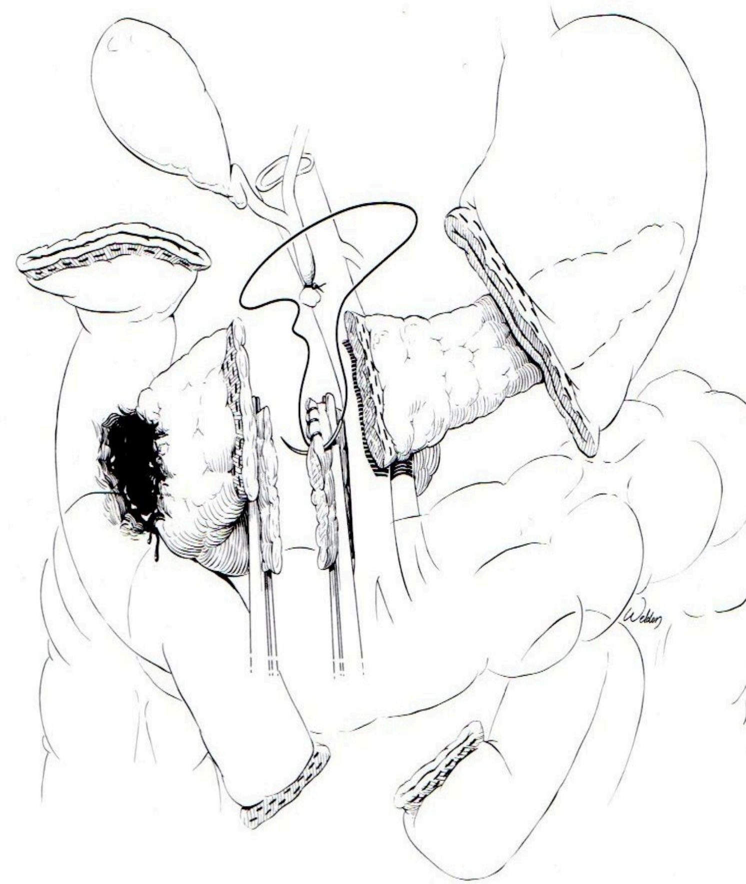
The Operation

- Liver
  - Hepatorraphy with omental packing
  - Lap pad packing
- Spleen
  - Grade III, IV, V → splenectomy
  - Grade I or II → splenorrhaphy and packing

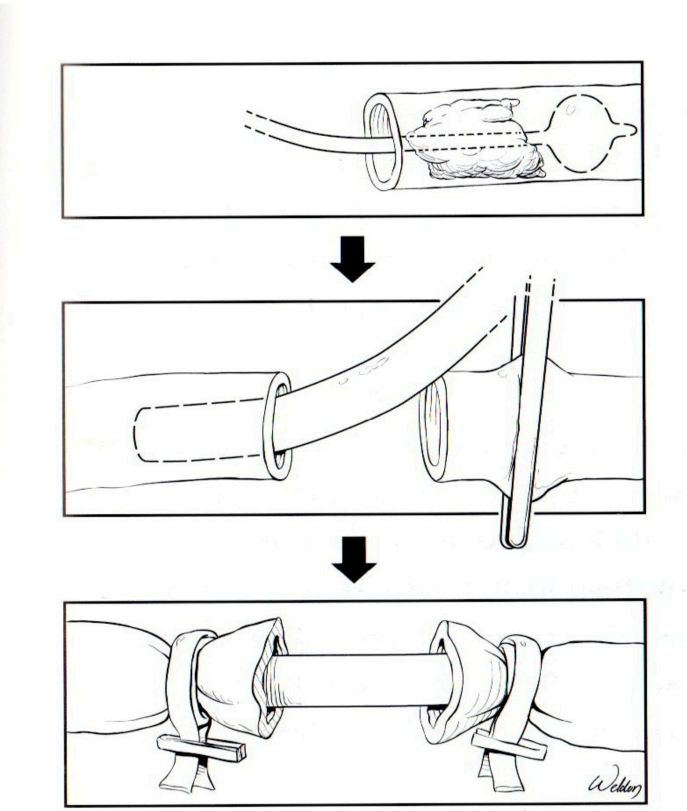
The Operation

- GI Tract
  - Stomach → repair, gastrectomy if severe
  - Duodenum → stapled off, pyloric exclusion
  - Small Bowel → repair vs resect
  - Colon → repair vs resect
- Pancreas
  - Pack, drain, resect when stable
  - Trauma Whipple


Weldon


Weldon

The Operation



- Vascular Injuries
  - Repair, ligate, shunt

What can you ligate

Table 2: Abdominal Vessel Ligation and Expected Complications

Vessel	Complication	Recommendations
Celiac axis	None	
Splenic artery	None if the short gastric vessels are intact	
Common hepatic artery	None if the portal vein is intact, possible gallbladder ischemia	Cholecystectomy (may be done at second look)
Superior mesenteric artery	Bowel ischemia	Second-look procedure
Superior mesenteric vein	Bowel ischemia	Second-look procedure
Portal vein	Bowel ischemia	Second-look procedure
Suprarenal inferior vena cava	Possible renal failure	Wrap and elevate legs, assess for compartment syndrome
Infrarenal inferior vena cava	Lower extremity edema	Wrap and elevate legs, assess for compartment syndrome
Left renal vein (proximal)	None	
Right renal vein	Renal ischemia	Nephrectomy
Common and external iliac artery	Lower extremity ischemia	Ipsilateral calf and sometimes thigh fasciotomies or extra-anatomic bypass
Common and external iliac vein	Lower extremity edema	Wrap and elevate legs
Internal iliac artery	None	
Internal iliac vein	None	

When to bail out

Table 4: Clinical Guidelines to Abort Initial Trauma Celiotomy and Initiate Damage Control Maneuvers

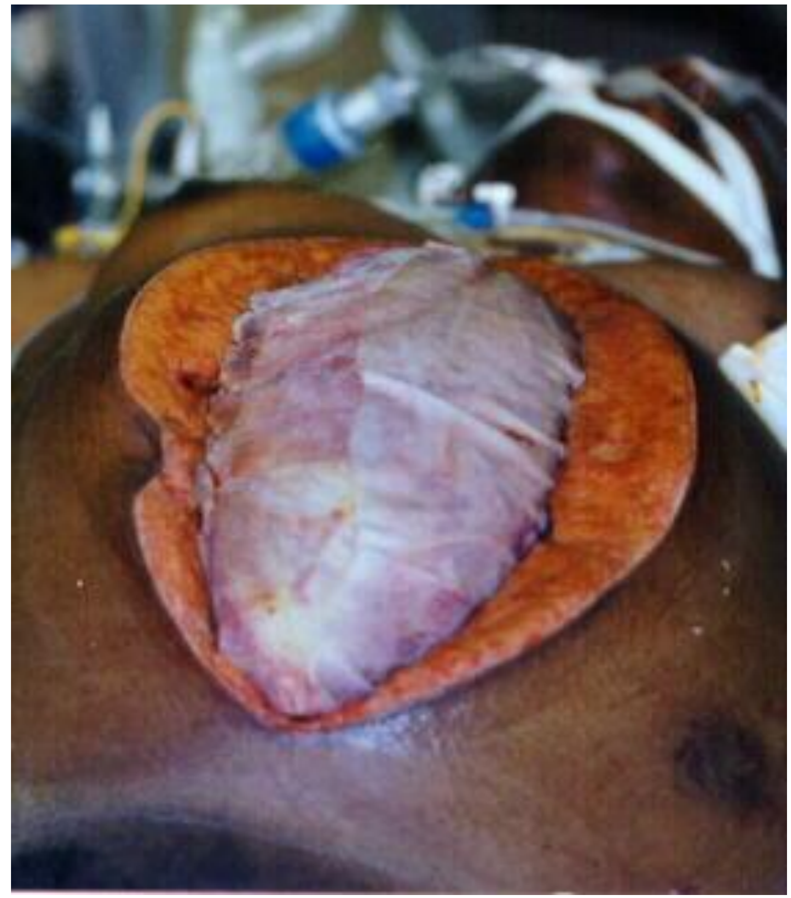
Hypothermia	<35° C
Acidosis	pH <7.2 Base deficit (BD) ≥–8 Lactate ≥4
Coagulopathy	Activated partial thromboplastic time (aPTT) >60 International normalized ratio (NR) >1.6
Ongoing resuscitation	Persistent shock systolic blood pressure <90 >10 liters crystalloid >10 units packed red blood cells
Operative time	>60–90 minutes with abdominal cavity opened

How to close

- Bogata Bag
  - Inexpensive
  - Readily available
  - Allows visualization of underlying structures
  - Can still eviscerate
  - Can lead to ventral hernia and need for skin grafting

How to close

- Whittman's Patch
  - Two sheets of biocompatable material sutured into opposing fascia
  - Sheets adhere to each other to provide secure temporary closure
  - Allows for progressive closure



How to close

- Skin Only closure
- Towel clips
- VAC closure
- Zippers
- Vicryl mesh

When to go back to OR

TABLE 41-7

Indications for Emergent Return to the Operating Room after A Damage Control Laparotomy

BLUNT TRAUMA	PENETRATING TRAUMA
Normothermic but bleeding >2 U/h	Bleeding >15 μ and hypothermia
Abdominal compartment syndrome with ongoing blood loss	Normothermic but bleeding >2 U/h
Abdominal compartment syndrome with ongoing blood loss	

Reproduced with permission from Morris JA Jr, Eddy VA, Rutherford EJ: The trauma celiotomy:

TABLE 41-8

Guidelines for Elective Return to the Operating Room After A Damage Control Laparotomy

Temperature >30°C [96.8°F]
Acid-base balance
Base deficit corrected to >–5 mmol/L if originally <–15 mmol/L
Serum lactate normal or correcting gradually
Coagulation
Prothrombin time <15 s
Partial thromboplastin time <35 s
Platelets >50,000/μL
Cardiovascular
Cardiac index >3 L/min/m^2, with or without low-dose inotrope
Pulmonary
Fraction of inspired oxygen <0.50
O_2 saturation >95%

Modified with permission from Morris JA Jr, Eddy VA, Rutherford EJ: The trauma celiotomy: The evolving concepts of damage control. Curr Prob Surg 33:611, 1996.

Abdominal Compartment Syndrome

- Increased intraabdominal pressure due to post-resuscitative and post-injury swelling
- Measure bladder pressure
  - 10-15mmHg – maintain normovolemia
  - 16-25mmHg – hypervolemic resuscitation
  - 26-35mmHg – decompression
  - >35 – decompression and re-exploration

TABLE 41-4

Clinical and Laboratory Manifestations of Increased Intra-abdominal Pressure[24,25,137,138,145–172]

Abdominal

Body wall[145,146]
- Decreased blood flow

Gastrointestinal tract[147–151]
- Decreased mucosal blood flow and intramucosal pH
- Possible bacterial translocation

Hepatic[152,153]
- Decreased portal blood flow and hepatocyte mitochondrial funtion

Renal[154–160]
- Increased renal vein pressure
- Increased plasma renin and aldosterone
- Decreased renal blood flow, glomerular filtration rate, and urine output

Thoracic

Lung[157,161–163]
- Increased intrathoracic pressure, peak airway pressure, peak inspiratory pressure, and intrapulmonary shunt
- Decreased dynamic compliance

Heart/cardiovascular[157,161,164–168]
- Decreased venous return and cardiac output
- "False" increase of central venous pressure and pulmanary artery wedge pressure
- Increased systemic and pulmonary vascular resistance

Central nervous system[169–172]
- Increased intracranial pressure secondary to decreased venous return
- Decreased cerebral perfusion pressure

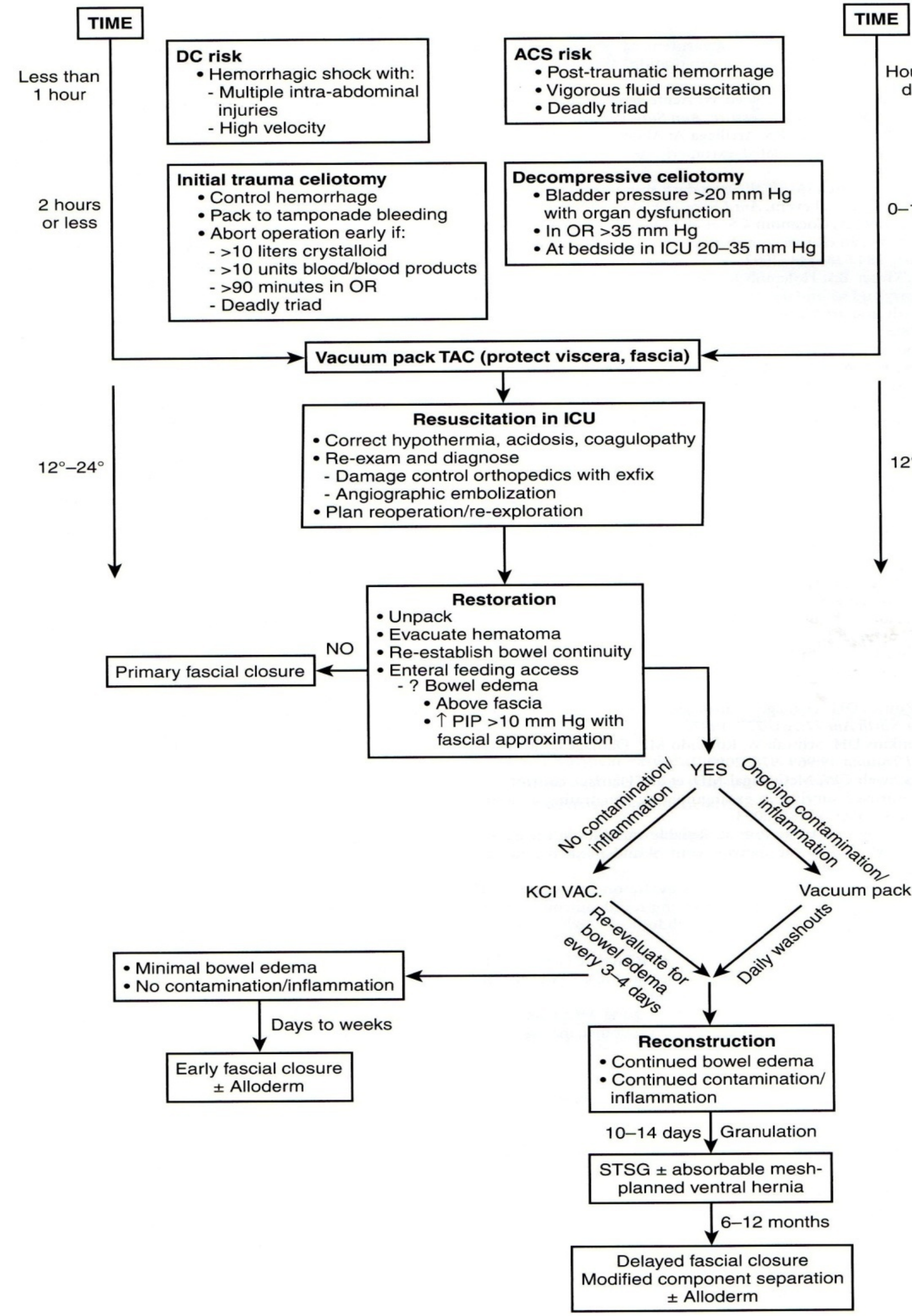


Figure 23 Algorithm for damage control and open abdomen management.

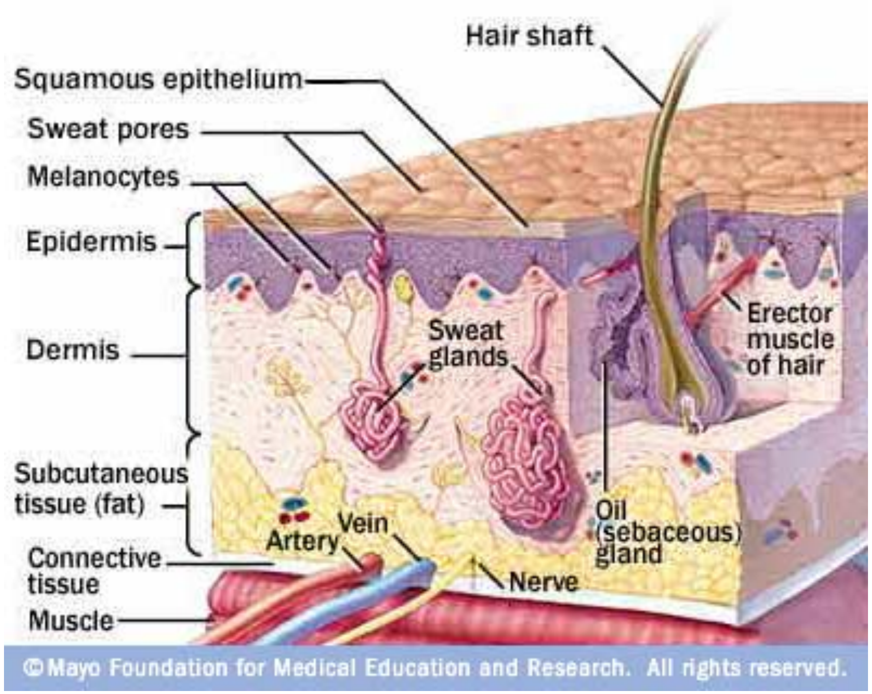
Burn Injuries

Outline

- Initial Assessment/Management
- Airway Management/Inhalation Injury
- Systemic Effects of Acute Burn
- Electrical Burns
- Chemical Burns
- Burn Wound Management

The Skin

- Many important tasks
  - Regulate body temperature
  - Prevents water loss
  - Prevents surface entry of bacteria
  - Stores water and fat
  - Many sensory organ



Primary Survey

- Airway
  - ?inhalation injury?
- Breathing
  - ?stridor?
- Circulation
  - ?burns impeding blood flow?
- Disability
  - AVPU
- Exposure
  - Need ALL skin exposed

Diagnostic Criteria

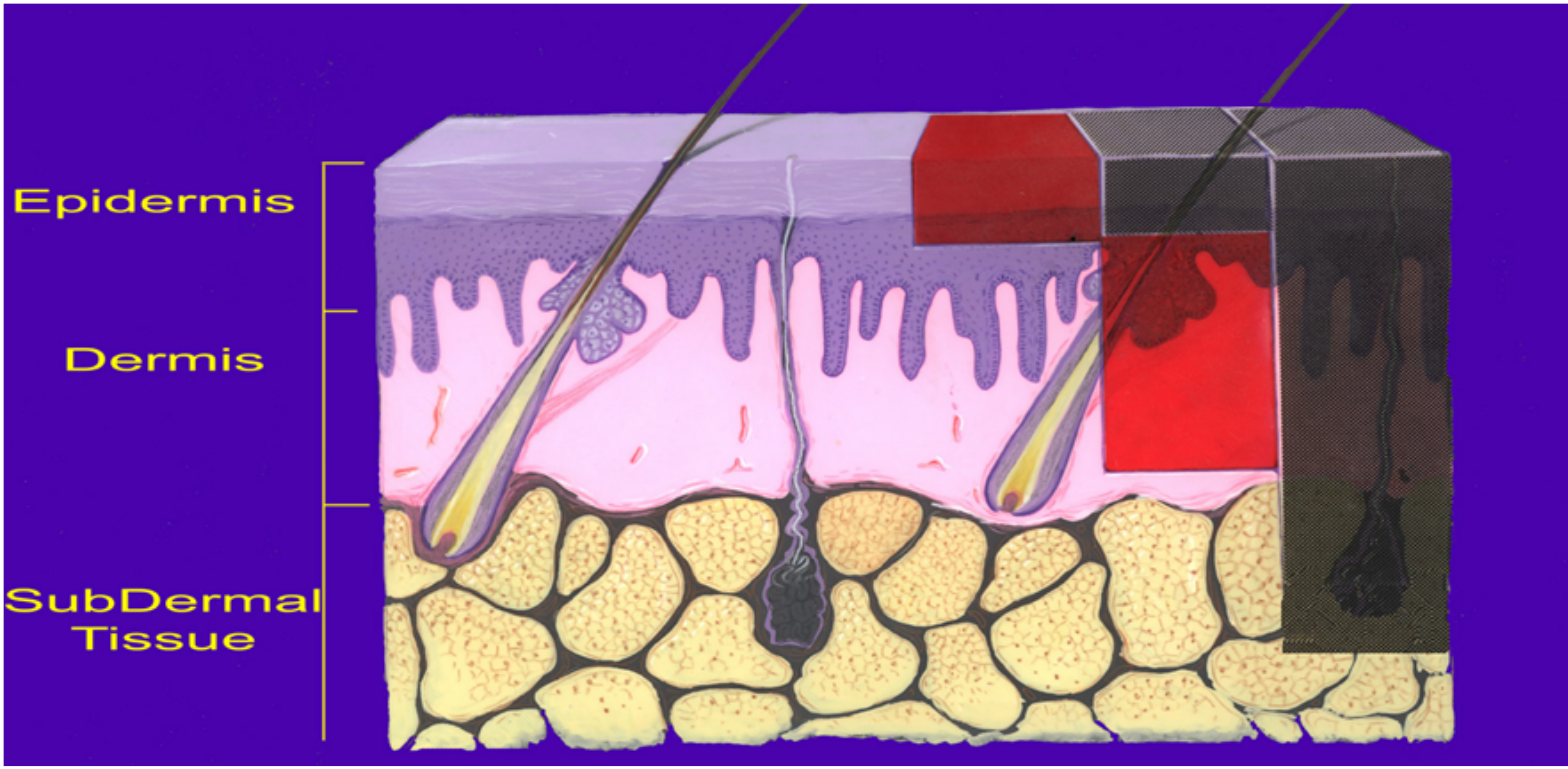
- 6 causal catagories
  - Fire, scald, contact, chemical, electrical, radiation
    - Fire → flash, flame
    - Scald → liquids, grease, steam
      - Liquid → spill, immersion
- 5 depth of injuries
  - 1st, Superficial 2nd, Deep 2nd, 3rd, 4th

TABLE 50-1

Definition of Burn Types, Zones, and Depth of Injury

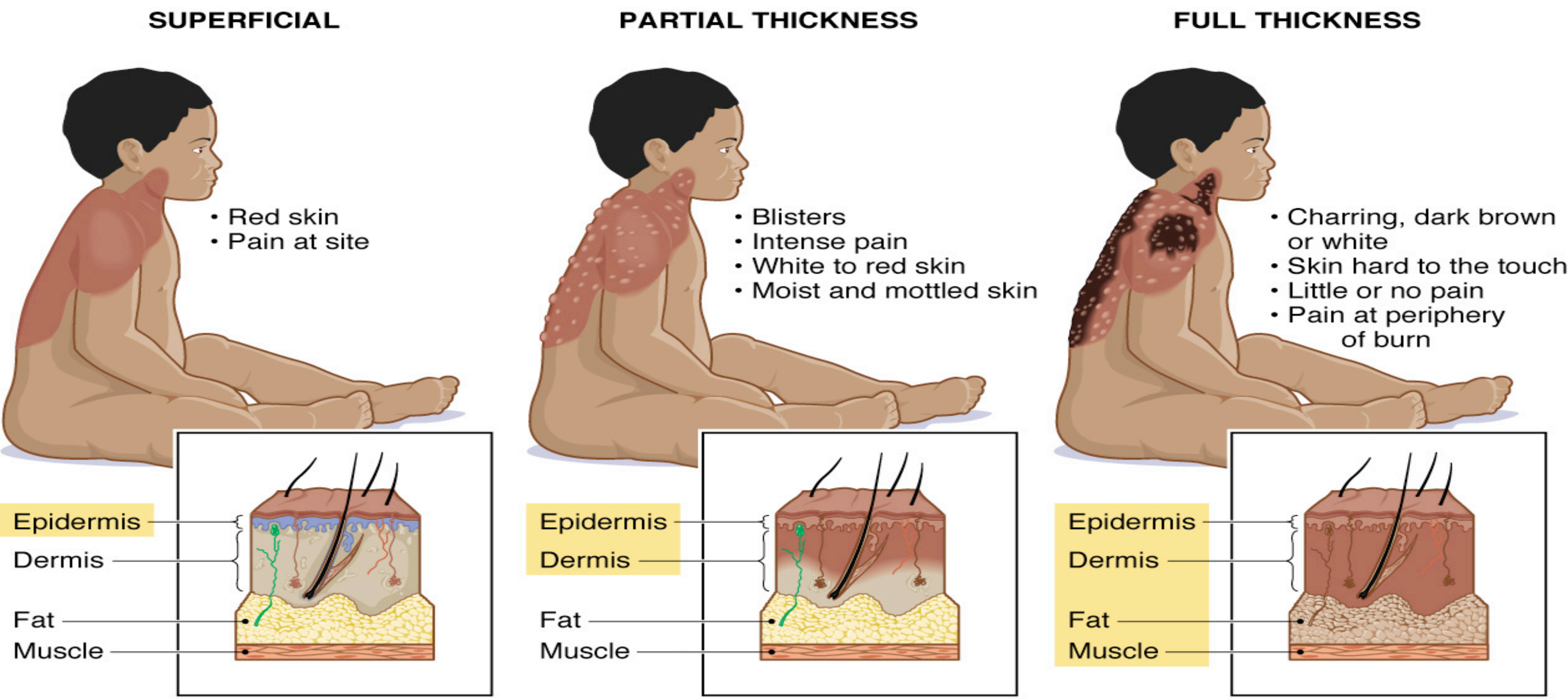
BURN CATEGORIES		ZONES OF INJURY	BURN DEPTH
Fire	Flash	Zone of coagulation	First Degree (epidermal)
	Flame		
Scald	Liquid – Spill – Immersion	Zone of stasis	Superficial second degree (superficial dermal)
	Grease	Zone of hyperemia	Deep second degree (deep thermal)
	Steam		Third degree (full thickness)
Contact			Fourth degree (deep organ involvement)
Chemical			
Electrical			
Radiation			

Burn Depth



Depth of Burn

- Superficial Burn
- Partial Thickness Burn
- Full Thickness Burn



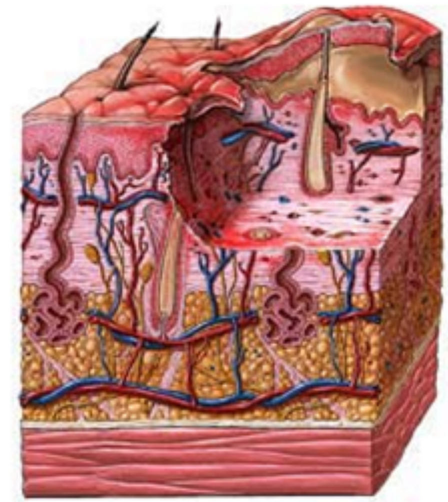
1st Degree

1st degree burn

- Confined to epidermis
- Painful, erythematous, blanch to touch, no blisters
- Heal in 3-6 days
- Pain control

smokinggun.com

2^{nd} degree



2nd degree burn

- Some degree of dermal damage
- 2 types
  - Superficial
    - Erythematous, painful, wet, blanch to touch, form blisters
    - Heal in 7-14 days
    - May cause skin discoloration
  - Deep
    - More pale than pink, will not blanch, painful
      - Pain is more blunted with deeper burns
    - Heal in 21-28 days
    - May need grafting





3rd degree

- Full thickness through the dermis
- Firm leathery eschar, painless, black/white/cherry color
- Require grafting

3rd degree burn




4th degree

- Involve organs beneath skin
  - Muscle, tendon, bone, fascia
- Charred appearance
- Seen mostly with electrical injuries or prolonged contact thermal burns

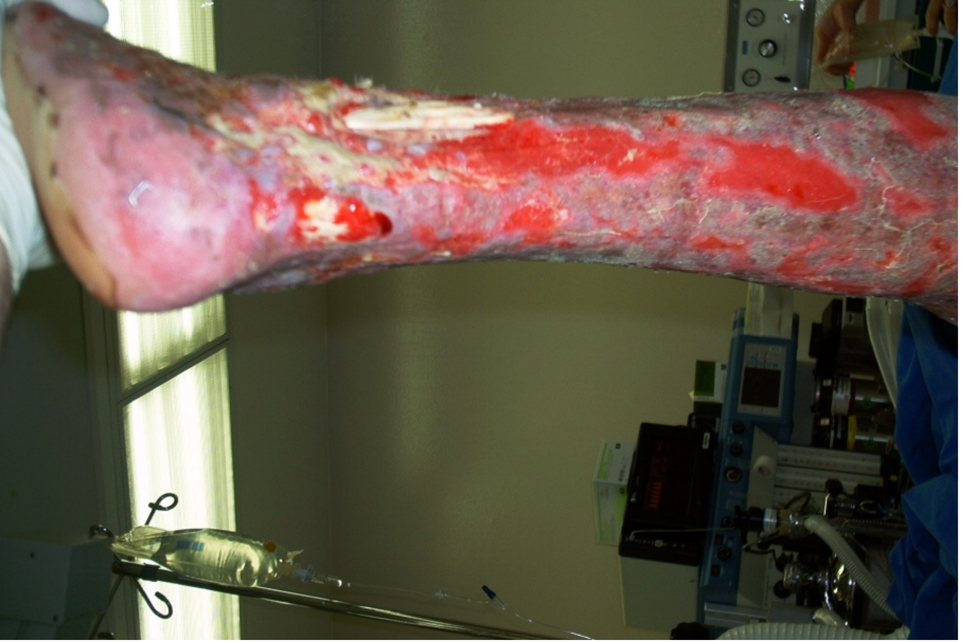



Table 2: Clinical Characteristics of Burn Injuries

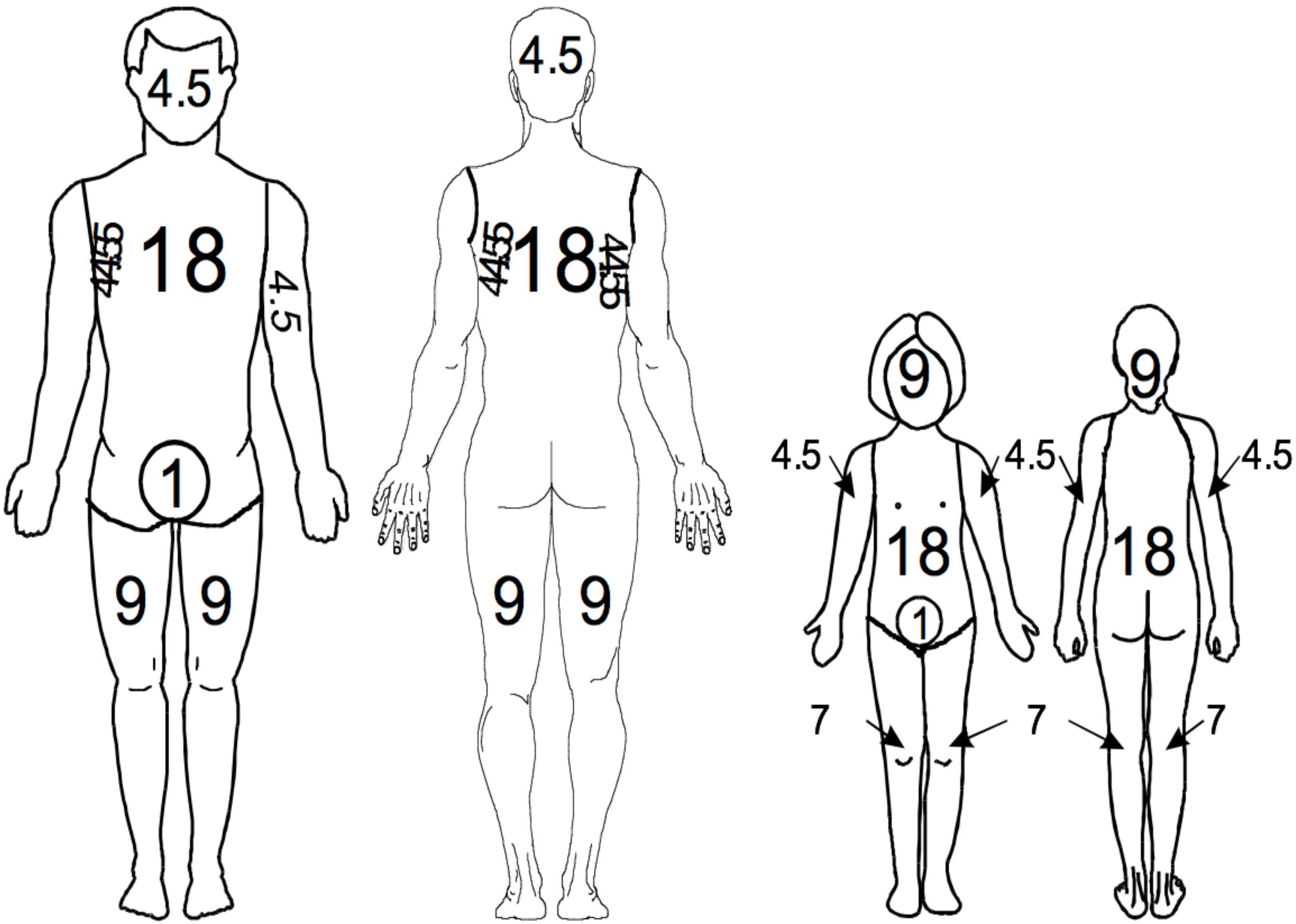
	Partial-Thickness Burns		Full-Thickness Burns
	First Degree	**Second Degree**	**Third Degree**
Cause	Sun or minor flash	Higher intensity or longer exposure to flash Relatively brief exposure to hot liquids, flames	Higher intensity or longer exposure to flash Longer exposure to flames or "hot" liquids Contact with steam or hot metal High-voltage electricity Chemicals
Color	Bright red	Mottled red	Pearly white Translucent and parchment-like Charred
Surface	Dry No bullae	Moist Bullae present	Dry, leathery, and stiff Remnants of burned skin present Liquefaction of tissue
Sensation	Hyperesthetic	Pain to pin prick inversely proportional to depth of injury	Surface insensate Deep pressure sense retained
Healing	3–6 days	Time proportional to depth of burns, 10–35 days	Requires grafting

Source: Pruitt BA Jr, Gamelli RL: Burns. In Britt LD, Trunkey DD, Organ CH, Feliciano DV, editors: *Acute Care Surgery*. New York, Springer, 2007, pp. 128, with permission.

Calculating Total Body Surface Area

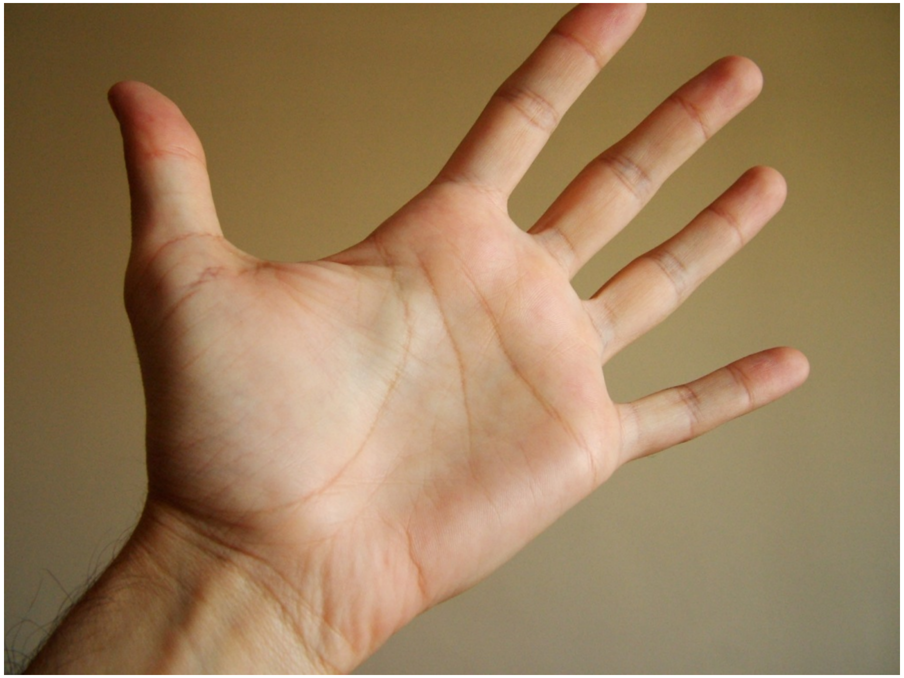
- Rule of Nines
  - Best used for large surface areas
  - Expedient tool to measure extent of burn
- Rule of Palms
  - Best used for burns < 10% BSA
- Lund and Browder Chart

Rules of Nines



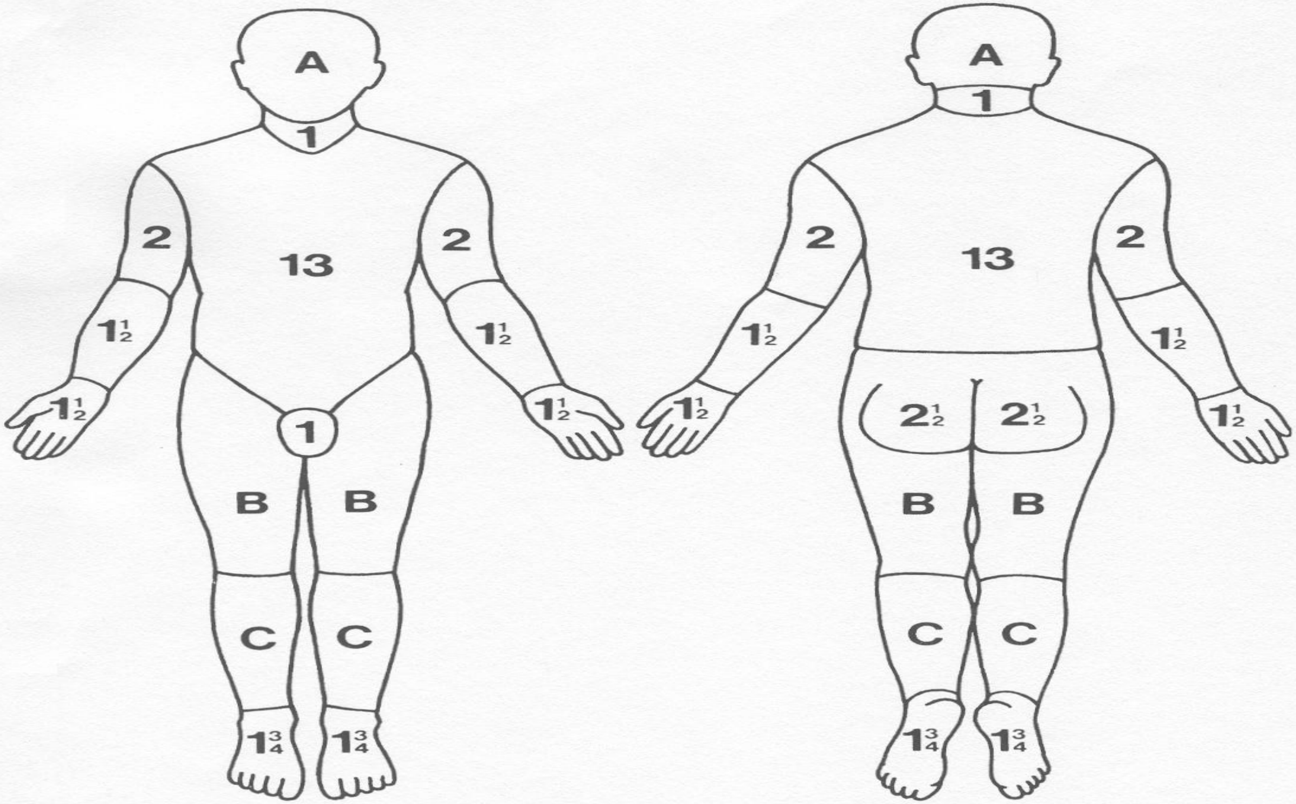
Rule of Palms

- A burn equivalent to the size of the ***patient's hand*** is equal to 1% body surface area (BSA)



LUND AND BROWDER CHARTS

IGNORE
SIMPLE ERYTHEMA



Superficial
Deep

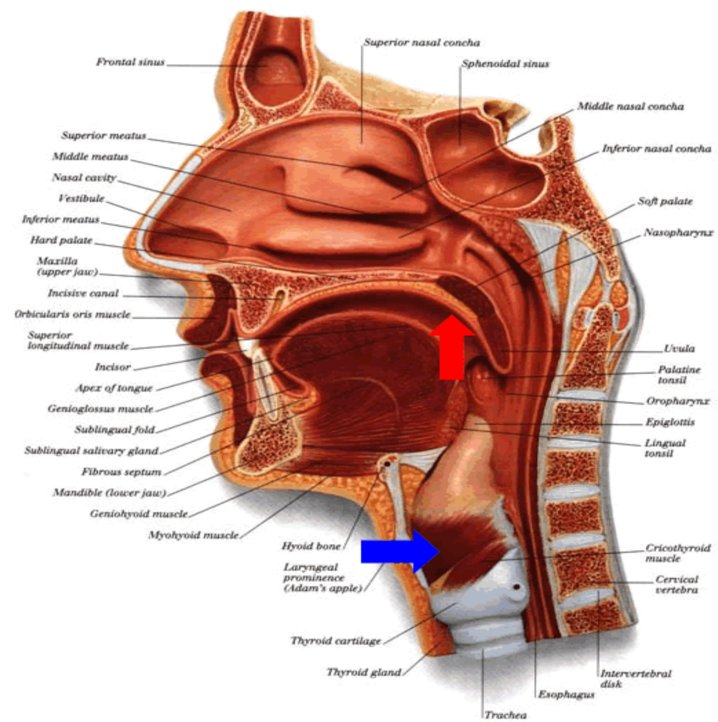
REGION	%
HEAD	
NECK	
ANT. TRUNK	
POST. TRUNK	
RIGHT ARM	
LEFT ARM	
BUTTOCKS	
GENITALIA	
RIGHT LEG	
LEFT LEG	
TOTAL BURN	

RELATIVE PERCENTAGE OF BODY SURFACE AREA AFFECTED BY GROWTH

AREA	AGE 0	1	5	10	15	ADULT
A = ½ OF HEAD	9½	8½	6½	5½	4½	3½
B = ½ OF ONE THIGH	2¾	3¼	4	4½	4½	4¾
C = ½ OF ONE LEG	2½	2½	2¾	3	3¼	3½

Inhalation Injury

- Inhalation injury presents in 20-50% of patients admitted to burn centers and 60-70% of the patients who die in burn centers
- Facial burn, carbonaceous sputum, singed nasal hair, oral airway edema and hyperemia, stridor
- History
  - Enclosed space
  - Loss of consciousness
  - Drugs and alcohol
- 3 levels of injury
  - Carbon Monoxide Injury
  - Supraglottic
  - Infraglottic



Carbon Monoxide

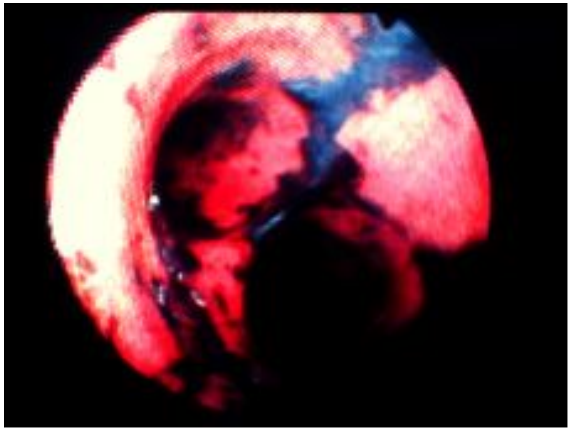
- Most frequent cause of death at the scene
- Cherry red discoloration of skin
  - Present in ~50% of patients with carbon monoxide poisoning
- Very high affinity for hemoglobin
  - Impairs oxygen availability and use in the tissues
    - Can have a falsely elevated SaO2 on pulse-ox
- Treatment
  - 100% O2
    - ½ life of CO is 4hr at RA, 40min with 100% O2

Carbon Monoxide

0-10%	None
10-20%	Slight headache
20-30%	Headache and throbbing in temples
30-40%	Severe headache, dizziness, vomiting, weakness
40-50%	All the above plus syncope
50-60%	Syncope, coma
60-70%	Coma, convulsions
70-80%	Weak pulse, slow respirations death within hours
80-90%	Death in less than one hour
90-100%	Death within minutes

Inhalation Injury - Supraglottic

- Usually due to thermal or chemical burns
- Due to immediate thermal effect, hyperemia, and swelling, upper airway may be come edematous and cause obstruction
- Intubation is key



Inhalation Injury - Infraglottic

- Almost always chemical
  - Due to efficient heat exchange in upper airway during thermal injury
  - Noxious chemicals adhere to surface of smoke particles
    - Directly damaging the epithelium of airway

Inhalation Injury - Infraglottic

- Injuries below the glottis produce:
  - Impaired ciliary activity
  - Inflammation
  - Hypersecretion
  - Edema
  - Ulceration of airway mucosa
  - Increased blood flow
- Multiple FOB needed

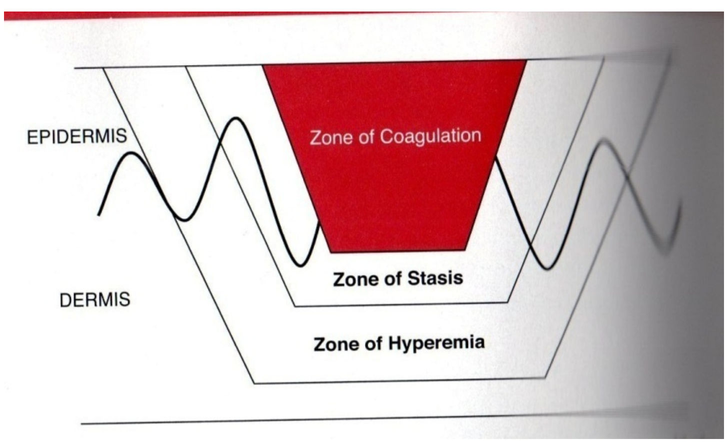
What do we do???

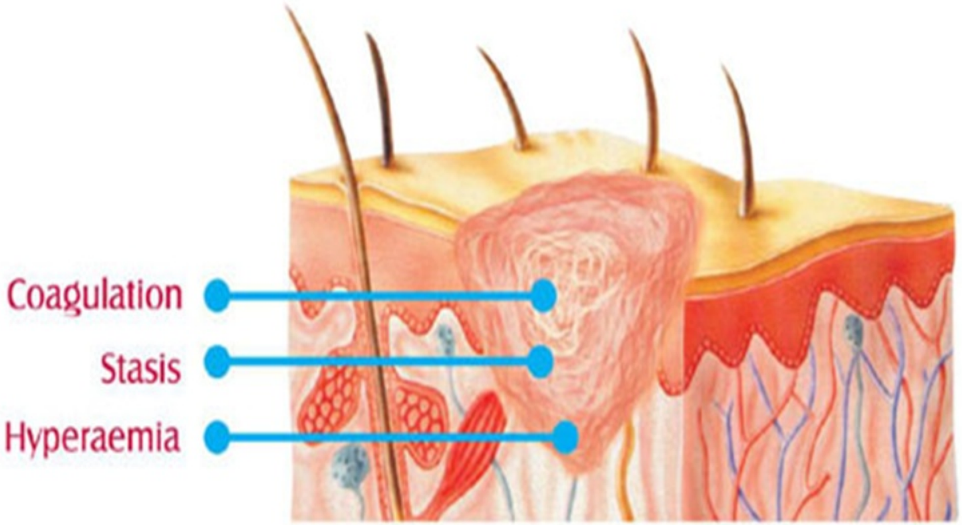
Fluid Resuscitation

- 20x increase in evaporative water loss in burn injured patients
- Use lactated ringers
- Parkland Formula
  - 4cc x kg x %TBSA
    - ½ is given over 1st 8 hours
    - ½ is given over 2nd 16 hours
- ***NEVER BOLUS A BURN***
- Urine output – 0.5cc/kg/hr or 30-50cc/hr
- Titrate your fluids based on urine output
  - $>$50cc/hr → decrease hourly rate by 10%
  - $<$30cc/hr → increase hourly rate by 10%

Systemic Effects of Burns

- Jackson's Theory of Thermal Wounds
  - Zone of coagulation: area of burn nearest the heat source that suffers the most damage as evidenced by clotted blood and thrombosed blood vessels.
  - Zone of stasis: area surrounding zone of coagulation characterized by decreased blood flow
  - Zone of hyperemia: peripheral area around burn that has increased blood flow





Systemic Effects of Burns

- 4 main phases
  - Emergent
    - Immediate
    - Pain response
      - Tachycardia, tachypnea, hypertension, anxiety
  - Fluid Shift
    - 18-36 hours post-burn
    - Inflammatory response is profound
      - Vessels adjacent to burn dilate and fluid shifts from intravascular to interstitial space
    - Electrolyte and acid/base imbalance
    - Hemoconcentration

Fluid Shift

- After 18-36 hours, fluid mobilizes back into vasculature.
- Will see continued electrolyte abnormalities (hyponatremia/hypokalemia), hemodilution.

- The Big Picture: the impact of fluid shift on the major organ systems is significant.
  - Cardiovascular
  - Renal
  - Immune
  - Gastrointestinal

Impact on Cardiovascular

- Decreased cardiac output:
  - Blood volume
  - Increased blood viscosity
  - Decreased contractility

- Hypotension can happen fast and be extreme

- Fluid resuscitation, and oxygen/ventilation: maximize blood volume and oxygen delivery

- In the face of circulatory shock, may require use of vasopressors

Impact on Renal

- Important in determining fluid status. Urine output should be maintained at 30-50 cc/hr.

- If >50cc/hr, decrease IVF by 10%.
- If < 30cc/hr, increase IVF by 10%.

- Decreased cardiac output means blood is shunted from kidneys and GI tract, redirected to brain, heart, lungs.

- Decreased blood flow to kidneys…decreased urine output…oliguria…acute renal failure.

Impact on Gastrointestinal

- As stated, blood is shunted from GI tract to more essential organs in circulatory shock.
- Decreased or absent motility
- Can lead to ulcers: always start PPI
- However, nutrition is critically important
- Enteral nutrition is initiated on arrival

Impact on Immune

- Temperature spikes common in first 24 hours. Usually not infection related.

- 3 most common enemies in ICU:
  - Ventilator associated pneumonia: with inhalation injury
  - Bacteremia: central lines, PA catheters
  - Urinary tract infection: Foley catheters

Sepsis: Bad news for the immuno –suppressed

Systemic Inflammatory Response Syndrome

(body temperature, respiratory rate, heart rate, WBC count)

Phase 3: Hypermetabolic

- Causes include sepsis, trauma, and burns. In burns it is the longest sustained and most severe. Mediated by catabolic hormones (cortisol, glucagon, epinephrine).

- Metabolic rates of burn patients can exceed twice normal, leading to protein catabolism of near 150 gm/day…

- Failure to satisfy these energy and protein requirements results in loss of lean muscle mass:
  - 10% loss = immune dysfunction
  - 20% loss = decreased wound healing
  - 30% loss = severe infection
  - 40% loss = death

Hypermetabolism continued…

- Treatment of hypermetabolic effects includes:
  - Early wound treatment
    - Excision and grafting
  - Aggressive treatment of sepsis
    - Source control, antibiotics
  - Provide adequate calories and protein
    - TEN, TPN
  - Environmental support
    - Heat, dressings
  - Manipulation of hypermetabolism
    - Beta blockers, insulin, anabolic steroids

Phase 4: Resolution

- Scar formation
- General rehabilitation and progression to normal function

  - PT
  - OT
  - wound care
  - Continued nutritional support (HPHC)
  - Scar release/compression therapy

Electrical Burns

- The “Grand Masquerader” of burn injuries—small surface injury, devastating internal injury. Extent of injury depends on the type of current, the pathway of flow, the local tissue resistance, and the duration of contact.
- A word on current:
  - Alternating current: in most commercial appliances. Flows back and forth from the power source to the anatomic contact point. More dangerous to the human body, producing tetany and death from cardiac fibrillation and respiratory muscle paralysis.
  - Direct current: Encountered with lightening, car batteries. Travels in one direction and, therefore, an entrance and exit site may be seen.

A word on tissue resistance:

- Skin is most resistant, but once overcome, current flows freely through underlying tissue.
- Bone resistance

Electrical Injury—findings

- Loss of consciousness
- Paralysis/mummification of an extremity
- Loss of peripheral pulse
- Myoglobinuria
- Cardiac/pulmonary arrest

Electrical burn on hand and arm.

Maintaining peripheral circulation

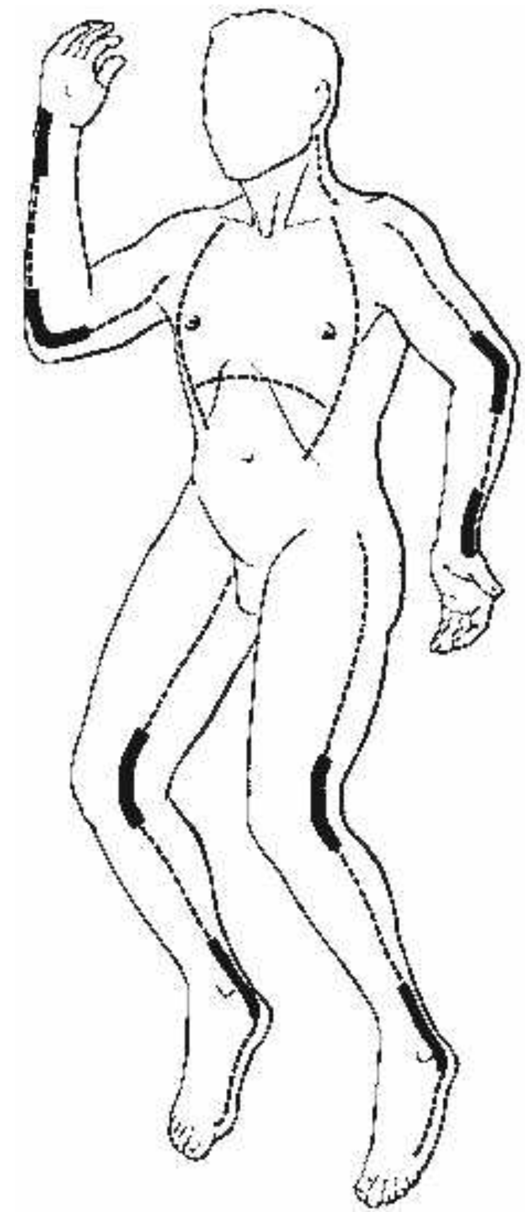
- Hourly check of skin color, capillary refill, and peripheral pulses
- If compartment pressure not relieved, muscle necrosis will occur. Symptoms include:
  - Severe pain with flexion or extension of muscles within compartment
  - Numbness/tingling
  - Decreased/absent pulses

Surgical Treatment of vascular compromise:

- Escharotomy: sufficient if secondary to circumferential eschar
- Fasciotomy: with development of subfascial edema—leads to tissue ischemia if muscle compartment pressure increases sufficiently. The compartment will be hard to palpation.

Escharotomies

- Full-thickness, circumferential burns to extremity or trunk
  - Diminished blood flow to extremity
  - Decreased pulmonary compliance
- Important to carry over joint lines



Escharotomy

Fasciotomy

Chemical Burns

- Extent of burn is directly related to the interval between injury and institution of medical therapy.
- Three most common chemical categories:
  - Alkalis: Oven cleaners, drain cleaners, fertilizers, heavy industrial cleaners. Damage by liquefaction necrosis and protein denaturation, allowing for deeper spread of chemical and more severe burns.
  - Acids: Household cleaners, rust removers, drain cleaners. Damage by coagulation necrosis and protein precipitation which limits the depth of tissue damage. Exception is hydrofluoric acid.
  - Organic compounds: Petroleum products, tar, disinfectants. Damage due to fat solvent action. Once absorbed, produce toxic effects to kidney and liver.

Alkali burns—treatment

- Remove clothing
- Identify chemical, dust off particles (lime, cement)
- Copious irrigation
- Monitor for systemic toxicity

Lime burn

Cement burn

Acid burns—treatment

- Copious water irrigation
- Reassess depth to evaluate systemic absorption
- Keep patient warm

sulfuric acid

Organic Compounds—treatment

- Again, copious irrigation
- Stop the burning process—tar burns should be cooled. Removal of tar is not emergent.

Hydrofluoric acid

- A weak acid, but extremely toxic. High concentrations cause immediate pain and tissue necrosis.
- With systemic absorption, death can occur from hypocalcemia as fluoride rapidly binds free calcium in blood.
- Flood burn with water. Use topical calcium gel to neutralize fluoride.
- Cardiac monitoring and preparation for infusing calcium gluconate may be necessary with exposure to high concentration.

Burn Wound Management

1st Degree: Aloe, moisturizer

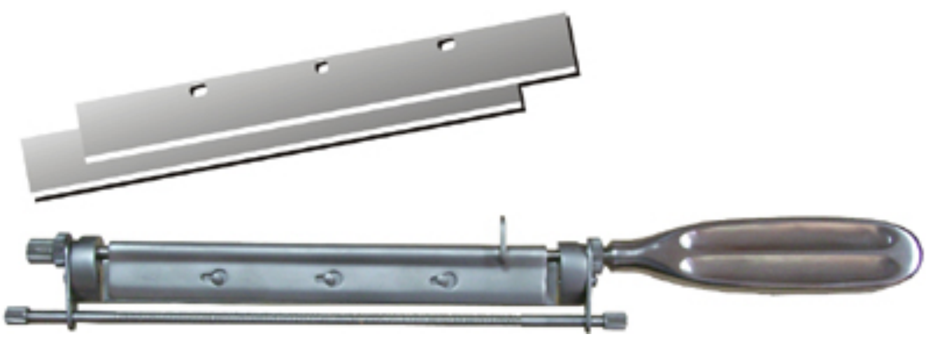
2nd Degree:

Topical antimicrobial— polysporin

Enzymatic debrider— santyl

3rd Degree: Excision and grafting

4th Degree: Excision/Wound Vac/Grafting vs. Amputation



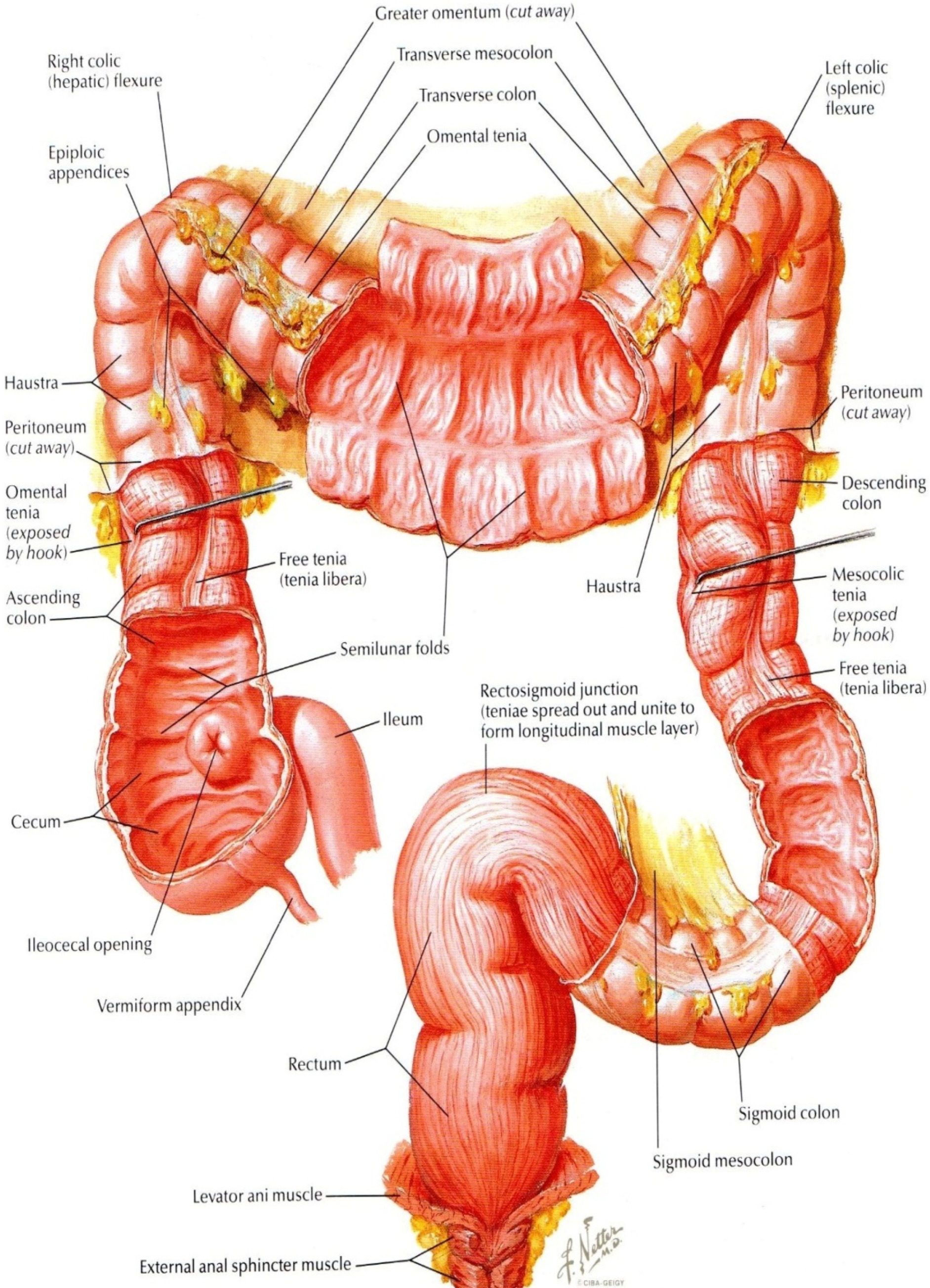
ABA Criteria for Transfer to a Burn Center

- 2nd or 3rd degree burns greater than 10% TBSA
- Full-thickness burns in any age group
- Any burn to the face, hands, feet, eyes, ears, or perineum that may result in cosmetic or functional disability
- Electrical burns
- Inhalation injury
- Chemical burns
- Burns in patients with significant cormorbidities
  - DM, COPD, CAD, CHF

Colon and Rectal Injuries

Statistics

- 2nd most frequently injured organ in penetrating trauma, but < 5% in blunt trauma
- Mechanism of injury
  - Penetrating
    - Direct penetration by missile or sharp object
  - Blunt
    - Creation of closed loop with acute increase in intraluminal pressure and blowout
    - Shearing forces causing tears at sites of transition from immobile section to a mobile one
      - Splenic flexure, rectosigmoid junction
    - Pure mesocolic avulsion
      - Not associated with immediate perforation, but can lead to devascularization, wall necrosis, and delayed perforation
  - Iatrogenic/Self-inflicted
    - Perforations from colonoscopy, sexual activity, and swallowed objects


Greater omentum (cut away)
Transverse mesocolon
Right colic (hepatic) flexure
Transverse colon
Left colic (splenic) flexure
Omental tenia
Epiploic appendices
Haustra
Peritoneum (cut away)
Peritoneum (cut away)
Omental tenia (exposed by hook)
Descending colon
Free tenia (tenia libera)
Mesocolic tenia (exposed by hook)
Ascending colon
Haustra
Semilunar folds
Free tenia (tenia libera)
Rectosigmoid junction (teniae spread out and unite to form longitudinal muscle layer)
Ileum
Cecum
Ileocecal opening
Vermiform appendix
Rectum
Sigmoid colon
Sigmoid mesocolon
Levator ani muscle
External anal sphincter muscle
F. Netter M.D.
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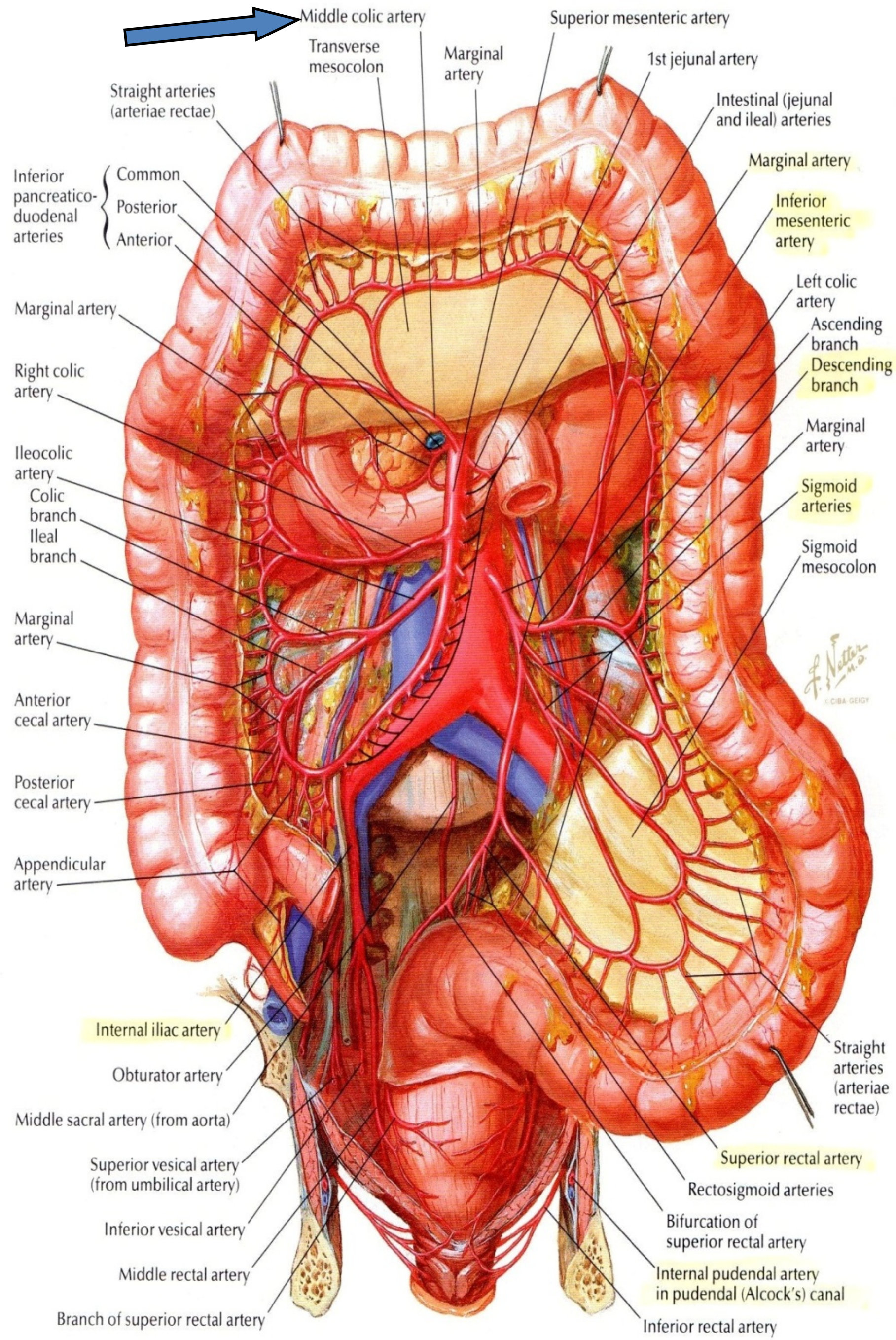
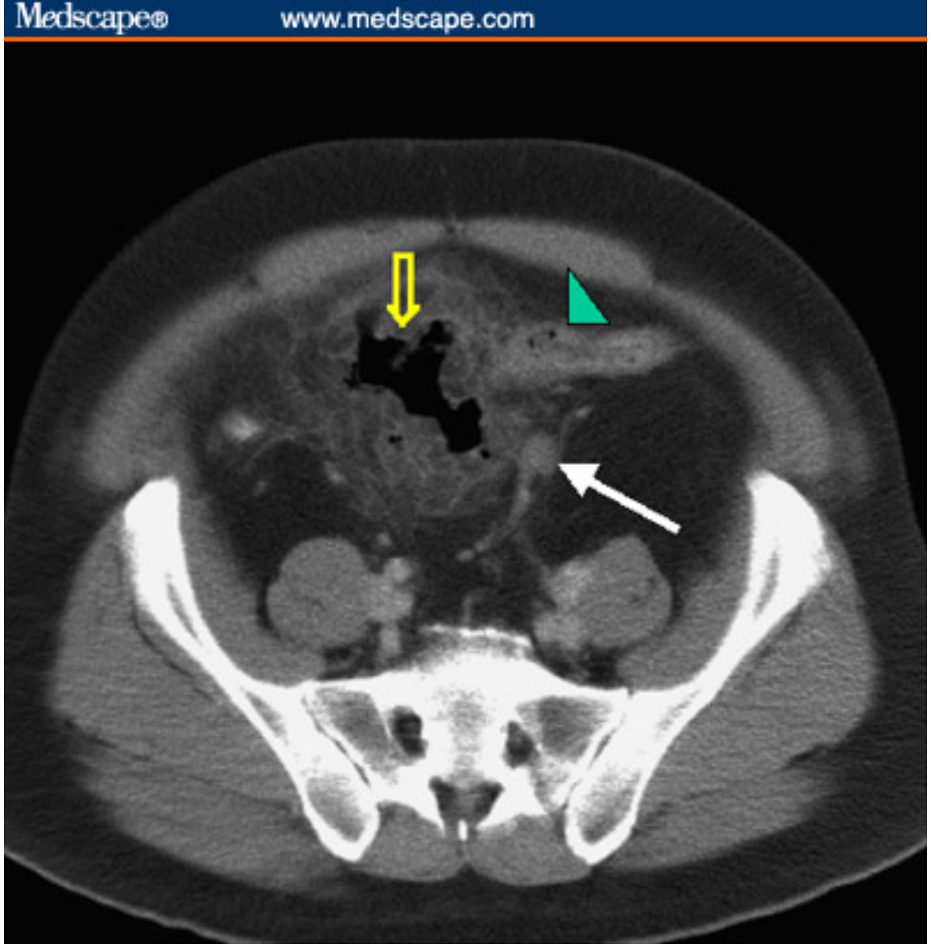

Middle colic artery
Superior mesenteric artery
Transverse mesocolon
Marginal artery
1st jejunal artery
Straight arteries (arteriae rectae)
Intestinal (jejunal and ileal) arteries
Inferior pancreaticoduodenal arteries
Common
Posterior
Anterior
Marginal artery
Inferior mesenteric artery
Marginal artery
Left colic artery
Ascending branch
Right colic artery
Descending branch
Marginal artery
Ileocolic artery
Colic branch
Ileal branch
Sigmoid arteries
Sigmoid mesocolon
Marginal artery
Anterior cecal artery
Posterior cecal artery
Appendicular artery
Internal iliac artery
Obturator artery
Straight arteries (arteriae rectae)
Middle sacral artery (from aorta)
Superior vesical artery (from umbilical artery)
Superior rectal artery
Rectosigmoid arteries
Inferior vesical artery
Bifurcation of superior rectal artery
Middle rectal artery
Internal pudendal artery in pudendal (Alcock's) canal
Branch of superior rectal artery
Inferior rectal artery
F. Netter M.D.
© CIBA-GEIGY

Diagnosis

- Physical exam
  - Limited due to need for OR in penetrating trauma and delayed S&S in blunt
    - Retroperitoneal rupture can take up to 24hrs to manifest clinically
- CT
  - Extraluminal air, rectal contrast extravasation, thickened colonic wall, mesocolic stranding



- A segment of sigmoid colon appears thickened (green arrowhead) and there is a large extraluminal air collection with marked mesenteric stranding (open arrow)

Intraoperative Diagnosis

- Look for areas of hematoma, discoloration, or contusion
  - Can hide small perforations or lead to delayed perforation
- Squeeze the bowel to increase intraluminal pressure to help in diagnosis in questionable areas

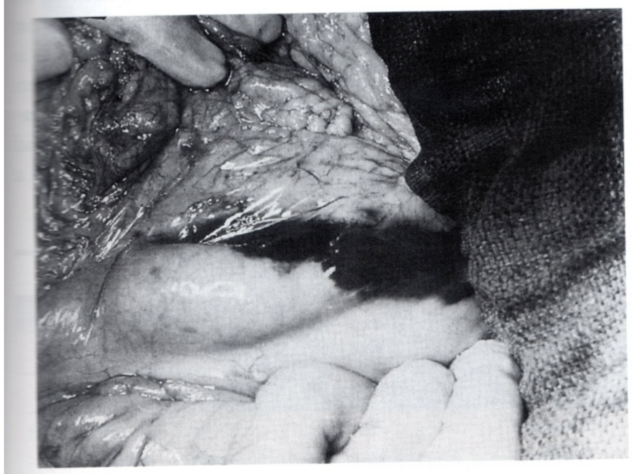


FIGURE 36-4. Hematomas such as this, which involves the antimesenteric portion of the transverse colon must be explored in order not to miss colonic injuries.

FIGURE 36-5. Method for the identification of small perforations by manually increasing the intraluminal pressure. A tiny perforation caused by a shotgun pellet can barely be seen in the center of the colon in this photograph.

Grading

TABLE 36-2

AAST Colon Injury Scale

GRADE[a]		INJURY DESCRIPTION	ICD-9[b]	AIS-90[c]
I	Hematoma	Contusion or hematoma without devascularization	863.40–863.44	2
	Laceration	Partial thickness, no perforation	863.40–863.44	2
II	Laceration	Laceration ≤50% of circumference	863.50–863.54	3
III	Laceration	Laceration >50% of circumference	863.50–863.54	
IV	Laceration	Transection of the colon	863.50–863.54	4
V	Laceration	Transection of the colon with segmental tissue loss	863.50–863.54	4

ICD-9 .4, .51=ascending; 42, .52=transverse; 43, .53=descending; .44, .54 = rectum.
[a]Advance on grade for multiple injuries, up to Grade III.
[b]International Classification of Diseases, 9th Revision.
[c]Abbreviated Injury Scale, 1990.
(Reproduced with permission from Moore EE, Cogbill TH, Malangoni MA, et al: Organ injury, scaling II: Pancreas, duodenum, small bowel, colon, and rectum. J Trauma 30:1427, 1990.)

Treatment

- Primary repair
  - Handsewn, one-layer repair with 3-0 silk
    - Handsewn > staples
      - Less anastomotic leak due to placement of suture line closer together than staples can get
    - One-layer > two-layer
      - Safer, faster, more convenient
- Resection
  - If large injury to colon, arterial injury supplying the colon, or if there is mesenteric root injury, resection is safest approach
    - If proximal to middle colic artery, then an ileocolostomy is performed
- Colostomy
  - If significant distal colon injury, a Hartmann's procedure with end colostomy is warranted
    - Re-anastomosis will require laparotomy with extensive dissection

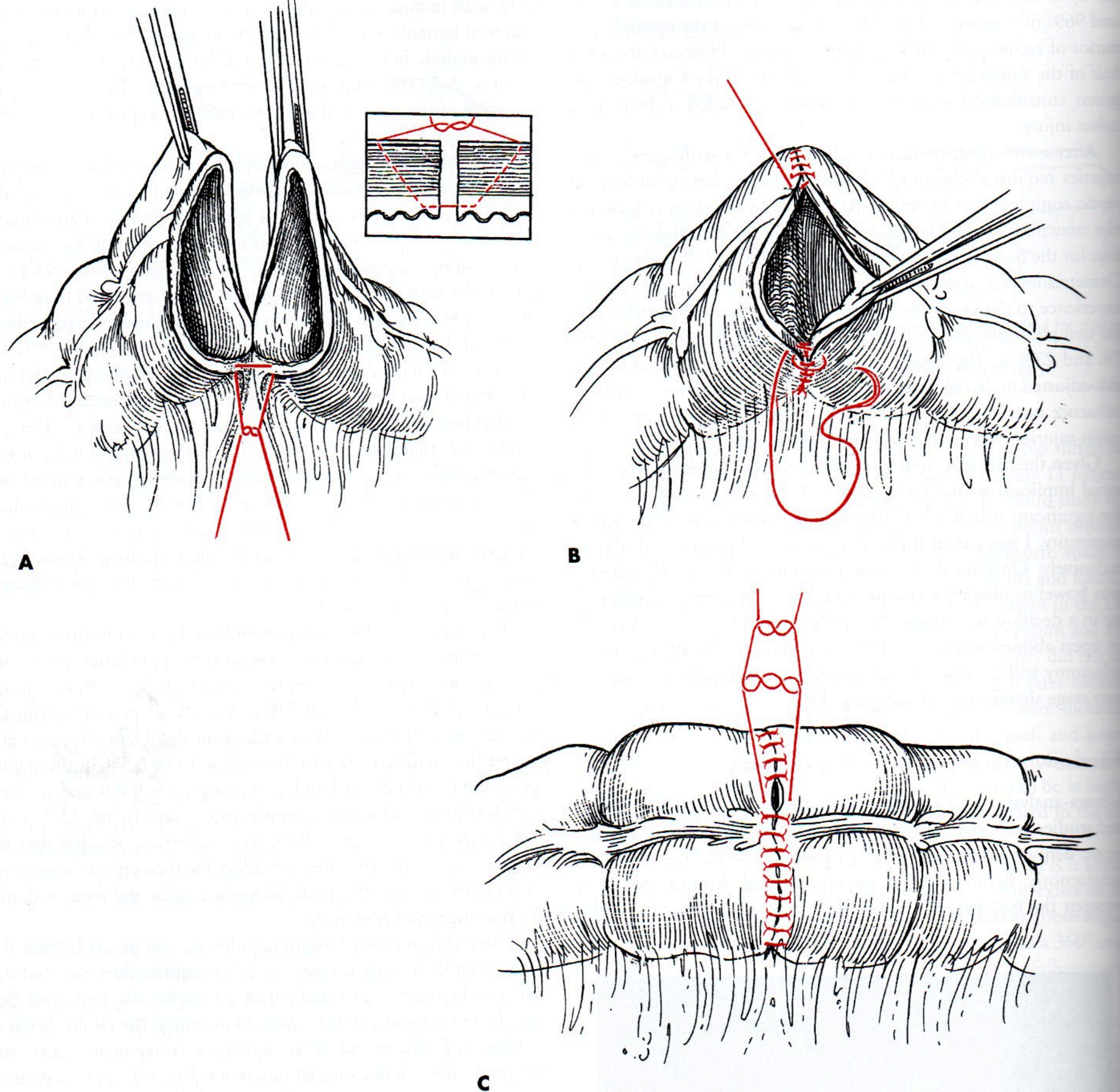


FIGURE 36-9. Single-layer running monifilament suture anastomosis after a distructing injury to the colon requiring resection. The anastomosis is faster and probably safer than the traditional two-layer repair. **(A)** Anastomosis begins at the mesenteric border. **(B)** The sutures are placed 3–4 mm from the edge of the bowel and advance 3–4 mm with each stitch. **(C)** The double-needle suture is tied at the antimesenteric border.

Ileocolostomy and Hartmann's

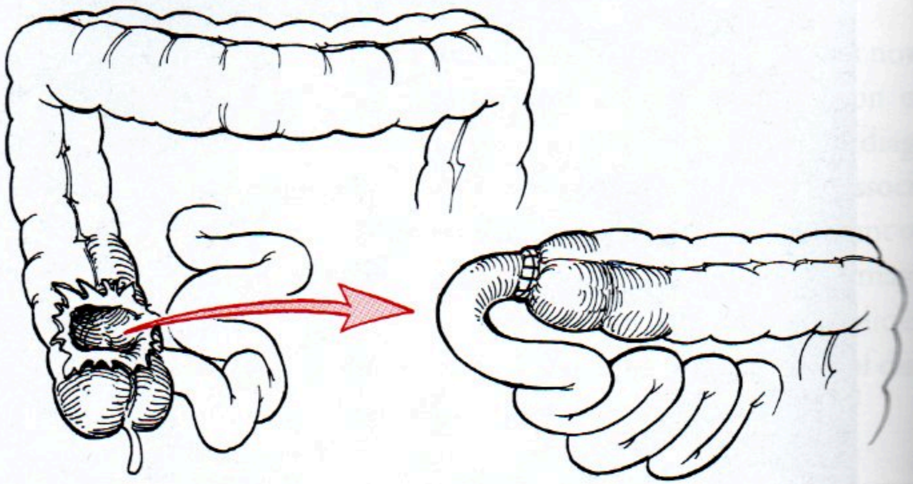


FIGURE 36-7. Resection and ileocolostomy is ideally suited for injuries that require resection proximal to the middle colic artery.
(Reproduced with permission from Baylor College of Medicine.)

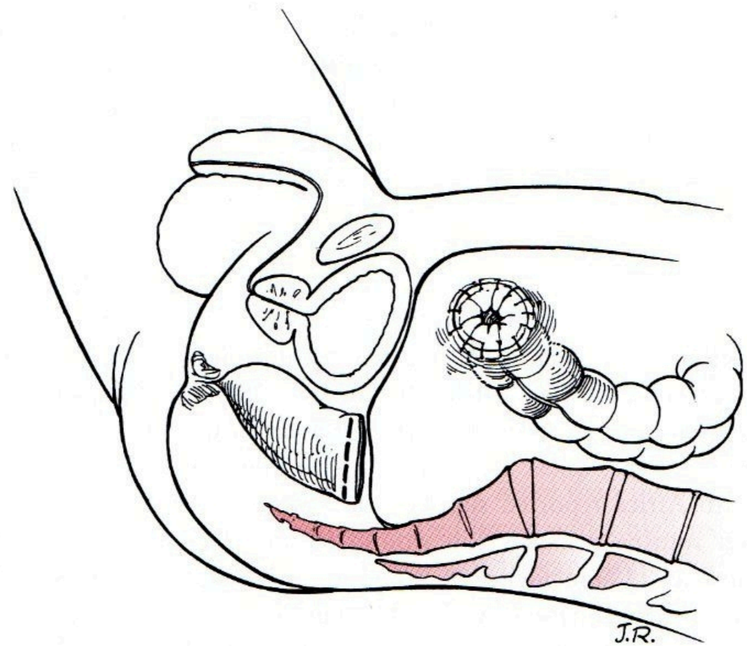
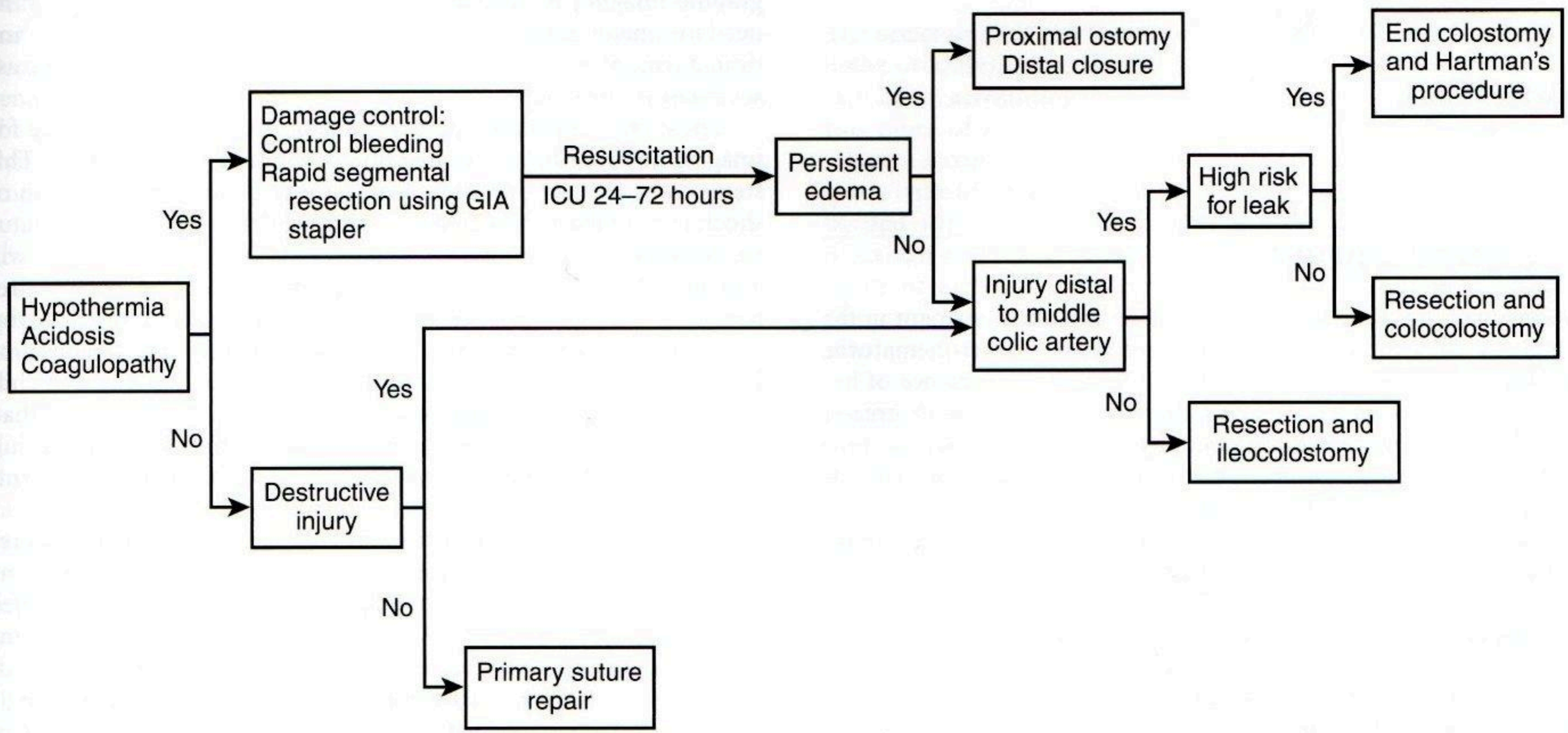


FIGURE 36-12. Hartmann's procedure with an end colostomy and a rectal pouch. Reconstituion of bowel continuity will require a full laparotomy and extensive dissection.
(Reproduced with permission from Baylor College of Medicine.)

Special Considerations

- Drainage
  - Can leave drain to drain infectious sucus for 24-48hr
- Open vs Closed skin wound
  - Close the skin, but opened liberally if any suspicion of infection
- Prophylactic Antibiotics
  - 10-70% chance of intra-abdominal infection s/p colon injury
  - Single, broad spectrum antiobiotic for 24hr
    - 2nd generation cephalosporin, Zosyn

Algorithm for Colon Injuries



Rectal Injuries

- Majority of injuries from penetrating trauma
  - Need to be diligent in gluteal GSW and stabbings for missed rectal injuries
- Blunt trauma can result in rectal injuries from pelvic fractures
- Also from this....

Diagnosis

- Physical exam
  - Injuries to anterior and lateral walls of the upper 2/3 of rectum will cause intraperitoneal perforation and peritonitis
  - Injuries to posterior wall of upper 2/3 of rectum is extraperitoneal and may not cause immediate S&S
  - DRE, for frank blood
  - Rigid proctoscopy in OR
- CT with rectal contrast

Grading

TABLE 36-3

AAST Rectal Organ Injury Scale

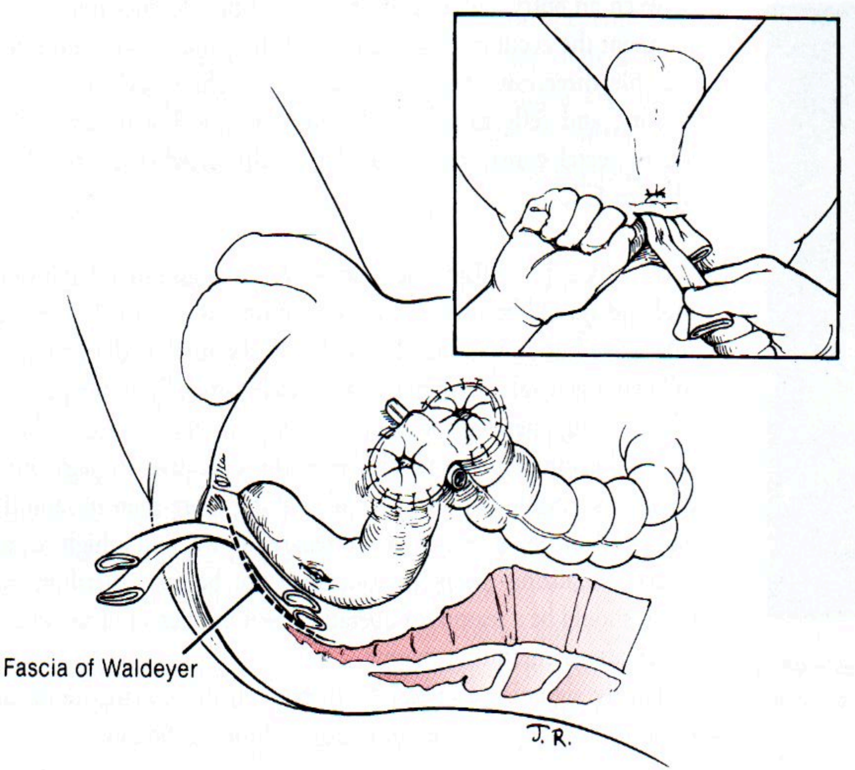
GRADE[a]		INJURY DESCRIPTION[b]	ICD-9[c]	AIS-90[d]
I	Hematoma	Contusion or hematoma without devascularization	863.45	2
	Laceration	Partial-thickness laceration	863.45	2
II	Laceration	Laceration ≤50% of circumference	863.55	3
III	Laceration	Laceration >50% of circumference	863.55	4
IV	Laceration	Full-thickness laceration with extension into the perineum	863.55	5
V	Vascular	Devascularized segment	863.55	5

[a]Advance on grade for multiple injuries to same organ.
[b]Based on the most accurate assessment at autopsy, laparotomy, or radiologic study.
[c]International Classification of Diseases, 9th Revision.
[d]Abbreviated Injury Scale, 1990.
(*Reproduced with permission from Moore EE, Shackford SR, Pachter HL, et al: Organ injury scaling—Spleen, liver and kidney. J Trauma 29:1664, 1989.*)

Treatment

- Primary repair for intraperitoneal rectal injuries
- Primary repair for simple distal injuries via transanal approach
- Diverting colostomy for middle rectal injuries
  - Loop, total diverting, Hartmann's
  - Timing of closure
    - Standard is 3-6 months after initial operation
    - Unrepaired rectal injuries are healed 7-14 days after injury
      - Feasible for same admission closure
- Presacral drains to drain infectious sucus
  - Leave for 4-7 days

Colostomy



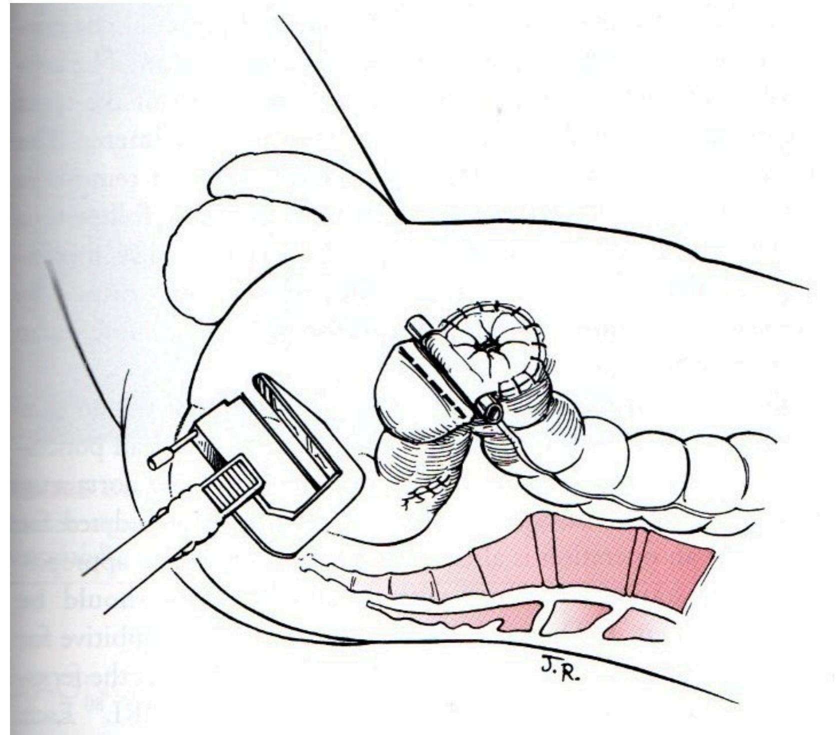


FIGURE 36-11. The use of a linear stapler for definitive fecal diversion. (Reproduced with permission from Baylor College of Medicine.)

Genitourinary Injuries

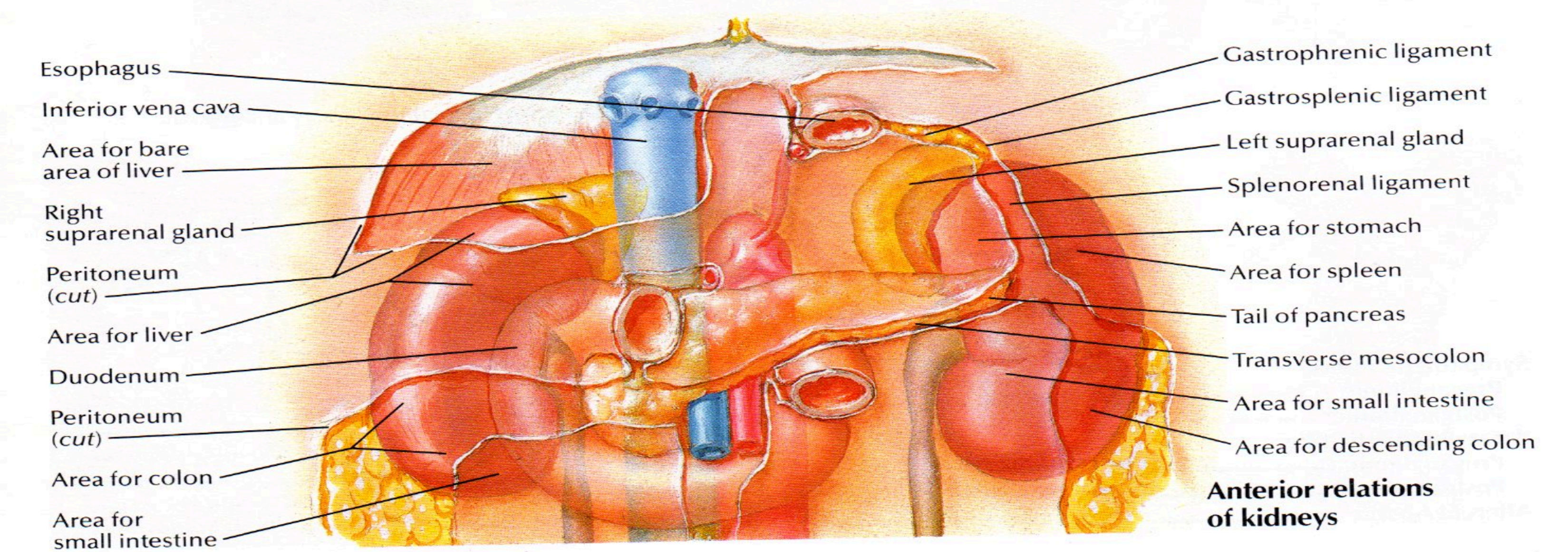
Kidney, Ureter, Bladder, Urethra

Statistics

- Occurs in 2-5% of all trauma patients and at least 10% of patients with abdominal trauma
- Need for collaboration between trauma and urology

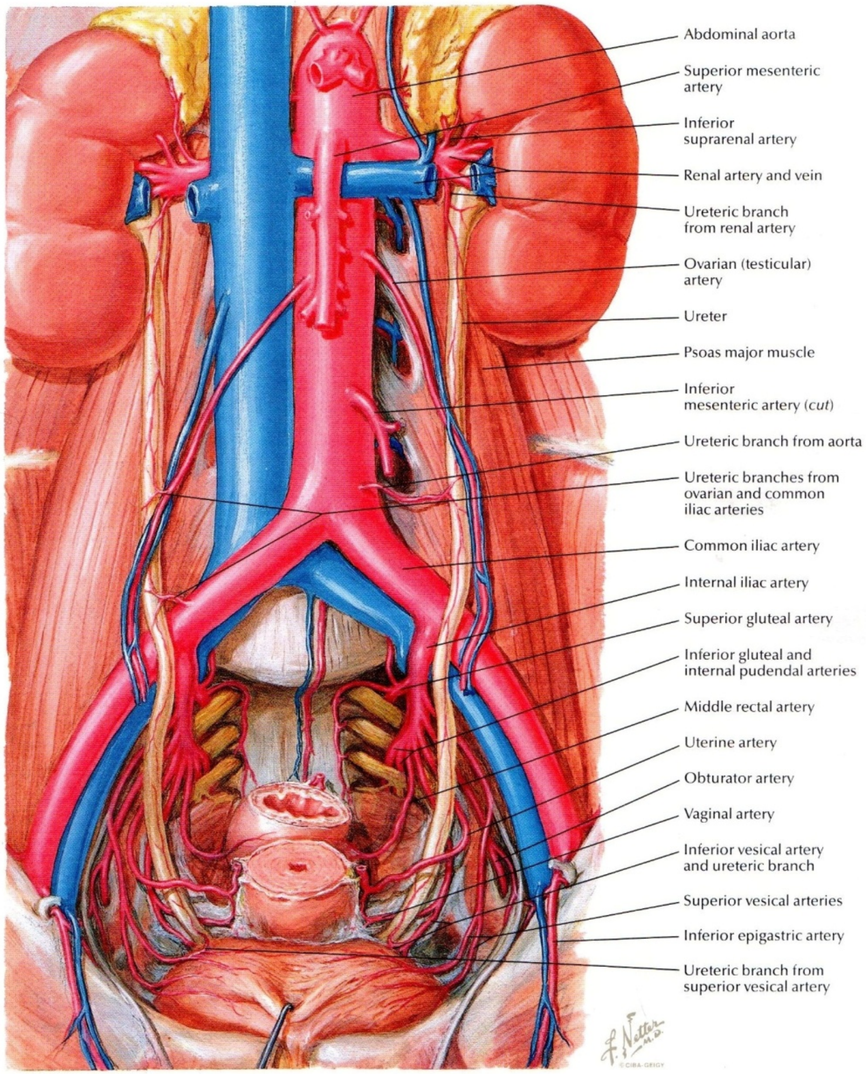
Anatomy

- Left kidney
  - Pancreas, spleen, decending colon
- Right Kidney
  - Duodenum, ascending colon, liver



Anatomy

- Vein, artery, and renal pelvis located in an A/P orientation
- Gonadal vein
  - Right → IVC
  - Left → renal vein
- Collaterals
  - Left renal vein can be ligated with > 85% kidney preservation



Anatomy

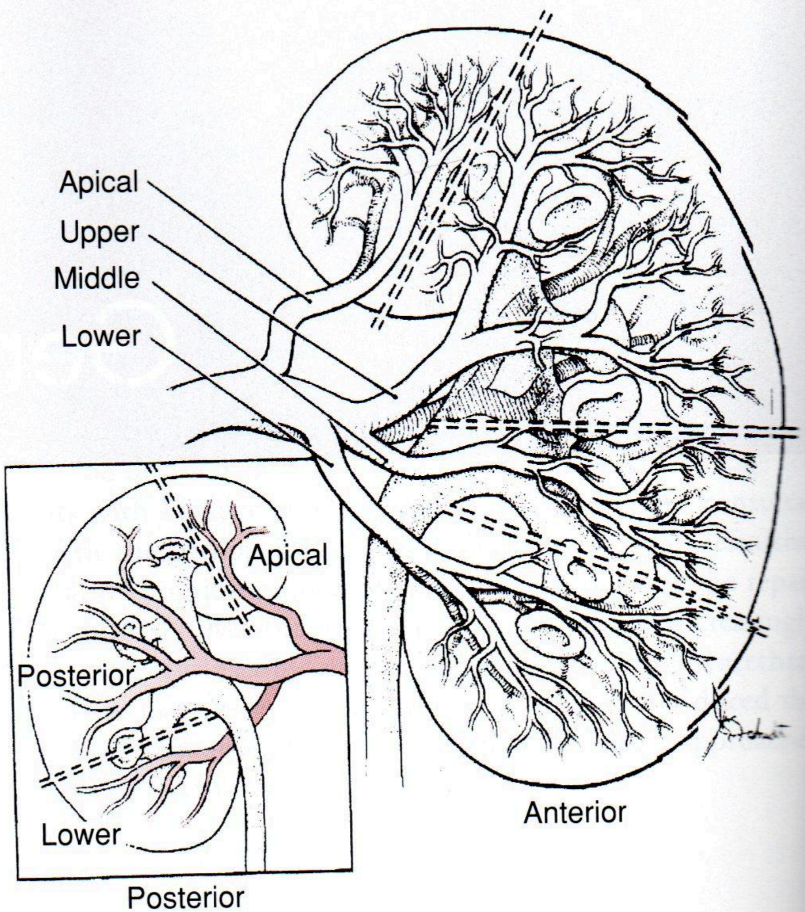


FIGURE 39-2. Intrarenal vascular anatomy: Vascular branches supply-ing various arterial segments of the renal parenchyma. Knowledge of intrarenal anatomy is critical to successful reconstructive efforts.

- Intrarenal arterial supply
  - 25% of blood flow is from accessory branches directly off aorta
  - 5 arterial segments
    - Apical
    - Superior
    - Middle
    - Inferior
    - Posterior
  - Important to know for reconstruction

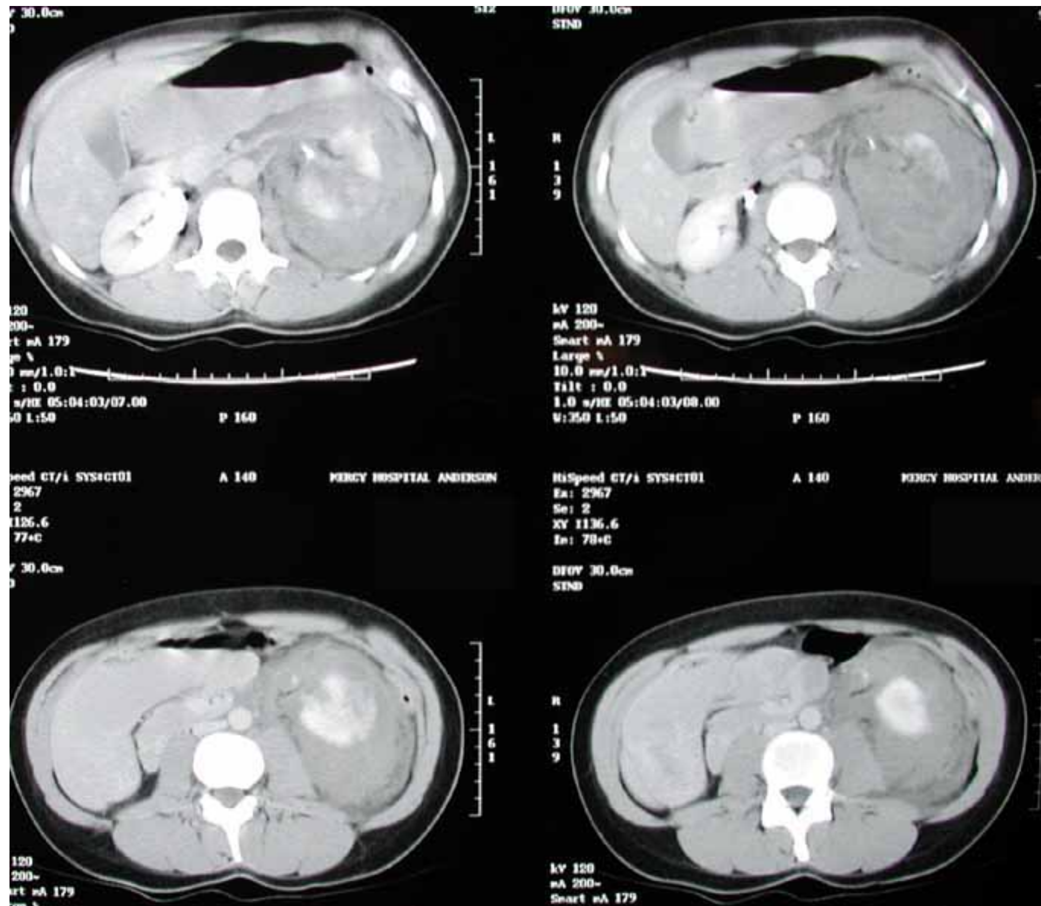
Kidney Injuries

- 1-3% of all trauma and up to 10% of abdominal trauma
- Mechanism
  - 90% of significant renal injuries are from blunt trauma

Diagnosis

- History
  - Blow to flank, deceleration trauma, fall from height, or penetrating abdominal, pelvic, and lower chest injuries
- PE
  - Hematuria
    - Magnitude of hematuria <u>*does not*</u> correlate with the magnitude of injury
  - Flank tenderness, CVA tenderness, ecchymosis

Imaging


DFOV 30.0cm
STND
kV 120
mA 200-
Smart mA 179
Large %
10.0 mm/1.0:1
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MERCY HOSPITAL ANDERSON
Ex: 2967
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XY I136.6
Im: 78+C
DFOV 30.0cm
STND
kV 120
mA 200-
Smart mA 179

Imaging

TABLE 39-1

Urologic Injury Scale of the American Association for the Surgery of Trauma

GRADE[a]		INJURY DESCRIPTION[b]
RENAL INJURY SCALE		
I	Contusion	Microscopic or gross hematuria; urologic studies normal
	Hematoma	Subcapsular, nonexpanding without parenchymal laceration
II	Hematoma	Nonexpanding perirenal hematoma confined to the renal retroperitoneum
	Laceration	<1 cm parenchymal depth of renal cortex without urinary extravasation
III	Laceration	>1 cm parenchymal depth of renal cortex without collecting-system rupture or urinary extravasation
IV	Laceration	Parenchymal laceration extending through the renal cortex, medulla, and collecting system
	Vascular	Main renal artery or vein injury with contained hemorrhage
V	Laceration	Completely shattered kidney
	Vascular	Avulsion of renal hilum that devascularizes kidney
URETER INJURY SCALE		
I	Hematoma	Contusion of hematoma without devascularization
II	Laceration	≤50% transection
III	Laceration	>50% transection
IV	Laceration	Complete transection with 2 cm devascularization
V	Laceration	Avulsion of renal hilum that devascularizes kidney
BLADDER INJURY SCALE		
I	Hematoma	Contusion, intramural hematoma
	Laceration	Partial thickness
II	Laceration	Extraperitoneal bladder wall laceration ≤2 cm
III	Laceration	Extraperitoneal (>2 cm) or intraperitoneal (≤2 cm) bladder wall lacerations
IV	Laceration	Intraperitoneal bladder wall laceration >2 cm
V	Laceration	Intra- or extraperitoneal bladder wall laceration extending into the bladder neck or ureteral orifice (trigone)
URETHRAL INJURY SCALE		
I	Contusion	Blood at urethral meatus; urethrography normal
II	Stretch injury	Elongation of urethra without extravasation on urethrography
III	Partial disruption	Extravasation of urethrographic contrast medium at injury site, with contrast visualized in the bladder
IV	Complete disruption	Extravasation of urethrographic contrast medium at injury site without visualization in the bladder; <2 cm of urethral separation
V	Complete disruption	Complete transection with >2 cm urethral separation, or extension into the prostate or vagina

[a] Advance one grade for multiple injuries to the same organ.

[b] Based on most accurate assessment at autopsy, laparotomy, or radiologic study.

Reproduced with permission from Moore EE, Shackford SR, Pachter HL, et al: Organ injury scaling: Spleen, liver, and kidney. J Trauma 29:1664, 1989.

Grading

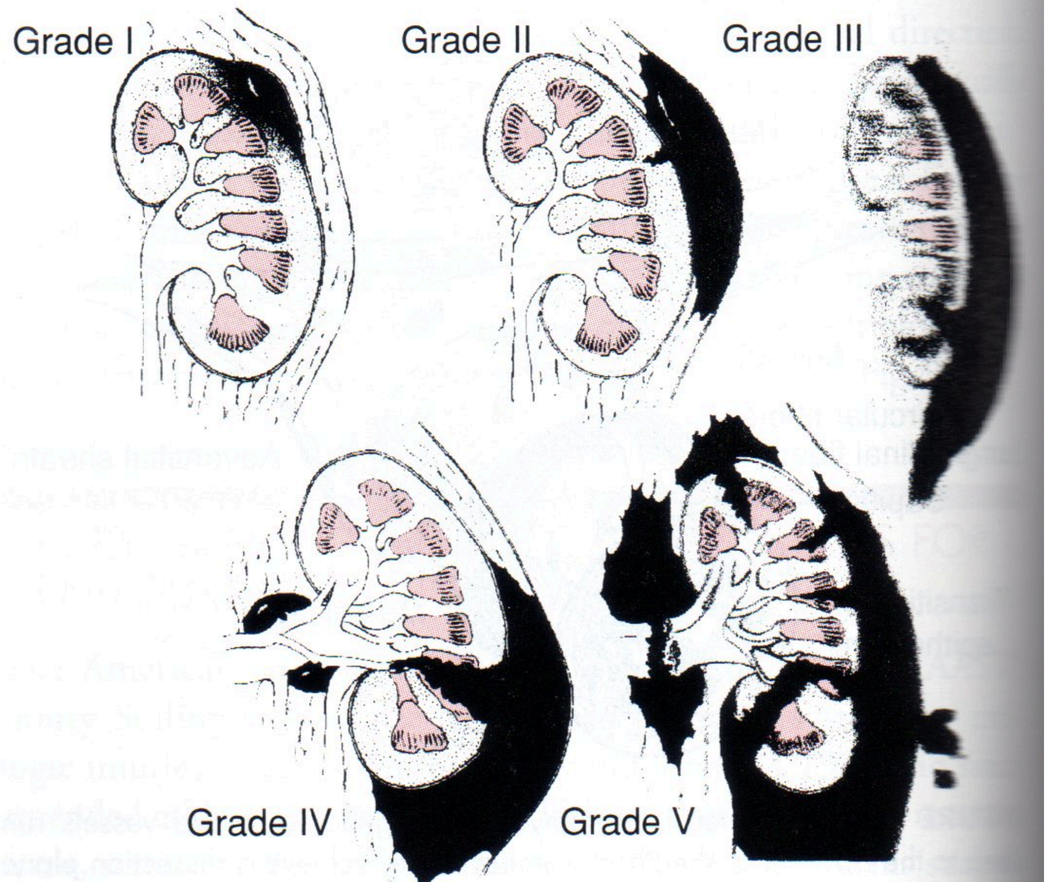


FIGURE 39-6. Organ injury scaling system for renal trauma.

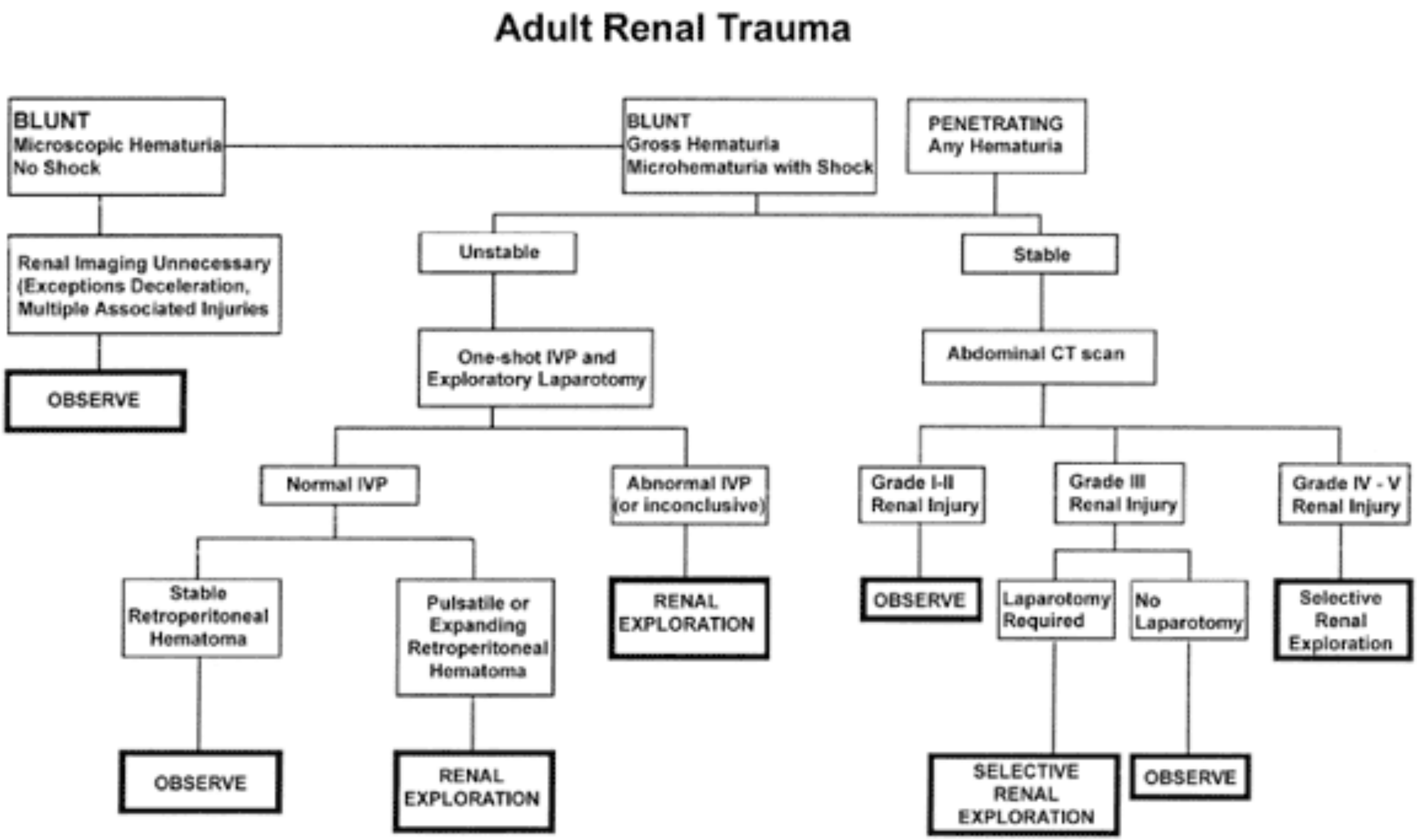


Figure 1 *- Algorithm for treating patients with renal trauma. (Reprinted with permission from: Meng MV, Brandes SB, McAninch JW. Renal trauma: indications and techniques for surgical exploration. World J Urol. 1999; 17: 71-7).*

Treatment

- Nonoperative Management
  - Grade I, II
  - Grade III if hemodynamically stable
  - Bedrest until hematuria clears with re-image at 48-96 hours
  - Treatment (if complications arise)
    - Percutaneous drainage, stenting, IR embolization
- Operative Management
  - Grade IV or V
  - Uteropelvic avulsion or complete avulsion of fornices
  - Intraoperative
    - Pulsatile or expanding zone II hematoma

Operative Management

- Mobilize small bowel and open posterior peritoneum over the aorta, above the IMA, medial to renal vessels
- Vessel loop the renal vessels
- Mobilize the colon and mesocolon on side of injury
- Enter Gerota's Fascia
  - If significant bleeding encountered, a non-crushing pedicle clamp can be applied to renal pedicle

Exposure

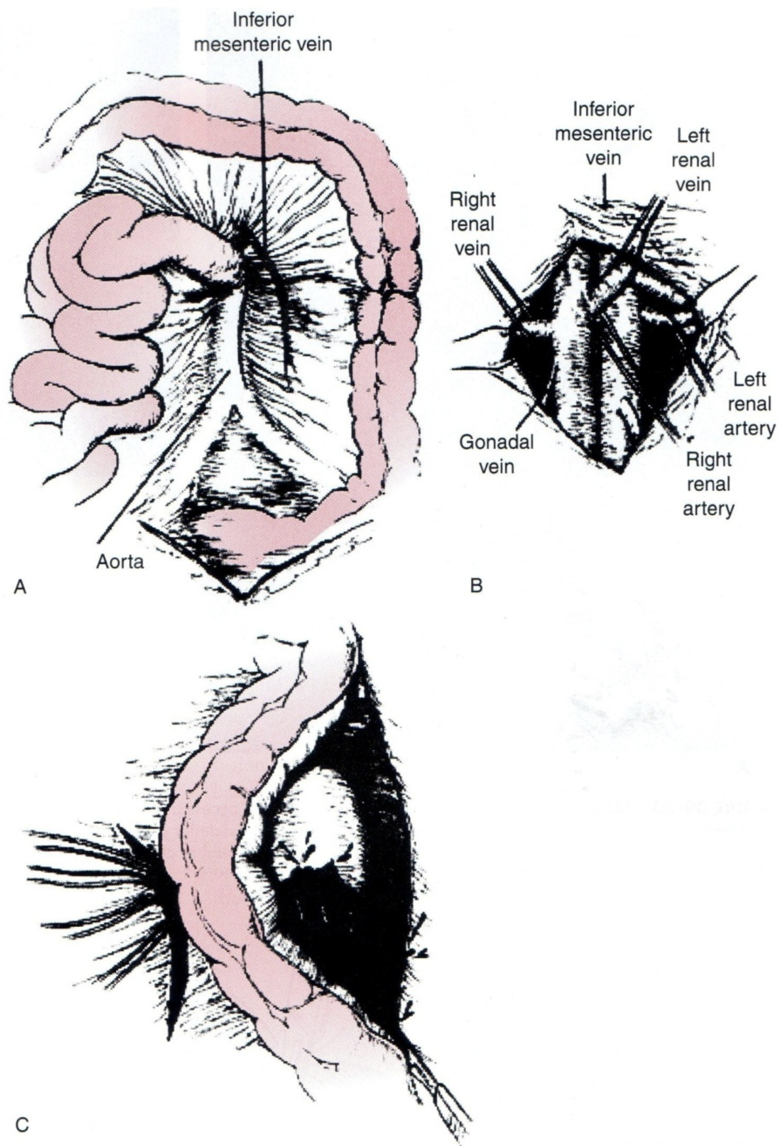


FIGURE 39-19. Surgical management of renal trauma: vascular control. Diagram demonstrating early vascular control prior to renal exploration. **(A)** The posterior peritoneum is opened over the aorta medial to the inferior mesenteric vein. **(B)** The renal vessels are individually dissected and surrounded with vessel loops. **(C)** The colon is reflected medially exposing the perinephric hematoma. Some clinicians believe preliminary control of the renal vessels is not necessary when performing renal exploration for trauma, though best renal salvage rates are reported when vascular access or control is obtained.

Repair

- Evacuate hematoma
- Identify lacerated vessels, collecting systems, devitalized parenchyma
- Debride/excise devitalized parenchyma
  - Use absorbable 3-0/4-0 suture
    - Non-absorbable sutures create a nidus for stone formation
- If repair of collecting system is tenuous/in-complete, an internal stent or nephrostomy tube is warranted to prevent post-op urine Extravasation or urinoma
- Injection of methylene blue in to renal pelvis to check for leaks
- Close repaired kidney within Gerota's fascia or use patch from peritoneum

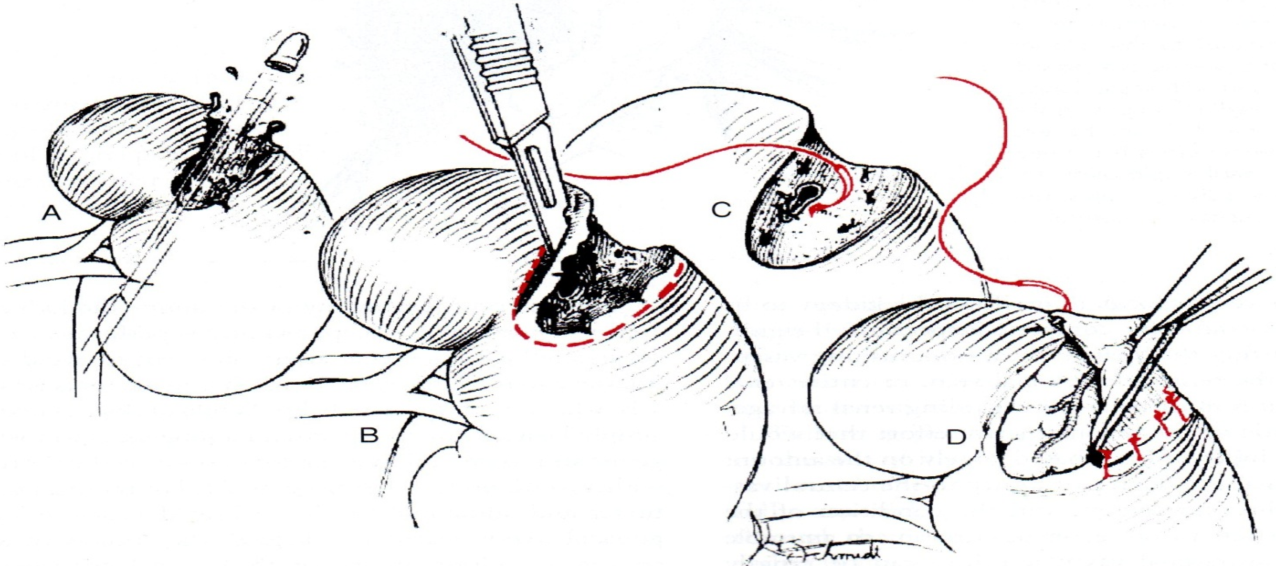


FIGURE 39-21. **(A,B)** Wedge resection of injured parenchyma. **(C)** Suturing of open collecting system and significant vessels with absorbable suture. **(D)** Capsule, if present, may be closed, or reconstructed using peritoneal patch, with absorbable gelatin sponge or local fat pedicle to aid in hemostasis.

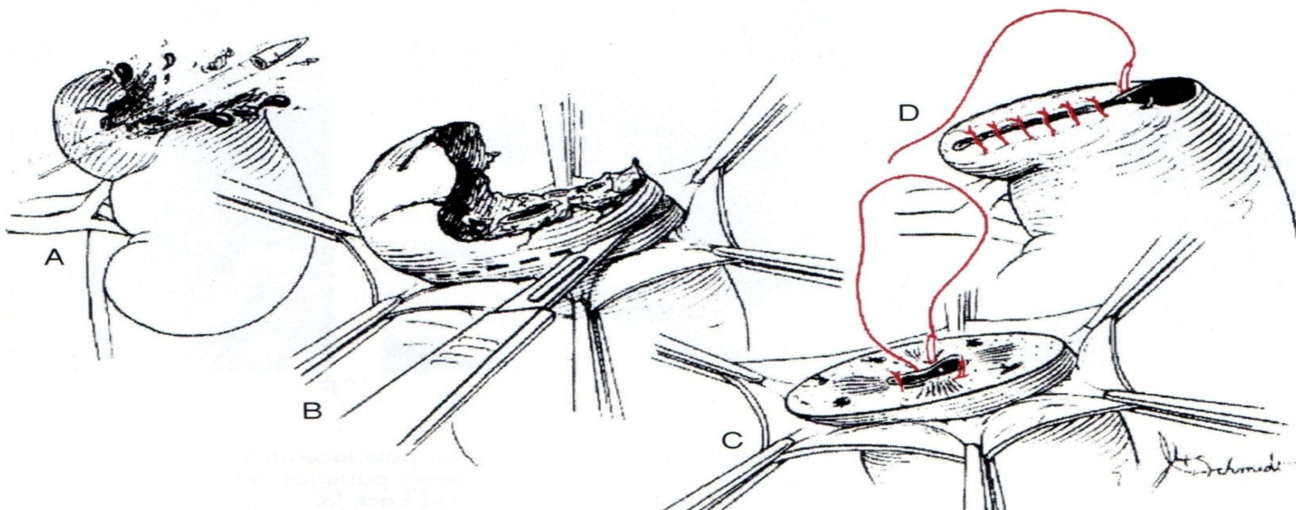
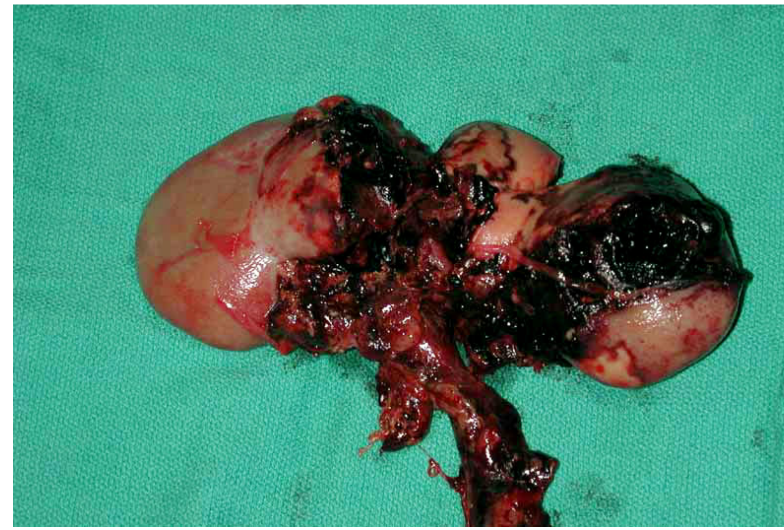
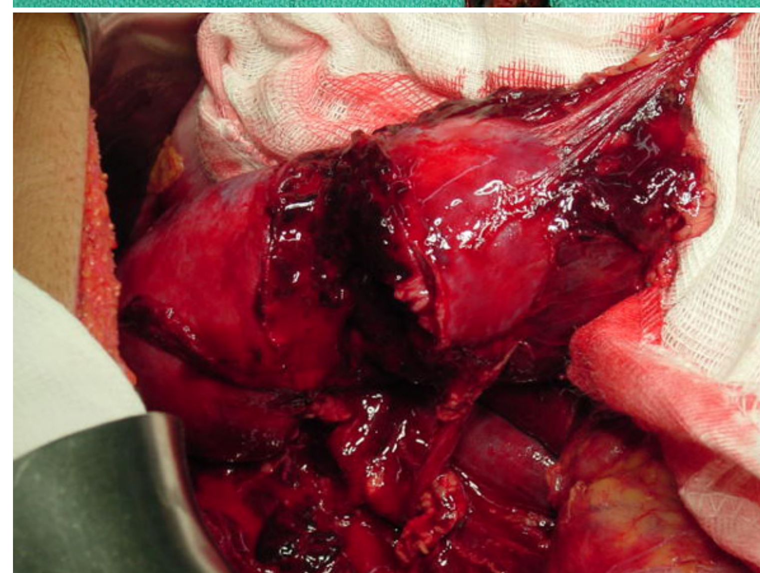


FIGURE 39-22. **(A,B)** Partial nephrectomy for major injury to upper pole. **(C)** Repair of collecting system and suturing of bleeding vascular branches. **(D)** Mattress sutures of 2-0 chromic gut to reconstruct parenchyma and aid in hemostasis.

Nephrectomy

- ALWAYS CHECK CONTRALATERAL KIDNEY
- Ligate vessels seperately
  - Reduce risk for AV fistula
- 3-0 prolene





Ureteral Injuries

- Relatively uncommon
  - < 1% of abdominal trauma
- Hematuria can be absent in 15-45% of patients
- One of the most commonly missed injuries
- Diagnosis
  - CT Cysto
    - Failure of distal ureter to opacify should raise concern

Treatment

- Non-operative management
  - Limited applications
    - Missed ureteral injuries, damage control patients
  - Increased risk of inflammation, edema, friability, urinoma formation, reconstruction complications
  - Percutaneous nephrostomy tube until surgical intervention

Operative Management

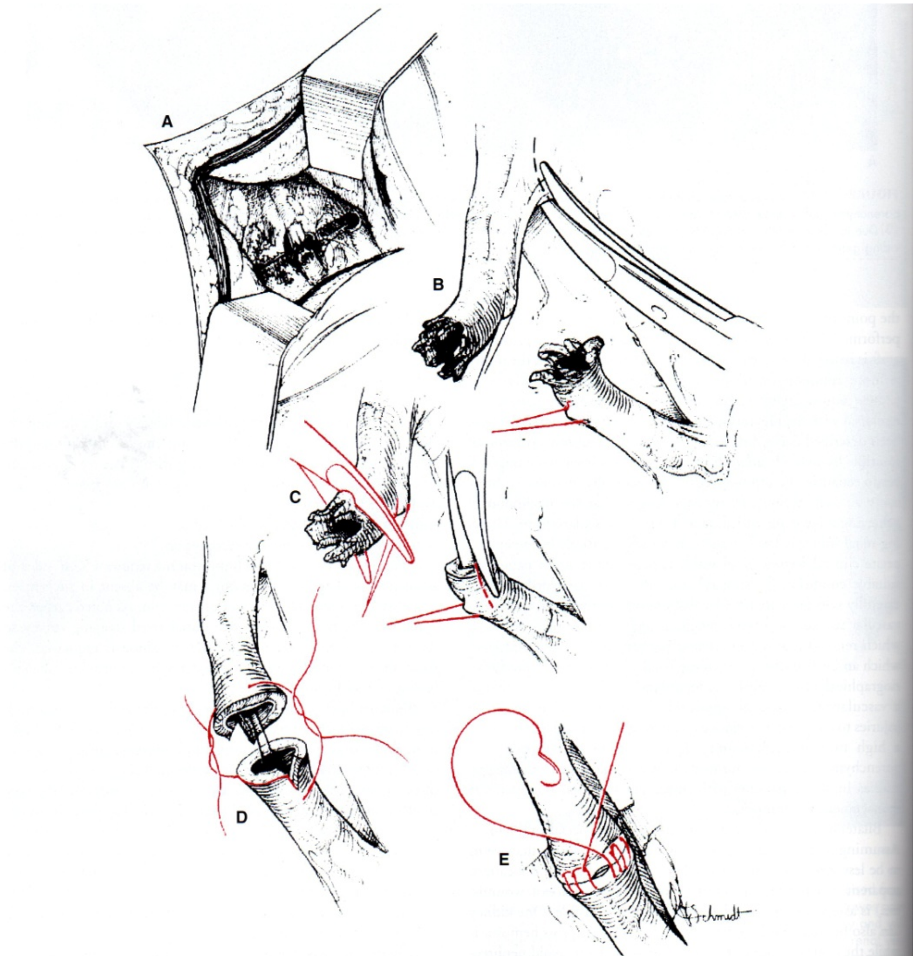
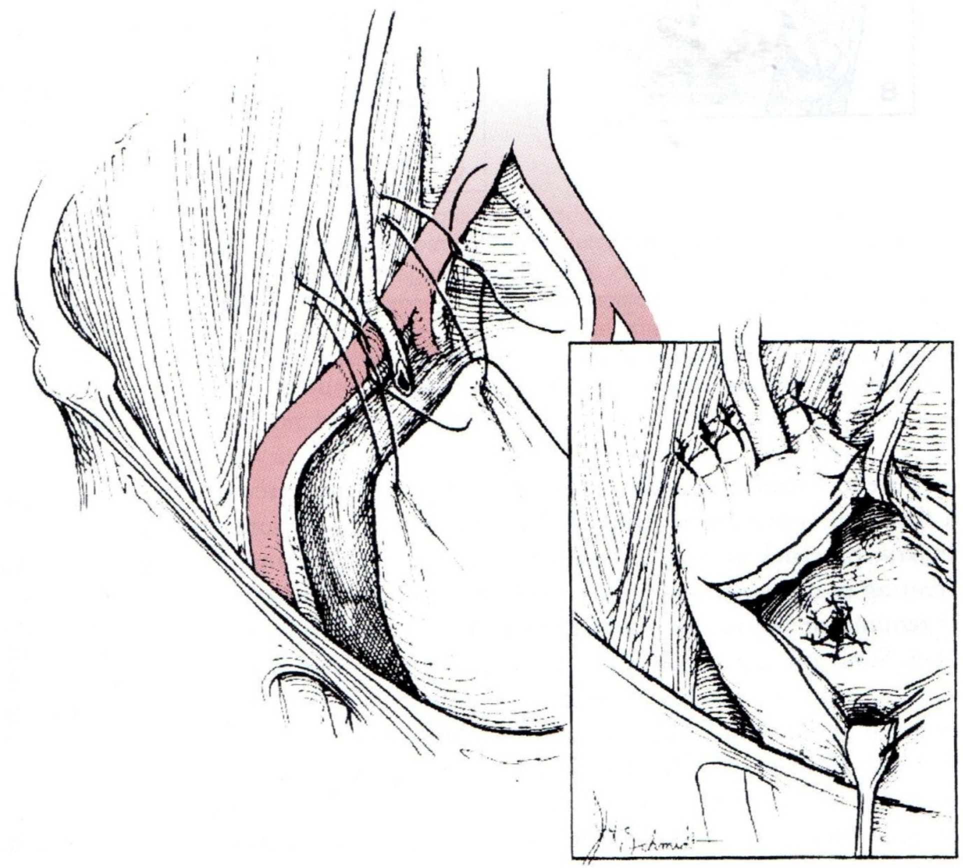


FIGURE 39-25. Techniques of ureteral reconstruction. Debridement and primary anastomosis for ureteral transection from gunshot wound. **(A,B)** Mobilization of ureter superficial to adventitial plane. **(C)** Limited debridement of lacerated ureter to viable tissue with spatulation for repair. **(D,E)** End-to-end anastomosis with fine absorbable suture, over stent (not shown).

- Simple Repair
  - Debridement of devitalized tissue
  - Spatulated end-to-end anastomosis with 4-0 absorbable suture
  - Stent placement
    - Endoscopic retrieval in 4-6 weeks

Operative Management

- Psoas Stitch
  - Open bladder anteriorly
  - Lateral peritoneal attachments are divided
  - Bring bladder to side of injury
  - Suture to psoas muscle with absorbable 2-0 sutures
  - Re-implant ureter in bladder if distal avulsion injury



B

Operative Management

- What if ureter length prevents repair?
- Transureteroureterostomy
  - Tunnel injured ureter under mesentery
  - End-to-side anastomosis with contralateral ureter with 4-0 absorbable suture
- Renal Autotransplantation

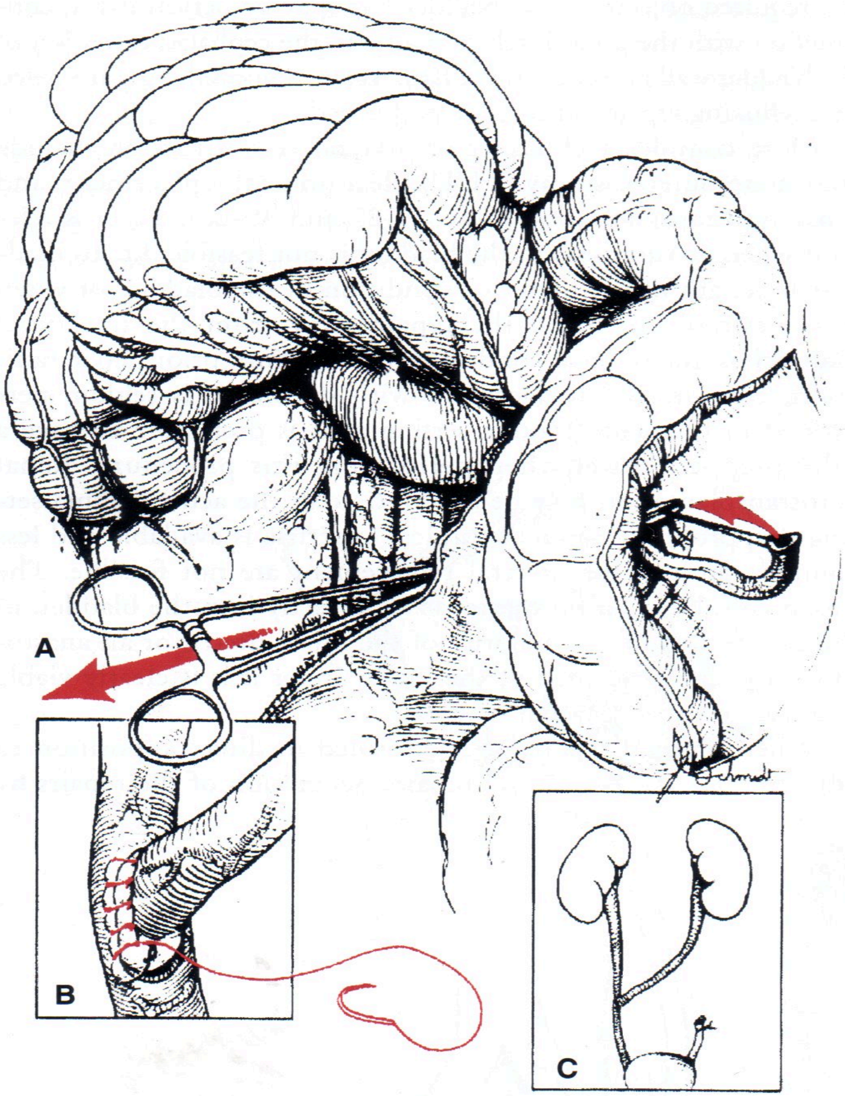


FIGURE 39-27. Transureteroureterostomy for reconstruction following extensive midlower ureteral injury. Prior bladder surgery or pelvic inflammatory or neoplastic disease, among other factors, may make psoas hitch or bladder flap repair undesirable. The injured ureter is mobilized and transposed to the contralateral side underneath the mesentery, then anastomosed with an end-to-side technique to the recipient ureter.

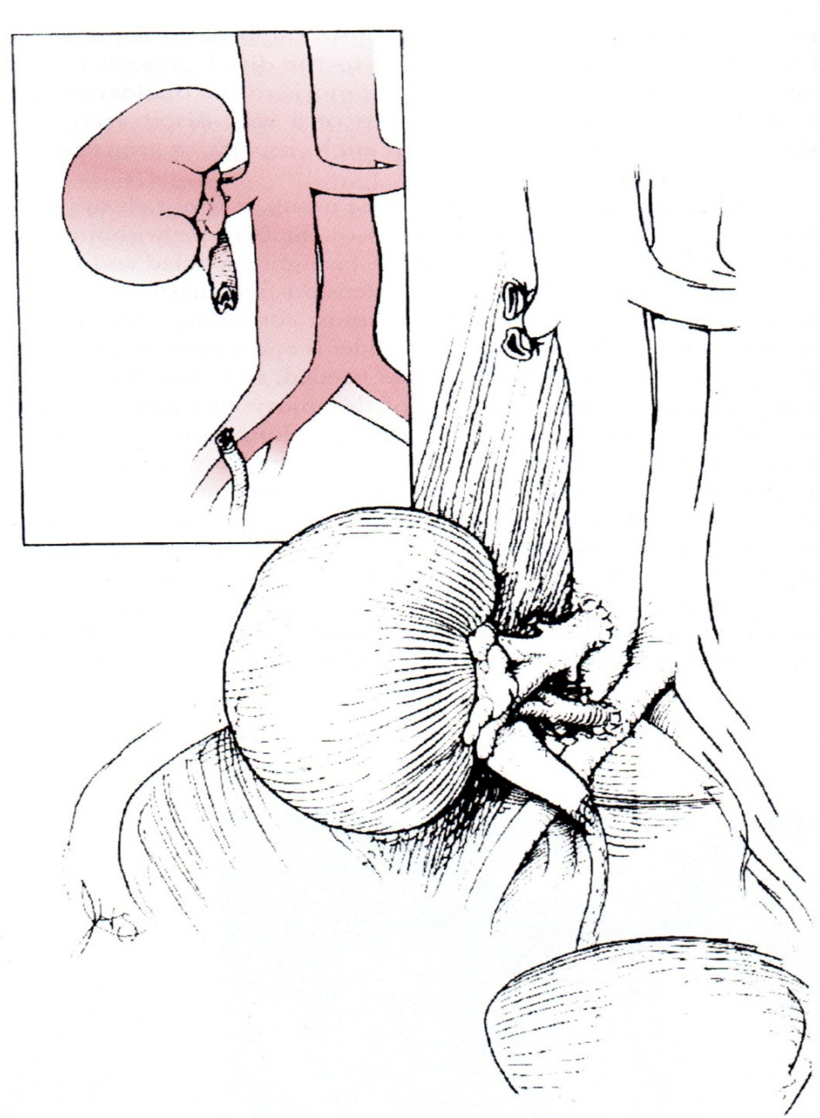
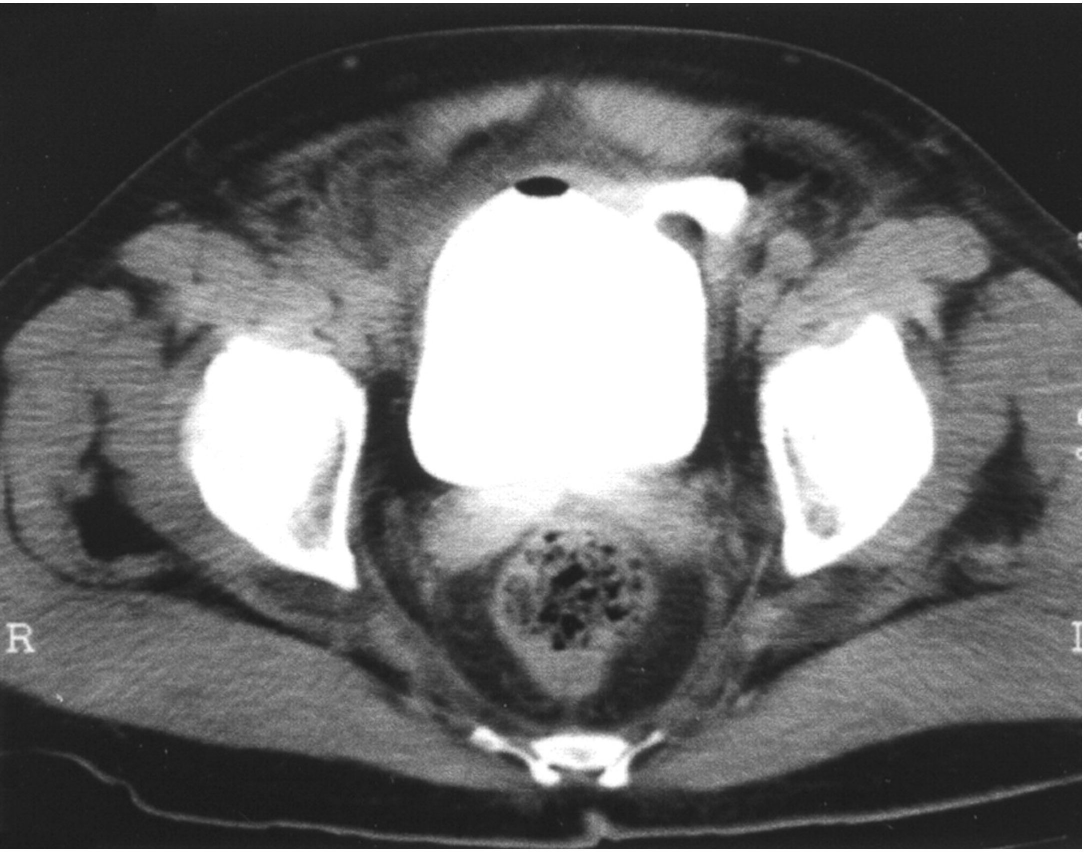


FIGURE 39-28. Renal autotransplantation for reconstruction following extensive loss of midureter, making direct union of upper ureter to bladder impossible. Alternative to ileal-ureteral replacement of most of the ureter. Nephrectomy must be tailored to include as much of the renal vessels as possible to aid in anastomosis to iliac vessels (in general, vein generally transected flush with vena cava on right, with artery transected more proximally, behind vena cava, than shown here). Anastomosis of proximal ureter to viable lower ureter.

Bladder

- Mechanism
  - Compression of full bladder, shear forces, pelvic fracture
    - 80% of bladder injuries have associated pelvic fracture
- Gross hematuria present in > 95% of patients
- CT Cysto

CT Cystogram



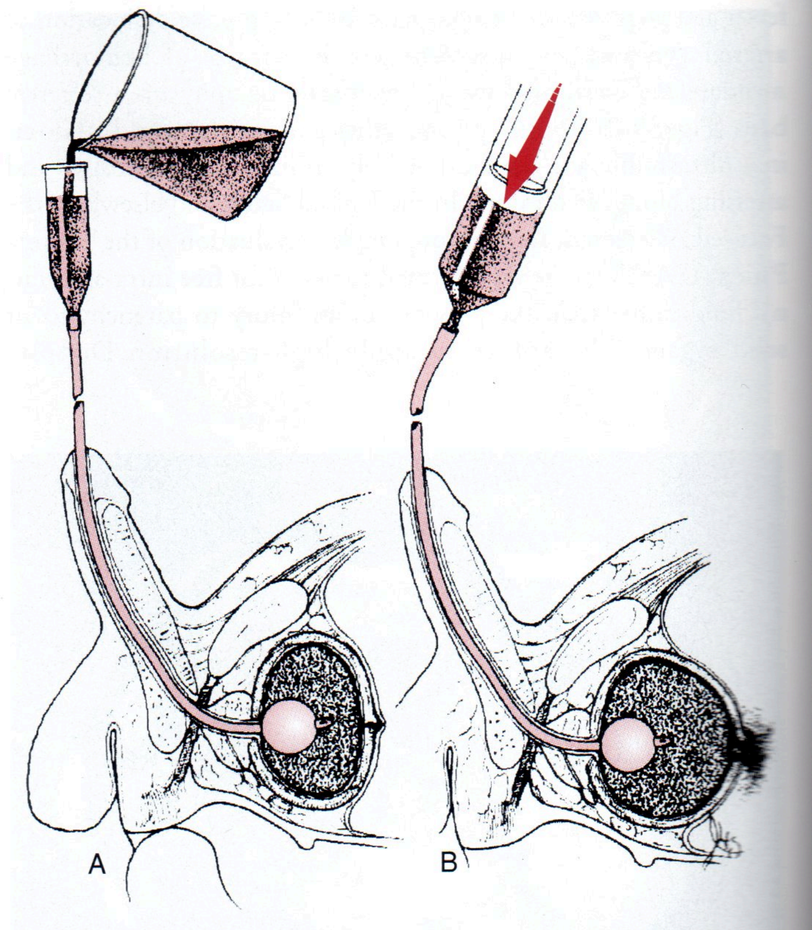


FIGURE 39-9. Stress cystogram: Through Foley catheter, the bladder is filled by gravity to a standard volume (300 to 400 mL typically in adult), or to the point of perceived fullness by patient. Plain radiograph obtained to allow visualization of upper and lower abdomen, followed by washout film.

Extraperitoneal

Intraperitoneal

Treatment

- Non-operative Management
  - Extraperitoneal rupture
    - Foley drainage for 10-14 days
    - Repeat CT Cysto
    - If +, another 7-10 days
- Intraperitoneal rupture warrants operative repair

Operative Management

- Most injuries are at the dome of the bladder
- Debride edges of laceration
- Repair with 2 layers of heavy absorbable sutures

Urethral Injuries

- Mechanism
  - Straddle injuries with sudden decompression at the level of mid-to-deep bulbous urethra against the inferior pubic arch
  - Bilateral pubic rami fractures
- PE
  - Blood at urethral meatus, inability to void, presence of perineal hematoma, inability to palpate prostate on rectal exam
- Retrograde Urethrogram
  - Partial vs Complete
    - If positive → suprapubic cath and CT Cysto
      - 10-15% of urethral injuries have concomitant bladder injuries

Saddle Injury

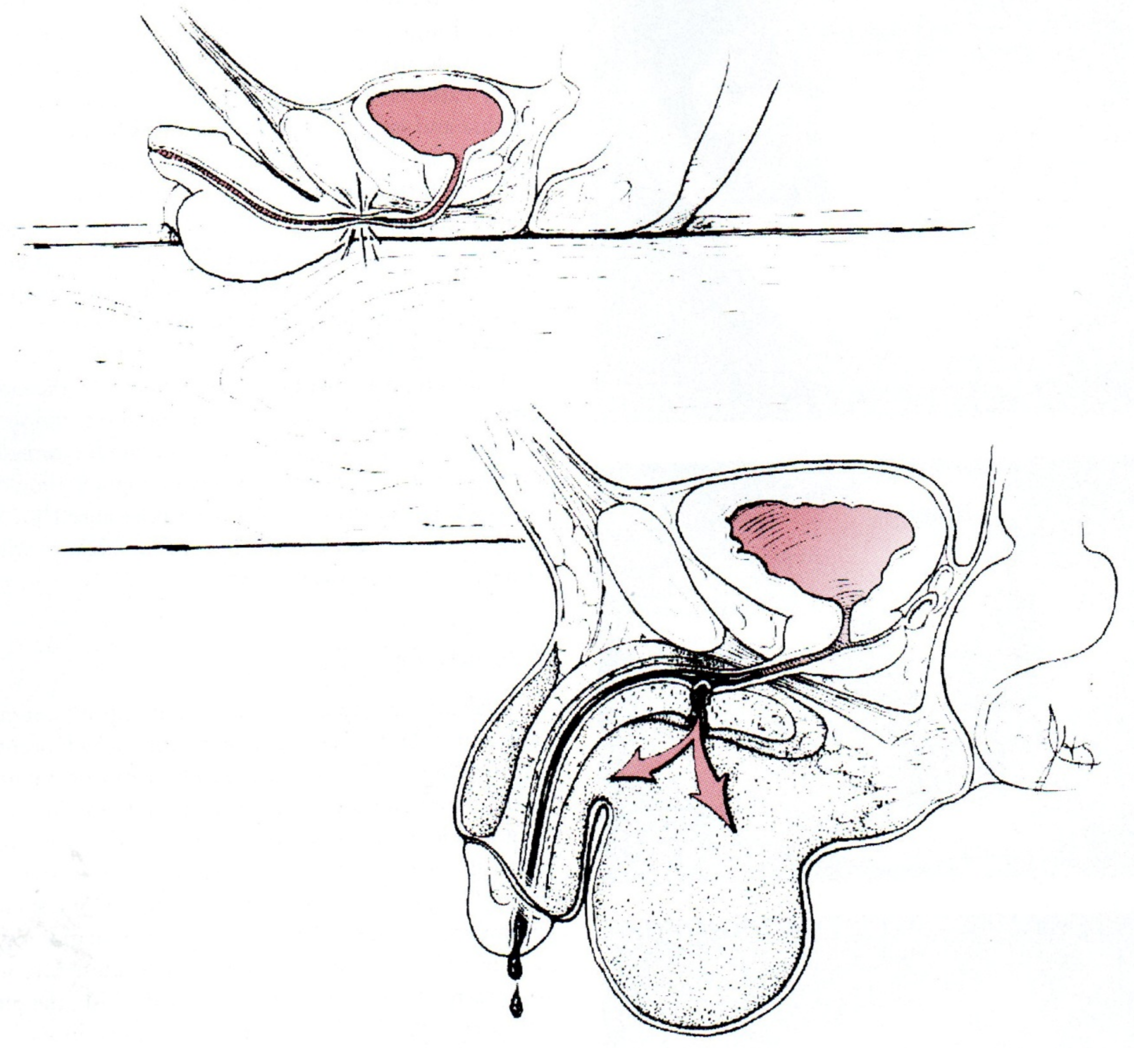


FIGURE 39-12. Mechanism of anterior urethral disruption due to straddle injury; extravasation pattern and hematoma limited in this case by Colles' fascia, due to rupture of Buck's fascia along with full thickness of urethral wall. Hematoma and urinoma may extend along shaft of penis and into scrotum and perineum.

Retrograde Urethrogram

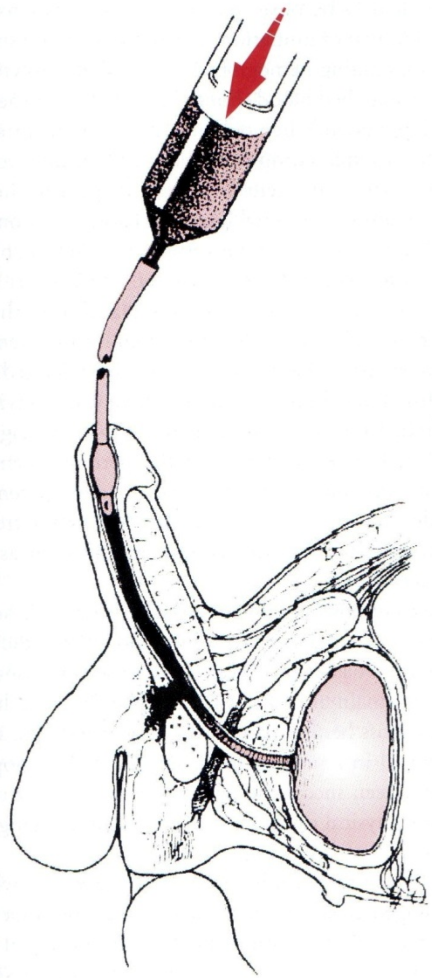
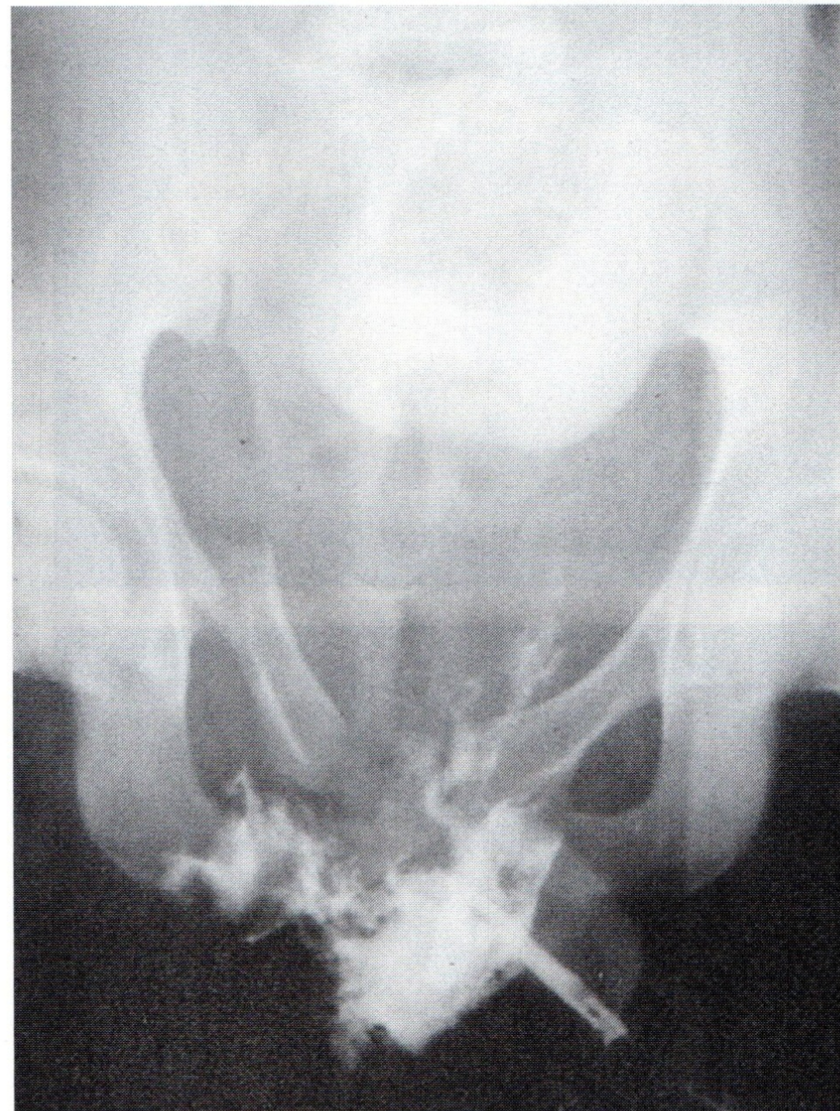


FIGURE 39-13. Technique of retrograde urethrogram. Retrograde urethrogram: Catheter is inserted into urethral meatus, with miminal balloon inflation to maintain position and allow hands to be out of x-ray field. Contrast is instilled to distend urethra.



A

Treatment

- Non-operative Management
  - If RUG shows some contrast in bladder, then gently passage of catheter should be attempted by urology under endoscopic guidance

Operative Management

- Anterior urethral injury
  - Transurethral catheter or suprapubic cath with drainage of > 3months followed by elective end-to-end urethroplasty
- Posterior urethral injury
  - Suprapubic cath drainage for 3-6 months with urethroplasty

Liver Injuries

Liver Injuries

- 5% of all trauma admissions
  - Anatomic location makes it the most susceptible organ for injury in blunt abdominal trauma
  - 80% penetrating, 20% blunt
  - Rapid deceleration can cause avulsion of hepatic veins and injure the retro-hepatic IVC
- Right sided rib fractures 9-11 have 20% chance of underlying liver injury
- Can be managed operatively and non-operatively

Anatomy

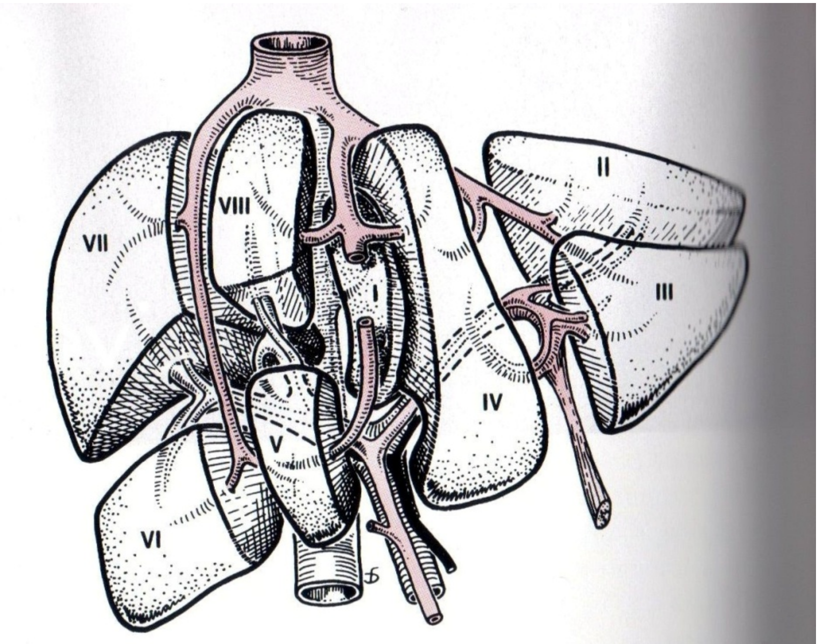
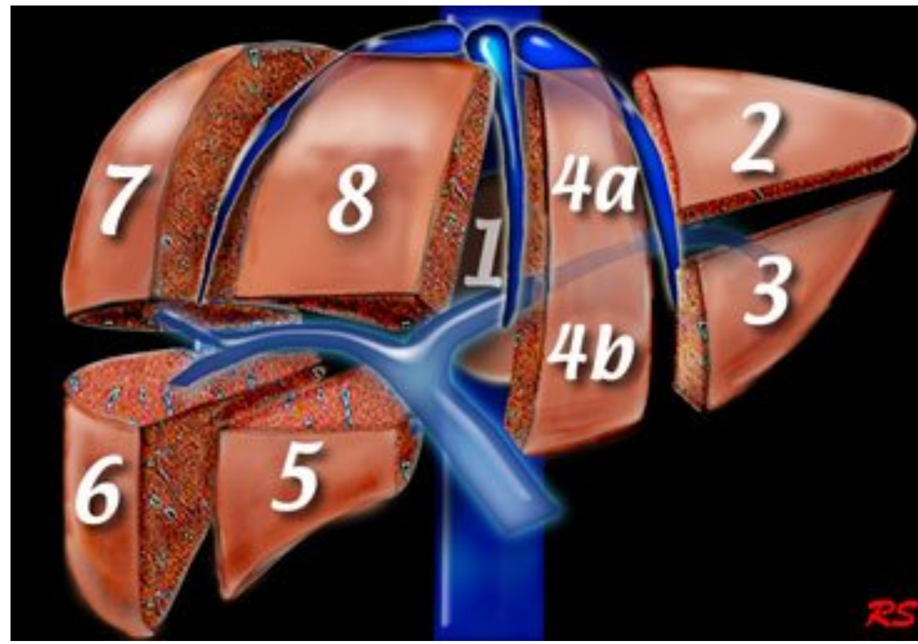


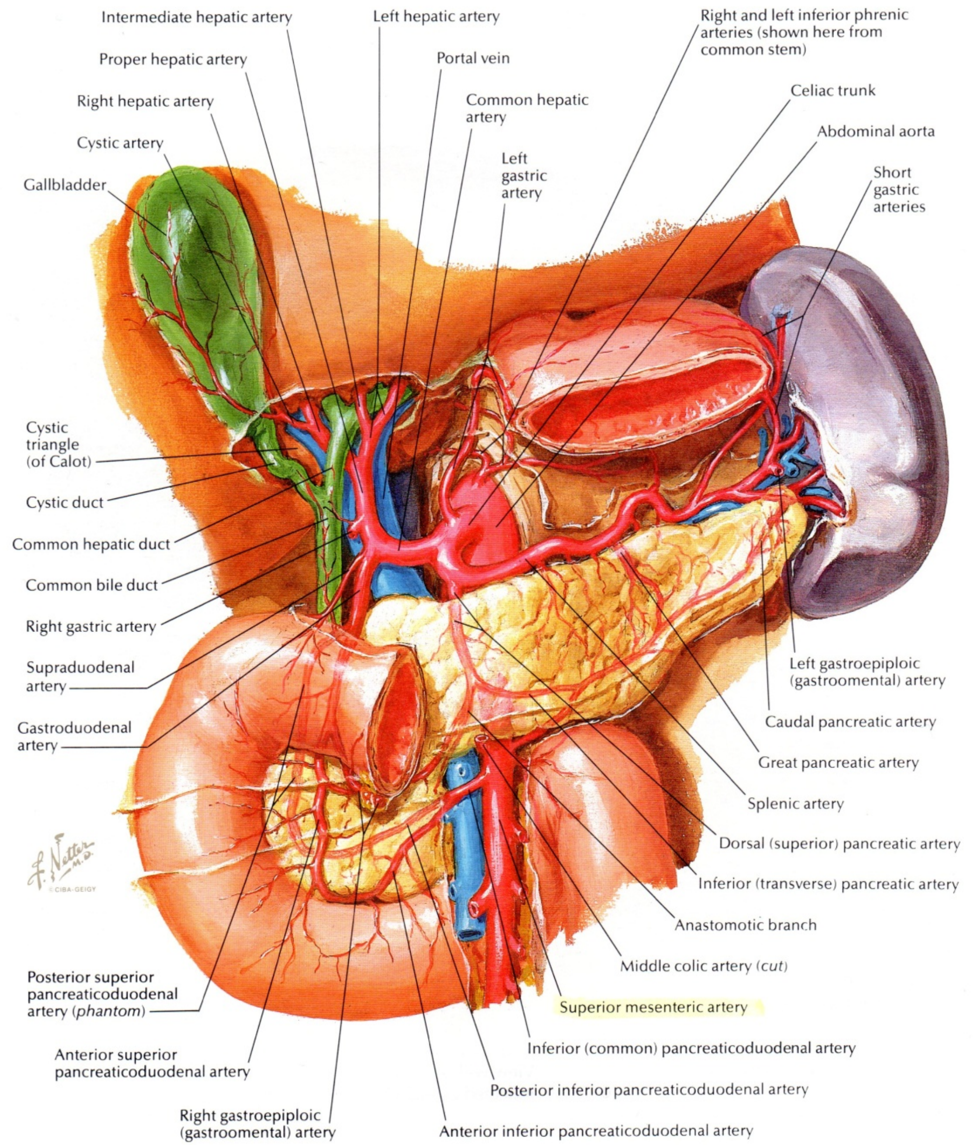
FIGURE 32-2. Functional division of the liver, according to Couinaud nomenclature.
(Reproduced with permission from Blumgart LH (ed): Surgery of the Liver and Biliary Tract. New York, Churchill Livingstone, 1988.)



- Couinaud's Nomenclature
  - Dividing the liver based on the distribution of hepatic veins

Anatomy

- Hepatic arteries
  - Common hepatic gives off the left, right, and intermediate branches
  - Provides 25% of hepatic blood flow and 50% of hepatic oxygenation



Anatomy

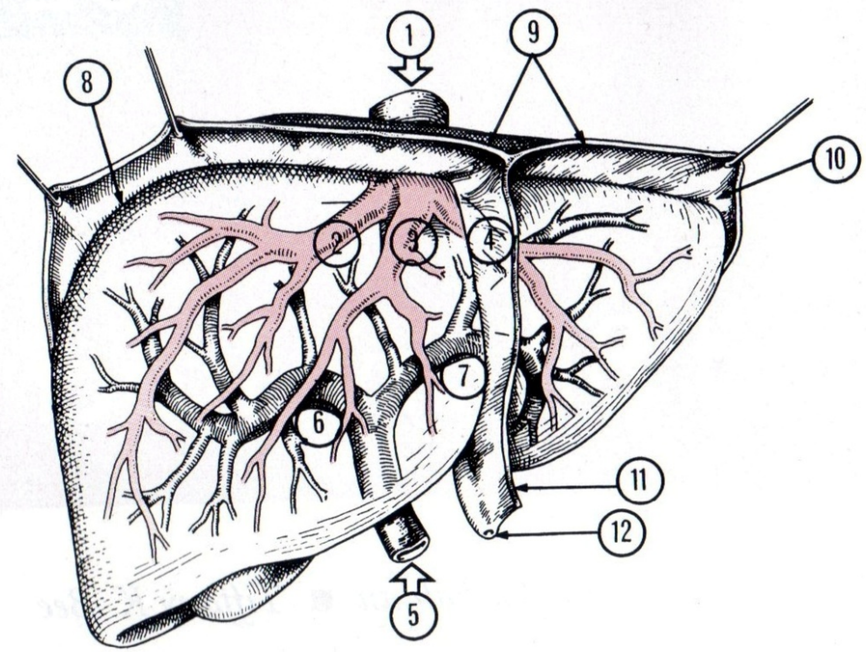
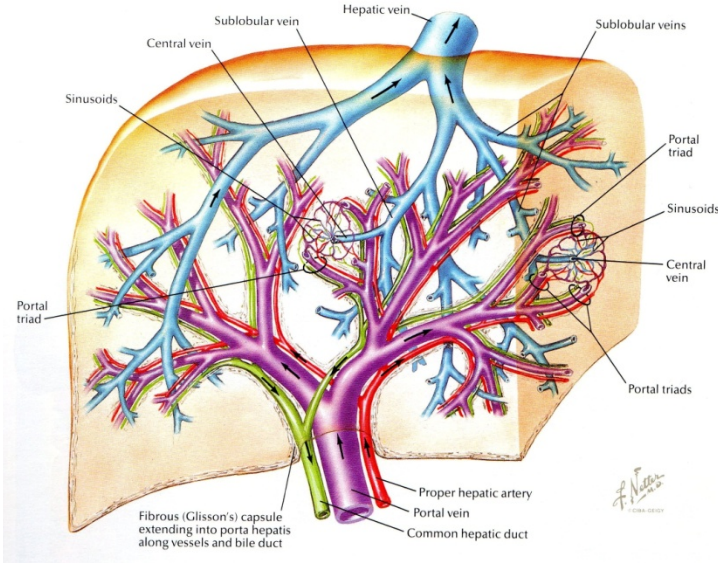


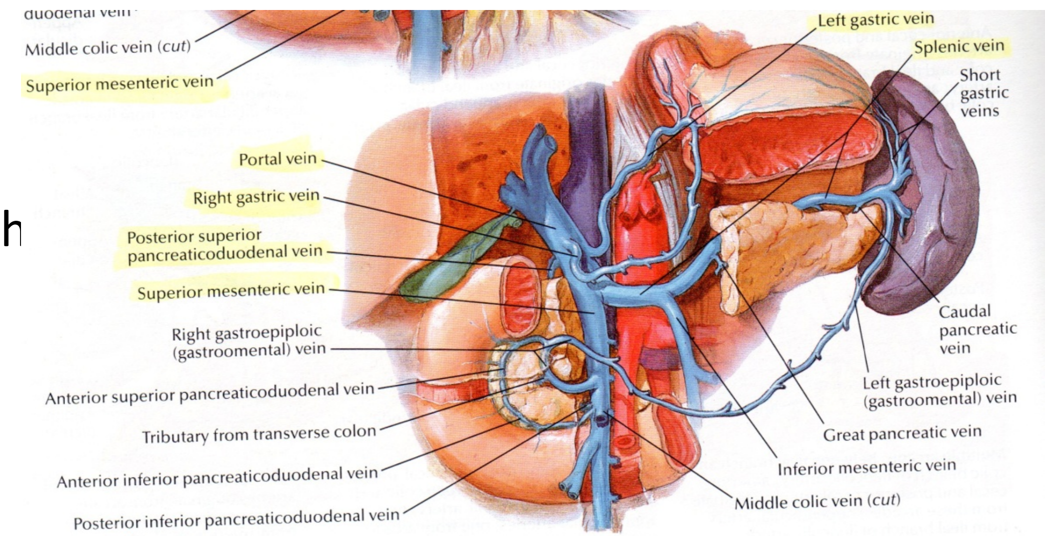
FIGURE 32-1. Surgical anatomy of the liver: (1) inferior vena cava; (2) right hepatic vein; (3) middle hepatic vein; (4) left hepatic vein; (5) portal vein; (6) right branch portal vein; (7) left branch portal vein; (8) right triangular ligament; (9) coronary ligament; (10) left triangular ligament; (11) falciform ligament; (12) ligamentum teres.

- Hepatic veins
  - Develop from within the hepatocytes' central lobar veins
  - Right hepatic vein
    - Superior, middle, and inferior branches from right lobe
  - Middle hepatic vein
    - 2 branches from segment IV and V and a posterior branch from segment VIII
  - Left hepatic vein
    - 2 branches from left lobe
    - Posterior in position and can result in iatrogenic injury when taking down the left coronary ligament

Anatomy

- Portal vein
  - Formed by convergence of the splenic and superior mesenteric vein
  - Provides 75% of hepatic blood flow and 50% of oxygenation
  - Posterior to hepatic artery and bile ducts
  - Divides into short right and long left extrahepatic branch





Anatomy

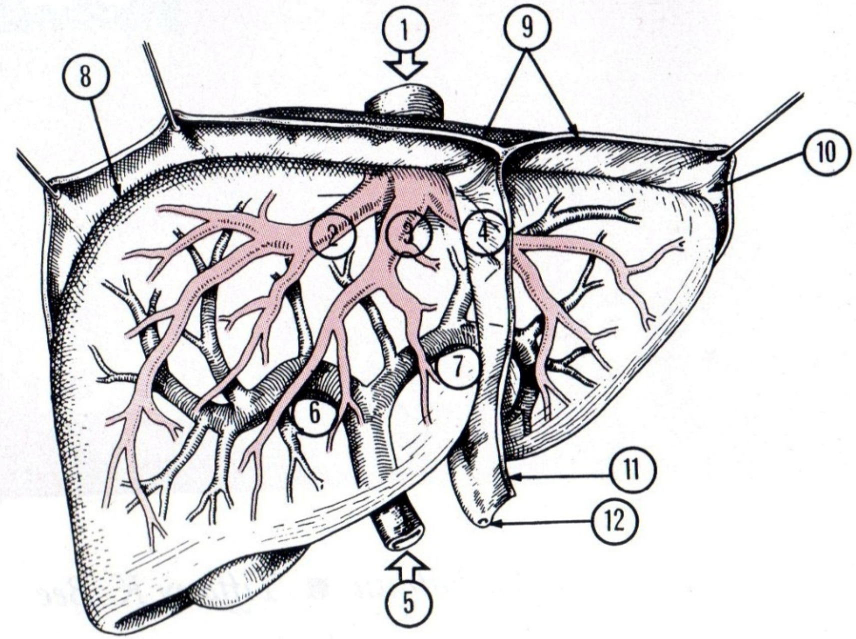


FIGURE 32-1. Surgical anatomy of the liver: (1) inferior vena cava; (2) right hepatic vein; (3) middle hepatic vein; (4) left hepatic vein; (5) portal vein; (6) right branch portal vein; (7) left branch portal vein; (8) right triangular ligament; (9) coronary ligament; (10) left triangular ligament; (11) falciform ligament; (12) ligamentum teres.

- Ligaments of the liver
  - Coronary ligaments attaches diaphragm to the parietal surface of liver
    - Triangular ligaments are at the lateral extensions of the right and left coronary ligaments
    - Medial portion of coronary ligaments is where the hepatic veins traverse
  - Falciform ligament and ligamentum teres attach to the anterior peritoneal cavity

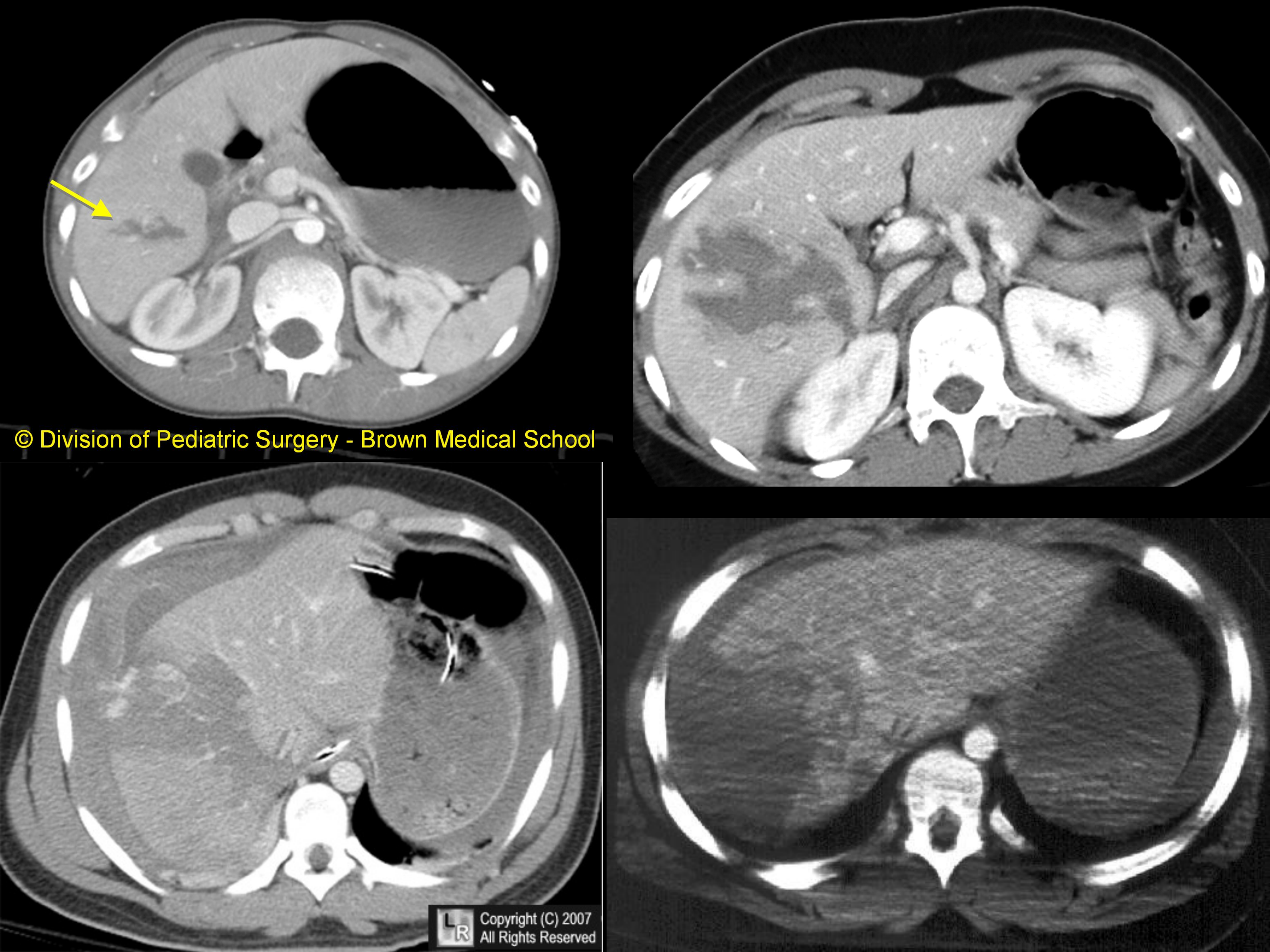
Management

- Unstable
  - DPL, FAST → OR
- Stable
  - FAST, CT → Non-op vs OR

- Management in the stable patient depends on the grading system……..

Table 1: American Association for the Surgery of Trauma Liver Injury Scale

	Grade[a]	Injury Description	ICD-9	AIS-90
I	Hematoma	Subcapsular, <10% surface area	864.01 864.11	2
	Laceration	Capsular tear, <1 cm parenchymal depth	864.02 864.12	2
II	Hematoma	Subcapsular, 10%–50% surface area; intraparenchymal, <10 cm in diameter	864.01 864.11	2
	Laceration	1–3 cm parenchymal depth, <10 cm in length	864.03 864.13	2
III	Hematoma	Subcapsular, >50% surface area or expanding; ruptured subcapsular or parenchymal hematoma. Intraparenchymal hematoma >10 cm or expanding		3
	Laceration	>3 cm parenchymal depth	864.04 864.14	3
IV	Laceration	Parenchymal disruption involving 25%–75% of hepatic lobe or 1–3 Couinaud's segments within a single lobe	864.04 864.14	4
V	Laceration	Parenchymal disruption involving >75% of hepatic lobe or >3 Couinaud's segments within a single lobe		5
	Vascular	Juxtahepatic venous injuries, i.e., retrohepatic vena cava/central major hepatic veins		5
VI	Vascular	Hepatic avulsion		6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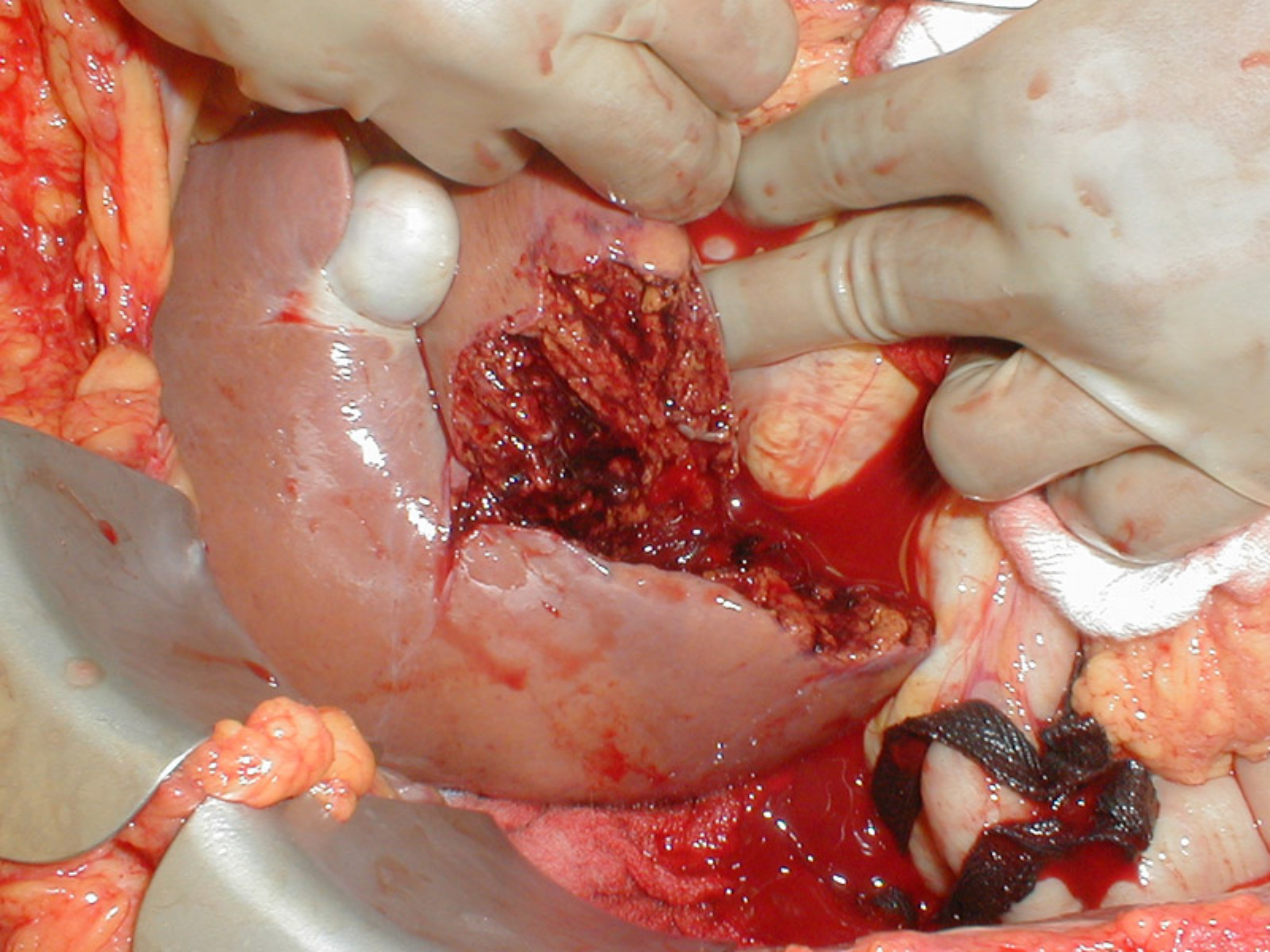
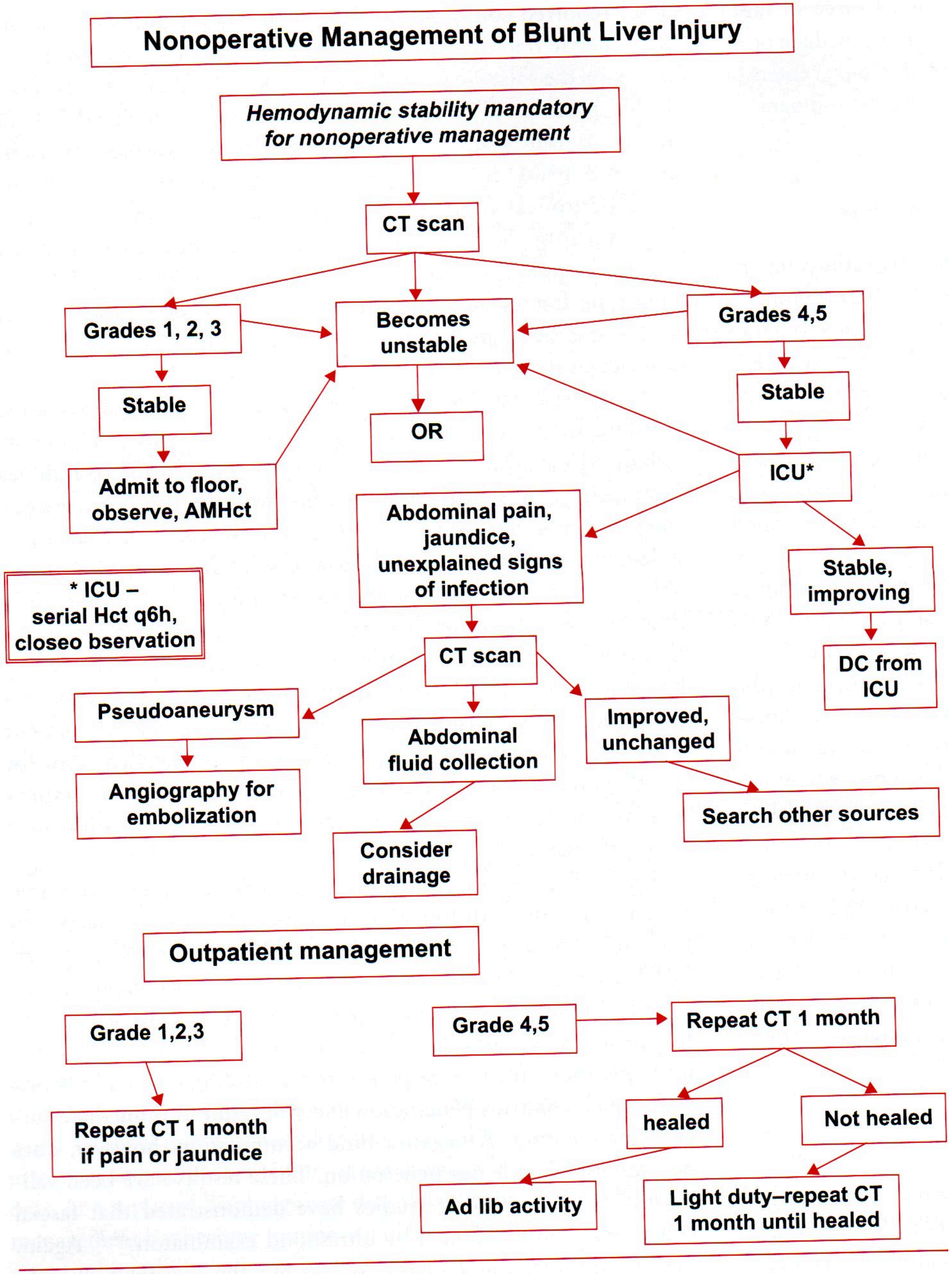
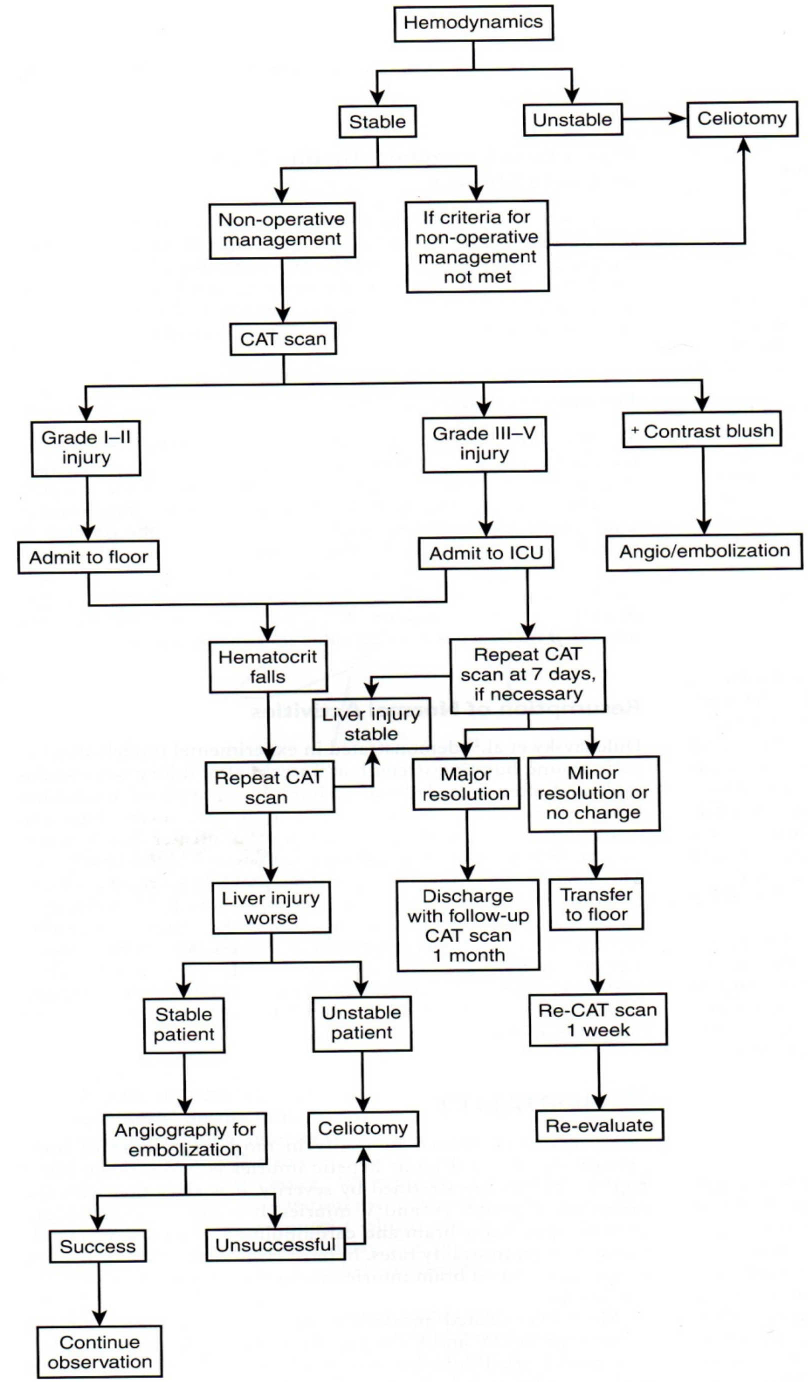
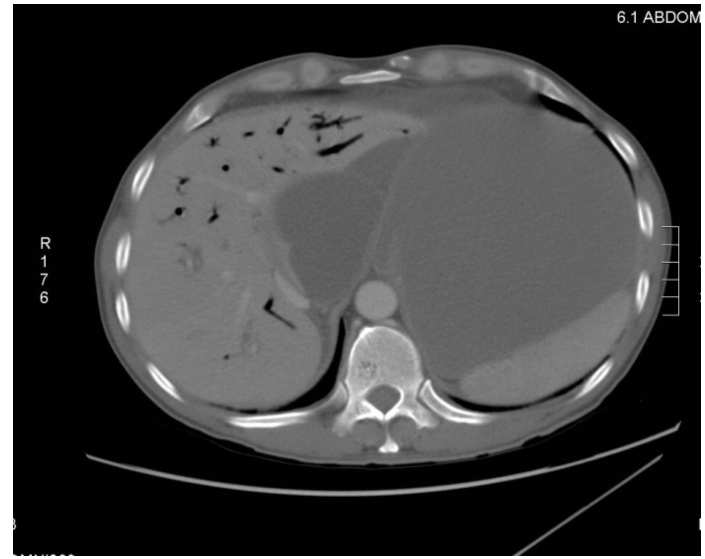


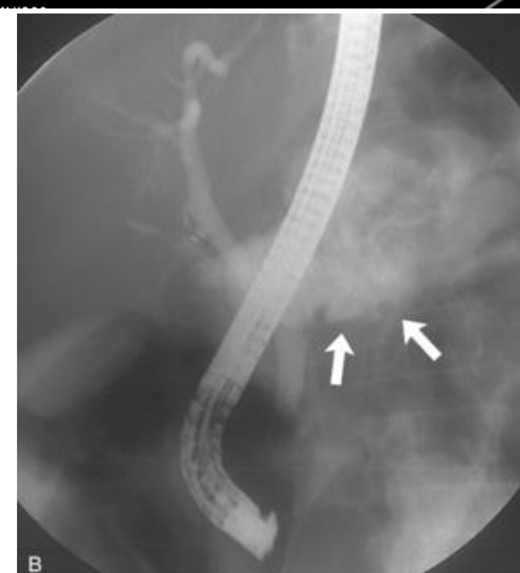

Nonoperative Management of Blunt Liver Injury
Hemodynamic stability mandatory for nonoperative management
CT scan
Grades 1, 2, 3
Becomes unstable
Grades 4,5
Stable
OR
Stable
Admit to floor, observe, AMHct
ICU*
Abdominal pain, jaundice, unexplained signs of infection
Stable, improving
* ICU – serial Hct q6h, closeo bservation
CT scan
DC from ICU
Pseudoaneurysm
Abdominal fluid collection
Improved, unchanged
Angiography for embolization
Search other sources
Consider drainage
Outpatient management
Grade 1,2,3
Grade 4,5
Repeat CT 1 month
healed
Not healed
Repeat CT 1 month if pain or jaundice
Ad lib activity
Light duty–repeat CT 1 month until healed


Hemodynamics
Stable
Unstable
Celiotomy
Non-operative management
If criteria for non-operative management not met
CAT scan
Grade I–II injury
Grade III–V injury
+ Contrast blush
Admit to floor
Admit to ICU
Angio/embolization
Hematocrit falls
Repeat CAT scan at 7 days, if necessary
Liver injury stable
Repeat CAT scan
Major resolution
Minor resolution or no change
Liver injury worse
Discharge with follow-up CAT scan 1 month
Transfer to floor
Stable patient
Unstable patient
Re-CAT scan 1 week
Angiography for embolization
Celiotomy
Re-evaluate
Success
Unsuccessful
Continue observation

Complications of Non-operative Management

- Bile Leaks
  - 3-20%
  - S&S
    - Abnormal LFT, abdominal distention, intolerance to feeding
  - Treatment
    - Ex-lap with repair and drainage
    - ERCP with sphincterotomy
      - Decreases biliary pressure to allow healing
    - CT guided drain into biloma
    - PTC Drain





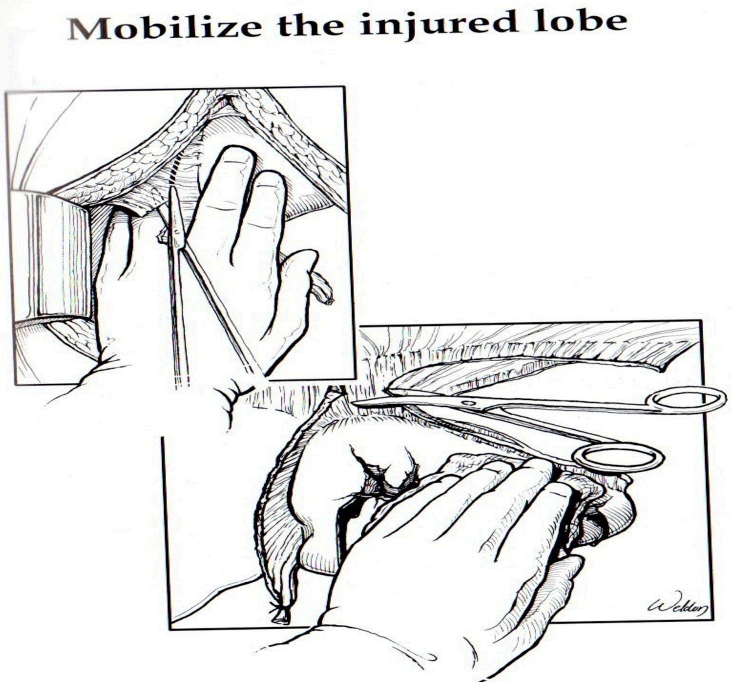
Complications of Non-operative Management

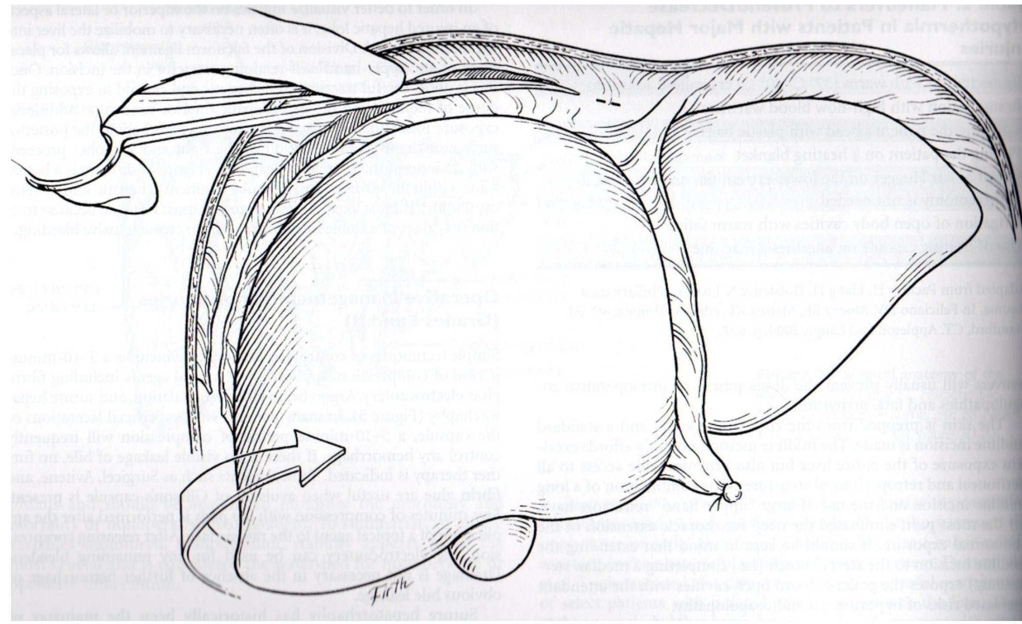
- Pseudoaneurysm
  - Decreasing H/H
- Delayed hemorrhage
  - 0-14%
  - Hemodynamic instability
- Abscess
  - Sepsis, abnormal LFT, abdominal pain
- Devascularization
  - Abnormal LFT, coagulopathy, bile leaks, abdominal pain, renal failure, sepsis
  - Can occur after embolization

Operative Management

- You have 20min and 8-10 units of blood to stop the bleeding
- Standard Ex-lap position and incision
- Evacuate blood from abdomen
- Mobilize the liver
- Fix the problem

Left ← Mobilize → Right



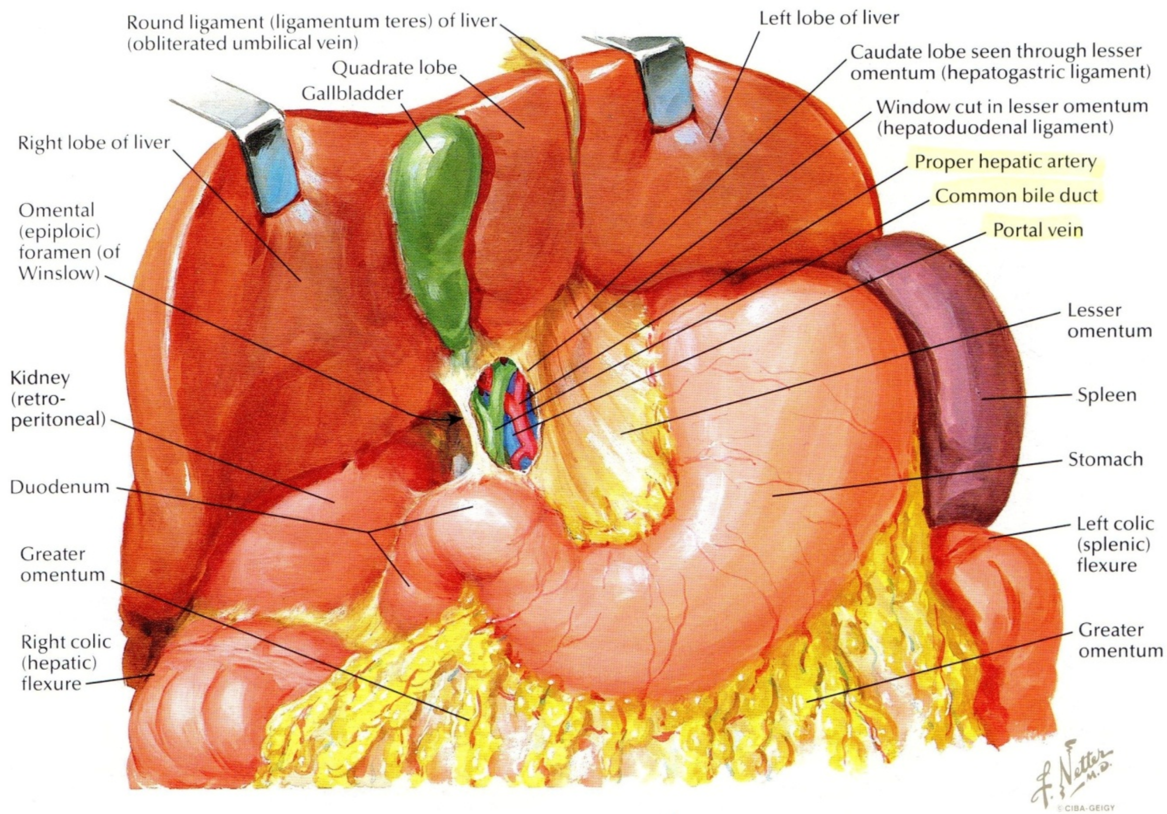


- Divide the falciform ligament and release it all the way up to diaphragm
- Divide the left triangular ligament and continue into the anterior and posterior coronary ligaments
  - What structures do you need to be concerned with?
    - Left Hepatic Vein, Phrenic Nerve

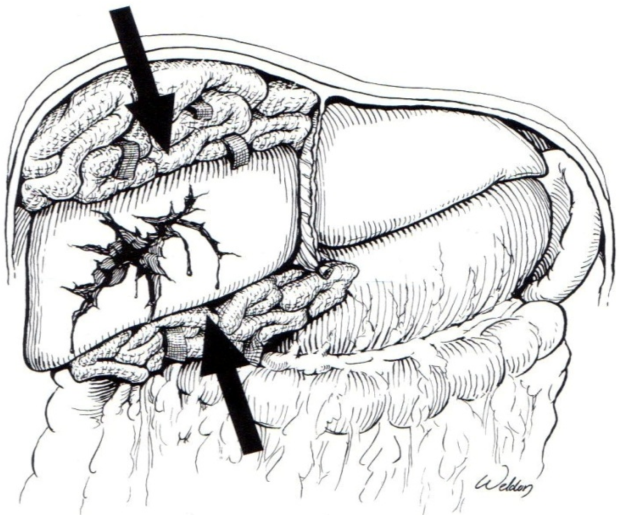
- Rotate right lobe medially to stretch right triangular ligament
- Release the right coronary ligament and then the posterior coronary

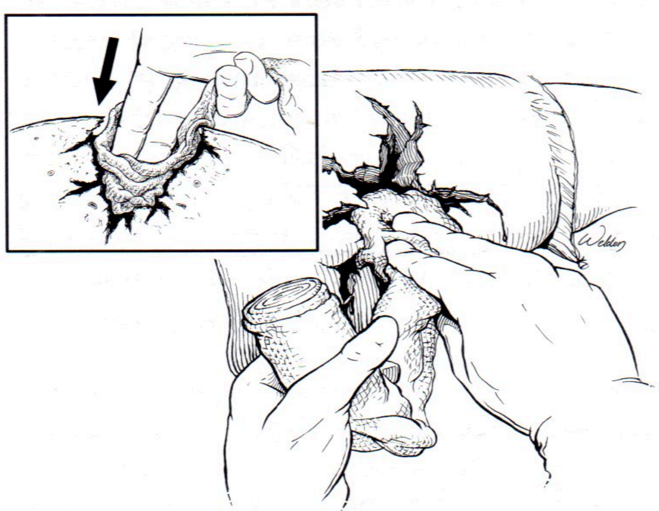
Stop the bleeding!!!

- Pringle Maneuver
  - Controls inflow from what 2 structures?
    - Hepatic artery and Portal vein



Stop the bleeding!!!





- Packing
  - Good for damage control operation
  - 3 rules
    - Pack early
      - Relies on clot formation...coagulopathy=BADNESS
    - 2 opposing pressure vectors
    - Avoid overpacking
      - Compression of IVC

Stop the bleeding!!!

- Finger fracture
  - Careful extension of laceration into parenchyma until vessels can be identified and suture-ligated or clipped
    - Tissue is crushed between thumb and index finger
  - Can cause significant injury trying to find initial injury

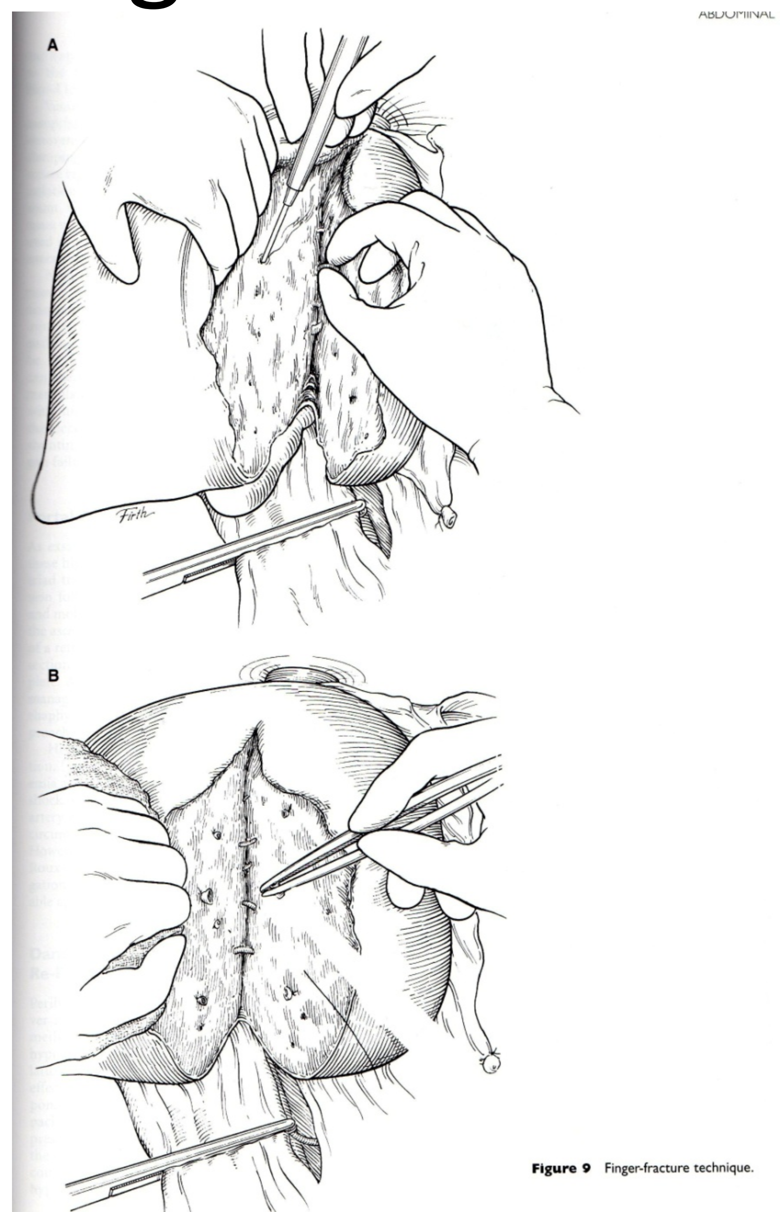
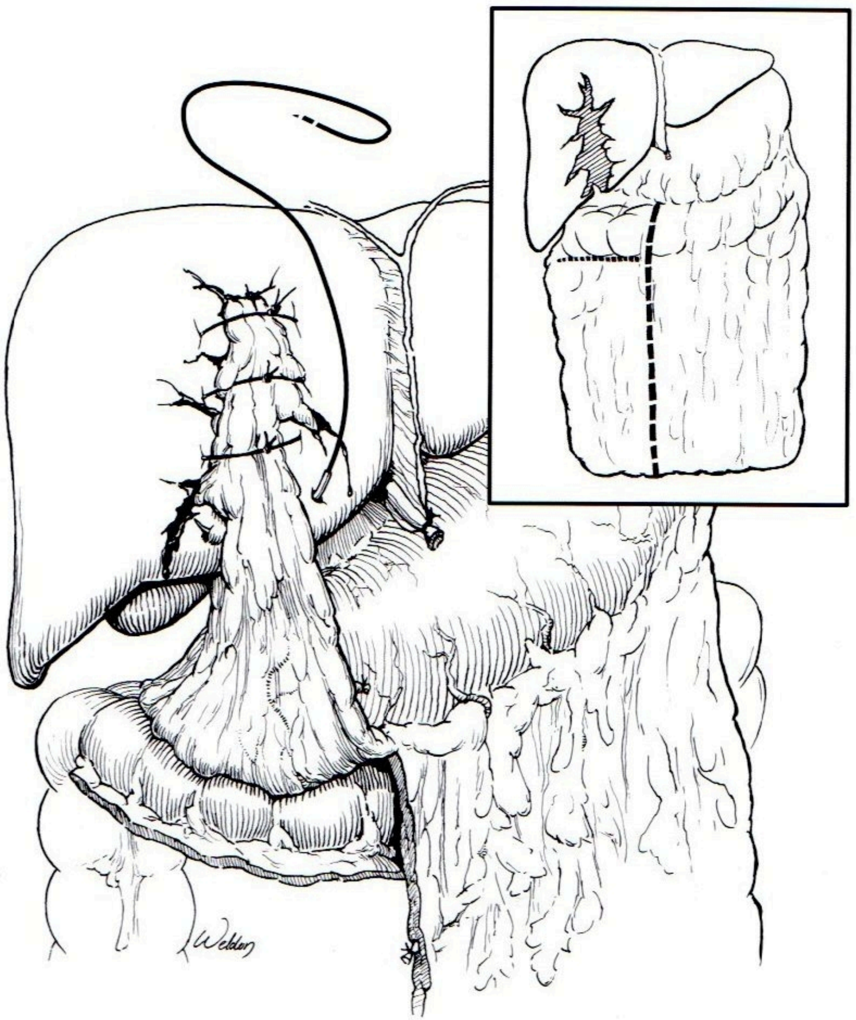


Figure 9 Finger-fracture technique.

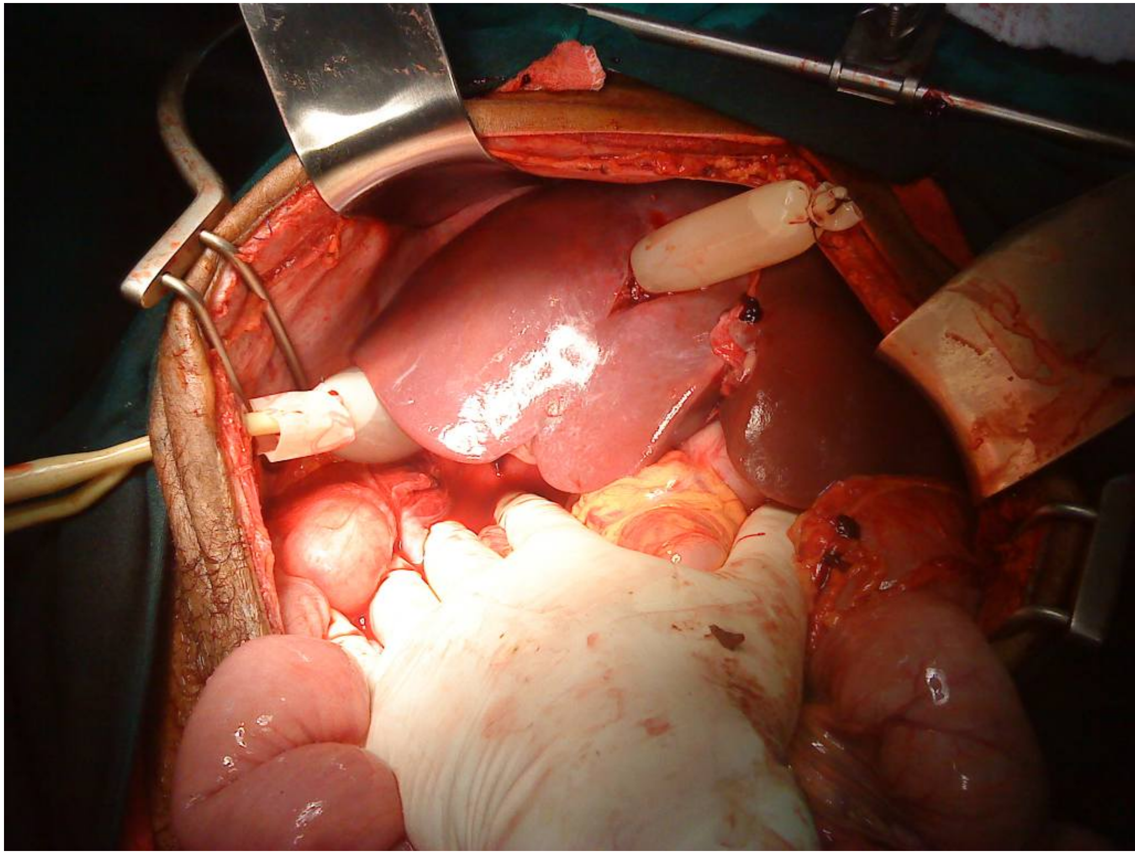
Stop the bleeding!!!

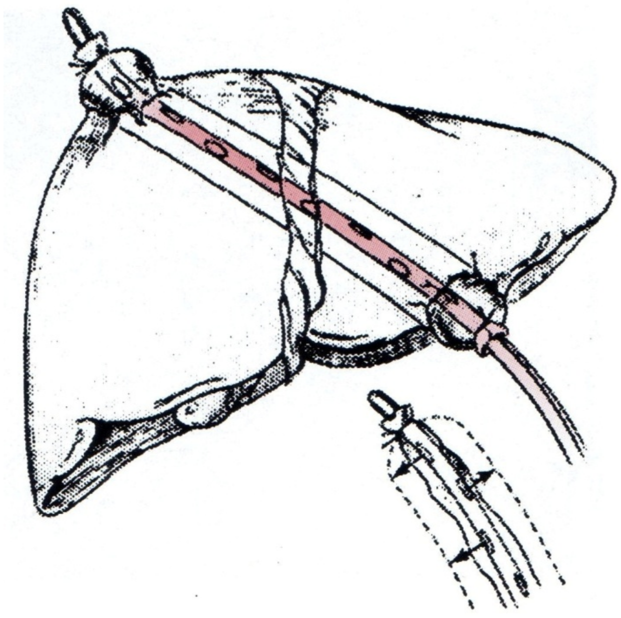


- Omental Packing
  - Used after finger fracture
  - Superior to most of the direct techniques
  - Create a potential dead space

Stop the bleeding!!!

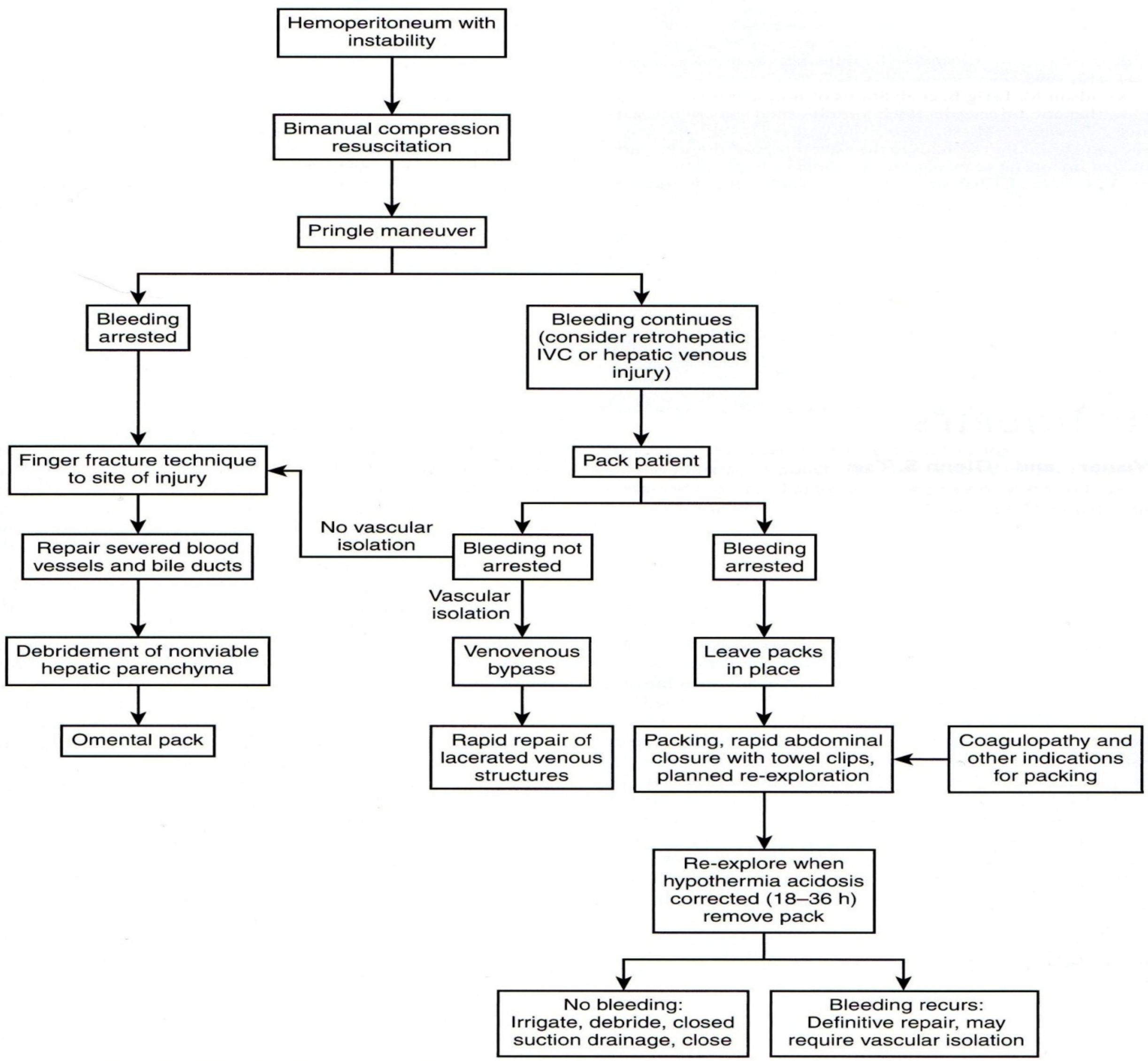
- Transhepatic plug
  - GSW through liver
  - Place through the wound tract to tamponade





Grade V Liver Injury

Operative Management



Monitoring

- CBC
  - Decreasing H/H for re-bleeding, pseudoaneurysm
- LFT
  - Elevated AST/ALT/LDH for liver injury, elevated Bili/ALP/GGT for obstruction
- Amylase
  - Elevated with concomitant pancreatic injury
- Lactic Acid
  - Elevated with significant bleeding

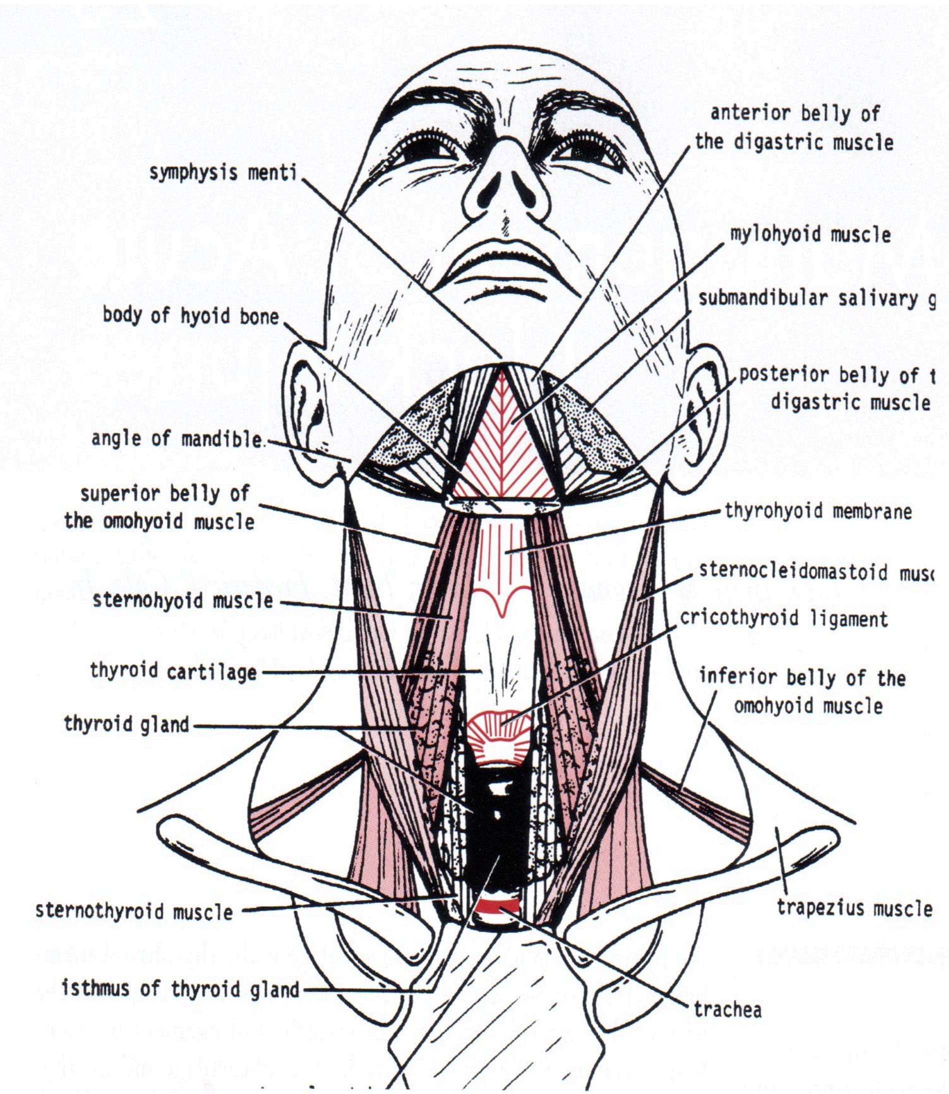
The Neck

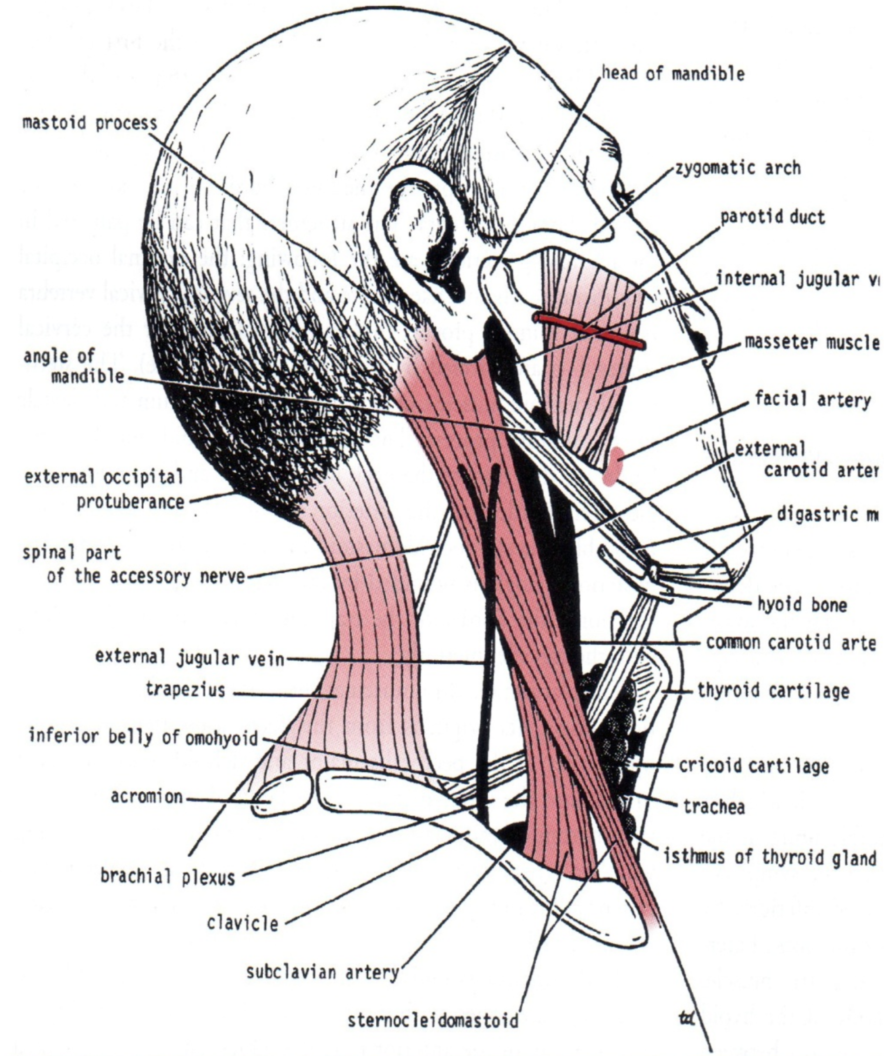
Vascular, Esophageal, Tracheobronchial Injuries

Issues

- High density of vital structures in relatively small and unprotected anatomic region
- Occur in setting of multisystem trauma
  - Can mask injury
- Not always apparent
  - Esophageal and tracheal injuries clinically manifest later
- Not knowing patients baseline neuro status can lead to missed diagnosis
  - AMS due to delirium/dementia, intoxication, or vascular injury

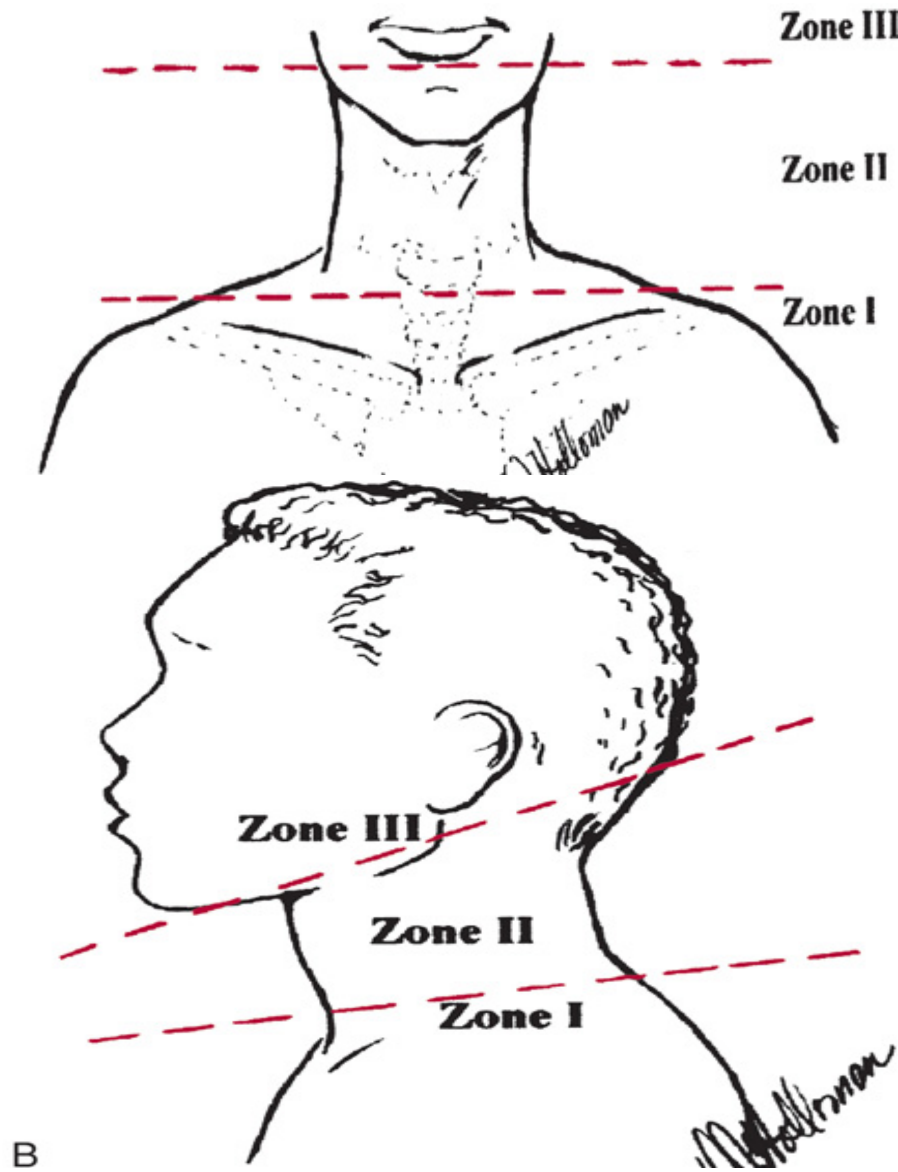
Surface Anatomy





Zones of the Neck

- Zone I: Between the clavicles and the cricoid cartilage
  - the thoracic outlet vasculature,
  - vertebral and proximal carotid arteries
  - lung, trachea, esophagus, spinal cord, thoracic duct, and major cervical nerve trunks.
- Zone II: Between the cricoid cartilage and the angle of the mandible
  - The jugular veins, vertebral and common carotid arteries, and external and internal branches of the carotid
  - The trachea, esophagus, spinal cord, and larynx also traverse this area.
- Zone III: Between the angle of the mandible and the base of the skull.
  - The pharynx is located in this zone, along with the jugular veins, vertebral arteries, and the distal internal carotid arteries.



Initial Evaluation

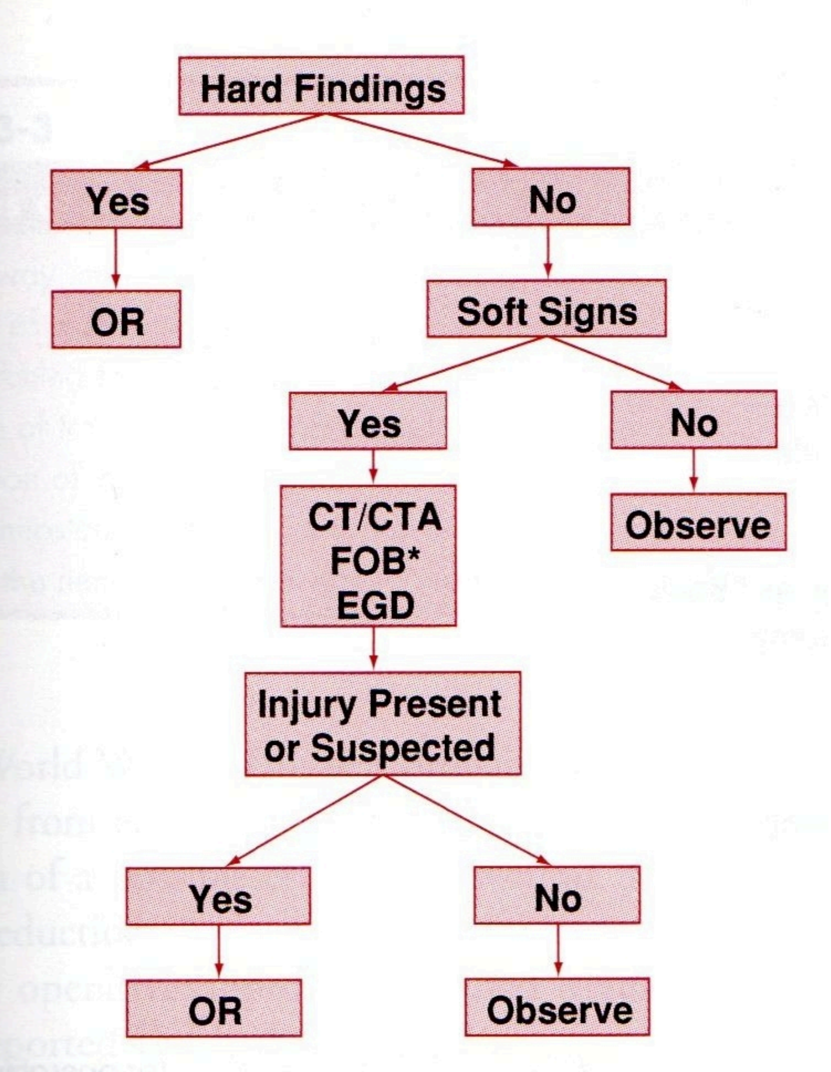
- Securing an adequate airway
  - Intubation is necessary due to expanding hematoma, tracheal injury
  - Translaryngeal intubation is preferred
    - Emergent cricothyroidotomy or intubation through wound can be life saving
- PTX can occur with penetrating neck injuries
- Bleeding should controlled with direct pressure
  - Never blind clamp wounds in the neck

S/S of Vascular/Aero-Digestive Injury

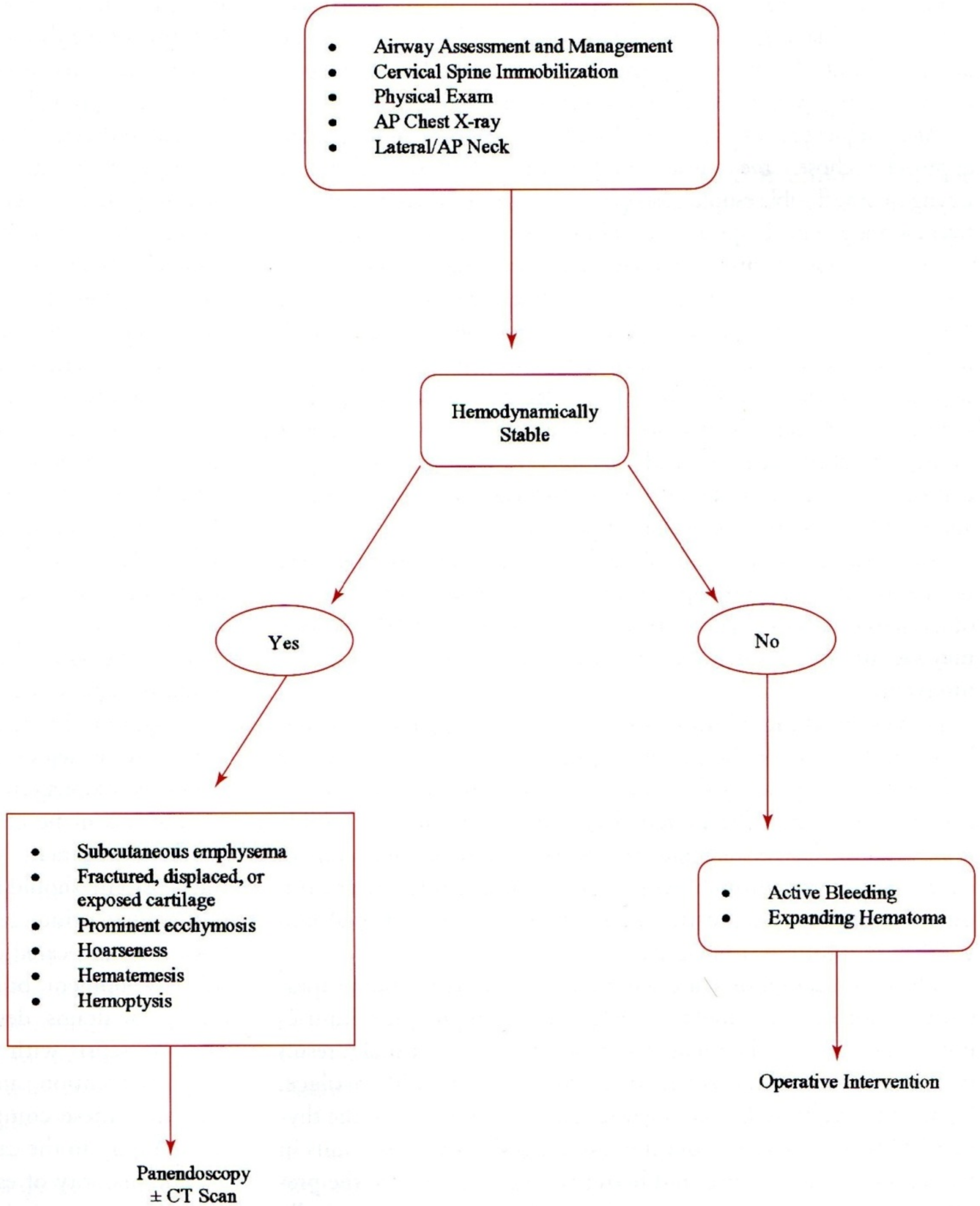
Table 1: Signs of Penetrating Neck Injury

Hard Signs	Soft Signs
Active bleeding	Dysphagia
Expanding or pulsatile hematoma	Voice change
Subcutaneous emphysema or air bubbling from wound	Hemoptysis
	Wide mediastinum

Penetrating Trauma

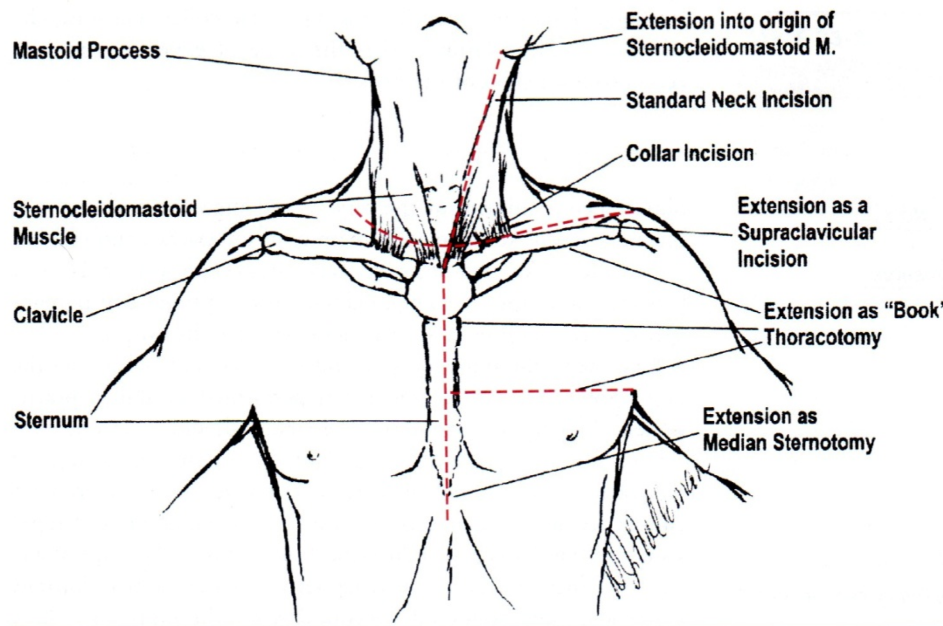


Blunt Trauma



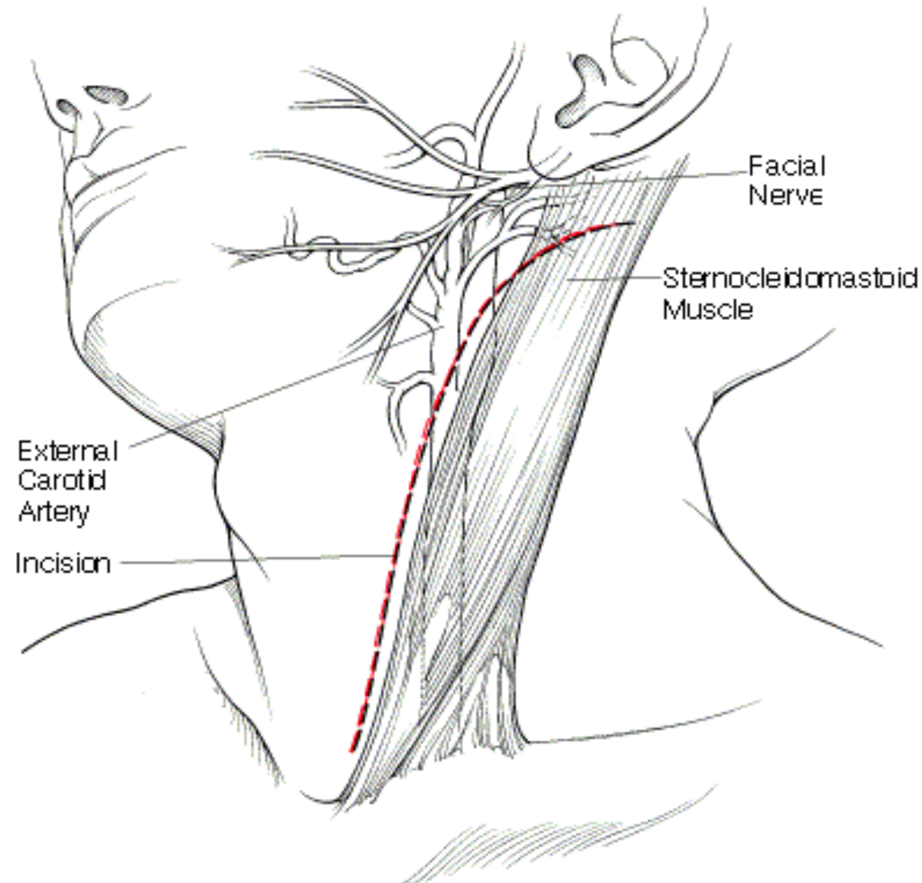
Exposure Options

- Zone I injuries
  - Supraclavicular incision
  - Many need a clavicle resection or median sternotomy
- Zone II Injuries
  - Standard neck incision
  - Transverse collar incision
- Zone III injuries
  - extension of an incision at the anterior border of the SCM +/- disarticulation or partial resection of the mandible.
  - limited craniotomy



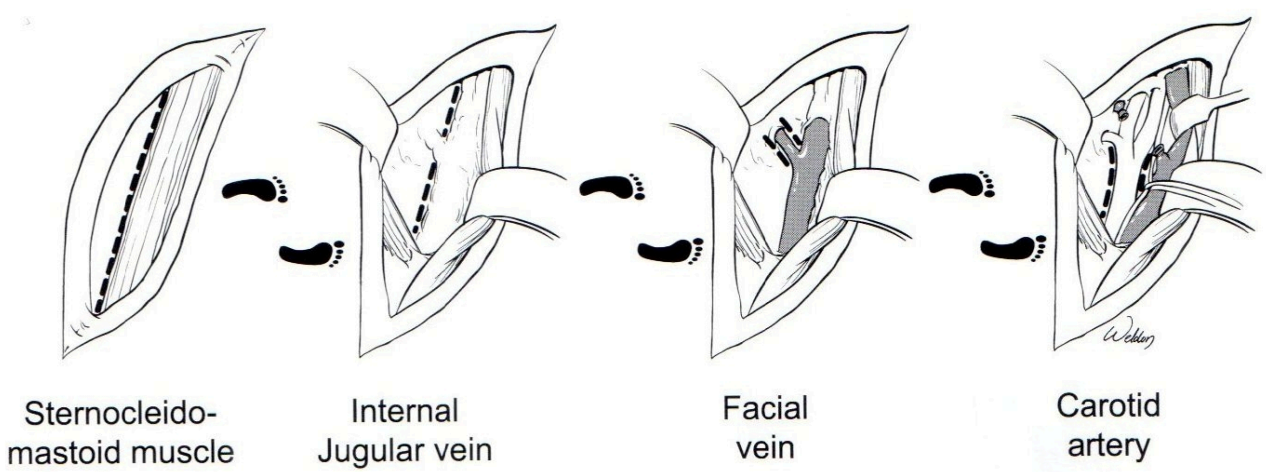
The Incision

- Incision is centered over the anterior border of the SCM
  - Can extend to mastoid process to sternal notch
  - Proximally extend incision posteriorly to avoid the marginal mandibular branch of facial nerve.

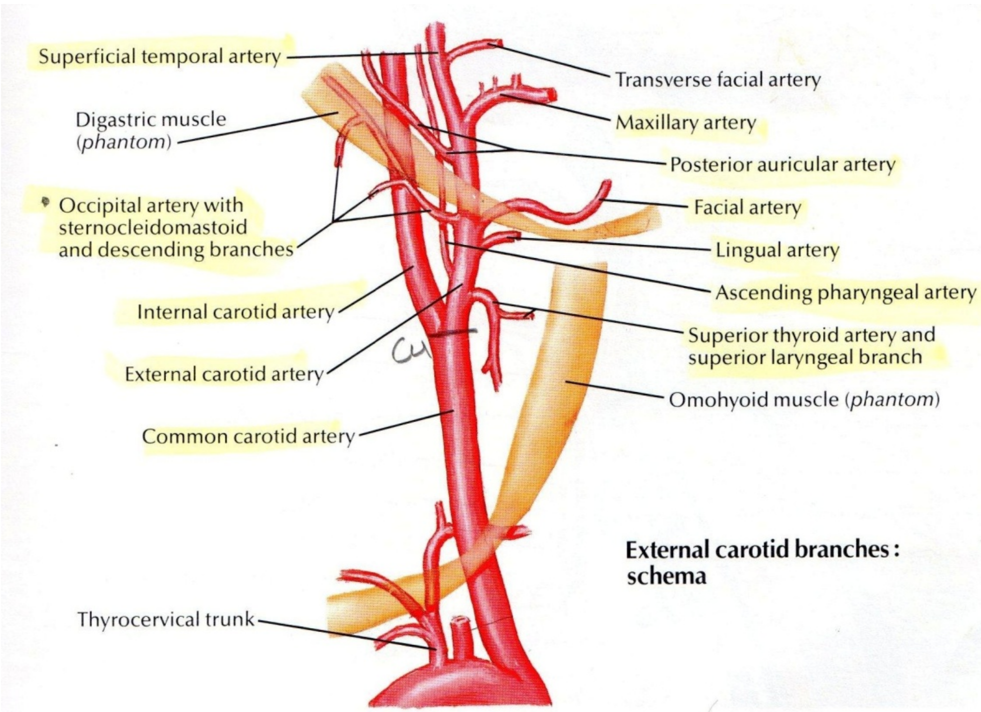


The Exploration

- Retract SCM and begin dissection
- Next identify the IJ
  - Most commonly injured vascular structure in the neck.
  - Repair with 5-0 prolene or ligate if complex injury
- Continue dissection along the anterior border and identify the Facial vein
  - Ligate and divide the facial vein.
- The facial vein is a good landmark for the carotid bifurcation



Carotid Arteries



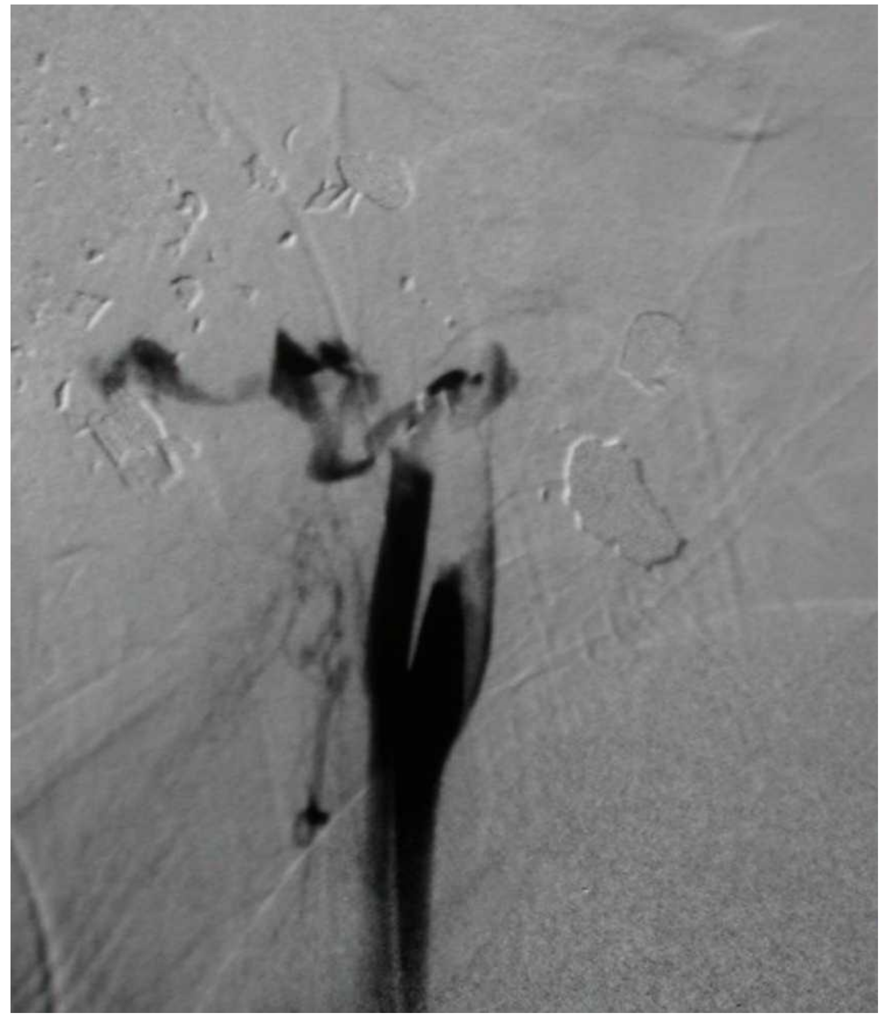
- Involved in 25% of head/neck trauma
  - 5% of all arterial injuries
- Mortality – 10-30%
- Permanent neurologic deficit – 40%
- Mechanism
  - Hyperextension with rotation

Diagnosis

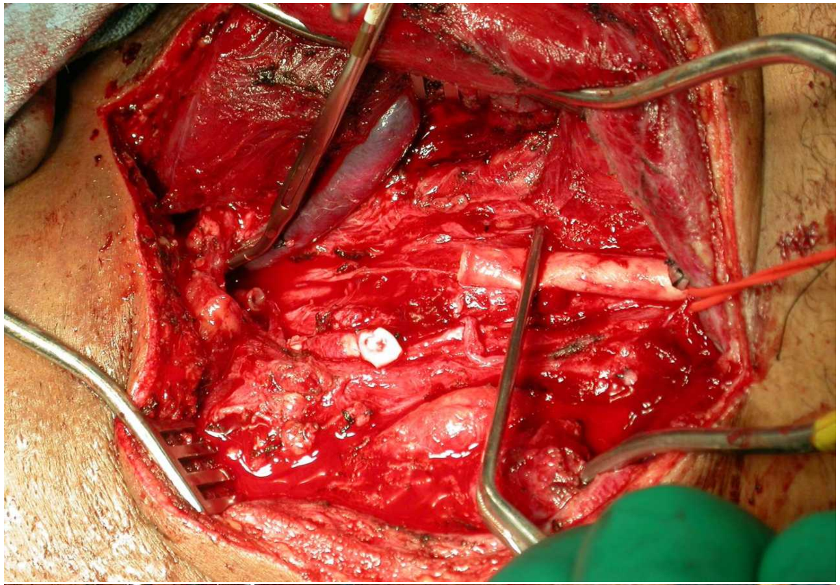
- S/S of a carotid artery injury
  - Expanding hematoma
  - Audible cervical bruit or palpable thrill
  - Seatbelt sign on neck
  - Neurologic deficits
  - Ipsilateral Horner's syndrome
    - What are the findings?
      - Ptosis, myosis, anhydrosis
  - Bleeding from oropharyngeal wounds
    - External carotid branches
  - CNIX-XII deficits
  - Diminished ipsilateral superficial temporal pulse

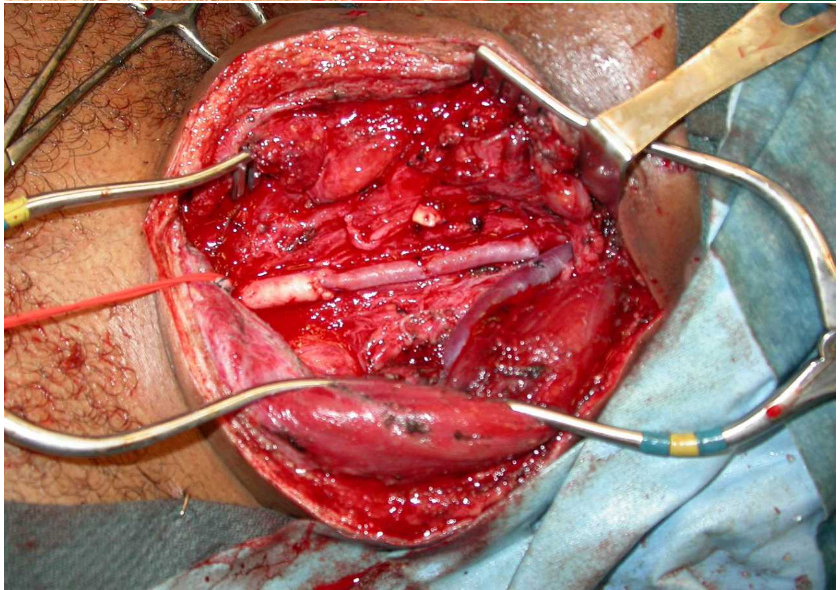
Studies

- Color flow doppler
  - >90% sensitive in zone II injuries
    - Not useful in zone I or III
  - Operator dependant
- CT Angio
  - In scanner anyway
  - Need nephrotoxic contrast
- MRA
  - No contrast needed
  - Longer study
- Angiography
  - Gold standard
  - Can instantaneously treat with endovascular therapy



Treatment

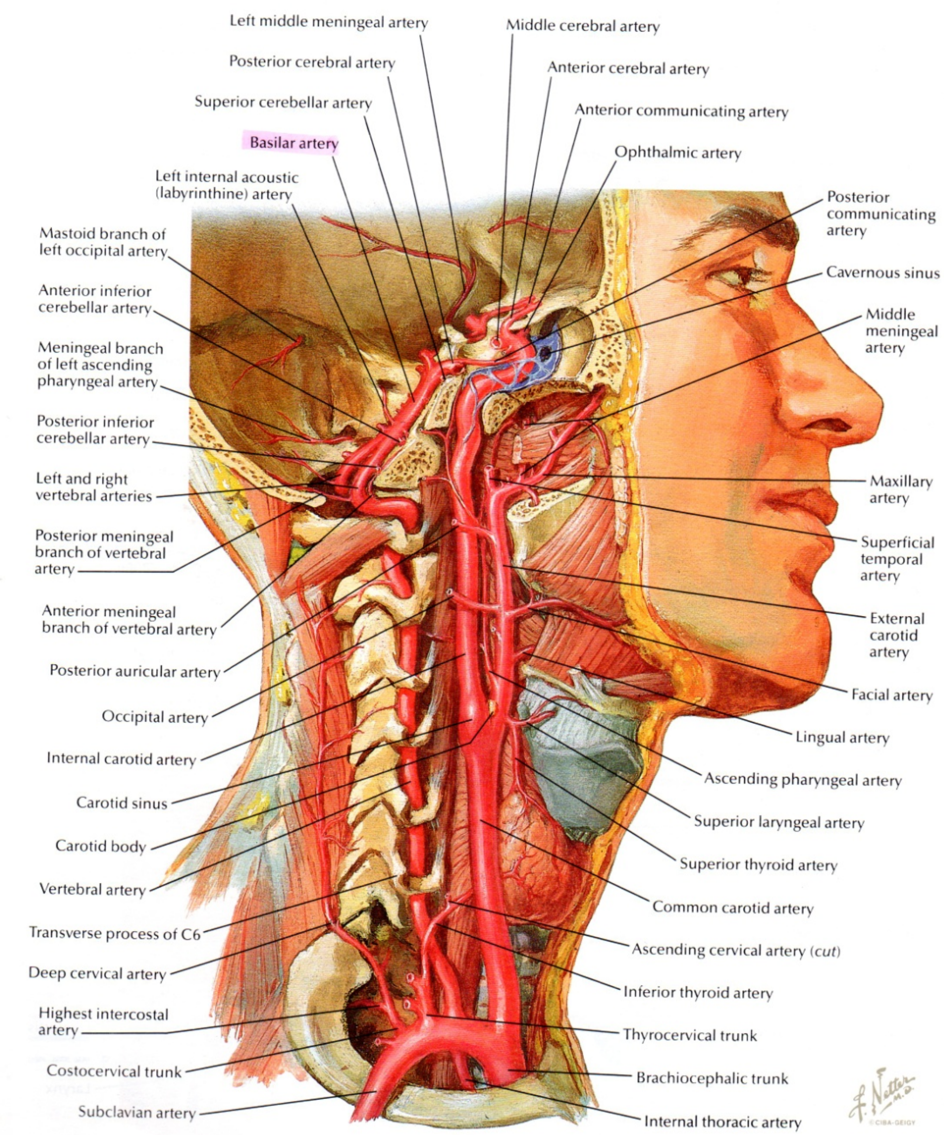




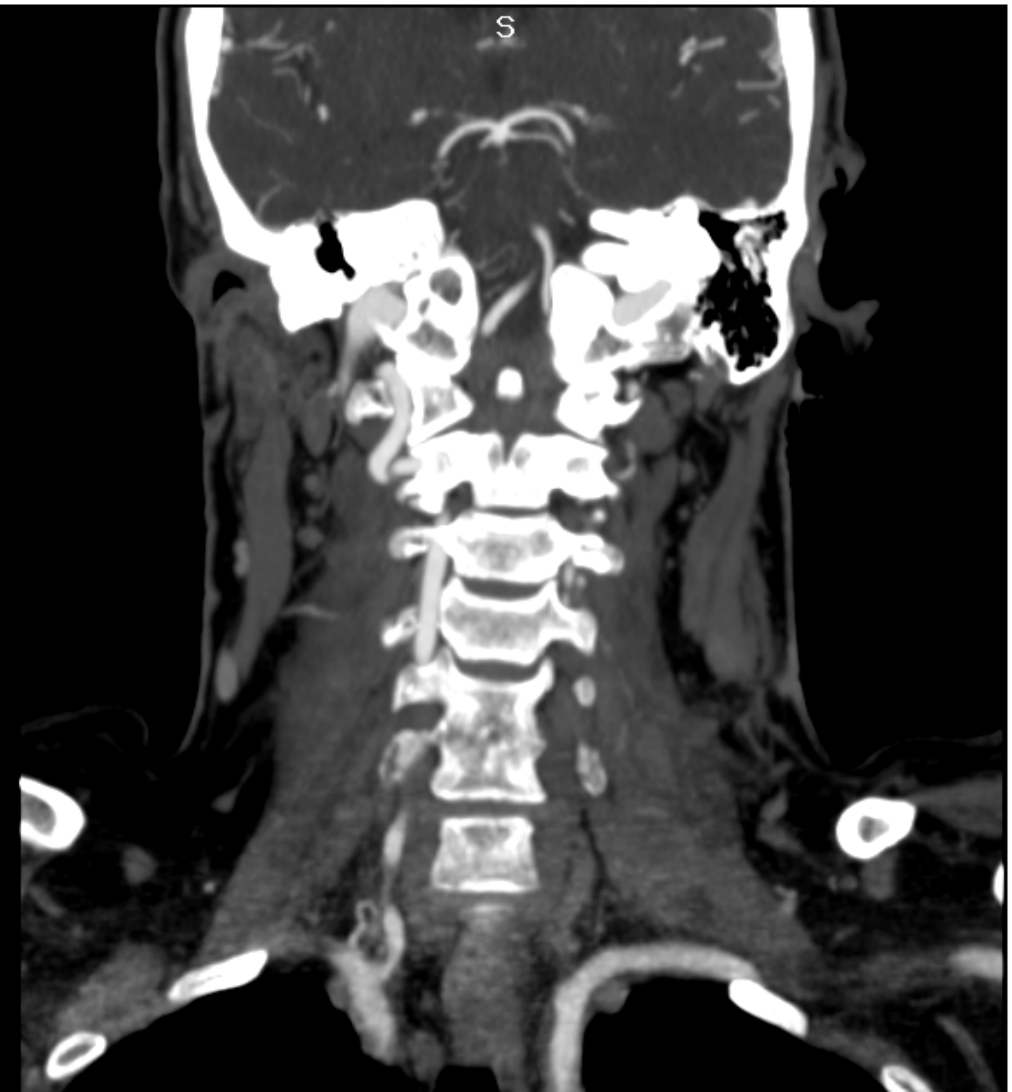
- Repair vs ligation
  - Ligate only if patient diagnosed with carotid artery occlusion, significant neurologic deficit, large cerebral infarct on the ipsilateral side
- Repair with 5-0 or 6-0 prolene
- Arteriotomy with interpositional graft placement
- Endovascular therapy
  - Can treat at time of diagnosis
  - Good for zone III and lower zone I injuries

Vertebral Artery

- First branch off the subclavian artery
- 4 parts
  - V-1 - 1st portion
    - SCA to C6 TP foramen
  - V-2 - 2nd portion (interosseous portion)
    - TP foramen of C6 to C2
  - V-3 – 3rd portion
    - TP foramen of C2 to formen magnum
  - V-4 – 4th portion
    - Foramen magnum to basilar artery



Diagnosis



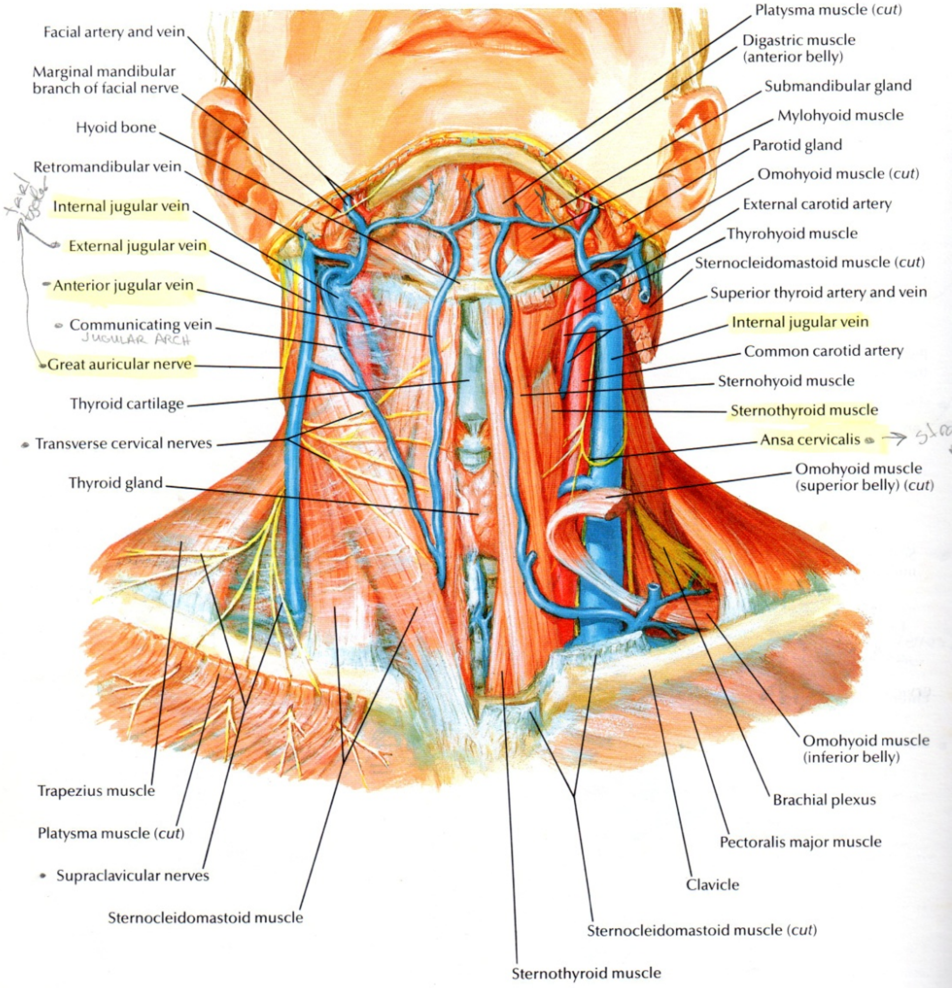
- Only 50% of patients with vertebral artery injuries presented with hard signs, 30% with soft signs
  - 20% had no clinical signs
- Doppler unreliable due to bony hindrance of majority of vessel
- CTA/MRA/Angio modalities of choice

Treatment

- Majority do not require treatment if contralateral vessel is free of injury
- Most injuries are treated with embolization
- Indication for surgery
  - Active hemorrhage or failed embolization

Jugular Veins

- Most injuries are from penetrating trauma
- Low pressure system usually tamponades or occludes without major hemorrhage or hematoma
- IJ
  - Repair if possible
  - OK to ligate if patient unstable
- EJ
  - Ligate



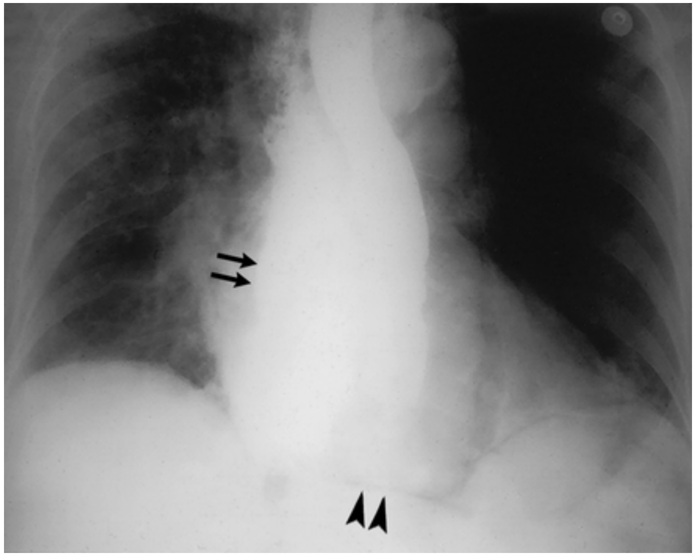
Esophageal Injuries

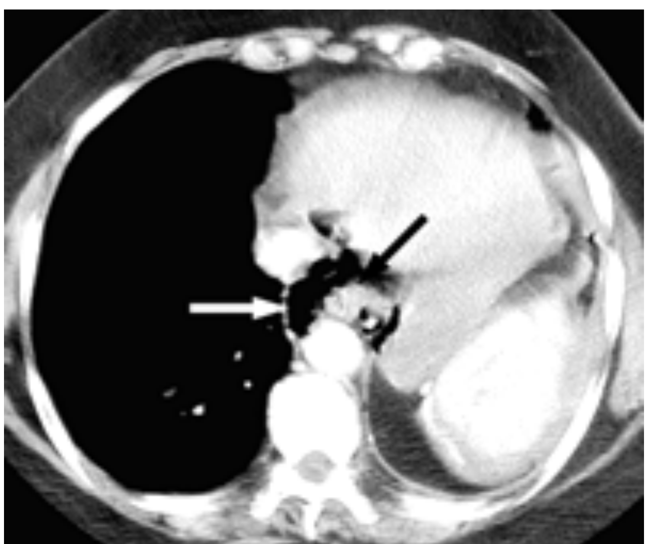
- Uncommon injury due to deep location and collapsed orientation
  - Most injuries occur with aortic or heart injuries and patient die at scene
- 3 parts
  - Cervical, thoracic, abdominal
    - In order of incidence

Diagnosis

- S/S
  - Cervical esophageal injury
    - Neck pain, dysphagia
    - Hematemesis, hemoptysis, blood NG aspirate without pharyngeal injury
    - Palpable crepitus, SQ air
  - Thoracic esophageal injury
    - Medistinal emphysema on CT
      - Hamman’s Sign
        - » Mediastinal crunch on auscultation of heart
  - Abdominal esophageal injury
    - Pneumoperitoneum

Diagnosis





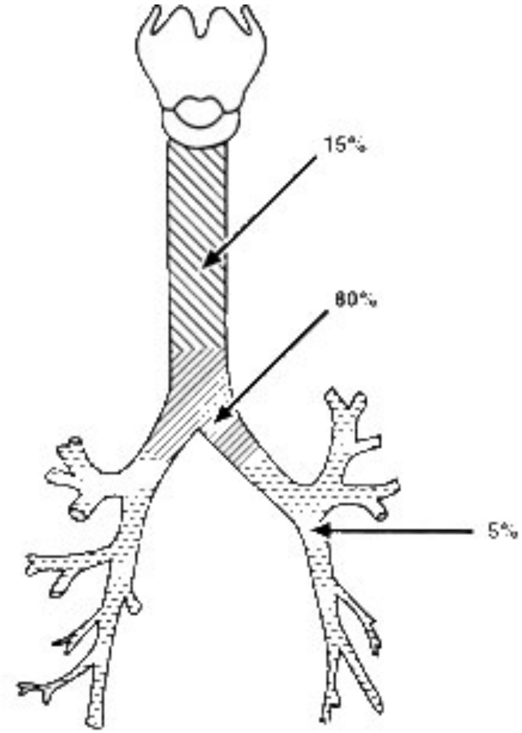
- Barium esophagram with water-soluble contrast
- Esophagoscopy
- Lateral C-spine x-ray
- CT Neck/Chest/Abdomen

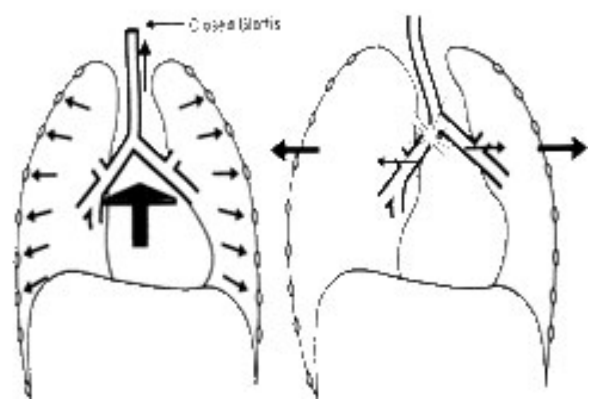
Treatment

- All esophageal injuries must be surgically repaired
- 3 principles
  - Close all defects
  - Use onlay muscular flaps as a buttress and protective layer
    - No serosa in esophagus
  - Drain the repair
- Cervical esophageal repair
  - Care to avoid recurrent laryngeal nerve
- Thoracic esophageal repair
  - Upper 2/3 best approached through a right posteriolateral thoracotomy in 5^{th} intercostal space
  - Lower 1/3 best approached through left posteriolateral thoracotomy in 6^{th} intercostal space
- Abdominal esophageal repair
  - Standard laparotomy

Tracheobronchial Injuries

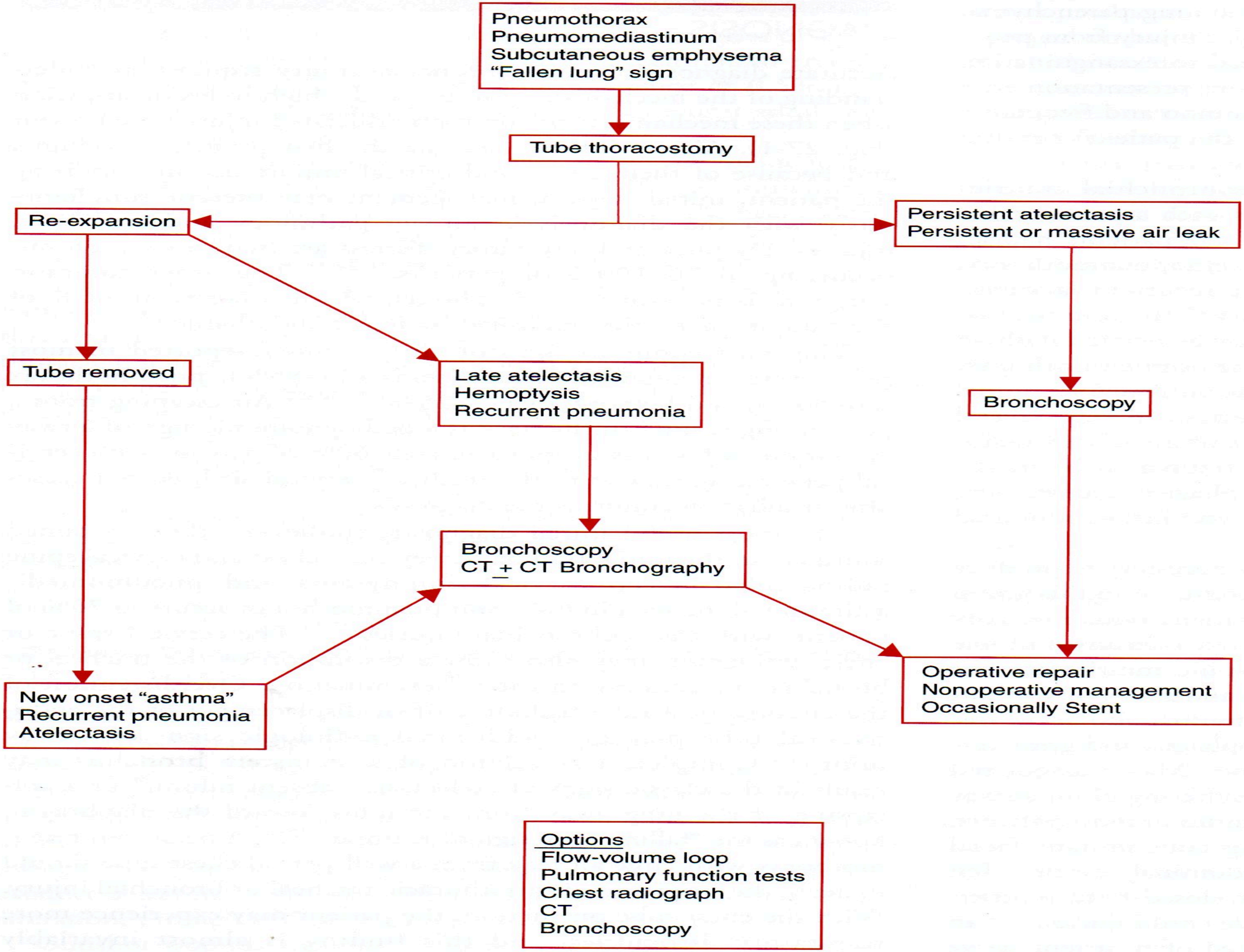
- Uncommon do to injuries to other vital structures
  - 75% fatal prior to arrival
- Mechanisms
  - Penetrating trauma
  - Blunt neck trauma
    - Crush against posterior vertebra
      - Clothesline injury
  - Burst fracture from sudden increase in intrathoracic pressure



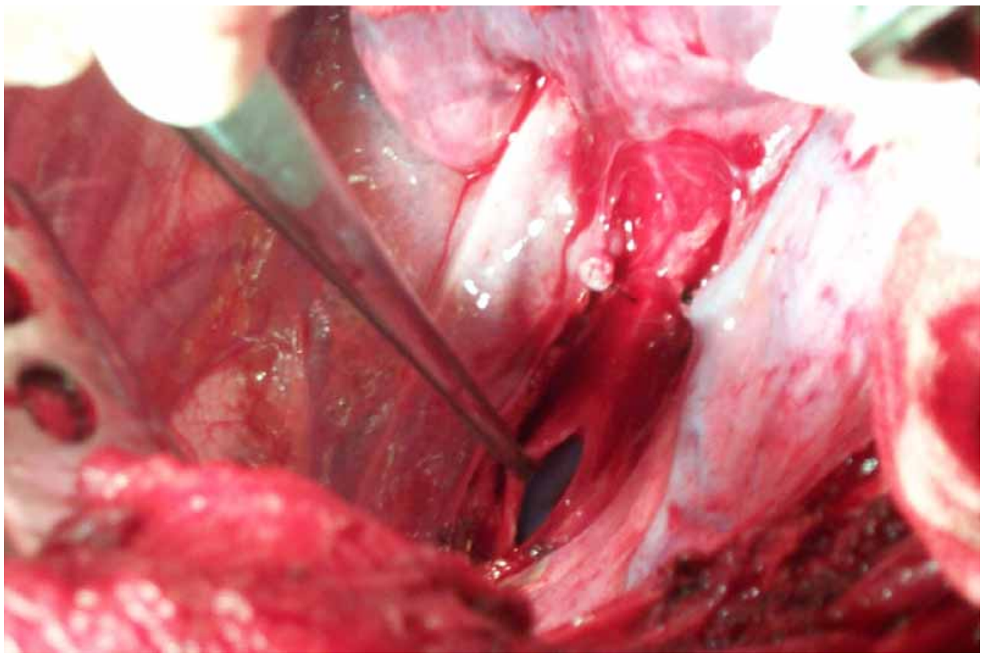


Diagnosis

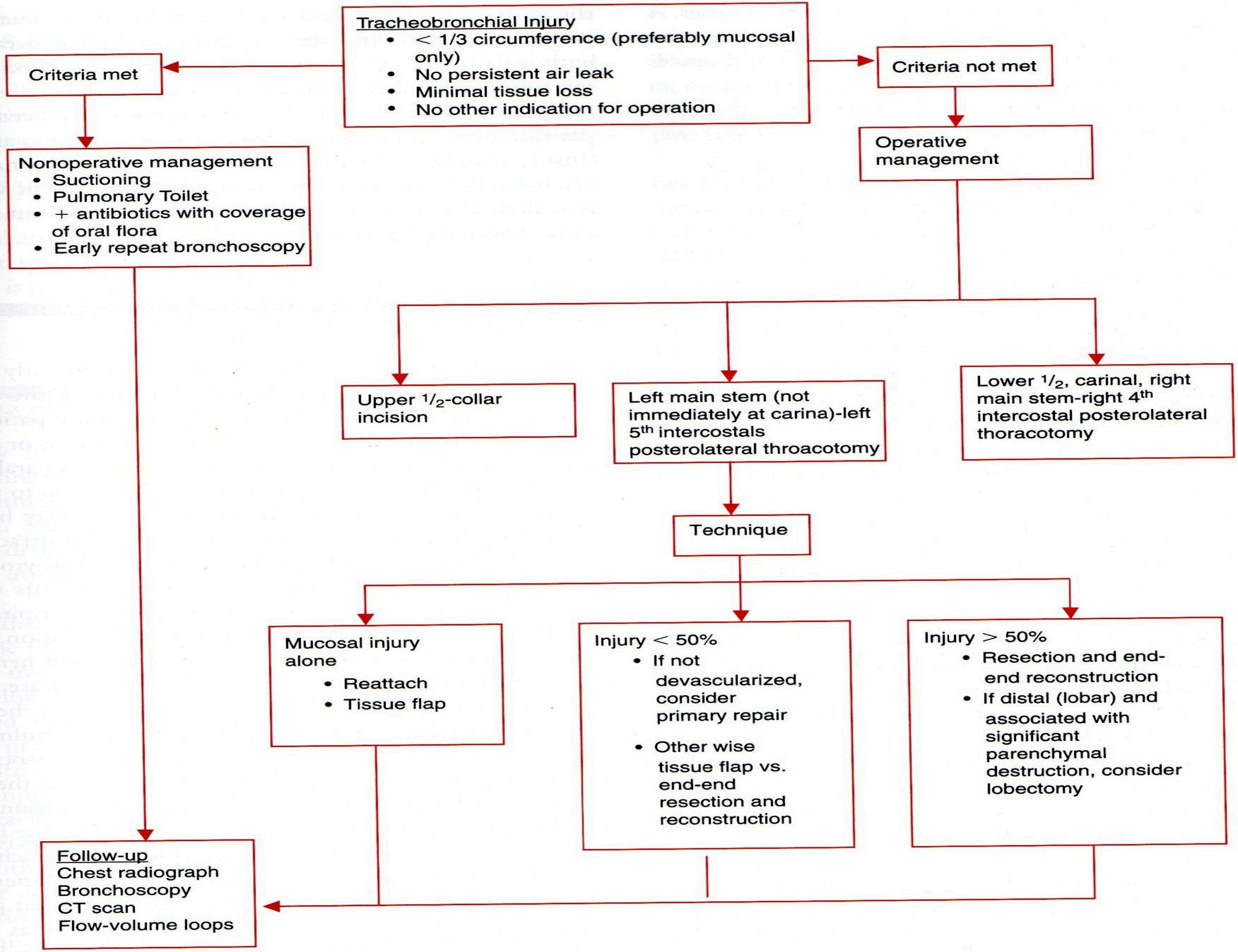
- Cervical tracheal injuries
  - Stridor, hoarseness, hemoptysis, SQ air
- Thoracic tracheal injuries
  - Depends on if injury is confined to medistinum or pleural space
    - Medastinum → pneumomedistinum, pneumopericardium
    - Pleural space→ PTX
      - Dyspnea can increase with chest tube insertion due to loss of total volume
  - Overdistention of ETT balloon outside the confines of the normal tracheal diameter
  - Fallen Lung Sign (bronchus injury)
    - Lung falling away from hilum (lateral and posteriorly) as opposed to a simple PTX where lung collapses towards the hilum
- Bronchoscopy
  - Gold standard
  - Indications
    - Large pneumomedistinum, refractory PTX, large air leak, persistent atelectasis, marked SQ air


Pneumothorax
Pneumomediastinum
Subcutaneous emphysema
"Fallen lung" sign
Tube thoracostomy
Re-expansion
Persistent atelectasis
Persistent or massive air leak
Tube removed
Late atelectasis
Hemoptysis
Recurrent pneumonia
Bronchoscopy
Bronchoscopy
CT ± CT Bronchography
New onset "asthma"
Recurrent pneumonia
Atelectasis
Operative repair
Nonoperative management
Occasionally Stent
Options
Flow-volume loop
Pulmonary function tests
Chest radiograph
CT
Bronchoscopy

Treatment



- Non-operative observation can be used if laceration is small and well approximated
- Cervical tracheal injuries
  - Tracheostomy incision
- Thoracic tracheobronchial injuries
  - Thoracotomy incision
- Protect repair with muscle flap
- Drain incision
- Damage control setting
  - Push ETT past injury



Tracheobronchial Injury
• < 1/3 circumference (preferably mucosal only)
• No persistent air leak
• Minimal tissue loss
• No other indication for operation
Criteria met
Criteria not met
Nonoperative management
• Suctioning
• Pulmonary Toilet
• + antibiotics with coverage of oral flora
• Early repeat bronchoscopy
Operative management
Upper $^1/_2$-collar incision
Left main stem (not immediately at carina)-left 5th intercostals posterolateral throacotomy
Lower $^1/_2$, carinal, right main stem-right 4th intercostal posterolateral thoracotomy
Technique
Mucosal injury alone
• Reattach
• Tissue flap
Injury < 50%
• If not devascularized, consider primary repair
• Other wise tissue flap vs. end-end resection and reconstruction
Injury > 50%
• Resection and end-end reconstruction
• If distal (lobar) and associated with significant parenchymal destruction, consider lobectomy
Follow-up
Chest radiograph
Bronchoscopy
CT scan
Flow-volume loops

Pancreatic and Duodenal Injuries

Wounds to the Surgical Soul

Logistics

- Relatively uncommon for isolated injuries
  - Most patients who die from pancreatic/duodenal injuries do so from associated vascular, liver, or splenic injuries
- Deep location of these organs provides protection, but also contributes to limited diagnostic capabilities of radiography
  - Can also lead to the delayed diagnosis of missed injuries

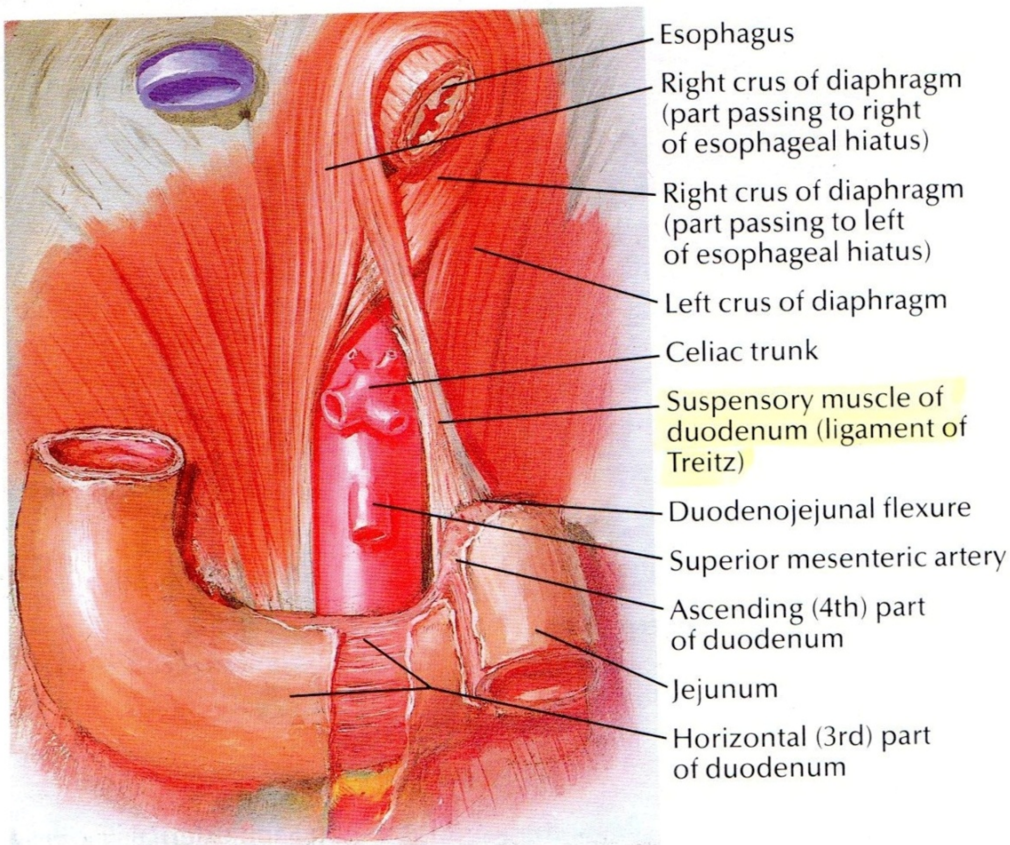
TABLE 35-5

Associated Organ Injuries in 1031 Patients with Pancreatic Wounds

ORGAN INJURED	TOTAL No.	TOTAL %
Liver	483	46.8
Stomach	436	42.3
Major arteries and veins	426	41.3
Spleen	289	28.0
Kidney	241	23.4
Duodenum	199	19.3
Colon	175	17.0
Small bowel	151	14.6
Common bile duct	35	3.4
Galbladder	15	1.4

Sources: Stone H, Fabian TBS, et al.: Experiences in the management of pancreatic trauma. J Trauma 21:257, 1981; Jones R: Management of pancreatic trauma. Am J Surg 150:696, 1985; and Graham K, Mattox KL, Vaughan G, et al.: Combined pancreatoduodenal injuries. J Trauma 19:340, 1979.

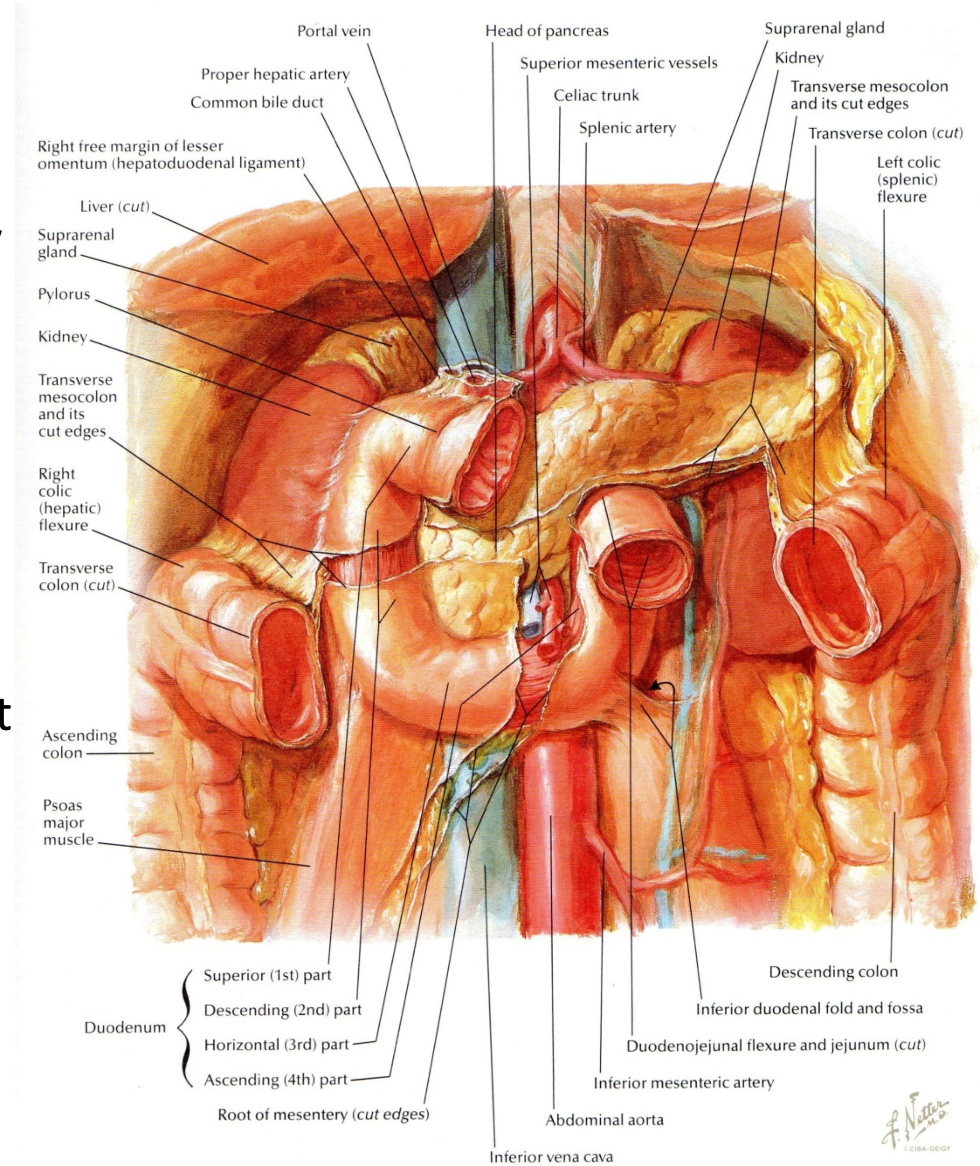
Anatomy



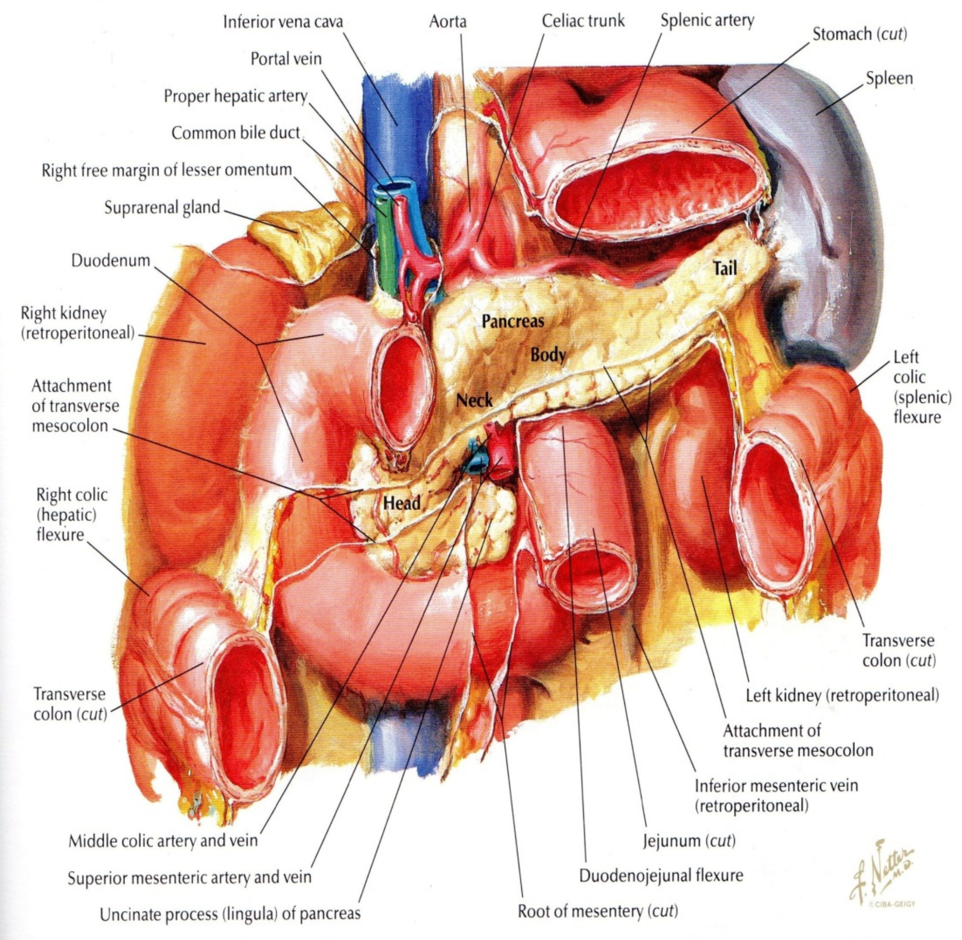
- Duodenum
  - From Latin "duodeni" or "12 each"
    - 12 fingerbreadths or 30cm from pylorus to Ligament of Trietz
  - Almost entirely retroperitoneal
    - Anterior half-circumference of the 1st portion
    - Most distal 4th portion

Anatomy

- 1^{st} portion – Superior
  - Pylorus to CBD anteriorly and gastroduodenal artery posteriorly
- 2^{nd} portion – Descending
  - CBD/GDA to the Ampulla of Vater
- 3^{rd} portion – Horizontal
  - AoV to superior mesenteric vessels which lie anterior
- 4^{th} portion – Ascending
  - SMV to Ligament of Trietz, just left of the 2^{nd} lumbar vertebra



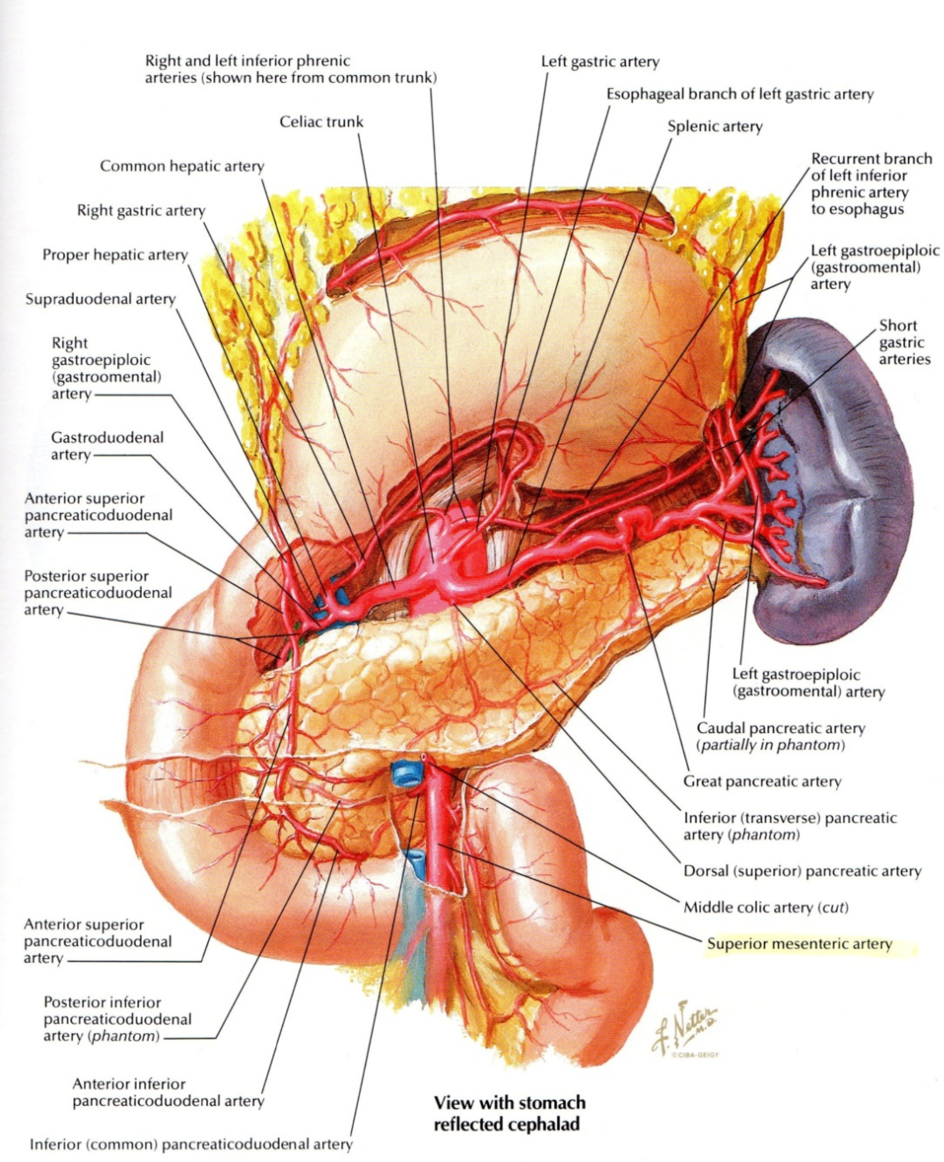
Anatomy

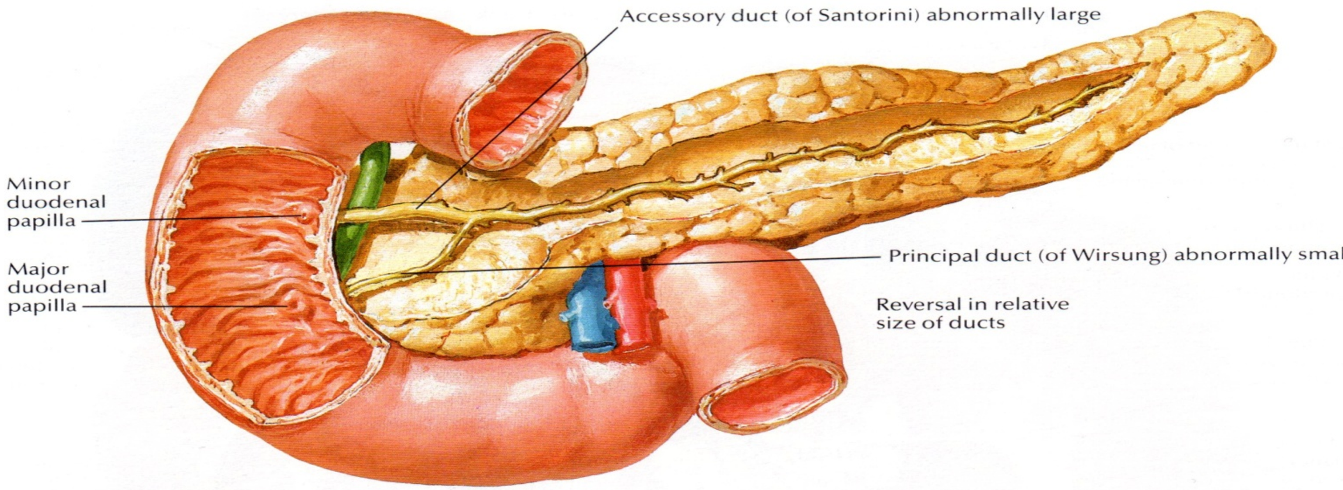


- Pancreas
  - Divided into head, neck, body, and tail
  - Attachment of the transverse mesocolon runs length of the pancreas
  - 2 pancreatic ducts
    - What are their names?

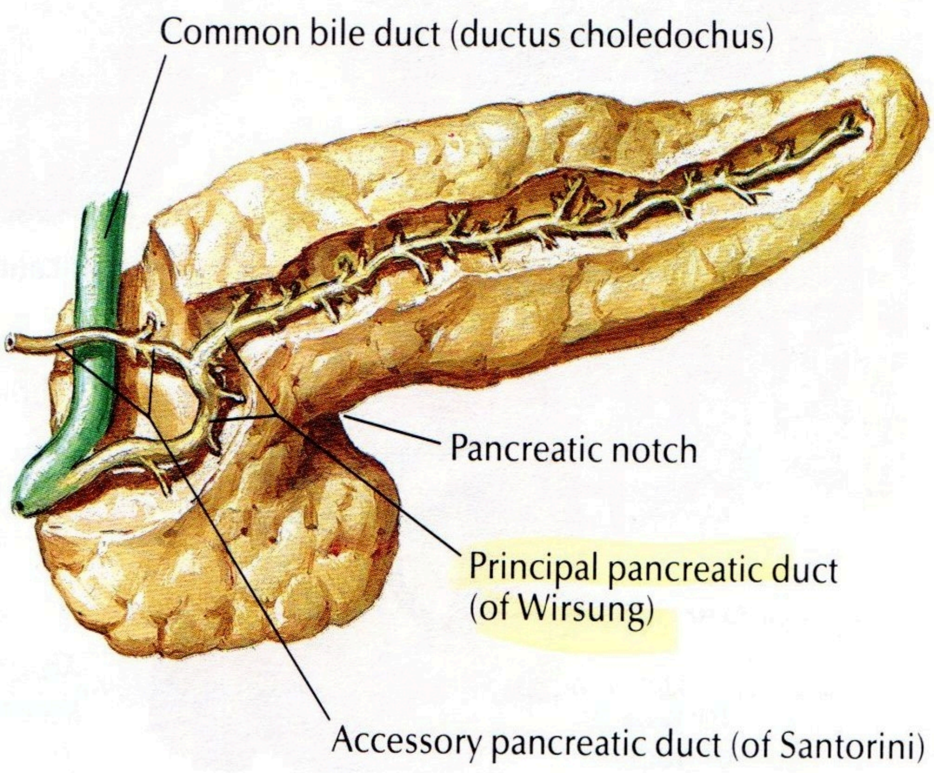
Anatomy

- Main blood supply comes from gastroduodenal, splenic, and superior mesenteric arteries
- Numerous collaterals of the pancreas that protect from ischemia, but contribute to vigorous bleeding
- Important
  - If both pancreaticoduodenal arteries are damaged, then a pancreaticoduodenectomy is necessary

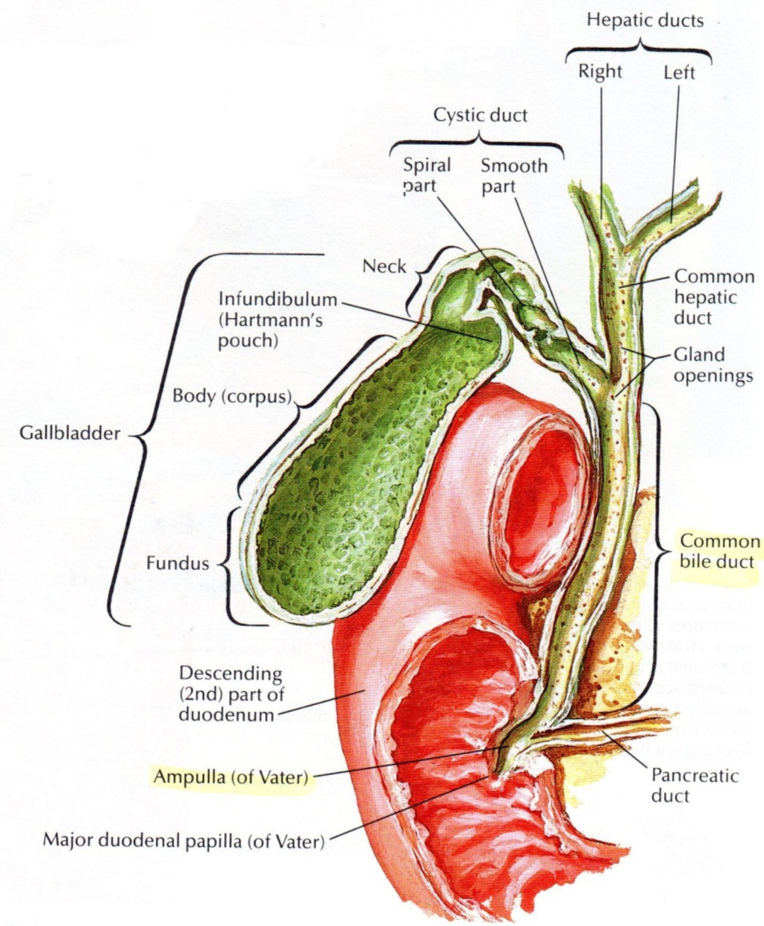




Accessory duct (of Santorini) abnormally large
Minor duodenal papilla
Major duodenal papilla
Principal duct (of Wirsung) abnormally small
Reversal in relative size of ducts



Common bile duct (ductus choledochus)
Pancreatic notch
Principal pancreatic duct (of Wirsung)
Accessory pancreatic duct (of Santorini)



Hepatic ducts
Right
Left
Cystic duct
Spiral part
Smooth part
Neck
Infundibulum (Hartmann's pouch)
Common hepatic duct
Gland openings
Body (corpus)
Gallbladder
Fundus
Common bile duct
Descending (2nd) part of duodenum
Ampulla (of Vater)
Pancreatic duct
Major duodenal papilla (of Vater)

Diagnosis

- Hemodynamically unstable
  - Straight to OR
    - FAST and DPL unreliable due to retroperitoneal location
- Hemodynamically stable
  - Penetrating injury
    - FAST, DPL, CT before OR

Diagnosis

- Blunt Injury
  - CT
    - If negative, observation and repeat scan in 24 hours
    - Duodenum
      - extraluminal gas or contrast in retroperitoneum, fat stranding with loss of sharp tissue planes
    - Pancreas
      - Peri-pancreatic fluid, fat stranding, fracture of 1^{st} lumbar vertebra

Grading of Duodenal injuries

TABLE 35-7

Duodenal Organ Injury Scale: American Association for the Surgery of Trauma

GRADE		INJURY DESCRIPTION
I	Hematoma	Involving single portion of duodenum
	Laceration	Partial thickness, no perforation
II	Hematoma	Involving more than one portion
	Laceration	Disruption <50% of circumference
III	Laceration	Disruption 50 to 75% circumference of D2
		Disruption 50 to 100% circumference of D1, D3, D4
IV	Laceration	Disruption >75% circumference of D2
		Involving ampulla or distal common bile duct
V	Laceration	Massive disruption of duodenopancreatic complex
	Vascular	Devascularization of duodenum

Adapted with permission from Moore EE, Cogbill T, Malangoni M, et al.: Organ injury scaling II: Pancreas, duodenum, small bowel, colon, and rectum. J Trauma 30:1427, 1990.

TABLE 35-8

Determinants of Duodenal Injury Severity

	MILD	SEVERE
Determinants of Injury		
Severity		
Agent	Stab	Blunt or missile
Size	<75% wall	>75% wall
Duodenal location	3rd, 4th	1st, 2nd
Injury to repair interval	<24 h	>24 h
Adjacent injury	No CBD	CBD
Outcome		
Mortality (%)	6%	16%
Duodenal mortality (%)	0%	6%
Duodenal morbidity (%)	6%	14%

CBD, common bile duct

Adapted with permission from Snyder W, Weigelt J, Watkins W, et al.: The surgical management of duodenal trauma. Arch Surg 115:428, 1980. Copyright 1980. American Medical Association.

Grading of Pancreatic Injuries

TABLE 35-9

Pancreatic Organ Injury Scale: American Association for the Surgery of Trauma

GRADE[a]		INJURY DESCRIPTION[b]
I	Hematoma	Minor contusion without duct injury
	Laceration	Superficial laceration without duct injury
II	Hematoma	Major contusion without duct injury or tissue loss
	Laceration	Major laceration without duct injury or tissue loss
III	Laceration	Distal transection or parenchymal injury with duct injury
IV	Laceration	Proximal (to right of superior mesenteric vein) transection or parenchymal injury
V	Laceration	Massive disruption of pancreatic head

[a]Advance one grade for multiple injuries to the same organ.

[b]Based on most accurate assessment at autopsy, laparatomy, or radiologic study.

(Modified with permission from Moore EE, Cogbill T, Malangoni M, et al.: Organ injury scaling II: Pancreas, duodenum, small bowel, colon, and rectum. J Trauma 30:1427, 1990.)

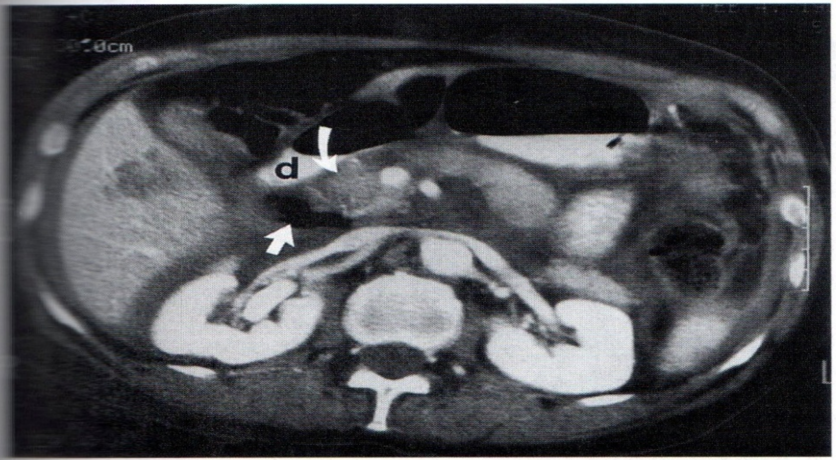


FIGURE 35-3. Computed tomography (CT) finding of retroperitoneal duodenal perforation. CT scan shows poor definition of the structures in the region of the head of the pancreas (curved arrow) and diminished enhancement of the head compared to the body. A collection of extraluminal, retroperitoneal gas (straight arrow) lies immediately posterior to the second portion of the duodenum (d), consistent with a duodenal perforation. This patient is also depicted in Fig. 35-4.
(From Smith DR, Stanley RJ, Rue LW III: Delayed diagnosis of pancreatic transection after blunt abdominal trauma. J Trauma 40:1009, 1996.)

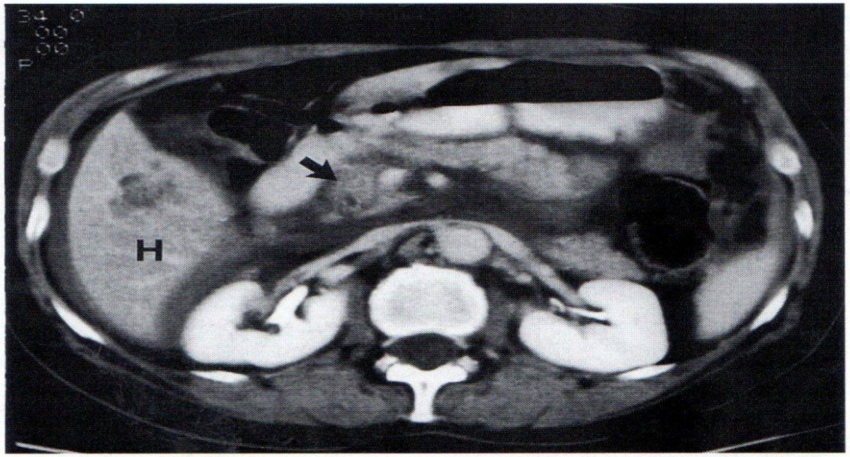


FIGURE 35-4. Computed tomography scan of pancreas, demonstrating subtle early signs of injury, including irregularity of the neck of the pancreas (arrow), peripancreatic fluid, and intrahepatic hematoma (H).
(From Smith DR, Stanley RJ, Rue LW III: Delayed diagnosis of pancreatic transection after blunt abdominal trauma. J Trauma 40:1009, 1996.)

become symptomatic when pancreatic secretions are activated by enteral leak from an associated small bowel injury. Other findings include transection, sometimes in association with fracture of the

A

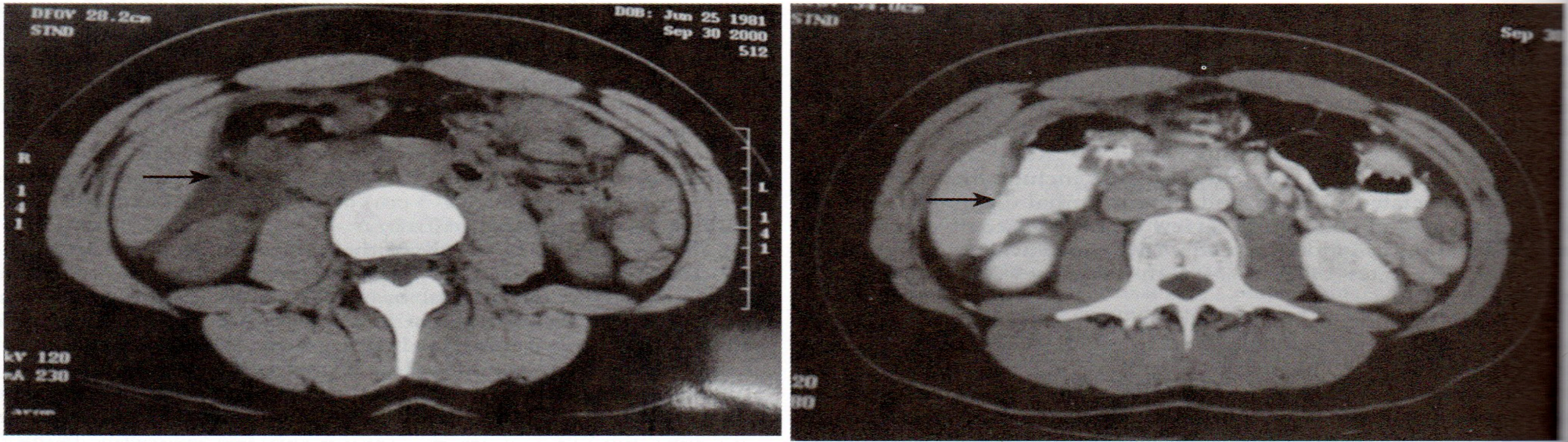
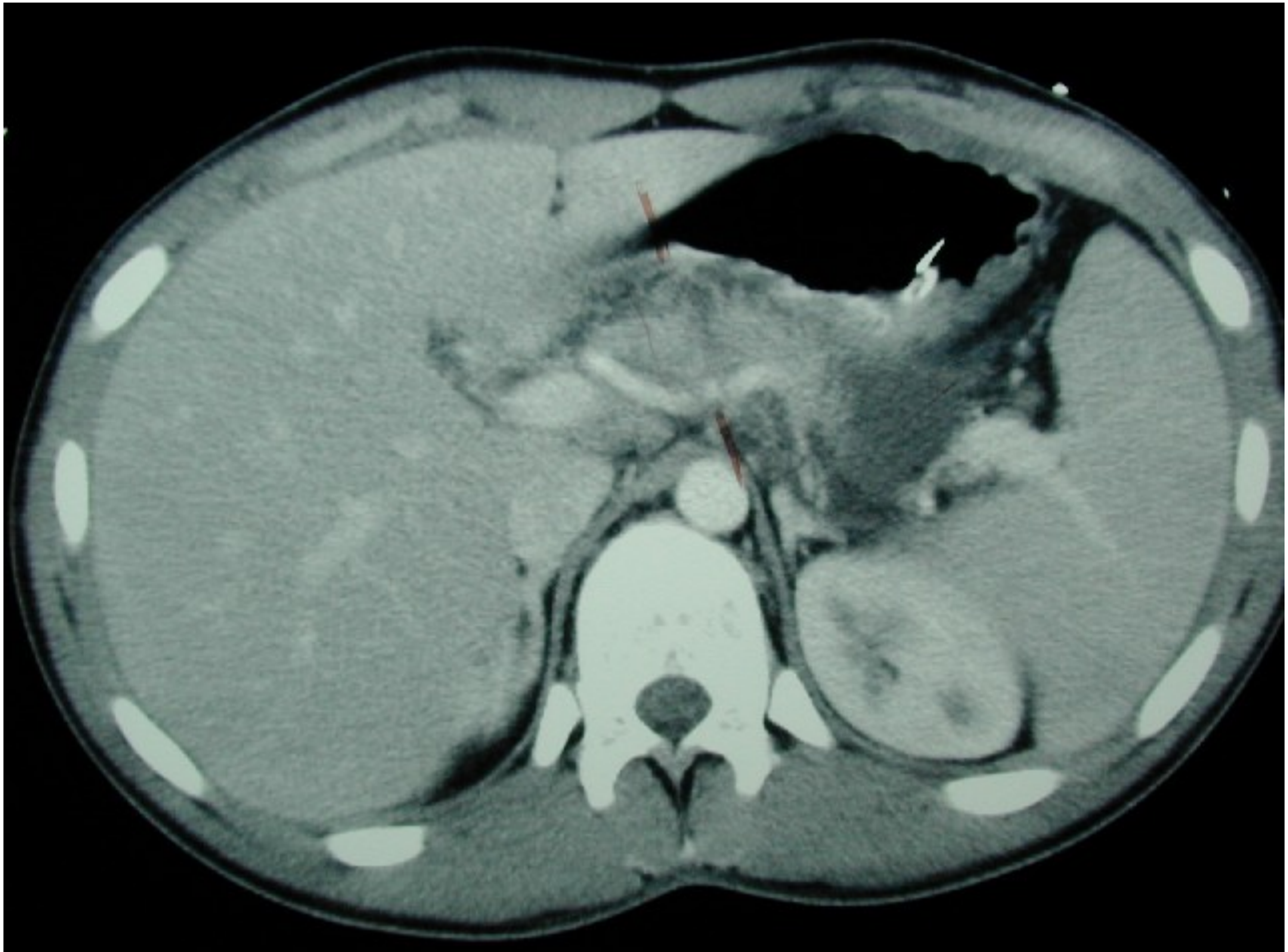
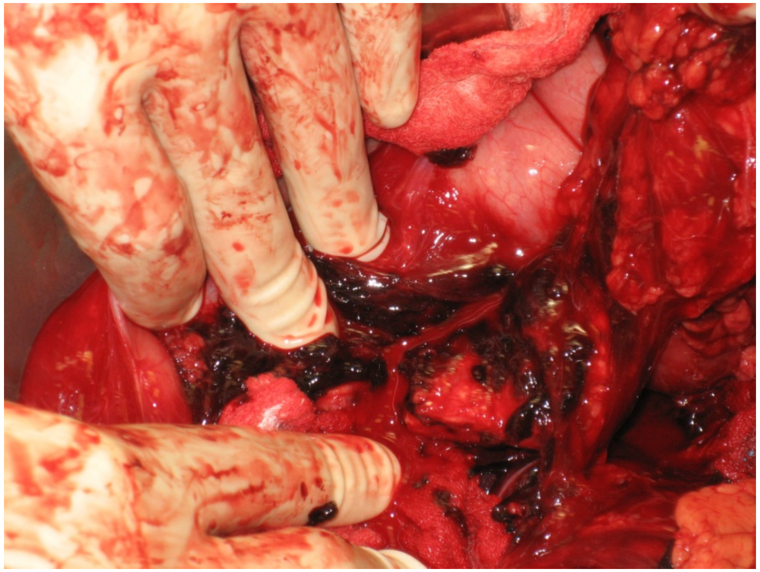


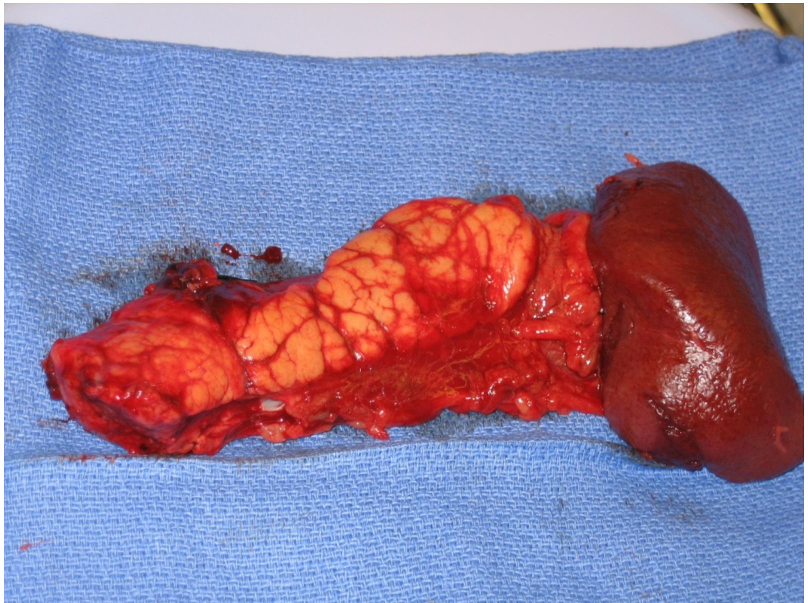
Figure 1 Duodenal perforation. Nineteen-year-old female dropped a 185-lb barbell on abdomen, presented to emergency department 4 hours later with mild abdominal pain and nausea. Afebrile, hemodynamics stable, persistent epigastric tenderness without peritoneal signs. WCC 16 K, amylase 114. Arrow points to nonluminal air in the retroperitoneum and free extravasation of contrast.

Grade III Pancreas



Complete Pancreas Transection





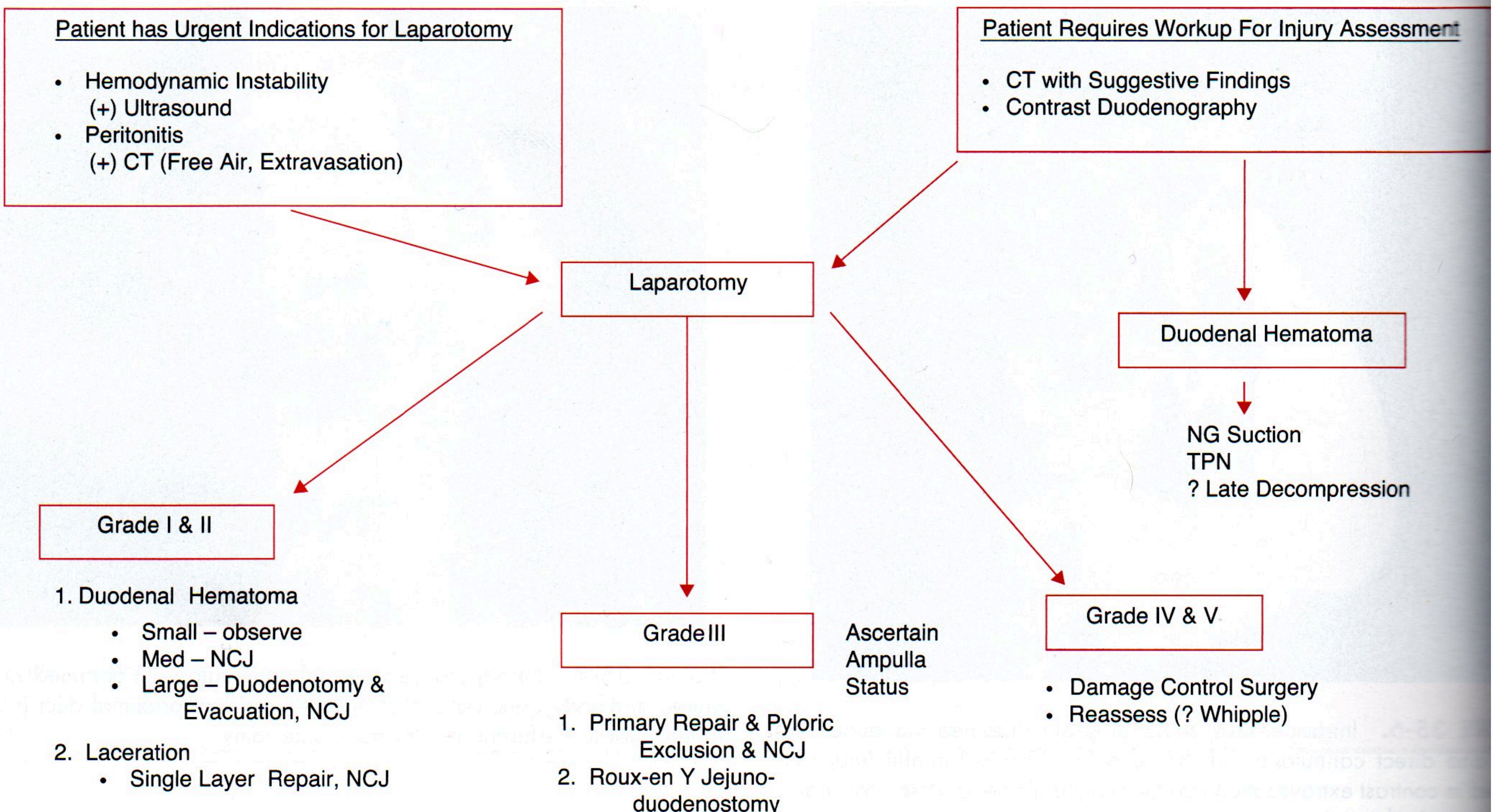


FIGURE 35-9. Algorithm I. Algorithm for duodenum injury.

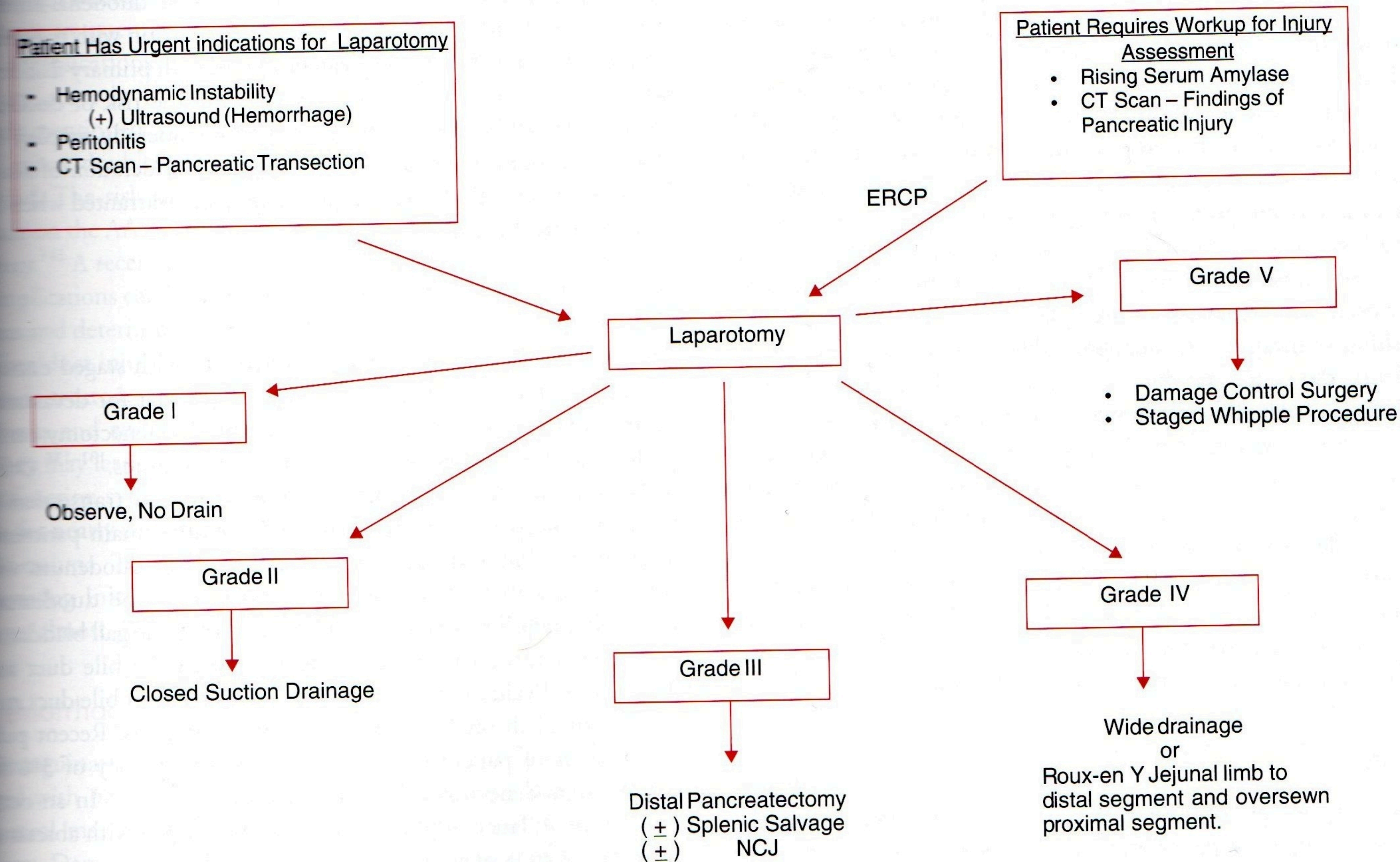


FIGURE 35-13. Algorithm II. Algorithm for pancreatic trauma.

Non-operative Management

- Duodenum
  - Only grade I
    - NGT, TPN
- Pancreas
  - Only grade I
- Follow amylase, lipase, CT scan at 24 hours to r/o pancreatic leak

Operative Management

- Goals
  - Gaining exposure
  - Identifying injuries
  - Determine need for damage control
  - Drains to monitor

Limited Exposure

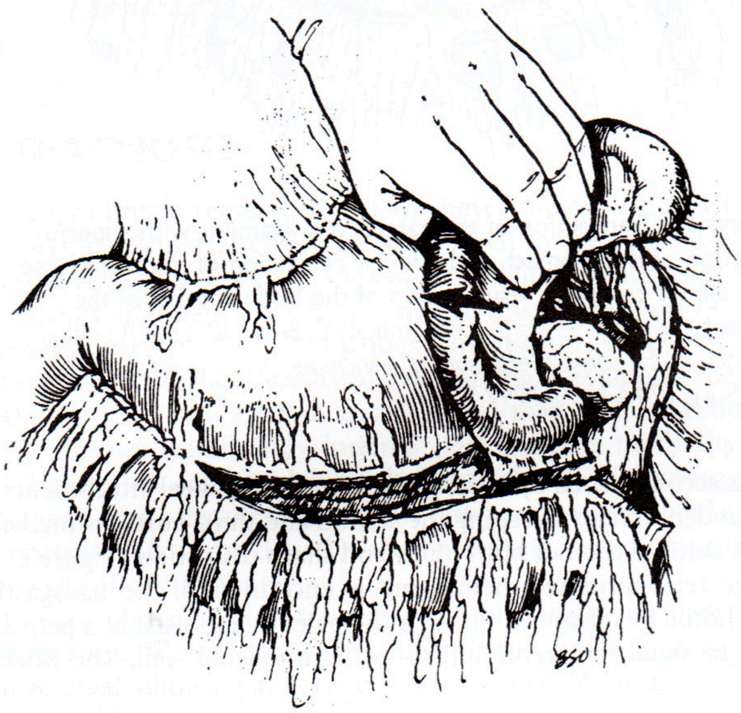


Figure 3 Mobilization of the spleen from a lateral to a medial position to visualize the spleen and posterior aspects of the tail of the pancreas. *(From Asensio JA, Demetriades D, Berne JD, et al: A unified approach to the surgical exposure of pancreatic and duodenal injuries. Am J Surg 174:54–60, 1997.)*

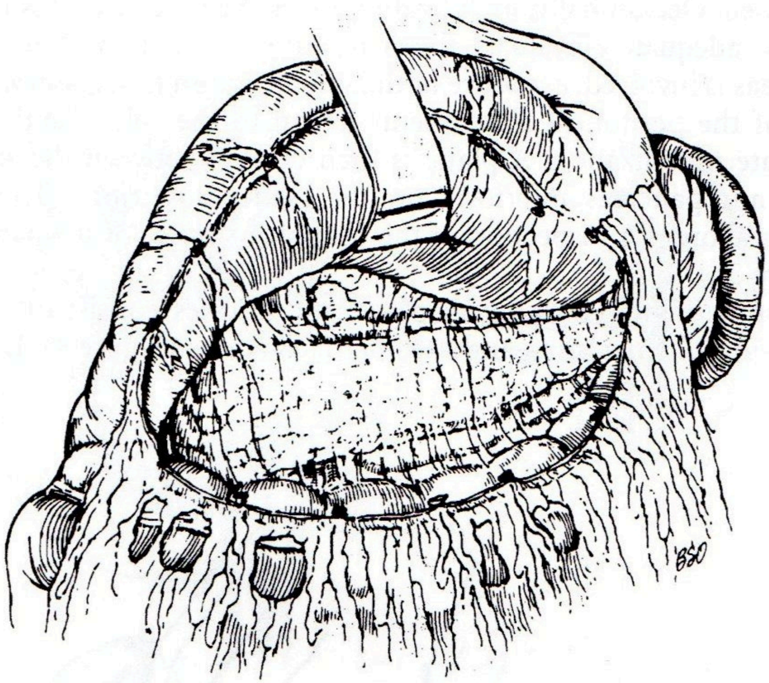
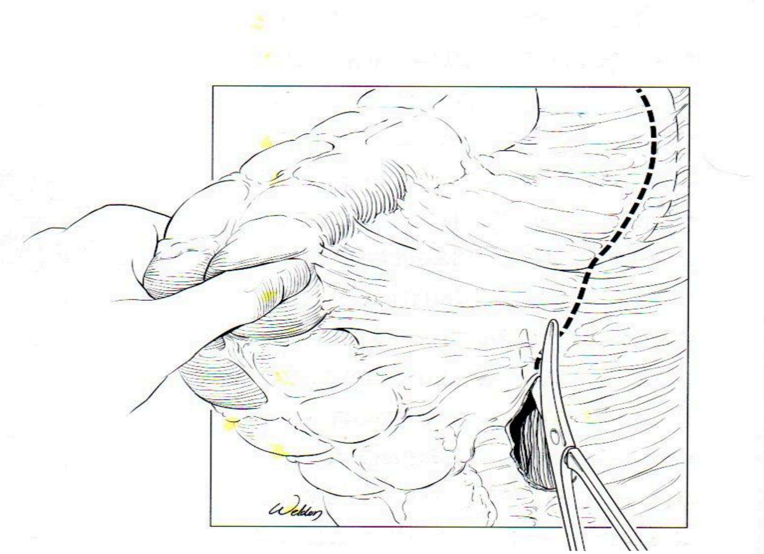
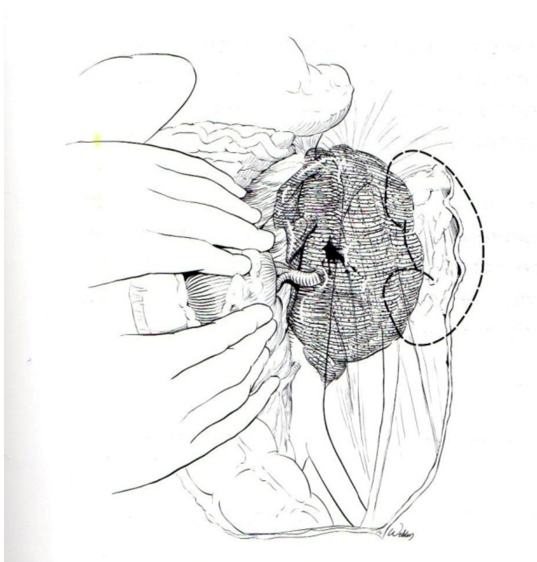


Figure 1 Transection of the gastrocolic ligament with superior retraction of the stomach and inferior retraction of the transverse colon allows complete visualization of the body and tail of the pancreas. *(From Asensio JA, Demetriades D, Berne JD, et al: A unified approach to the surgical exposure of pancreatic and duodenal injuries. Am J Surg 174:54–60, 1997.)*

Left Medial Visceral Rotation

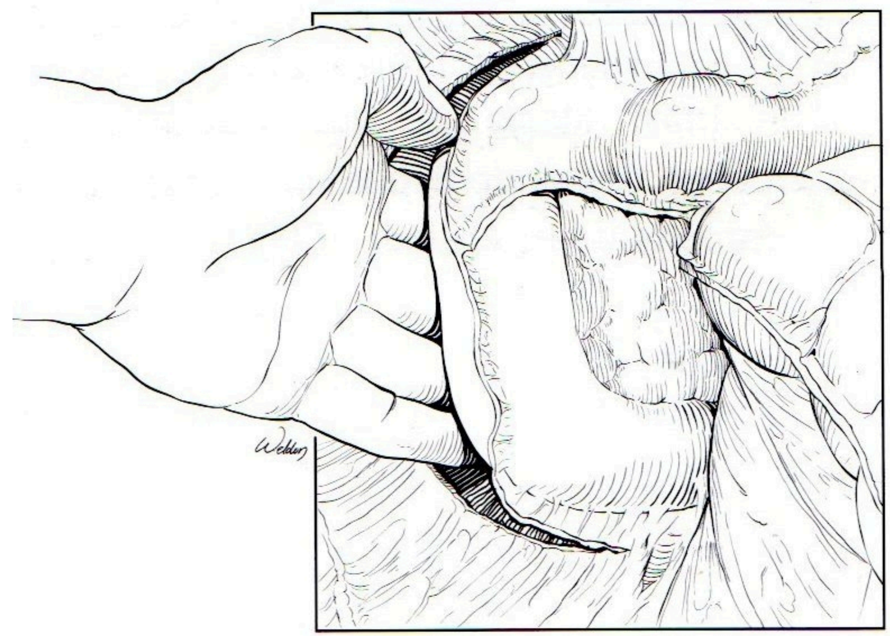




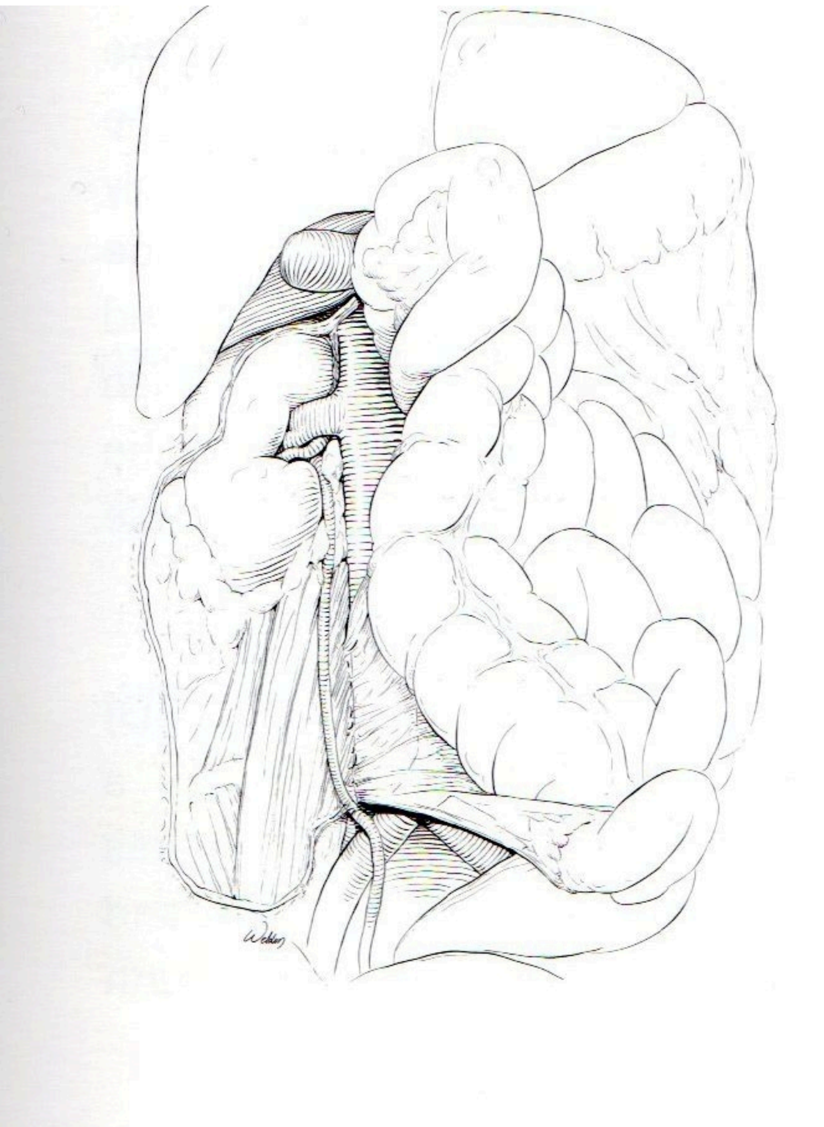
- Mattox Maneuver
  - Pull left colon medially, identify and incise white line of Toldt up to the splenic flexure
  - Continue upward along the same line and lateral to the spleen

Right Medial Visceral Rotation

- Kocher Maneuver
  - Identify the duodenum and incise the posterior peritoneum immediately lateral to it
  - Slide your hand behind the duodenum and head of pancreas and dissect to the CBD superiorly and to the SMV inferiorly



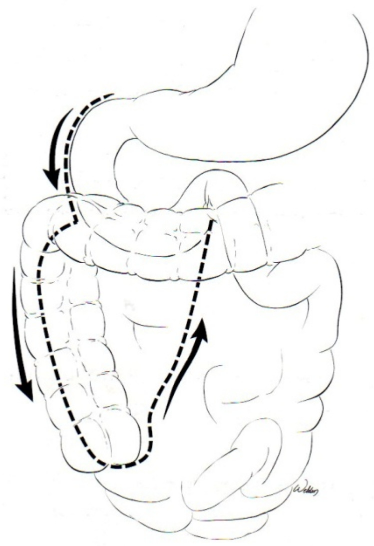
Right Medial Visceral Rotation

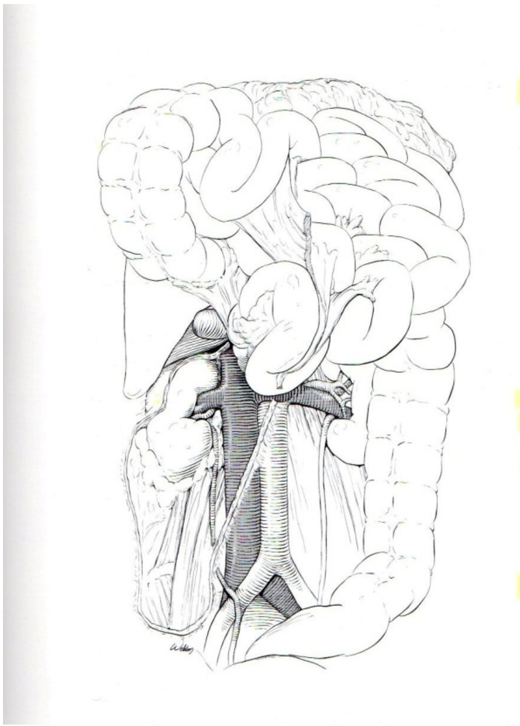


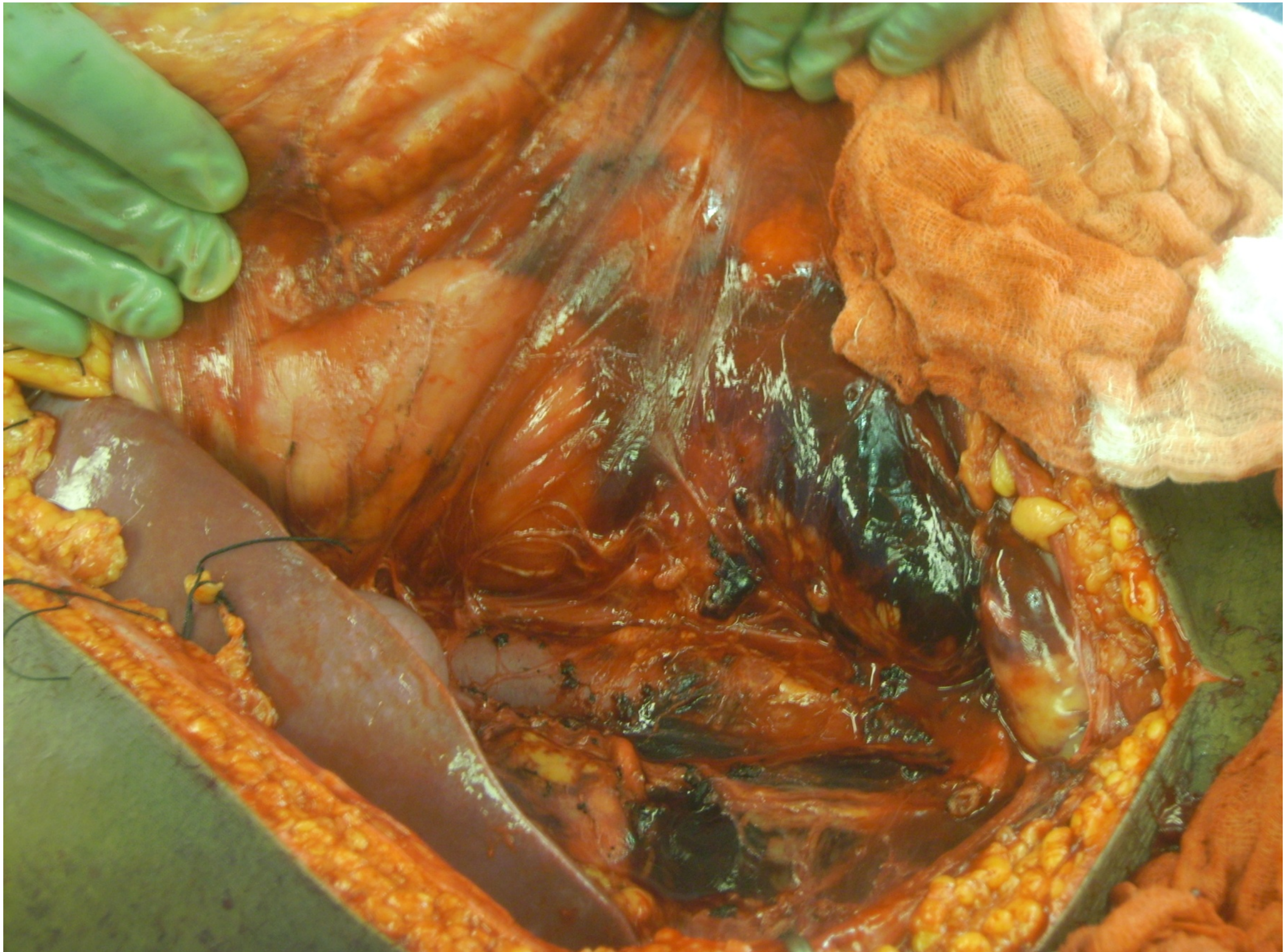
- Extended Kocher
  - Carry the incision caudal in the posterior peritoneum toward the White line of Toldt, immediately lateral to the right colon
  - Reflect right colon medially

Right Medial Visceral Rotation

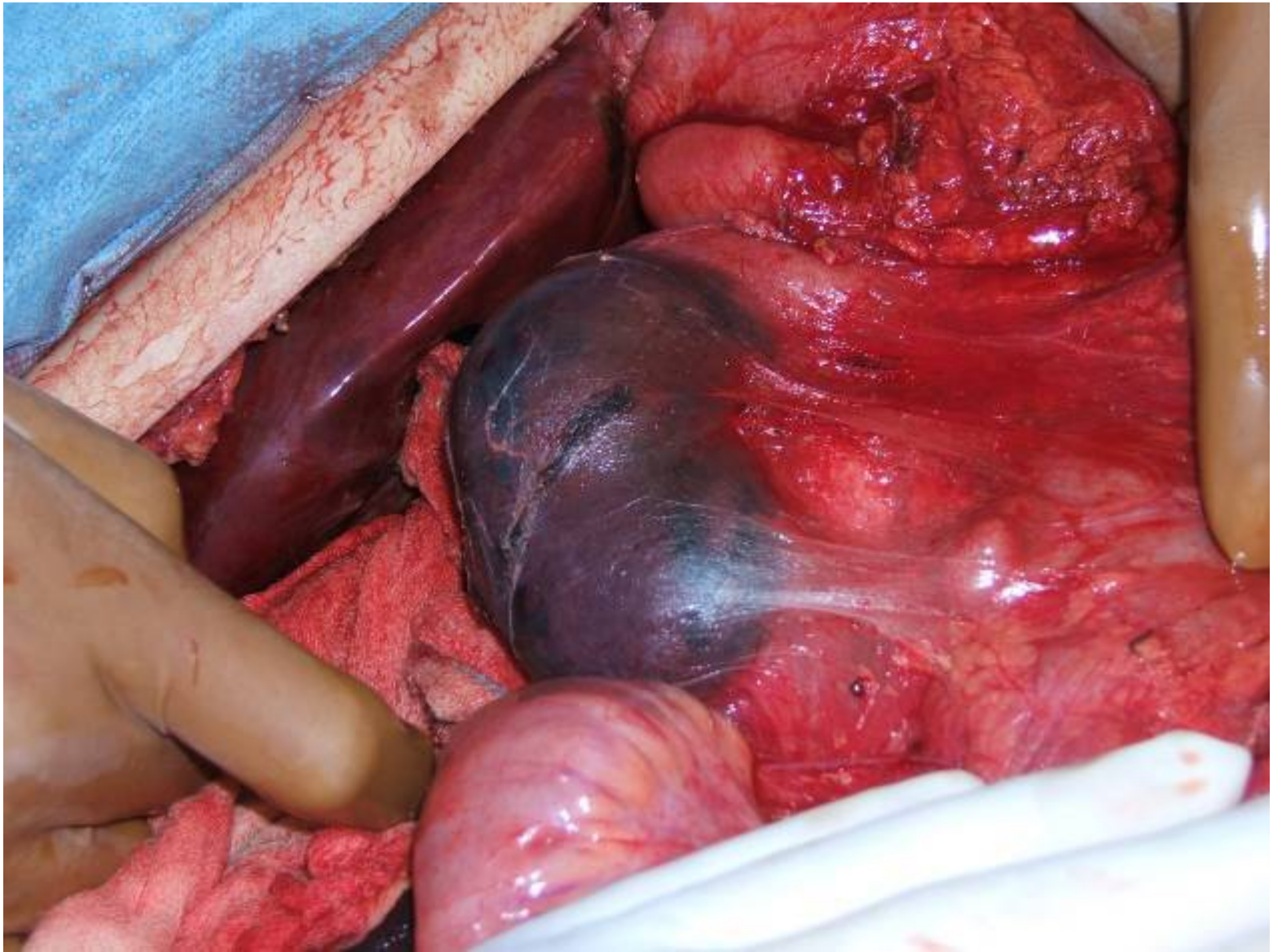
- Cattell-Braasch
  - Cary same incision in the posterior peritoneum around the cecum
  - Incise the line of fusion from the small bowel mesentary to the posterior peritoneum from the medial side of the cecum to the Ligament of Trietz







Grade III Duodenum



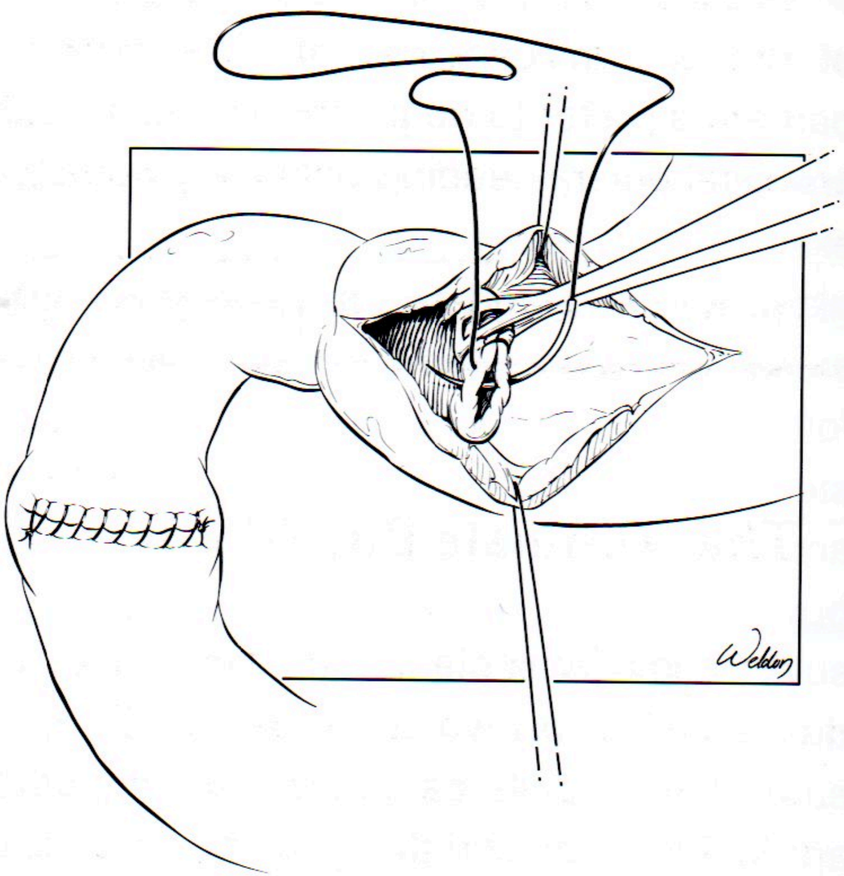
Duodenum Repair

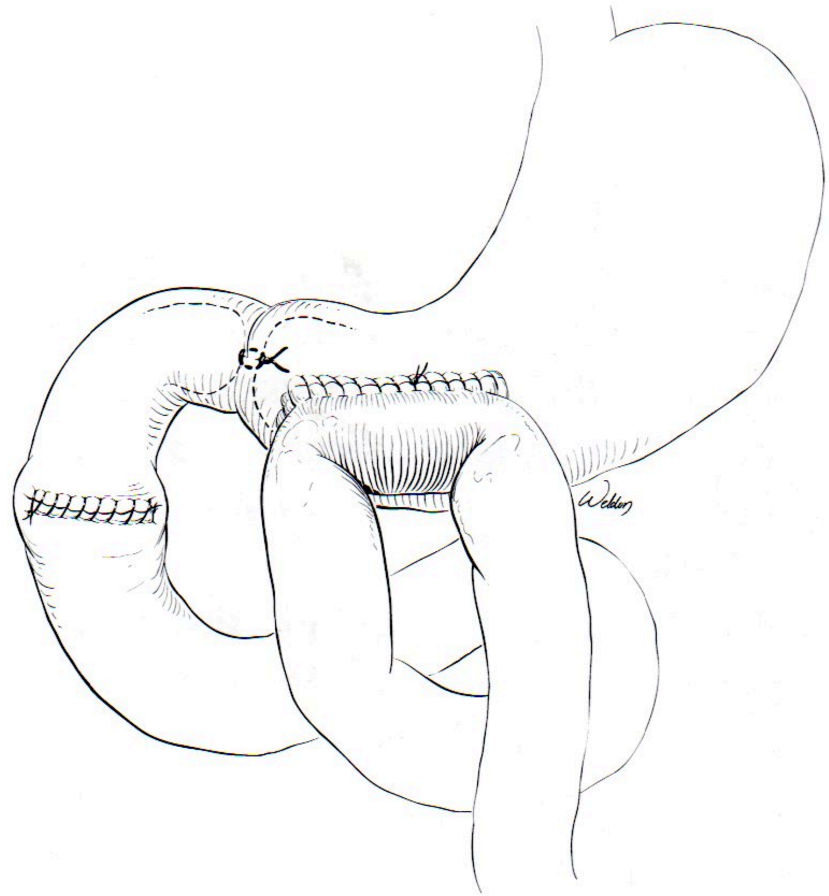
- Grade I and II
  - Hematoma
    - Small
      - Observe
    - Medium
      - Feeding jejunostomy Tube
    - Large
      - Unroof, evacuate, feeding jejunostomy tube
  - Laceration
    - Single layer repair
      - Transverse repair to avoid narrowing of the lumen

Duodenum Repair

- Grade III
  - Proximal to Ampulla of Vater
    - Primary repair, Pyloric exclusion, gastrojejunostomy, and feeding jejunostomy tube
  - Distal to Ampulla of Vater
    - End to End Roux-n Y Duodeno-jejunostomy

Primary repair with Pyloric Exclusion and Gastrojejunostomy





End to End Roux-en Y Duodenojejunostomy

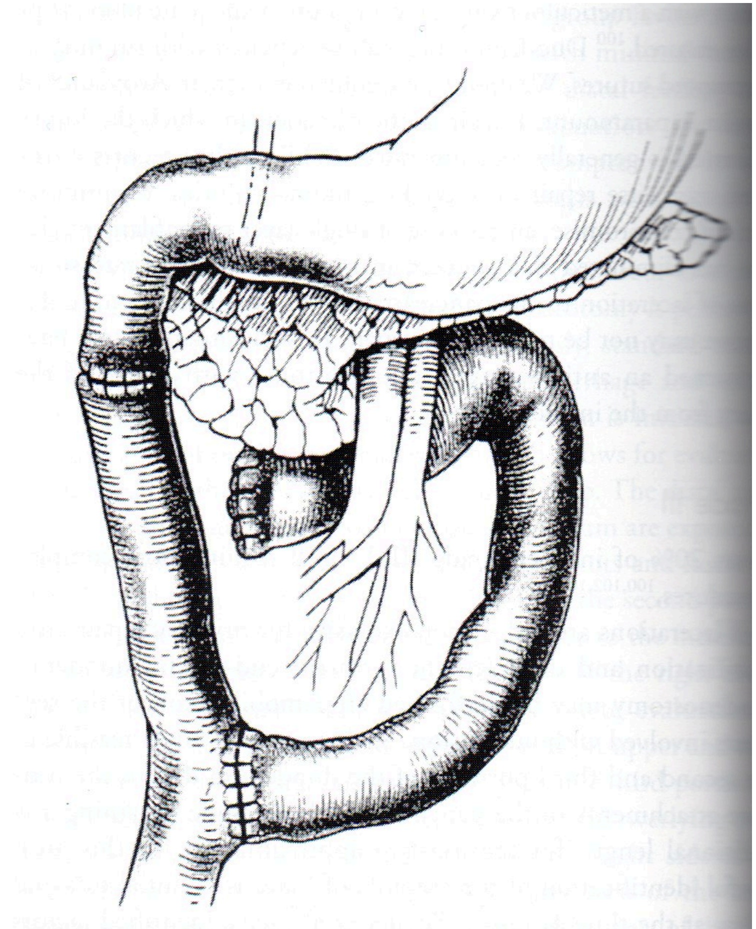


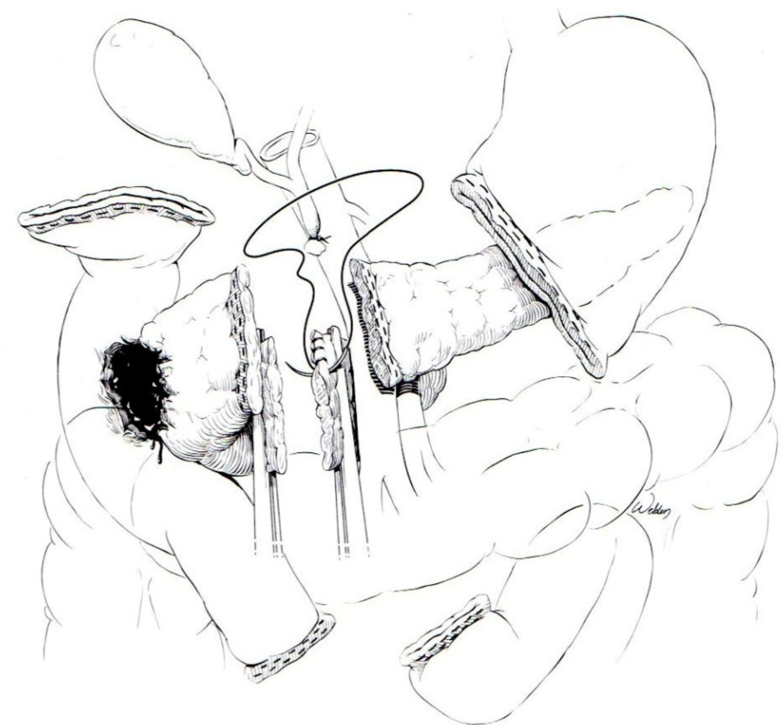
FIGURE 35-12. Roux-en-Y duodenojejunostomy is used to treat du nal injuries between the papilla of Vater and superior mesenteric ve when tissue loss precludes primary repair.
(Reproduced with Permission from Brunicardi FC et al. Schwartz's Princ of Surgery, 8th ed. McGraw-Hill, Inc., 2005. Fig. 6-52, p. 168.)

Duodenum Repair

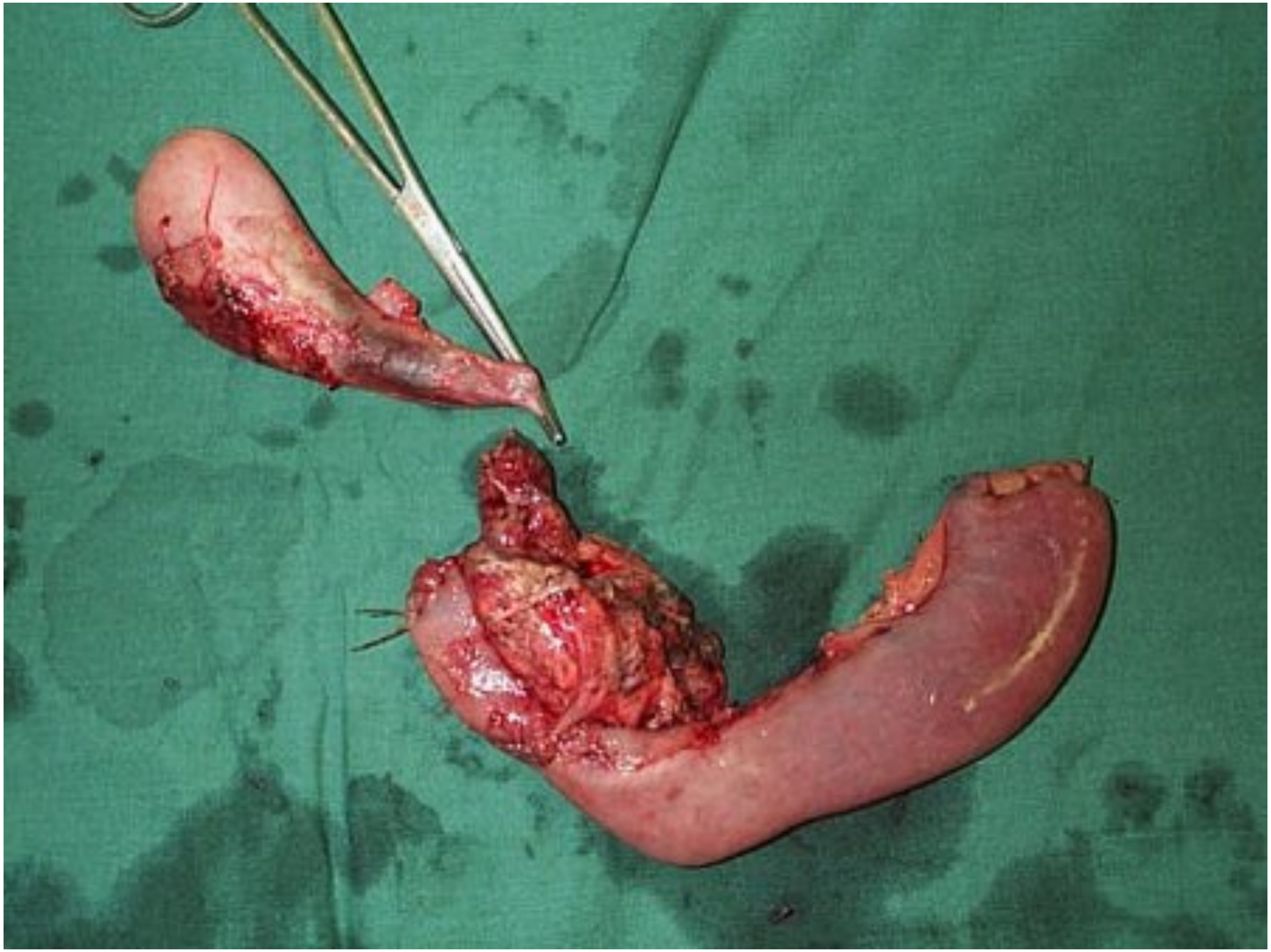
- Grade IV and V
  - Damage Control
  - Pancreaticoduodenectomy
    - aka…….Trauma Whipple

Trauma Whipple

- Only if the trauma has done most of the wok for you
- Staged procedure
  - leave things stapled/tied off and do anastomosis after patient more stable



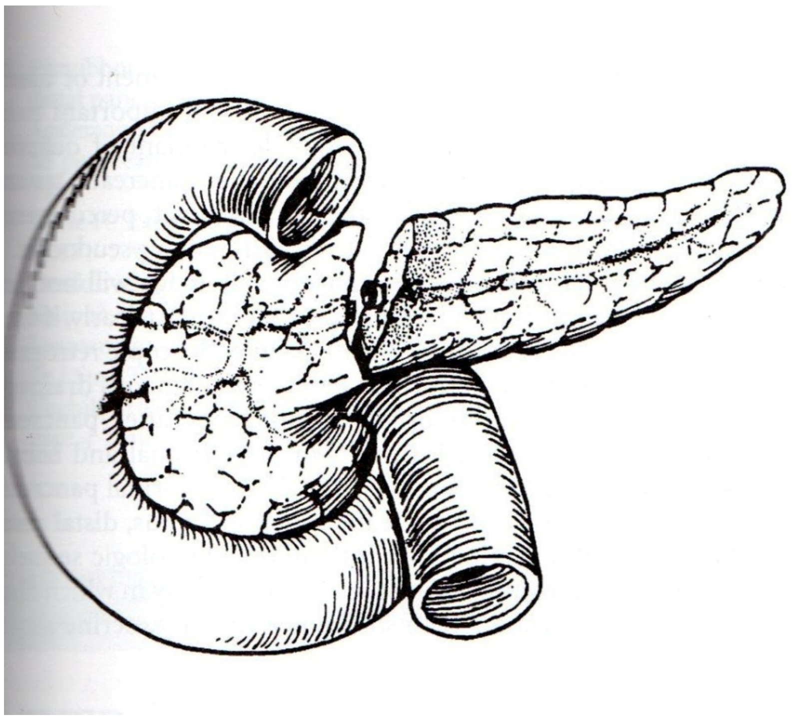
Trauma Whipple

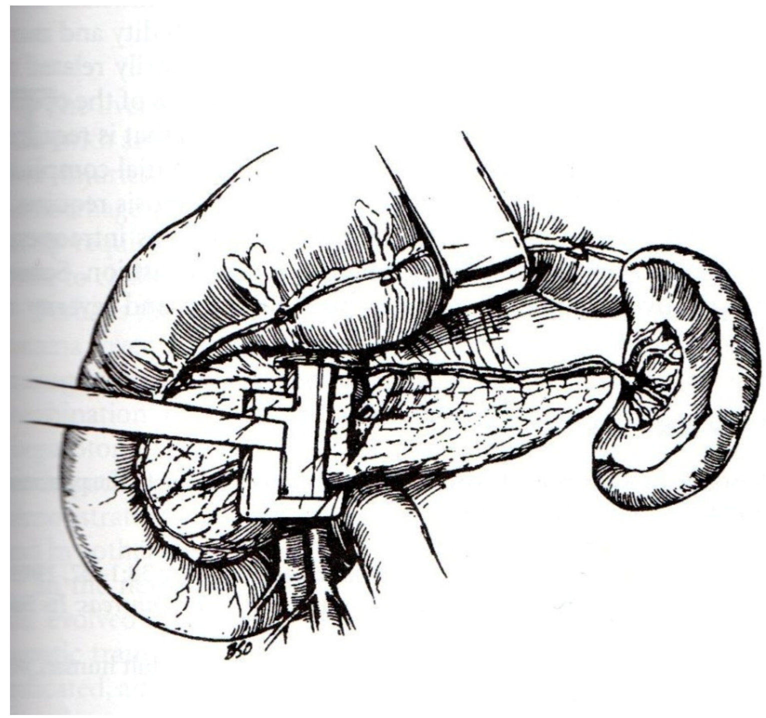


Pancreatic Repair

- Grade I
  - Observe, no drain
- Grade II
  - Drain
- Grade III
  - Distal Pancreatectomy
    - +/- splenectomy, feeding jejunostomy tube
- Grade IV
  - Wide drainage
  - Staple off proximal segment and distal segment drainage into a Roux-en Y pancreaticojejunostomy
- Grade V
  - Damage control
  - Trauma Whipple

Distal Pancreatectomy





Complications

- Recurrent (Secondary) Hemorrhage
  - Progressive pancreatic necrosis, intra-abdominal abscess
- Pancreatic Fistula
  - 7-20%
  - Defined as a drain output with amylase>3x serum
    - Low output < 200cc/d
      - Resolve in 2 weeks
    - High output > 700cc/day
      - Resolve in 6-8 weeks
    - Treatment
      - CT Abd/Pel
        - » Fluid pocket = IR Drainage
        - » No fluid = ERCP with sphincterotomy
- Duodenal Fistula
  - Failure of repair
    - Always drain suture lines to monitor for leak, use pyloric exclusion, and feeding jejunostomy tube
  - Heal in 6-8 weeks

Complications

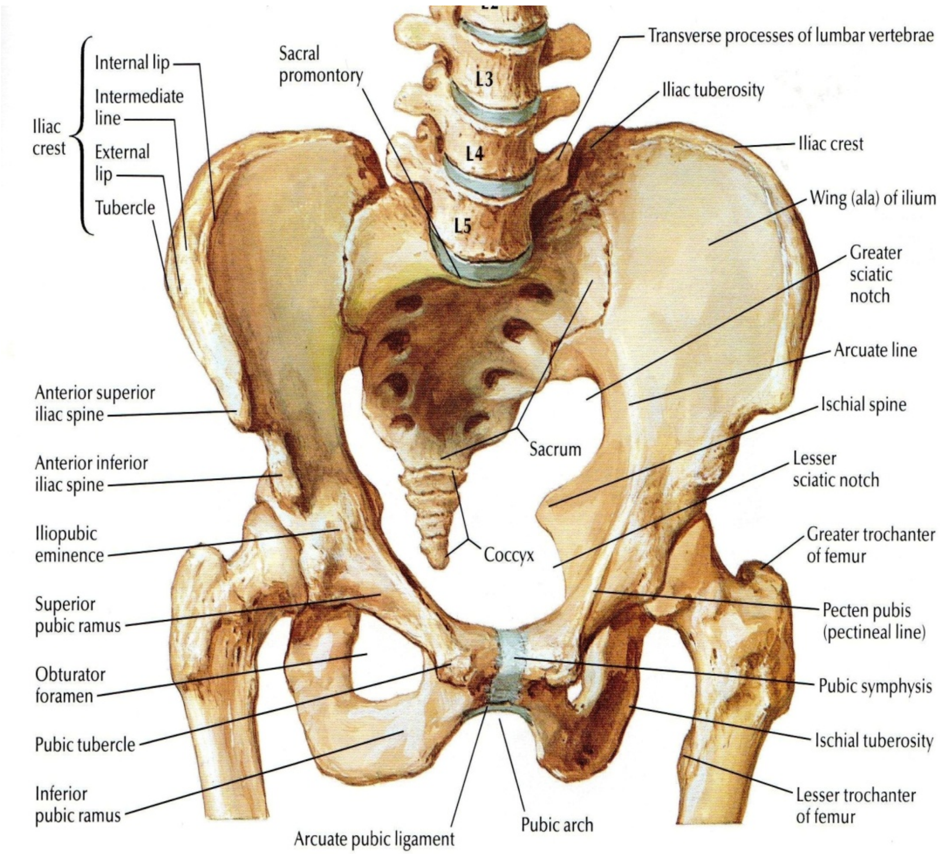
- Abdominal Abscess
  - 7-10 days after repair
  - Avoid exploration
  - CT guided percutaneous drainage
- Pancreatic Pseudocyst
  - Difficult to distinguish with abscess
    - ERCP to establish duct continuity with PTC drainage
- Pancreatic Insufficiency
  - Resection distal to mesenteric vessels decreases risk

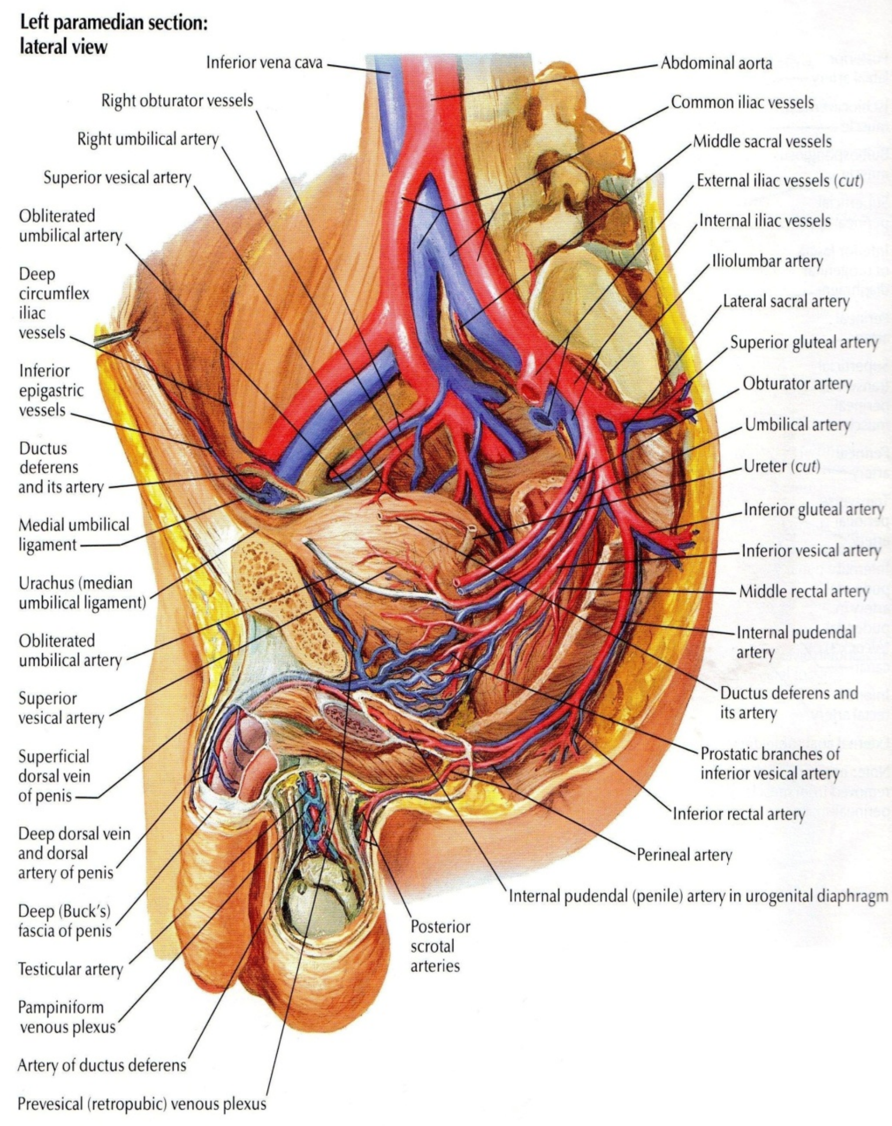
Pelvic Fractures

Issues

- Intricate meshwork of arteries, veins, nerves, and organs that lie within the bony pelvis
- Substantial force it takes to fracture the pelvis
  - Other structural and organ injuries involved

Anatomy


Iliac crest
Internal lip
Intermediate line
External lip
Tubercle
Sacral promontory
L3
L4
L5
Transverse processes of lumbar vertebrae
Iliac tuberosity
Iliac crest
Wing (ala) of ilium
Greater sciatic notch
Arcuate line
Ischial spine
Lesser sciatic notch
Greater trochanter of femur
Pecten pubis (pectineal line)
Pubic symphysis
Ischial tuberosity
Lesser trochanter of femur
Pubic arch
Arcuate pubic ligament
Sacrum
Coccyx
Anterior superior iliac spine
Anterior inferior iliac spine
Iliopubic eminence
Superior pubic ramus
Obturator foramen
Pubic tubercle
Inferior pubic ramus


Left paramedian section: lateral view
Inferior vena cava
Right obturator vessels
Right umbilical artery
Superior vesical artery
Obliterated umbilical artery
Deep circumflex iliac vessels
Inferior epigastric vessels
Ductus deferens and its artery
Medial umbilical ligament
Urachus (median umbilical ligament)
Obliterated umbilical artery
Superior vesical artery
Superficial dorsal vein of penis
Deep dorsal vein and dorsal artery of penis
Deep (Buck's) fascia of penis
Testicular artery
Pampiniform venous plexus
Artery of ductus deferens
Prevesical (retropubic) venous plexus
Posterior scrotal arteries
Abdominal aorta
Common iliac vessels
Middle sacral vessels
External iliac vessels (cut)
Internal iliac vessels
Iliolumbar artery
Lateral sacral artery
Superior gluteal artery
Obturator artery
Umbilical artery
Ureter (cut)
Inferior gluteal artery
Inferior vesical artery
Middle rectal artery
Internal pudendal artery
Ductus deferens and its artery
Prostatic branches of inferior vesical artery
Inferior rectal artery
Perineal artery
Internal pudendal (penile) artery in urogenital diaphragm

Biomechanics

- Lateral compression
  - Produces an acute shortening of the diameter across the pelvis
  - Typically does not destroy the ligamentous integrity of the pelvis
  - Does not cause massive blood loss from vascular structures

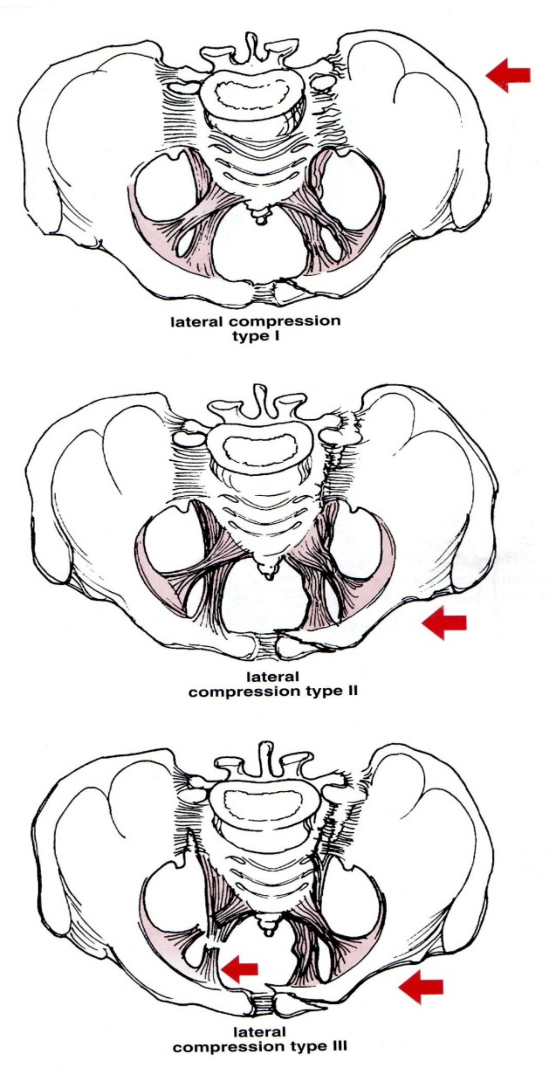


FIGURE 38-4. Lateral compression fractures are usually caused by T-bone motor vehicle crashes, pedestrians being struck from the side, or a fall from a height and produce acute shortening of the diameter across the pelvis.

Biomechanics

- Anterior-Posterior
  - Occurs through either direct contact with illiac spine or through secondary force transmitted from femur
  - Causes pelvic diameter to widen
  - Can cause no fracture, but devastating ligamentous and vascular injury
  - Manifests as widened PS or SI joint

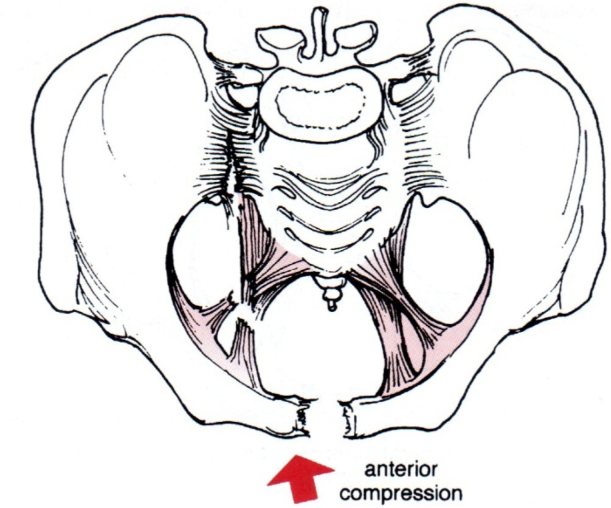


FIGURE 38-5. Anteroposterior compression injuries are usually caused by motor vehicle crashes from the front such as a crash in which force is transmitted through the femurs into the pelvis, or a straddle injury such as a motorcycle crash.

Biomechanics

- Vertical shear
  - Fall from height onto extended lower extremity
  - Shortens the vascular structures
    - Less hemorrhage

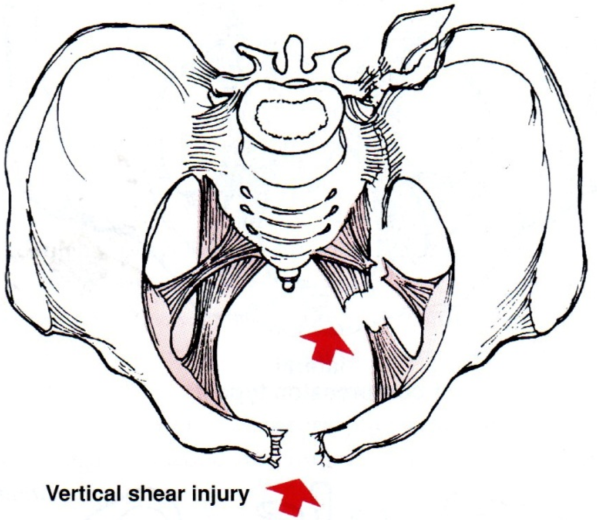
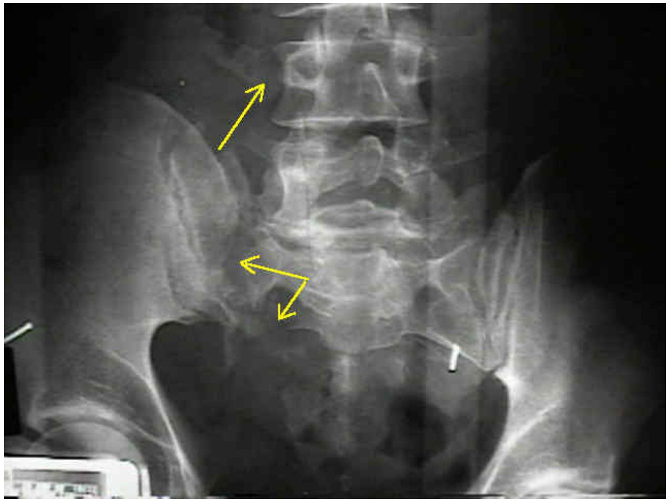


FIGURE 38-6. Vertical shear injuries are usually caused by a fall from a height and landing on extended lower extremities.



Diagnosis

- PE
  - Scrotal/vulvar hematoma
  - Assessing pelvic stability
    - Push on both sides of illiac crests
- A/P Pelvis
- CT Bony pelvis
- FAST
  - If unequivocal, then DPL

Special Considerations

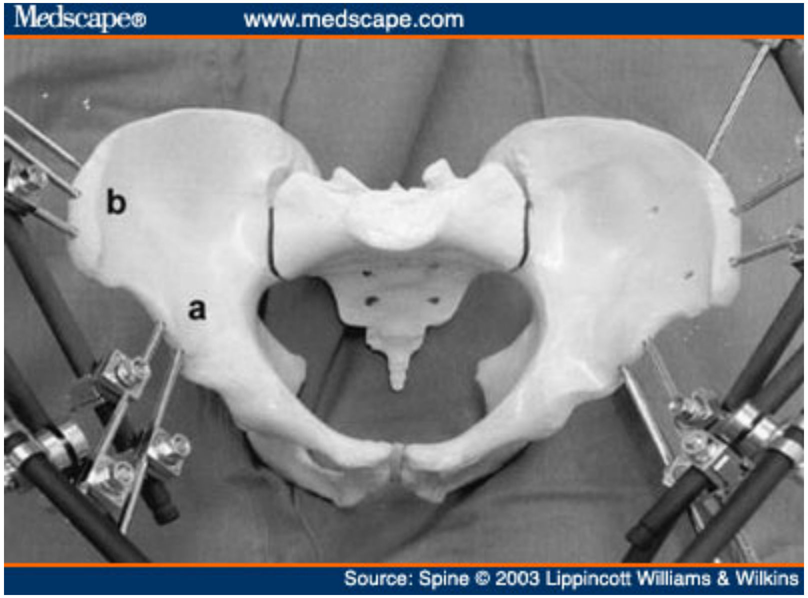
- Respiratory failure due to massive blood accumulation in retroperitoneum, increasing intraabdominal pressure and limiting thoracic excursion
- UE IV Access
- Transfusion
  - Mean 24hr blood requirement for patients with pelvic fractures is 5U, 20% of these require >15U

Stop the bleeding

- Pelvic Binder
  - Reduces pelvic volume
  - Realign pelvis to limit hemorrhage
  - Must be released every few hours to prevent pressure sores

Stop the bleeding

- External Fixation
  - Applied in < 20min
  - Aligns bony edges, can be definitive treatment
  - Can help tamponade venous bleeding, but not arterial
  - Good for damage control situations
  - Only helpful in anterior disruption



Stop the bleeding

TABLE 38-3

Indications for Angiography
4 U transfused for pelvic bleeding in <24 h
>6 U transfused for pelvic bleeding in <48 h
Hemodynamic instability with a negative FAST or DPL
Large pelvic hematoma on CT
Pelvic pseudoaneurysm on helical CT
Large and/or expanded pelvic hematoma seen at the time of laparotomy

- Embolization
  - Can be diagnostic and therapeutic
  - Good for damage control
  - 3 principles
    - Slow the bleeding so the body can control its own hemorrhage
      - Not create large areas collateral damage
    - Limit areas of ischemia and necrosis by embolizing several smaller branches rather than one large branch
    - Limit time in IR suite so resuscitative efforts can resume
  - Pitfalls
    - Clotted veins or spasming arteries can be missed, only to re-open during further resuscitation

Operative Management

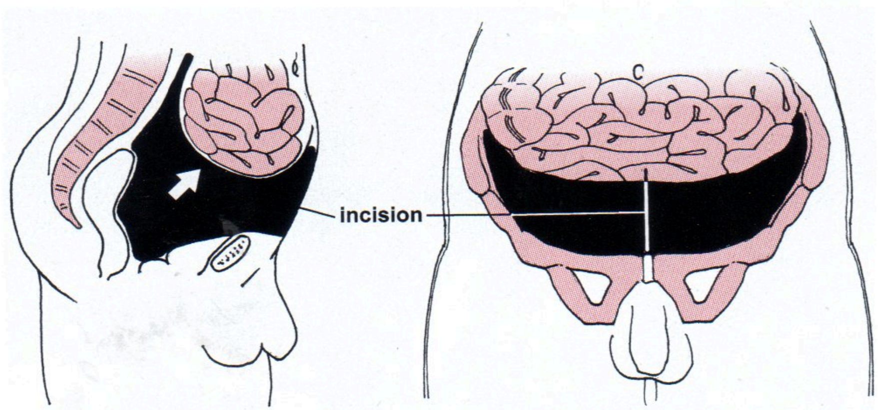
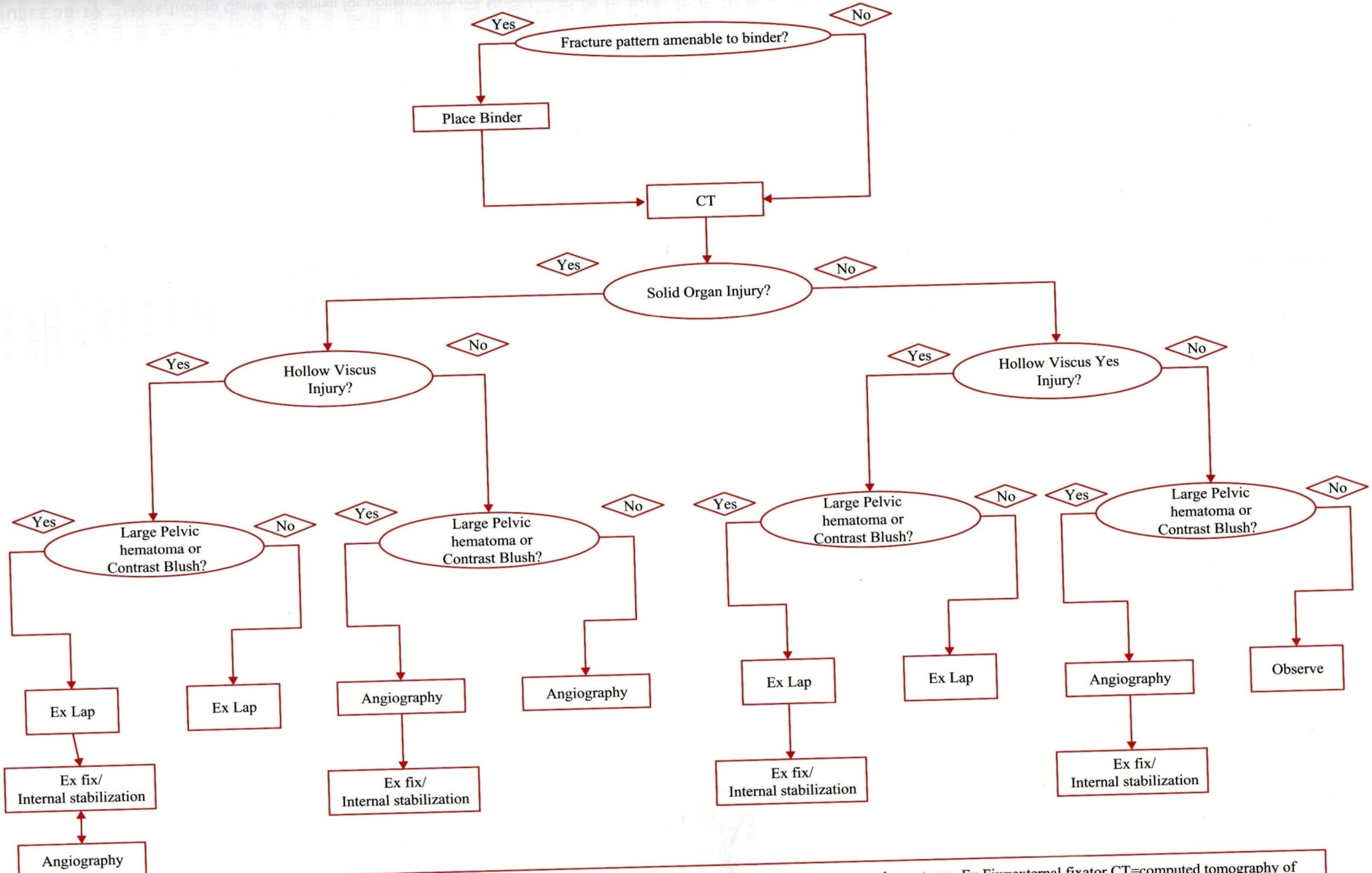


FIGURE 38-16. Preperitoneal packing is accomplished via a vertical or transverse incision. It is important not to enter the peritoneal cavity.

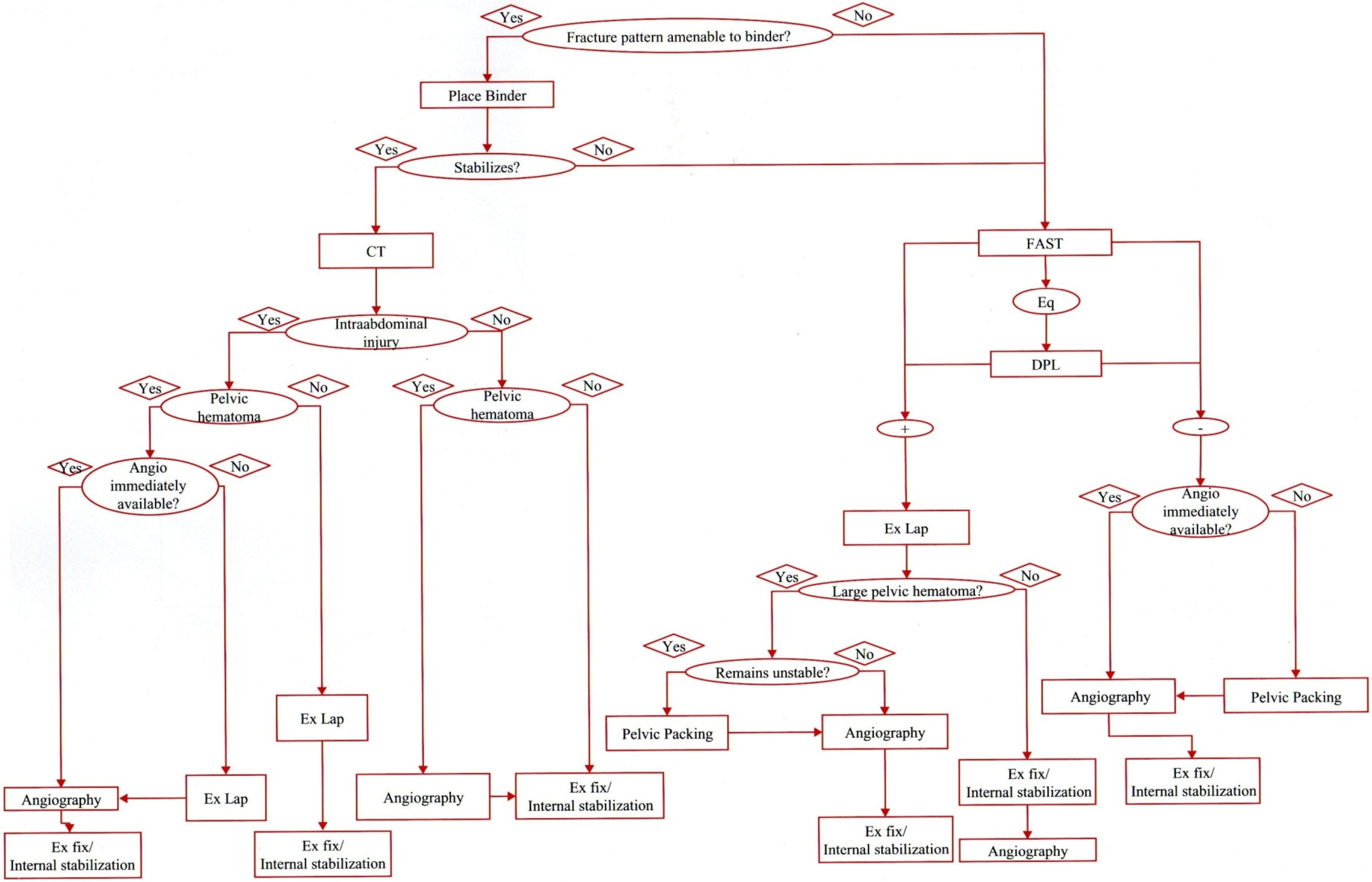
FIGURE 38-17. This patient had a damage control laparotomy and extraperitoneal pelvic packing. She was brought back to the operating room three days later when stable for unpacking.

- Direct surgical control of common/external illiacs is best
- Intraluminal shunting of distal injuries
- Intraperitoneal and extraperitoneal pelvic packing



Eq=equivocal, FAST=focused assessment with sonography for trauma, DPL=diagnostic periotoneal lavage, Ex Lap=exploratory laparotomy, Ex Fix=external fixator,CT=computed tomography of abdomen, Angio=biplanar angiography

FIGURES 38-18. Shock Trauma Center algorithm for patients who are hemodynamically stable.



Eq=equivocal, FAST=focused assessment with sonography for trauma, DPL=diagnostic periotoneal lavage, Ex Lap=exploratory laparotomy, Ex Fix=external fixator,CT=computed tomography of abdomen, Angio=biplanar angiography

FIGURES 38-19. Shock Trauma Center algorithm for patients who are hemodynamically unstable.

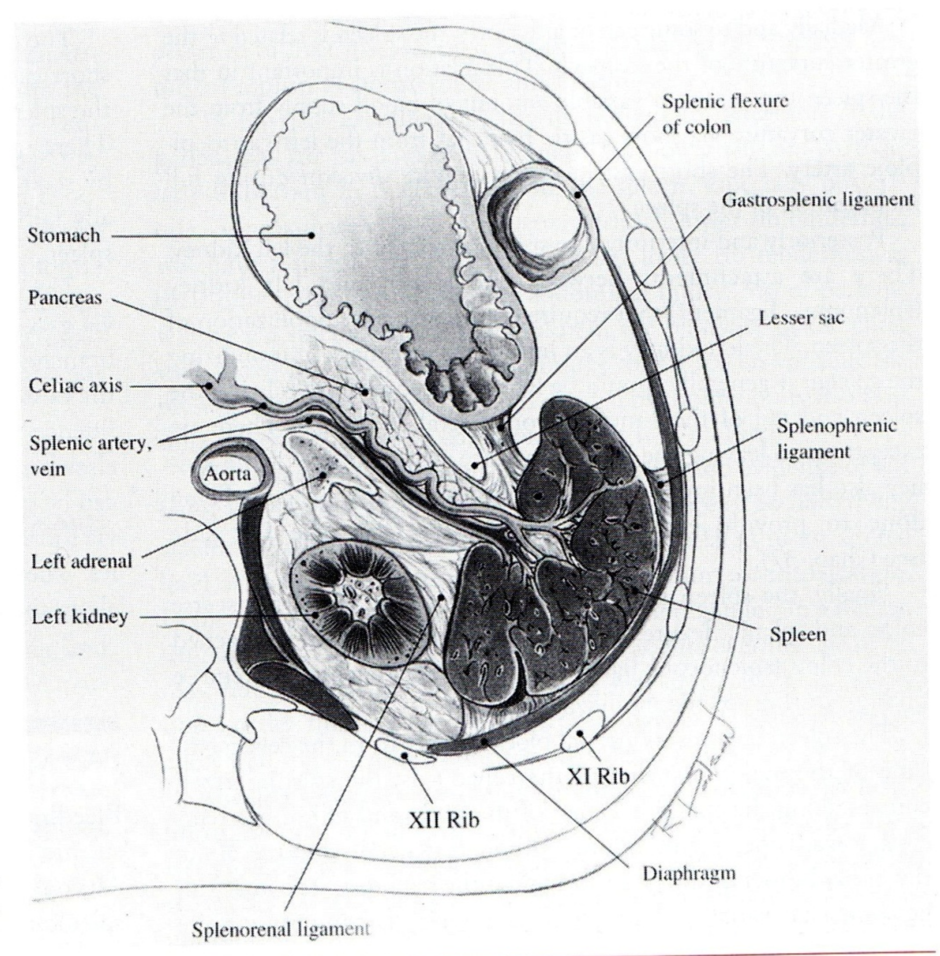
Injuries of the Spleen

The Spleen

- Very common injury in trauma
- Method of assassination in ancient India
  - Malaria causes large, fragile spleen
- Function
  - Filter RBC to keep Hct and blood viscosity within normal ranges, filter bacteria and expose lymphocytes to antigens to produce immunoglobulins

Anatomy

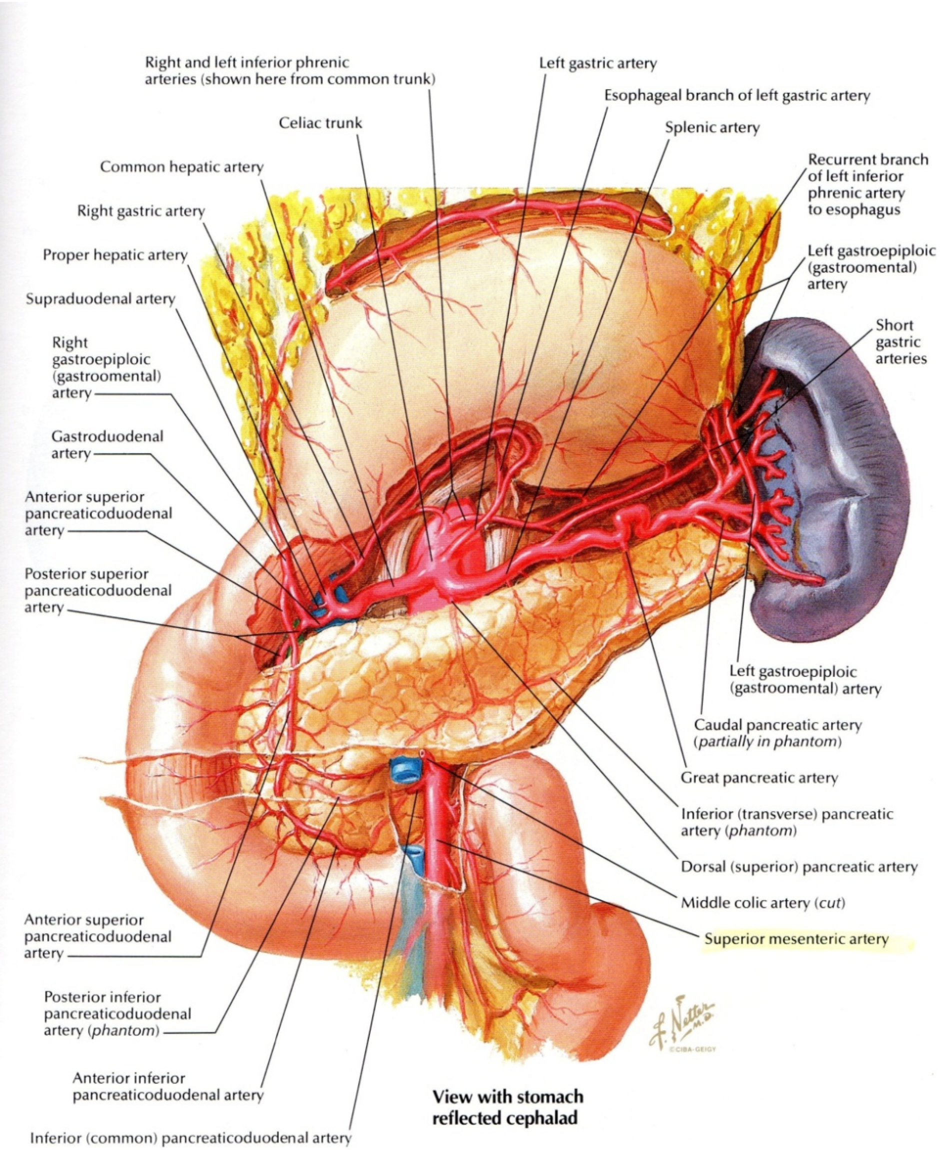
- Located very posteriorly
  – Posterior rib fractures 8-12 should raise suspicion of splenic injury
- Close relationship to diaphragm,distal pancreas, left kidney



Anatomy

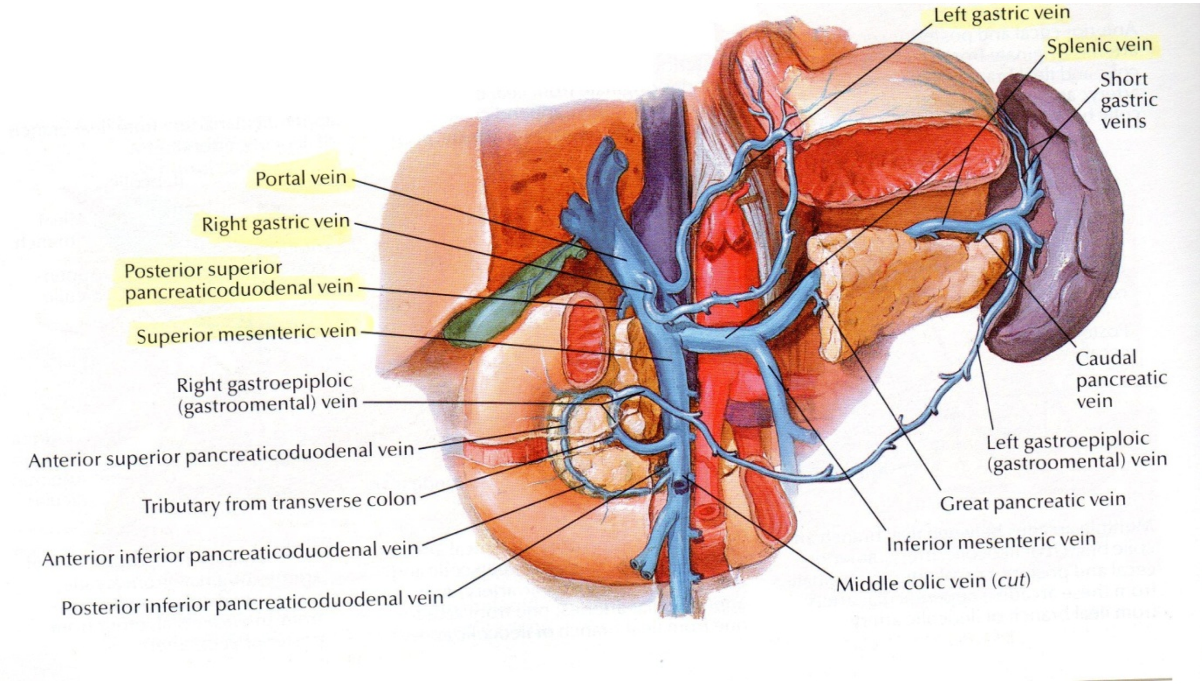
- Ligamentous attachments
  - Posterior/lateral to left hemidiaphragm
    - Splenophrenic ligament
  - Posterior to left kidney
    - Splenorenal ligament
  - Anterior/medial to stomach
    - Gastrosplenic ligament
  - Inferior to distal transverse colon
    - Splenocolic ligament

Anatomy



- Bloodflow
  - Anatomical variance with regards to splenic blood flow
    - Always one splenic artery
  - Some arterial flow from short gastric artery
    - 4-6 branches
  - Splenic vein, short gastric veins, and left gastroepiploic vein drain the spleen

Anatomy



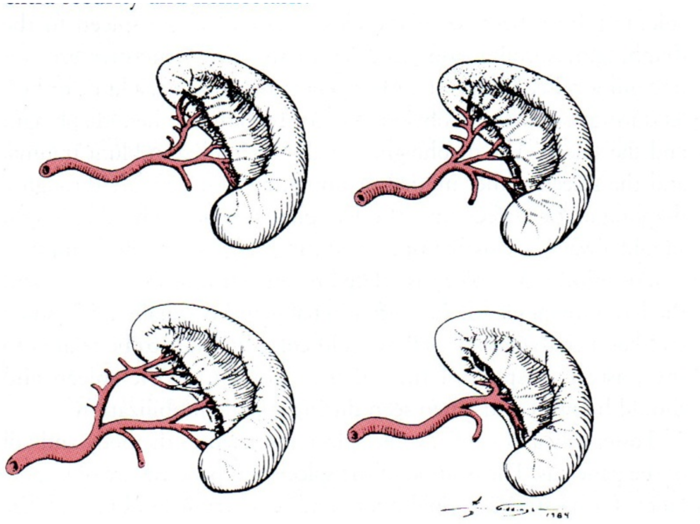


FIGURE 33-3. The arterial blood supply to the spleen can be quite variable. The most common configuration consists of two extraparenchymal divisions of the splenic artery (upper left figure).

Evaluation of splenic injury

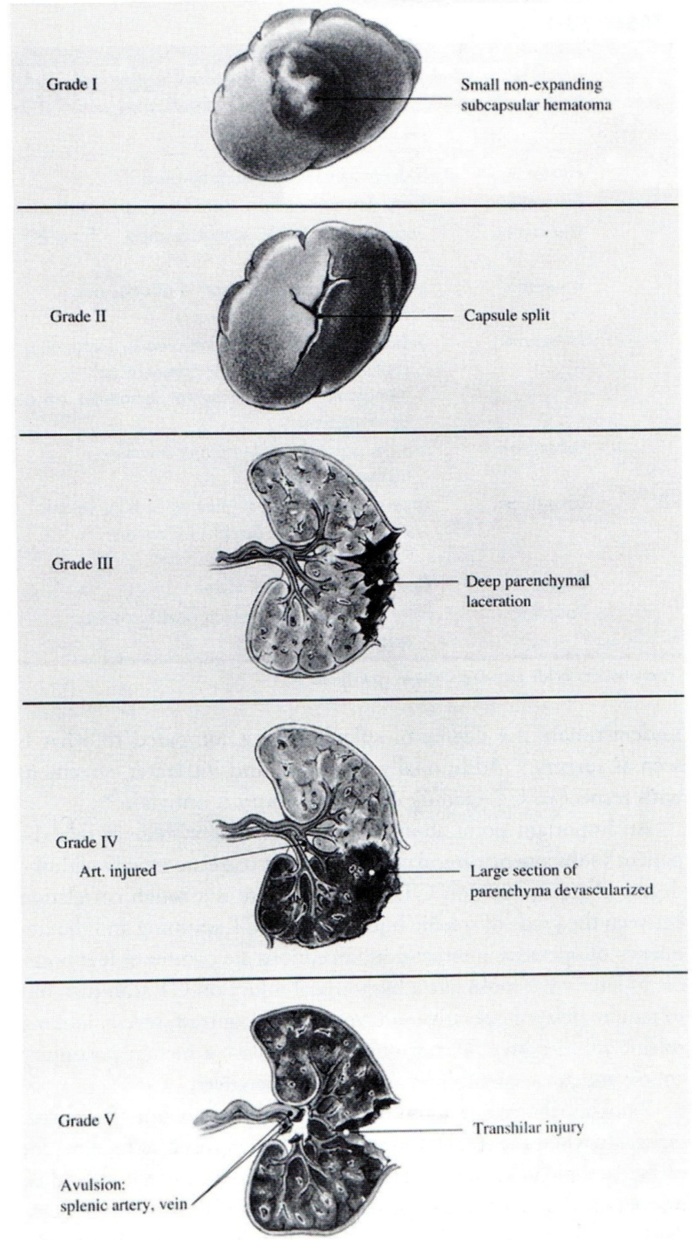
- h/o direct blows to LUQ/lower chest
- PMH
  - Non-Hodgkin's lymphoma, leukemia, h/o malaria,
- PE
  - LUQ tenderness, left flank tenderness
  - Pain referred to left shoulder
    - Kehr's Sign
- If unstable…
  - FAST exam
  - DPL
- CT is mainstay

Grading

Table 1: American Association for the Surgery of Trauma Organ Injury Scaling: Splenic Injury Grading

Grade[a]	Injury Type	Description of Injury
I	Hematoma	Subcapsular, <10% surface area
	Laceration	Capsular tear, <1 cm parenchymal depth
II	Hematoma	Subcapsular, 10%–50% surface area
	Laceration	Capsular tear, 1–3 cm parenchymal depth that does not involve a trabecular vessel
III	Hematoma	Subcapsular, >50% surface area or expanding; ruptured subcapsular or parenchymal hematoma; intraparenchymal hematoma 5 cm or expanding
	Laceration	>3-cm parenchymal depth or involving trabecular vessels
IV	Laceration	Laceration involving segmental or hilar vessels producing major devascularization (>25% of spleen)
V	Laceration	Completely shattered spleen
	Vascular	Hilar vascular injury which devascularizes spleen

[a]Advance one grade for multiple injuries, up to grade III.
Adapted from Moore EE, Cogbill TH, Jurkovich GJ, et al: Organ injury scaling: spleen and liver. *J Trauma*, 38:323, 1995.



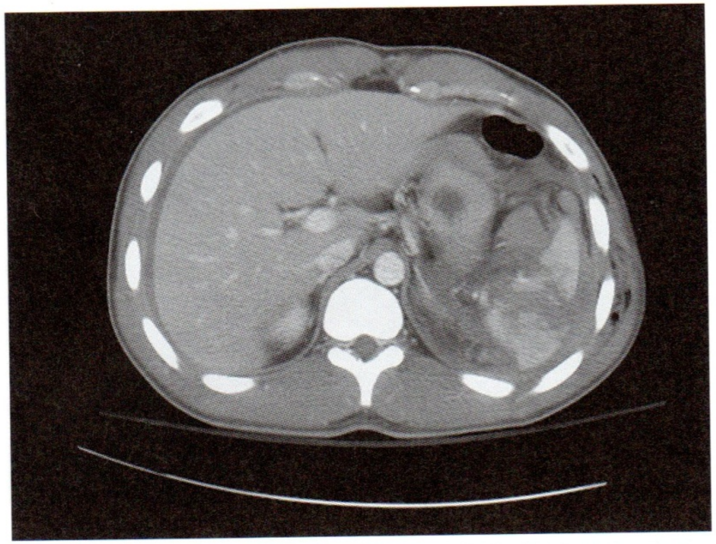


Figure 3 Computed tomography findings in blunt splenic injury, grade IV. A laceration through the parenchyma of the spleen with disruption of the capsule.

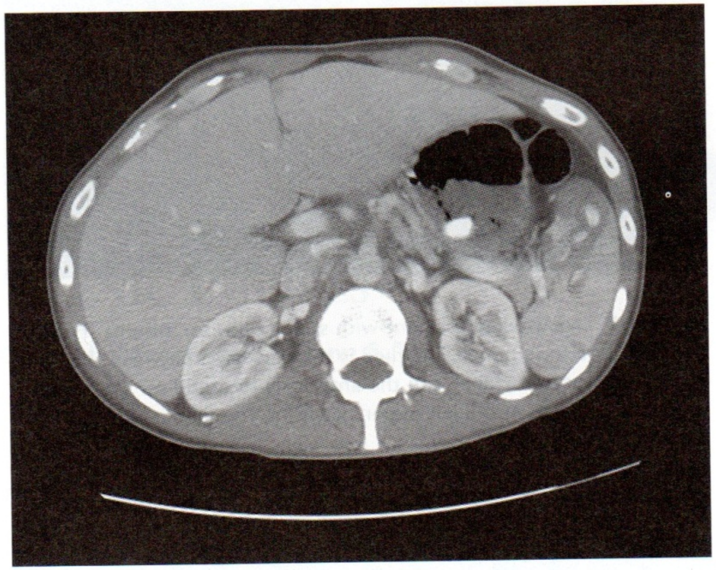


Figure 4 Computed tomography findings in blunt splenic injury, grade III. A laceration through the anterior portion of the spleen with a "blush" in the parenchyma.

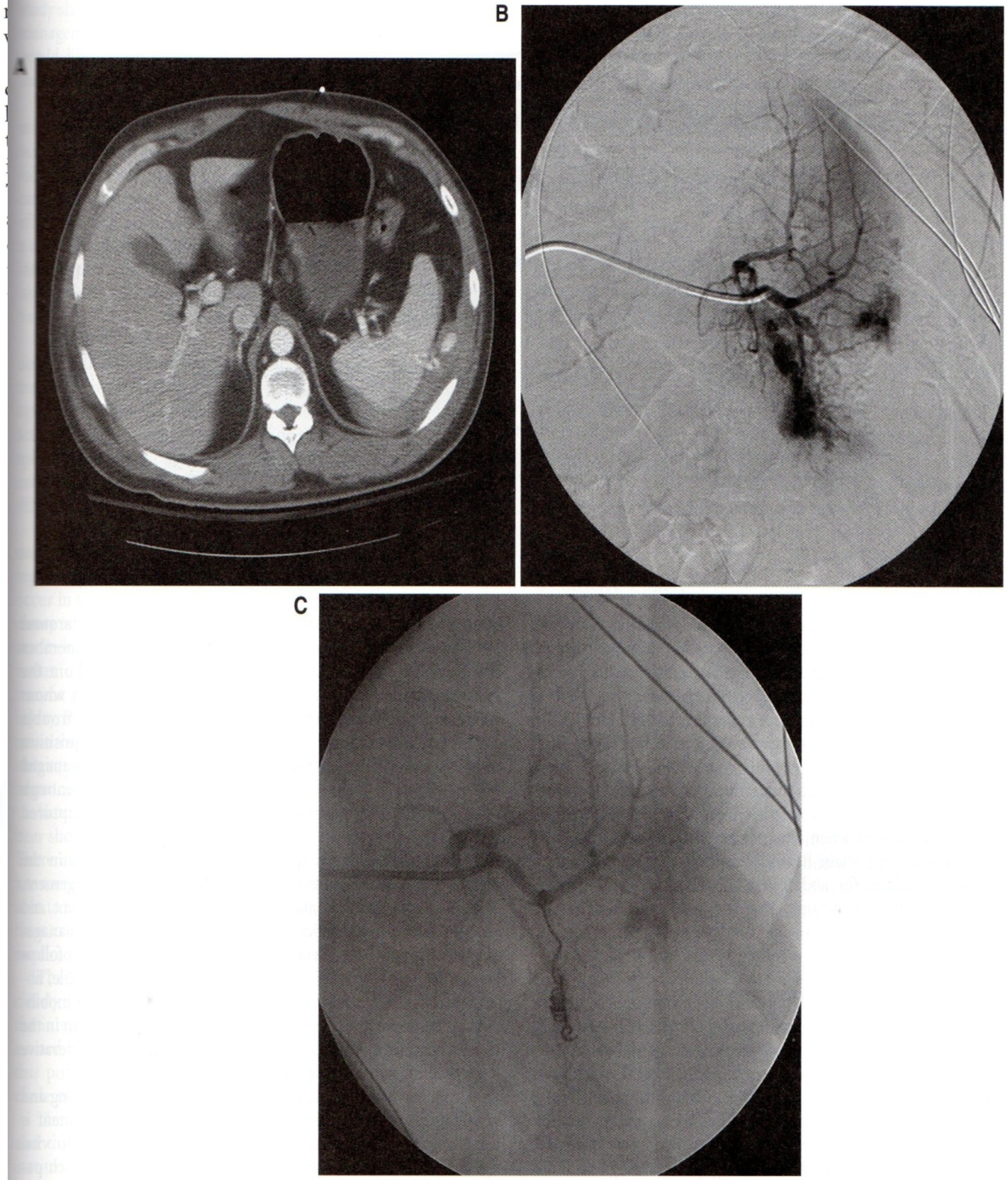
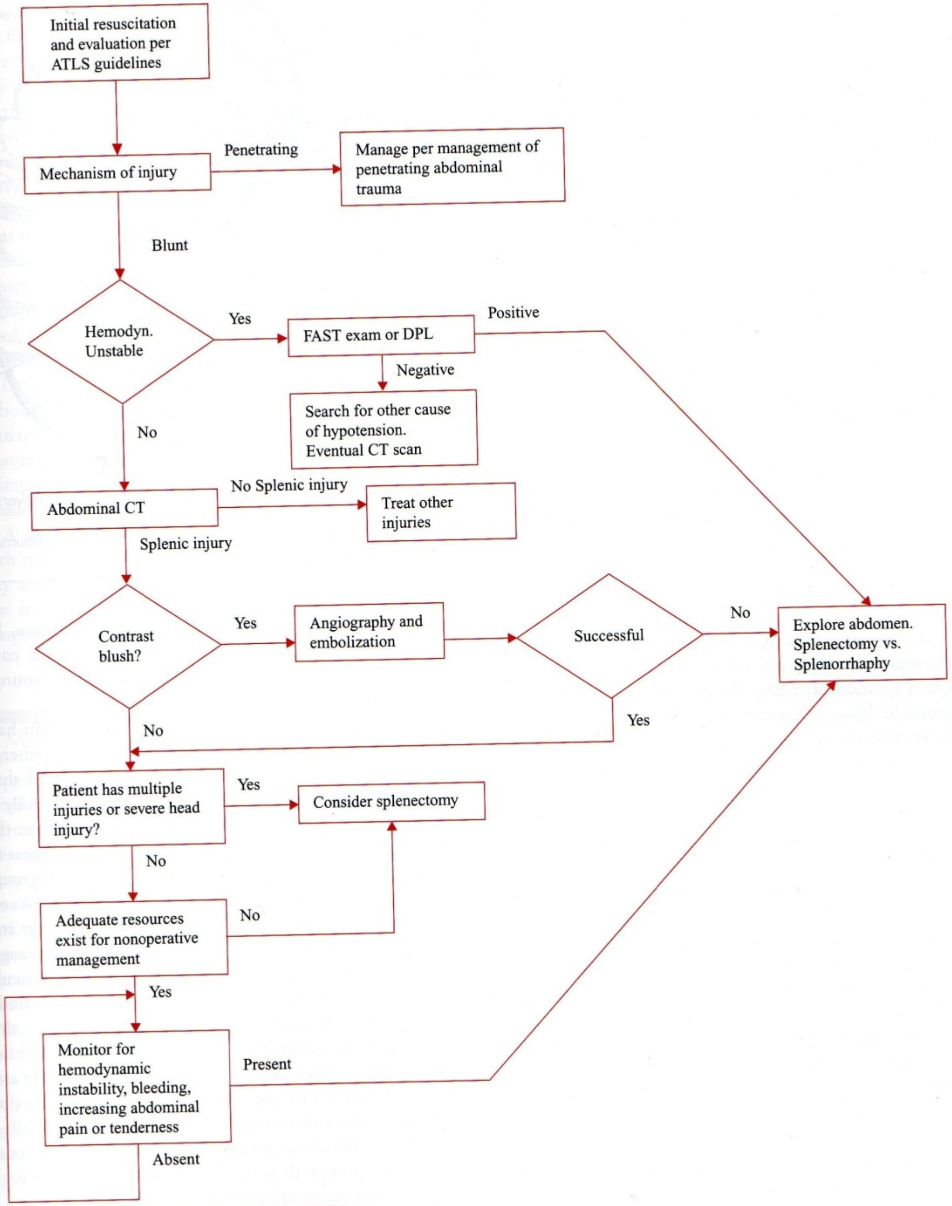


Figure 5 Catheter-based management of splenic injury. Computed tomography revealed a grade II splenic injury **(A).** Evidence of continued bleeding led to angiography. The angiogram demonstrated active extravasation **(B),** and the injured area was treated with embolization **(C).**



Patients may be immunized immediately after diagnosis of splenic injury.
Patients successfully managed for 24 hours may be allowed to eat.
The risk of delayed splenic rupture decreases steadily over time and is extremely low by the 7th postoperative day.

Non-operative Management

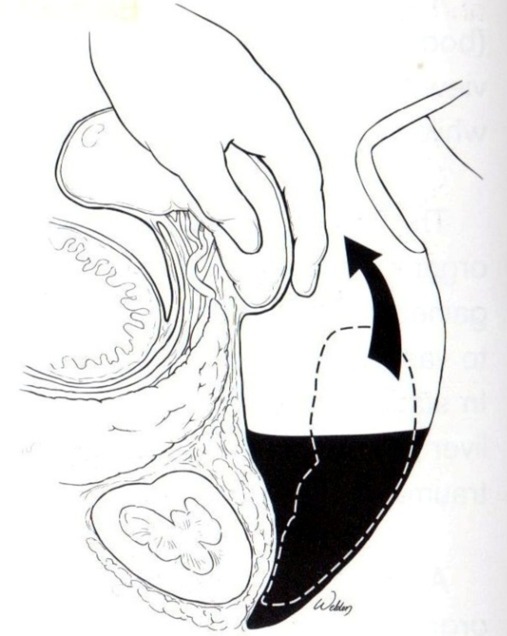
- Hemodynamically stable
  - BP, HR, H/H
- Grade I, II, and some III
- Pediatric patients
  - More likely to have isolated splenic injuries
  - Thicker capsule which prevents rupture
  - Tends to fracture parallel to artery, rather than transverse
  - Immunologic consequence is larger in children

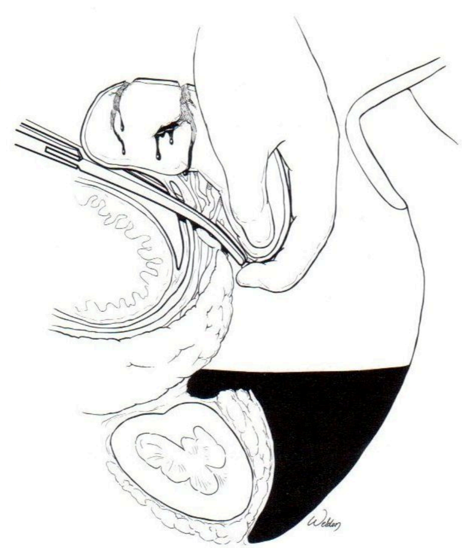
Operative Management

- Hemodynamically unstable
- Positive FAST or DPL
- Penetrating injury to LUQ/flank
- Standard Ex-lap position and incision
- Pack the spleen and inspect stomach, diaphragm, left lobe of liver, left kidney
- Mobilize the spleen

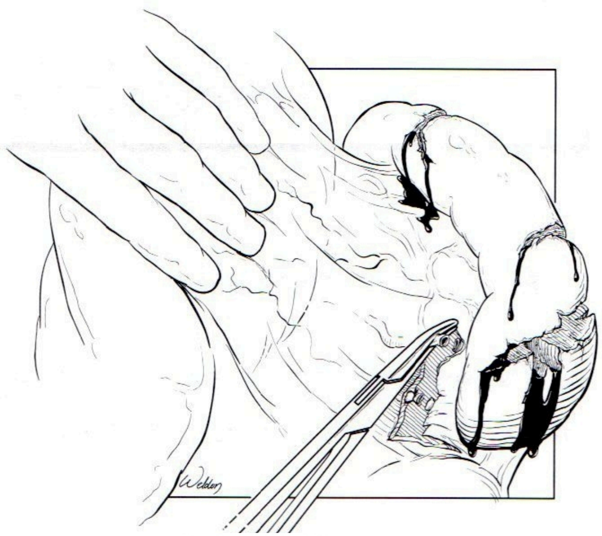
Mobilization

- Start with lateral attachments
  - Splenophrenic
    - Blunt dissection with fingers, pull spleen caudal to put ligament under tension and then ligate
  - Splenorenal
    - Reach posterior and pull spleen up to put ligament under tension and ligate
- Clamp splenic vascular pedicle
  - “Pringle maneuver of spleen”
    - Clamps gastrospenic ligament, splenic artery, and short gastric arteries





Completing the splenectomy



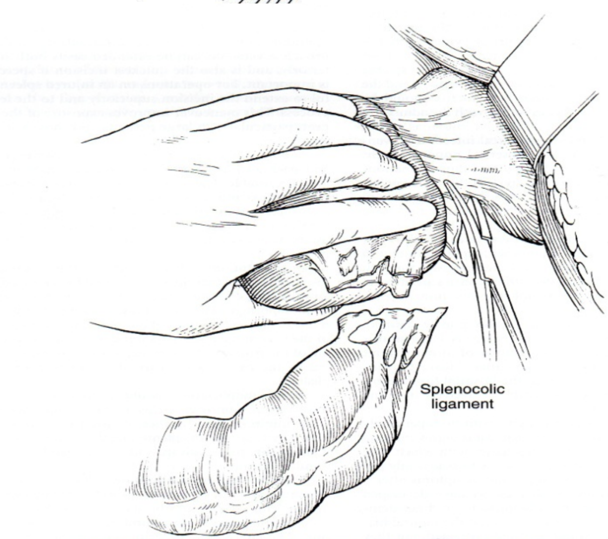


Figure 6 The spleen is grasped and the lateral peritoneal ligaments are divided. The splenocolic ligaments have been divided to release the splenic flexure. *(From Khatri V, Asensio JA: Operative Surgery Manual. Philadelphia, WB Saunders, 2002, p. 189.)*

- Ligate the gastrosplenic ligament and short gastrics
  - Stay close to spleen to avoid stomach injury
- Suture ligate splenic artery and branches
  - Careful to avoid pancreatic injury
- Ligate the lateral peritoneal attachments
- Ligate the splenocolic ligament

Post-op management

- Monitor H/H for re-bleeding
- Spleen vaccines
  - Polyvalent pneumococcal
  - H. Flu
  - Menigococcal
- Monitor drain output if suspected pancreas injury
- DVT prophylaxis → increased risk after splenectomy
- WBC will increase for 3-5 days post op, then begin to decrease, but may stay elevated for life
- ASA if platelet counts get above 1 million

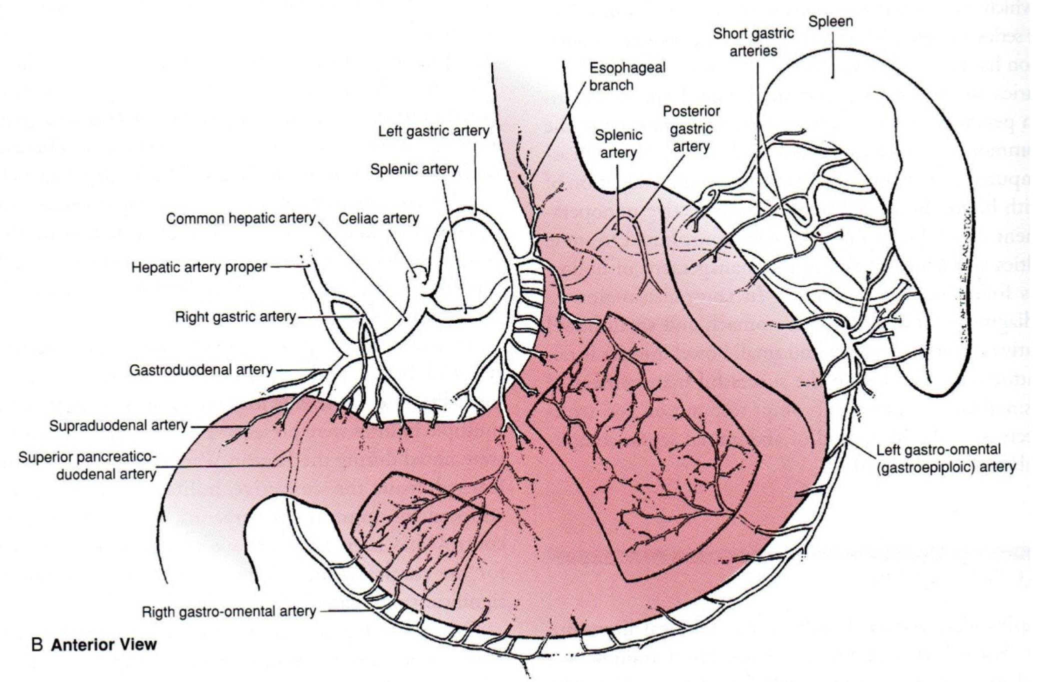
Stomach and Small Bowel Injuries

Gastric Injuries

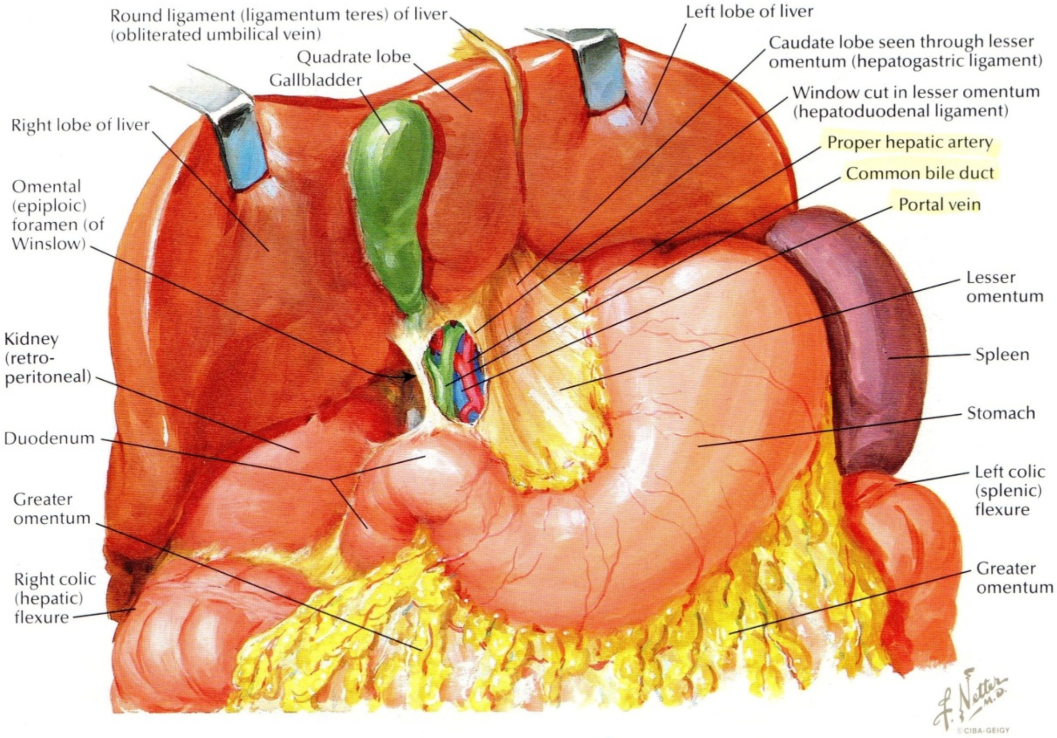
- Partially protected by lower rib cage, but size and location put it at risk for injury
  - Incidence
    - GSW – 20%
      - 2 or more injuries 90% of the time
    - KSW – 10%
    - Blunt – 2%
      - Sudden increase in intraluminal pressure
      - Compression against spine
      - Decelerating shear injury

Anatomy

- Blood supply
  - Left gastric
    - Branch of celiac trunk
  - Right gastric
    - Branch of hepatic artery
  - Right gastroepipolic
    - Branch of gastroduodenal arte
  - Left gastroepiploic
    - Branch of splenic artery
  - Short gastrics
    - Branches of splenic artery
- Venous Drainage
  - Right and Left gastric veins
  - Right and Left gastroepiploic veins



Anatomy



- Ligaments
  - Gastrohepatic
    - Lesser curvature
  - Gastrophrenic
    - Cephalad portion
  - Retroperitoneal duodenum
    - Distal potion
  - Gastrosplenic
    - Lateral greater curvature
  - Gastrocolic
    - Inferior greater curvature

Diagnosis

- Physical Exam
  - Peritoneal signs
    - pH of gastric contents
  - Seat belt sign
  - h/o of upper abdomen trauma
  - Blood NGT aspirate
- CT
  - Unexplained intraperitoneal fluid
  - Pneumoperitoneum
  - Extravasation of oral contrast

Surgical Repair

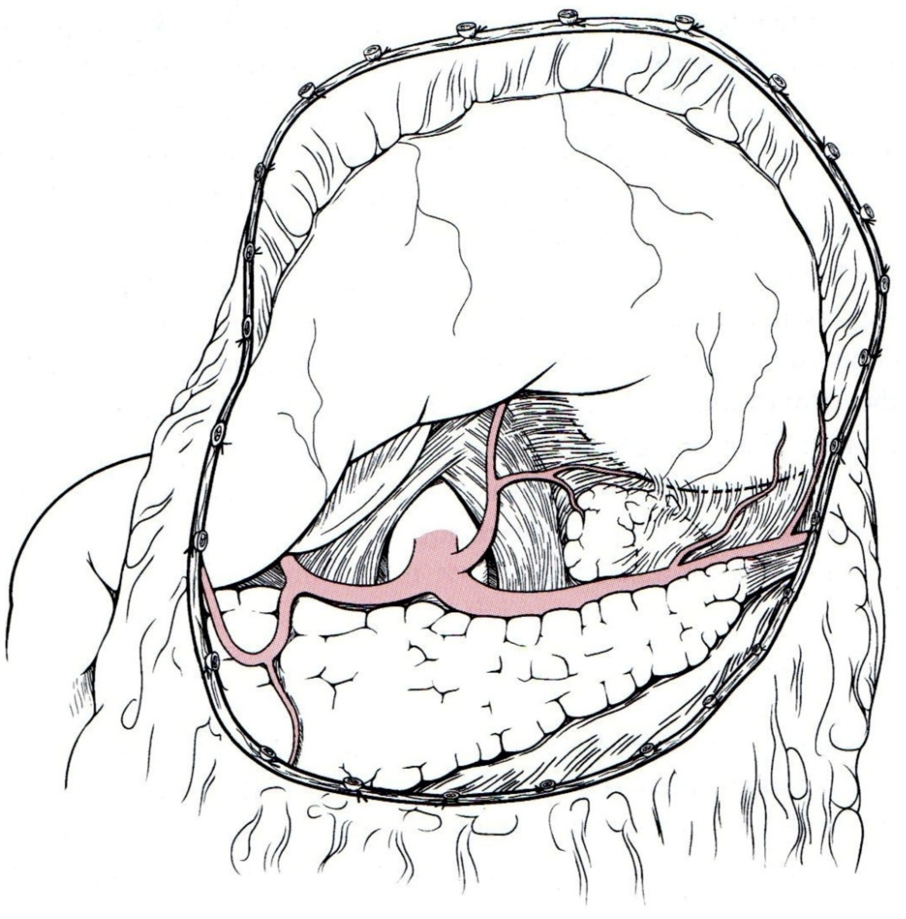


FIGURE 34-8. The posterior wall of the stomach, as well as the anterior surface of the pancreas, can be approached by dividing the gastrocolic ligament and lifting the stomach superiorly.

- Mobilize the stomach
  - Divide left triangular ligament of liver
    - Exposing GE junction
  - Divide the gastohepatic ligament
    - Look for vagus nerve or anomalous left hepatic artery
  - Ligate short gastrics and divide gastrosplenic ligament
    - Exposing high fundus
  - Divide gastrocolic ligament
    - Posterior body of stomach
    - Enter in mid to upper portion to avoid injury to transverse colon and middle colic artery

Surgical Repair

- If anterior hole is found, you must find second hole
  - Submerge stomach in saline and blow air through NGT
    - Look for bubbles
  - Rarely, enlarge first wound and inspect stomach from inside

Grading

Table I: AAST Organ Injury Scale for Stomach

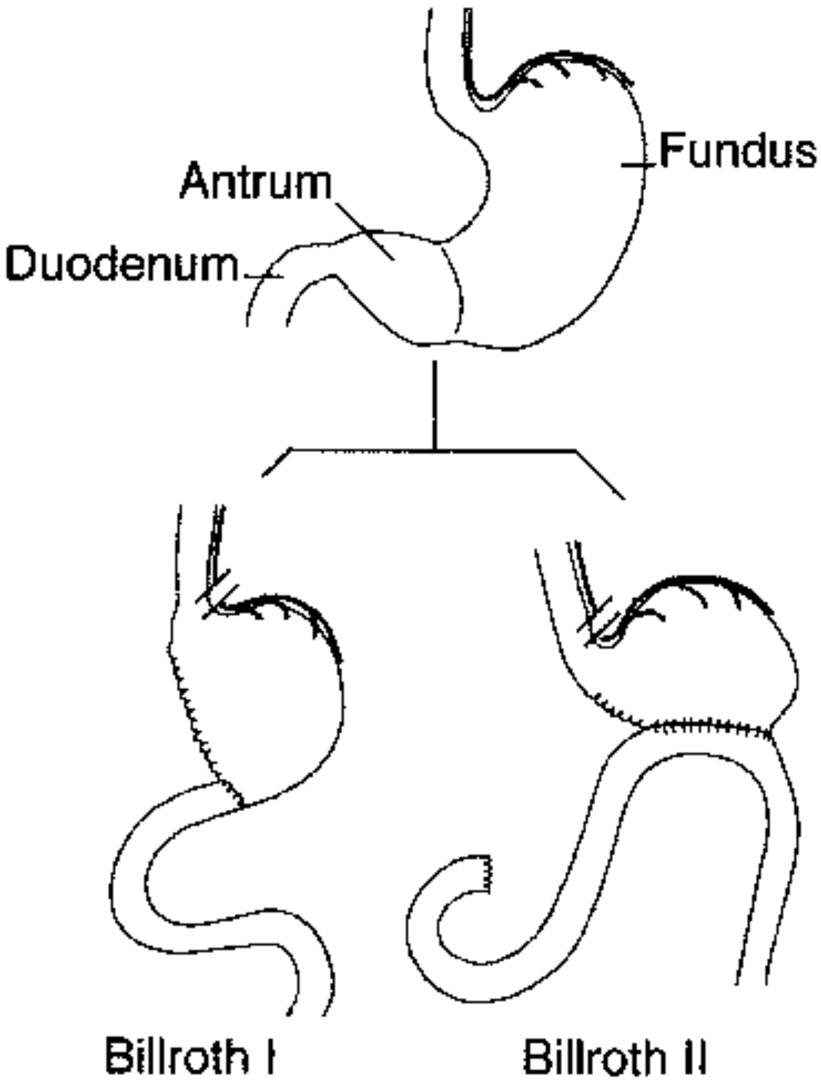
AAST Grade	Characteristics of Injury
I	Intramural hematoma <3 cm, partial thickness laceration
II	Intramural hematoma >3 cm; small (<3 cm) laceration
III	Large (>3 cm) laceration
IV	Large laceration involving vessels of greater or lesser curvature
V	Extensive (>50%) rupture; stomach devascularization

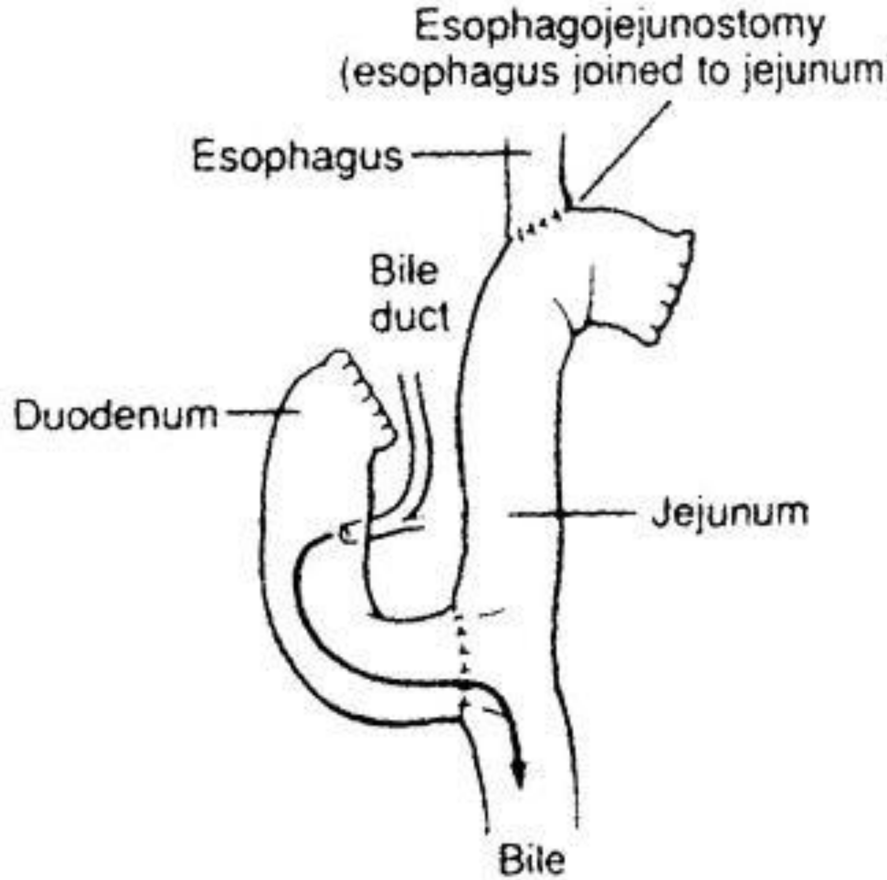
AAST, American Association for the Surgery of Trauma.
Modified from American Association for the Surgery of Trauma (AAST).

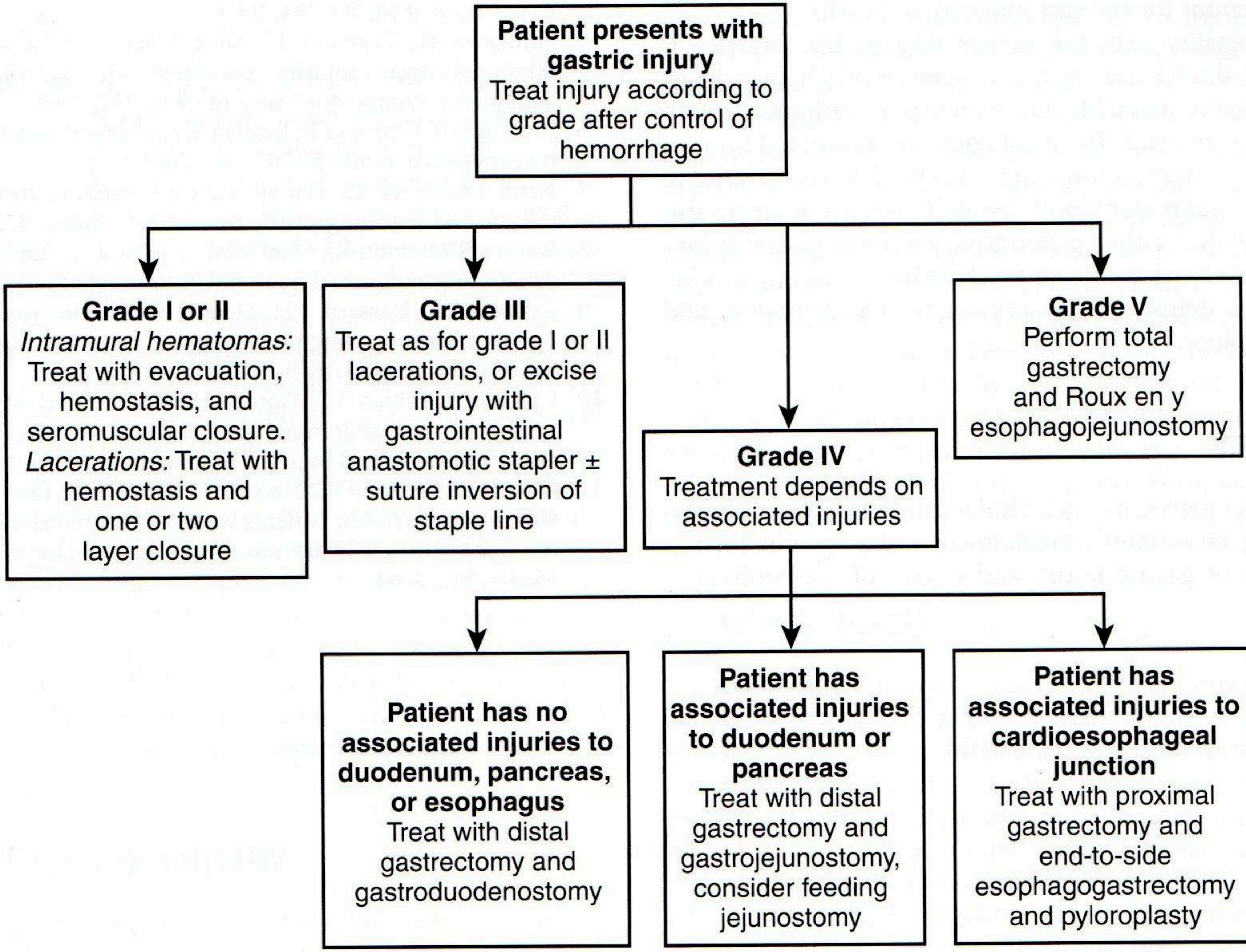
Surgical Repair

- Grade I and II
  - Evacuation of hematoma, hemostasis, and 2 layer closure with 3-0 or 4-0 silk
- Grade III
  - Same as above or GIA to remove injured portion
  - Be careful at GE and pyloric junction to avoid stenosis
- Grade IV
  - Proximal or distal gastrectomy with Billroth I or II depending if there is an associated duodenal injury
- Grade V
  - Total gastrectomy and Roux-en-Y esophagojejunostomy

Surgical Options






Patient presents with gastric injury
Treat injury according to grade after control of hemorrhage
Grade I or II
Intramural hematomas: Treat with evacuation, hemostasis, and seromuscular closure.
Lacerations: Treat with hemostasis and one or two layer closure
Grade III
Treat as for grade I or II lacerations, or excise injury with gastrointestinal anastomotic stapler ± suture inversion of staple line
Grade IV
Treatment depends on associated injuries
Grade V
Perform total gastrectomy and Roux en y esophagojejunostomy
Patient has no associated injuries to duodenum, pancreas, or esophagus
Treat with distal gastrectomy and gastroduodenostomy
Patient has associated injuries to duodenum or pancreas
Treat with distal gastrectomy and gastrojejunostomy, consider feeding jejunostomy
Patient has associated injuries to cardioesophageal junction
Treat with proximal gastrectomy and end-to-side esophagogastrectomy and pyloroplasty

Small Bowel Injuries

- Small bowel occupies the largest portion of the peritoneal cavity
  - 5-6m in length from Ligament of Trietz
- Protected only by abdominal wall
- Incidence
  - GSW – 80%
  - KSW – 25-30%
  - Blunt – 1-3%
    - Sudden increase in intraluminal pressure
    - Compression against spine
    - Decelerating shear injury
      - » Ligament of Trietz or terminal ileum

Associated Injuries

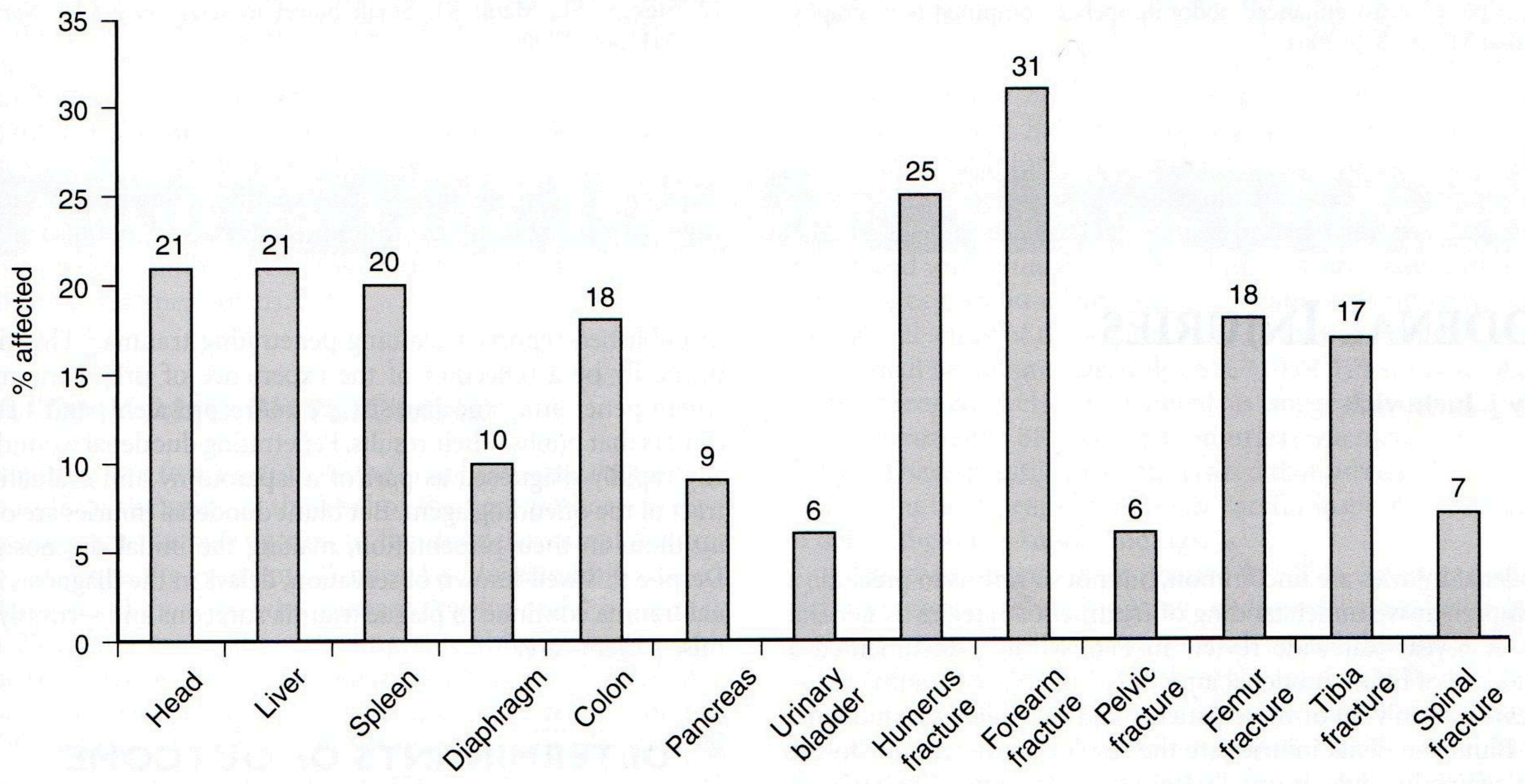
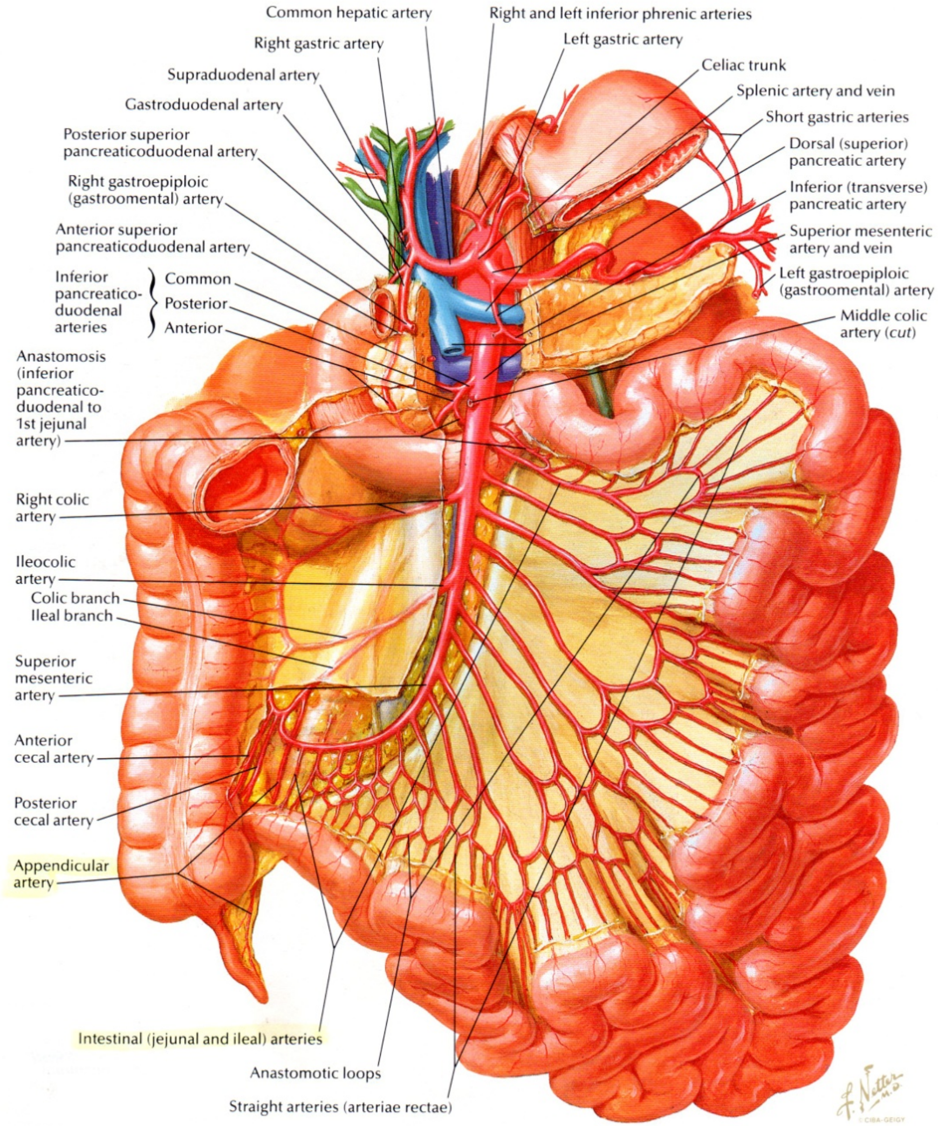


Figure 16 Typical injuries accompanying blunt small bowel trauma. *(Adapted from Neugebauer H, Wallenboeck E, Hungerford M: Seventy cases of injury of the small intestine caused by blunt abdominal trauma: a retrospective study from 1970 to 1994. J Trauma 46:116–121, 1999.)*

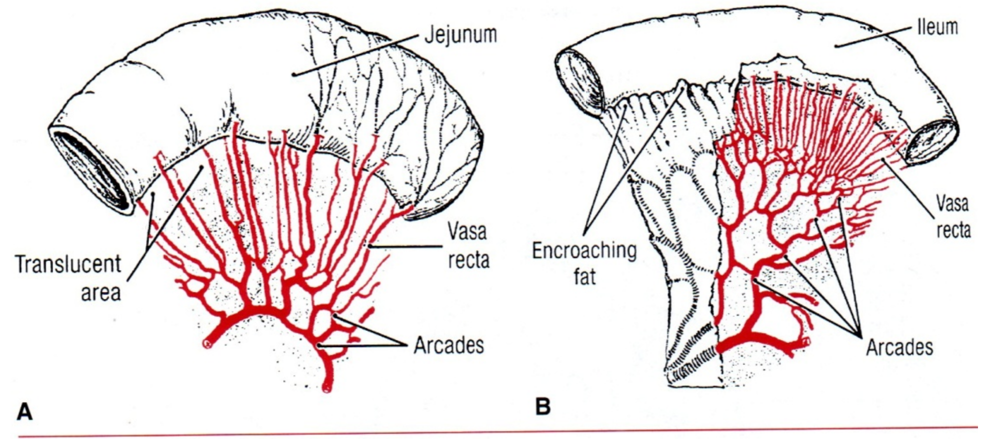
Anatomy

- Blood supply
  - Left side of SMA via intestinal arteries
  - Ileocolic artery supplies terminal ileum
- Venous Drainage
  - SMV



Jejunum vs Ileum

- Jejunum
  - 1st 40% of small bowel
  - Larger diameter lumen
  - Thicker folds
  - Single arterial arcade
- Ileum
  - Smaller diameter lumen
  - 2-3 arterial arcades
  - Encroaching mesenteric fat
- Only clinically important if significant resection must take place
  - Jejunum is the site for B-12 absorption and recirculation of enterohepatic bile salts



Diagnosis

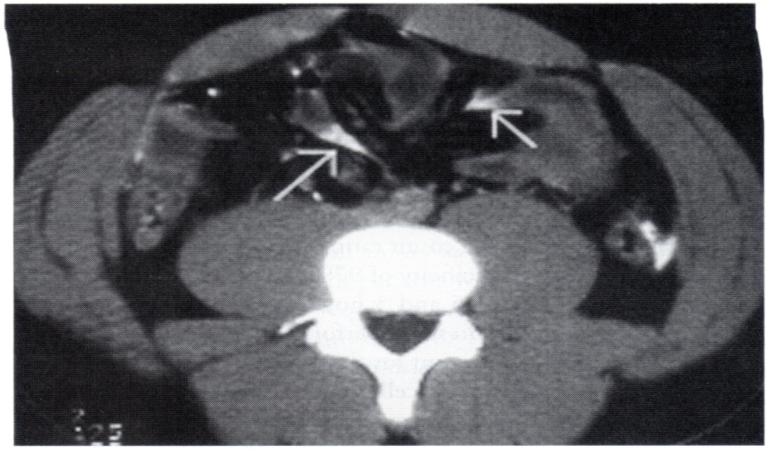


FIGURE 34-6. This CT was obtained a few hours after injury. The findings were highly suspicious of oral contrast extravasation (arrows). The patient was found to have rupture of the small intestine at surgery.

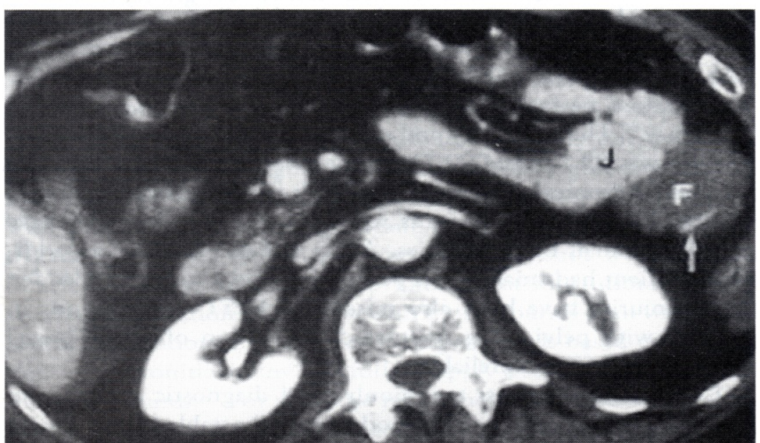


FIGURE 34-7. This CT was done shortly after injury. Multiple abnormalities are noted including thickened bowel and free fluid (arrows). However, a large amount of free air is the most notable finding. At operation a midjejunal perforation was found.

- Physical Exam
  - Generally limited in acute setting
    - Intestinal content has almost neutral pH
  - Seat belt sign
- CT
  - Pneumoperitoneum
  - Extravasation of oral contrast
  - Bowel wall thickening
  - Mesenteric fat streaking
  - Mesenteric hematoma

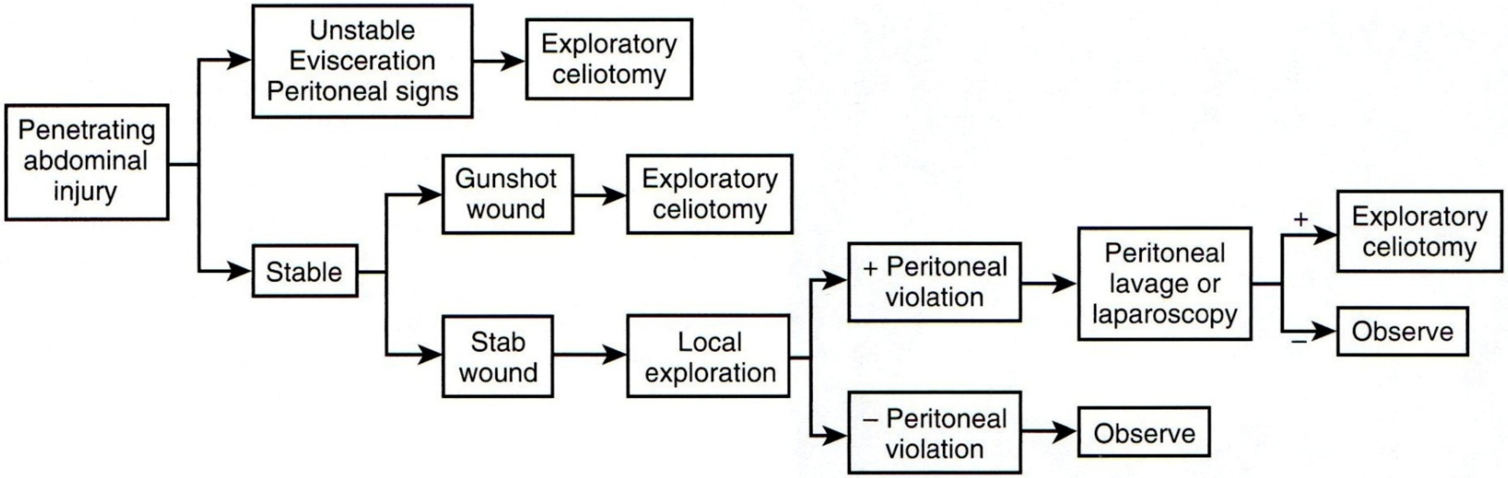


Figure 4 Algorithm for penetrating injuries to small bowel.

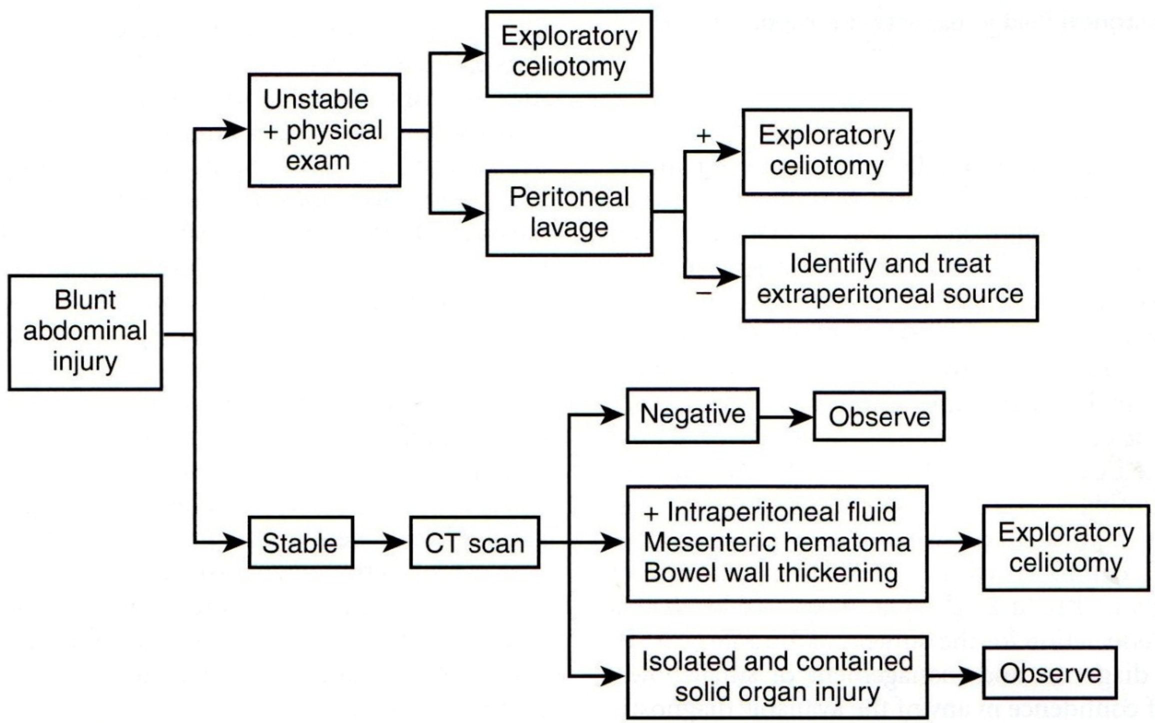
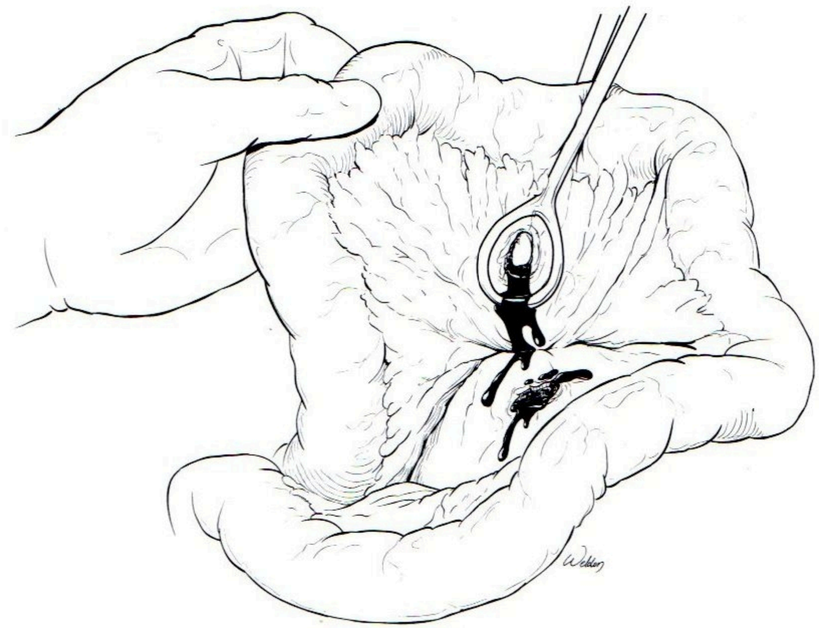
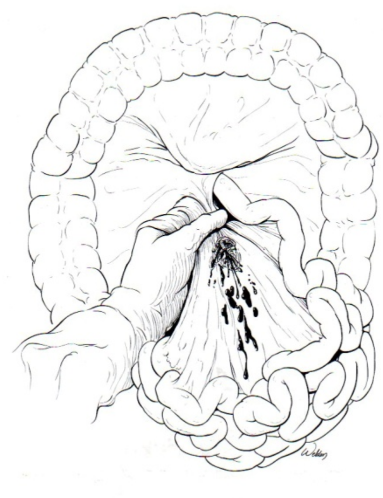


Figure 5 Algorithm for blunt injuries to small bowel.

Surgical Repair

- "Run the bowel"
  - Examination loop by loop
  - No injuries are repaired until entire bowel is inspected
- Stop the bleeding first
  - Clamp mesenteric bleeders
  - Suture in a figure-of-8 fashion
  - Caution with mesenteric root bleeders
    - Can compromise supply to bowel segment
    - Use fingers





Grading

TABLE 34-2

Small Bowel Injury Scale

GRADE[a]	TYPE OF INJURY	DESCRIPTION OF INJURY	AIS-90
I	Hematoma	Contusion or hematoma without devascularization	2
	Laceration	Partial thickness, no perforation	2
II	Laceration	Laceration $< 50\%$ of circumference	3
III	Laceration	Laceration $\geq 50\%$ of circumference without transection	3
IV	Laceration	Transection of the small bowel	4
V	Laceration	Transection of the small bowel with segmental tissue loss	4
	Vascular	Devascularized segment	4

[a]Advance one grade for multiple injuries up to grade III.

AIS, Abbreviated Injury Score.

Surgical Repair

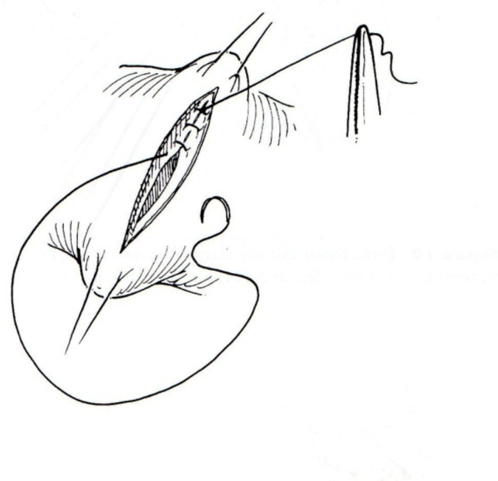


Figure 8 Perforations splayed with corner stay sutures. *(From Maull KI: Stomach, small bowel and mesentery injury. In Champion HR, Robbs JV, Trunkey DD, editors:* Rob and Smith's Operative Surgery: Trauma Surgery, *4th ed. London, Butterworth-Heinemann, London, pp. 401–413.)*

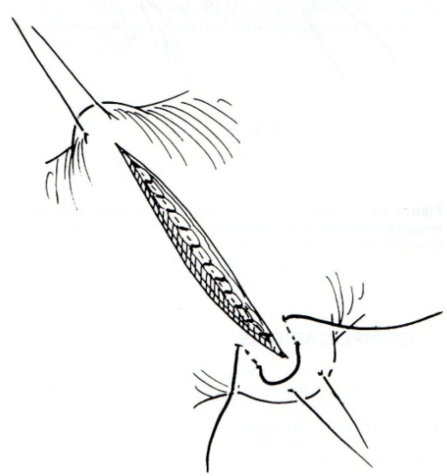
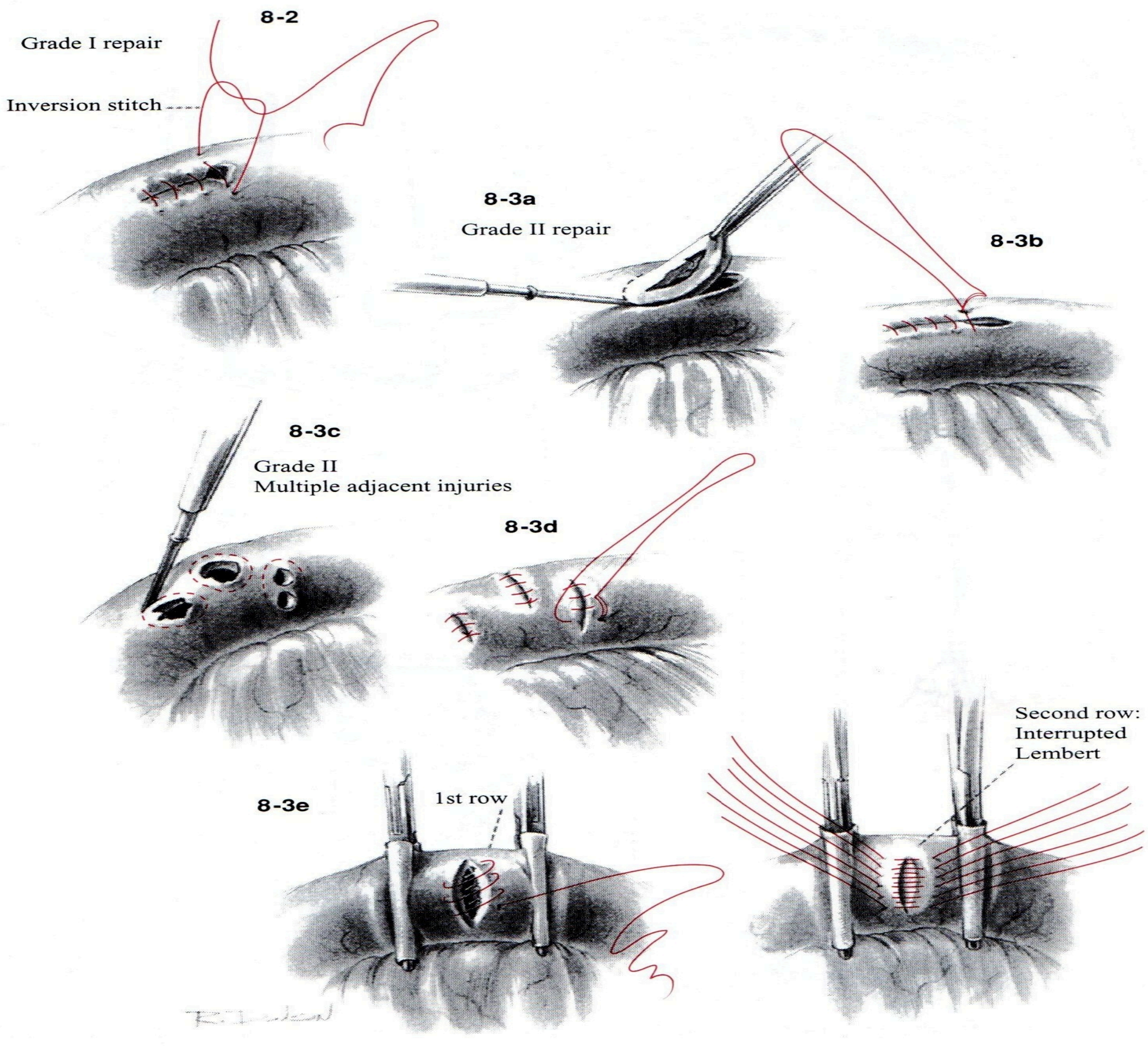


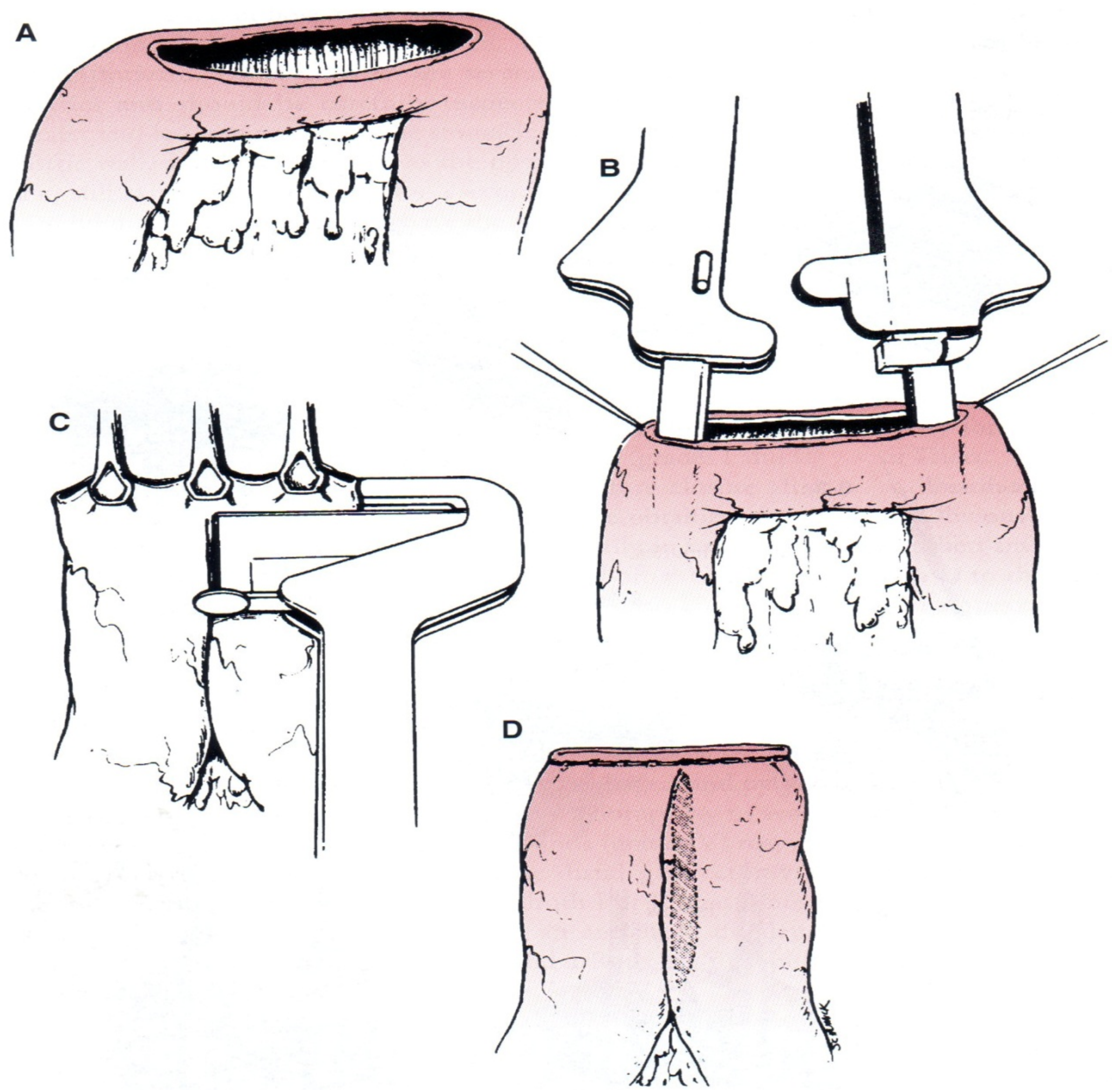
Figure 9 Perforations closed transversely in two layers. *(From Maull KI: Stomach, small bowel and mesentery injury. In Champion HR, Robbs JV, Trunkey DD, editors:* Rob and Smith's Operative Surgery: Trauma Surgery, *4th ed. London, Butterworth-Heinemann, London, pp. 401–413.)*

- *Always repair transversely, if possible, to avoid narrowing lumen*
- Grade I
  - One layer simple repair with 3-0 or 4-0 silk
- Grade II
  - Debridement with 2 layer repair
    - Continuous vicryl for 1st layer
    - Simple interrupted silk for 2nd layer
  - Make 2 holes 1 and repair
  - Long lacerations can be stapled anastomosed

Grade I and II



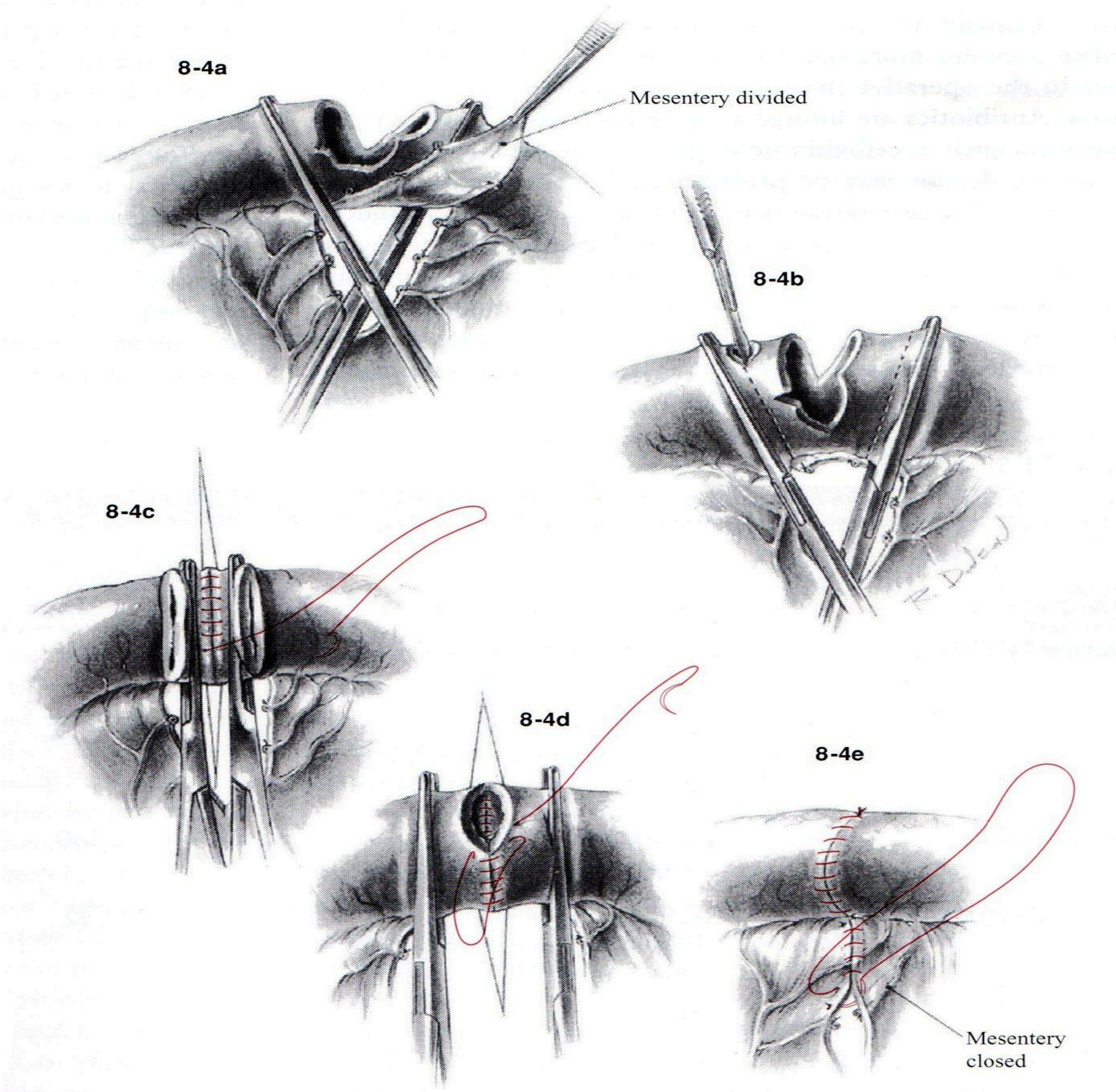
Staple Anastomosis



Surgical Repair

- Grade III
  - Wounds oriented transversely or in the relative large proximal to mid jejunum can be closed primarily
  - Injuries > 50% of circumference = resection
- Grade IV and V
  - Resection of injured bowel and blood supply

Grade III



Jejunal Repair

Complications

- Intraabdominal abscess
  - Open drainage vs IR drainage
- Anastomotic breakdown
  - Contained leak
    - Re-operation and repair
      - After 10-14 days, inflammation makes dissection difficult
        - » Proximal diversion or external drainage
  - Diffuse fecal peritonitis
    - Proximal diverting enterostomy with repair
  - Enterocutaneous fistula

Complications

- Enterocutaneous Fistula
  - Enteric contents coming up through wound or postoperative sepsis
  - Correction of electrolyte, fluid, and nutritional deficits
    - Replace output 1cc:1cc with NS or LR
    - TPN with trophic TF
  - Send off fluid to determine site of leak
  - 2 types
    - High output
      - > 500cc/day
    - Low output
      - <200 cc/day
  - Spontaneous closure in 3-6 weeks with adequate nutritional support and free of sepsis
    - Only 30% of trauma patients
  - Surgical closure in 4-6 months from initial operation
    - Bowel resection

TABLE 34-4

Composition and Volume of Gastrointestinal Secretions

TYPE	VOLUME (mL/DAY)	NA (mEq/L)	K (mEq/L)	CL (mEq/L)	HCO_3 (mEq/L)
Salivary	1500	10	26	15	50
Stomach	1500	60–100	10	100	0
Duodenum	2000	130	5	90	0–10
Illeum	3000	140	5	100	15–30
Pancreas	800	140	5	75	70–115
Bile	800	145	5	100	15–35

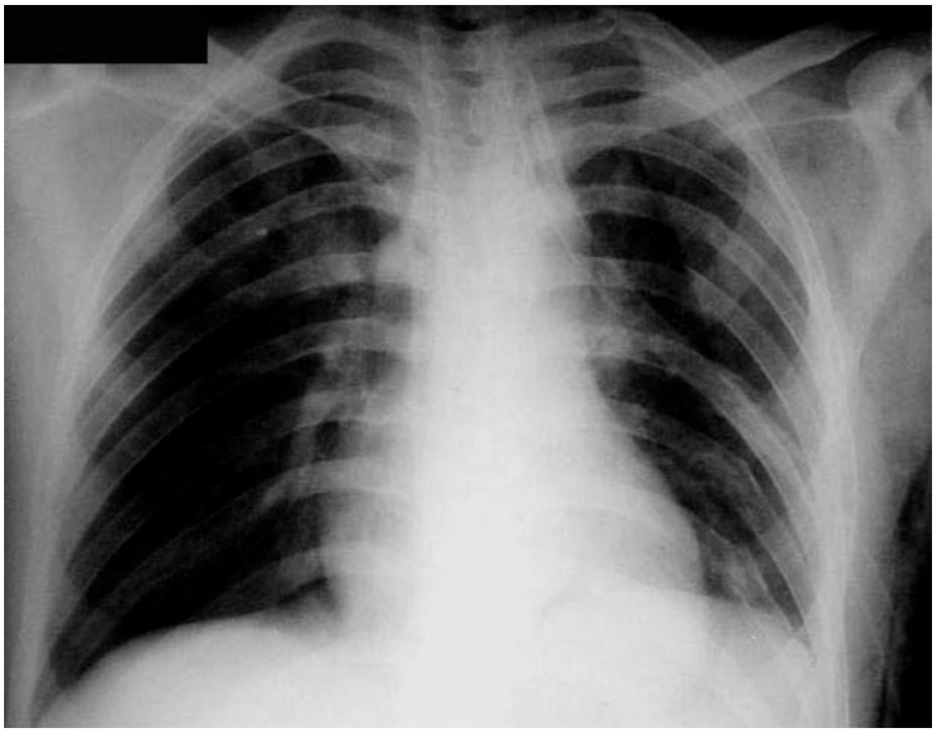
Thoracic Injuries

Pulmonary, Cardiac, and Diaphragmatic

Management of Chest Wall Injuries

- Pain
  - Splinting from pain increases chance of PNA
- Hemorrhage
  - Presents as a HTX
    - If parietal pleura intact, will tamponade off
- Instability
  - Flail Chest
- Defects
  - Open PTX

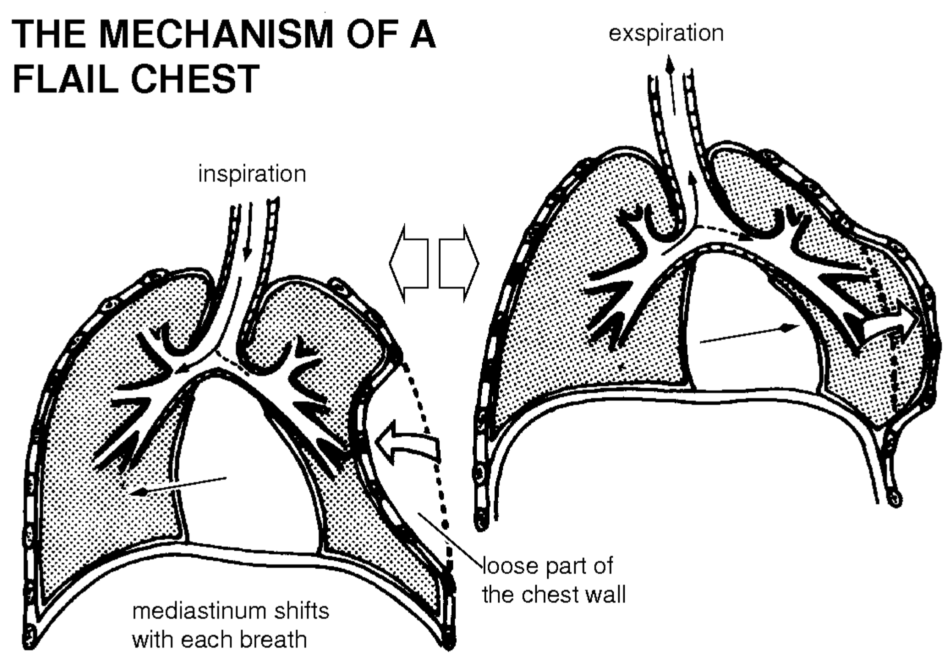
Rib Fractures



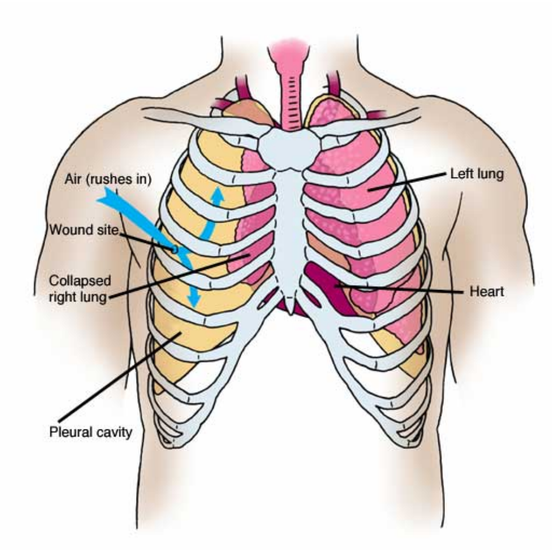
- *Hallmark of significant blunt chest trauma*
  - ↑ # = ↑ in M/M
  - > 3 is a marker for associated visceral trauma

Flail Chest

- 3 or more ribs fractured in 2 or more places
- Paradoxical movement of the flail segment
- Pendaluft
  - Air moves from lung to lung
- Treatment
  - Pain control
    - Epidural analgesia



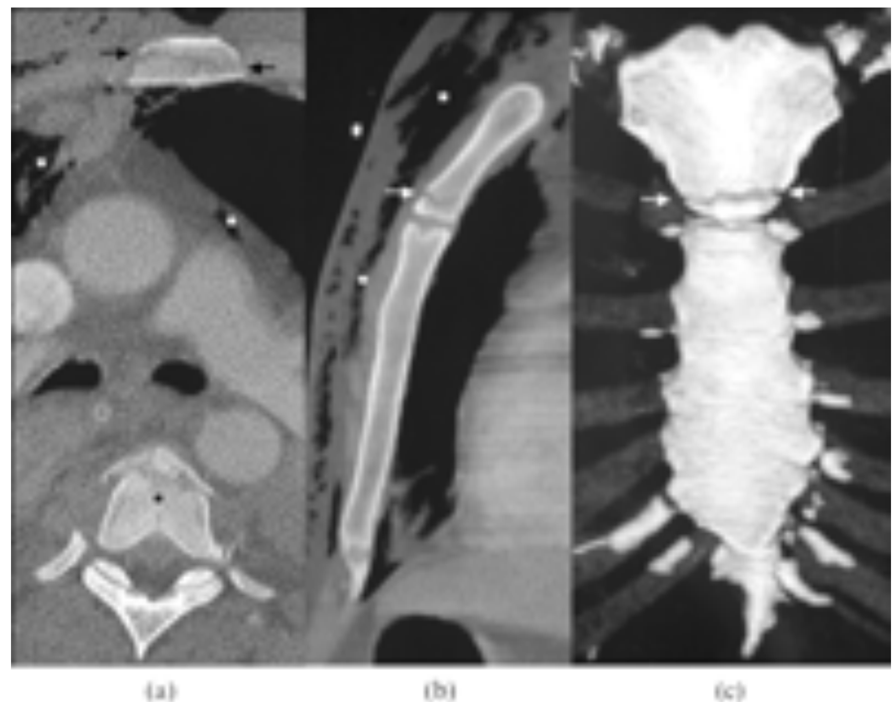
Open Pneumothorax



- aka....sucking chest wound
- If diameter is >2/3 of the trachea, spontaneous respiration is impossible
  - Atmospheric = intrathoracic
- Treatment
  - 3 sided bandage

Sternal Fracture

- MVC with impact on steering column
- 50-60% of patients have other associated injuries
- *Hallmark of severe thoracic trauma*
- Treatment
  - Pain control
  - EKG monitoring



Scapula Fracture

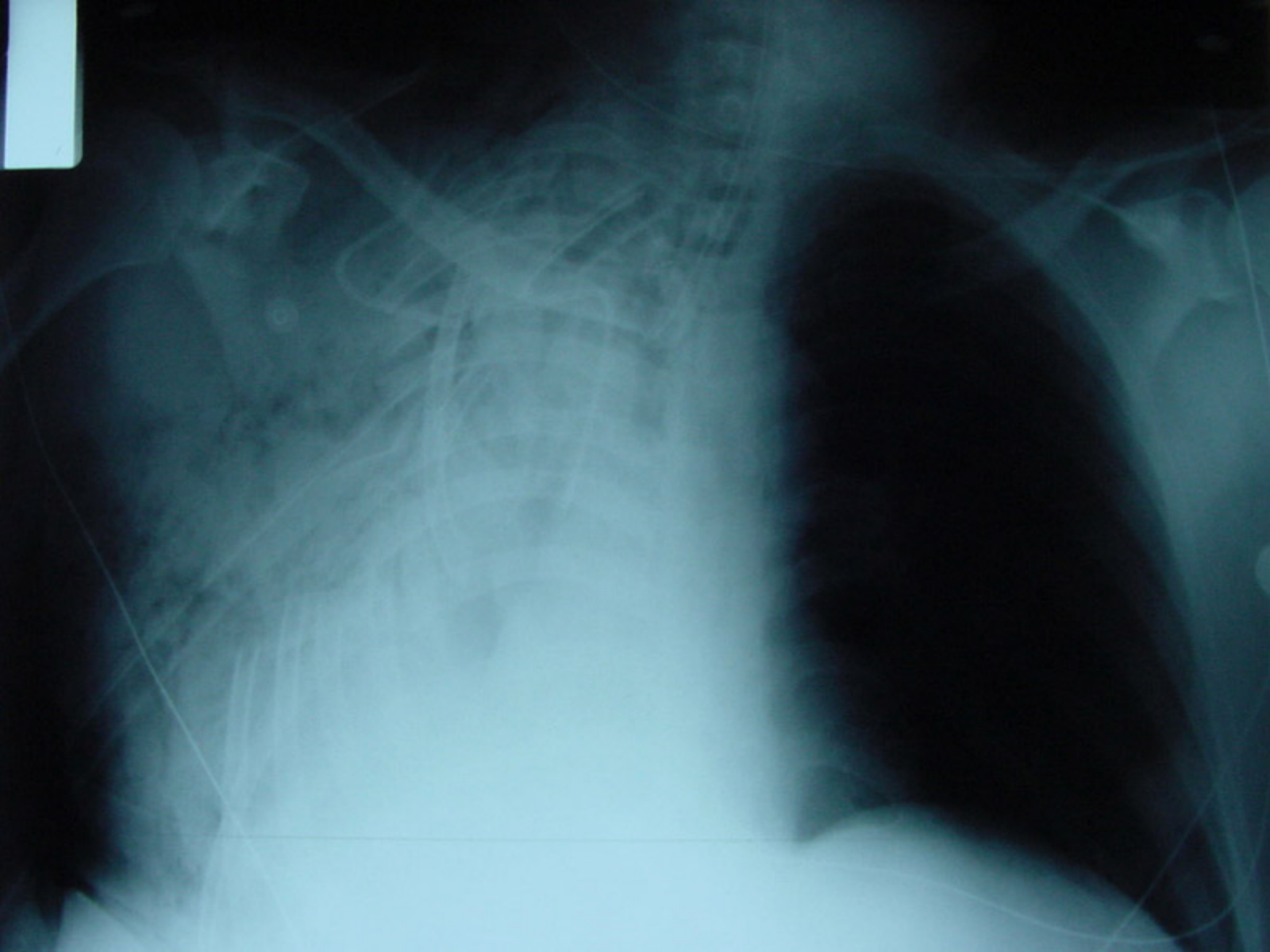
- *Hallmark of severe thoracic trauma*
- Treatment
  - Sling
  - Pain control

Clavicle Fracture

- Common injury
- Figure-8 brace superior to ORIF
  - Surgery needed in severe displacement

Table 1: Chest Wall Injury Scale

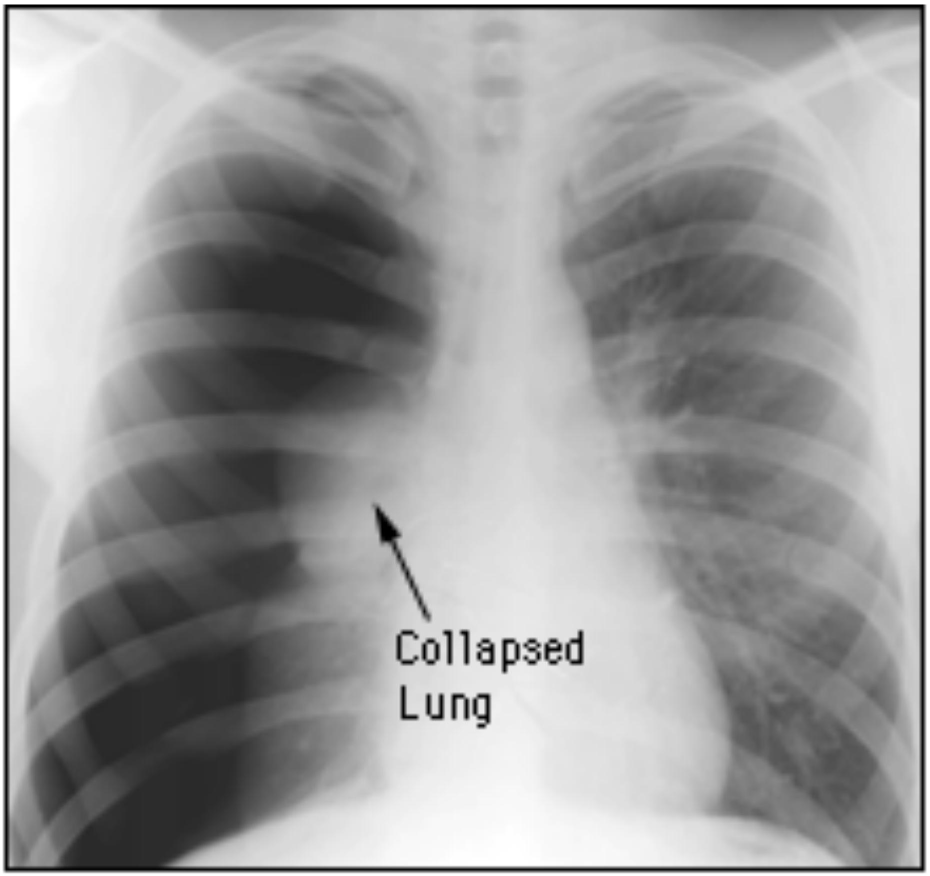
Grade	Injury Type	Description of Injury
I	Contusion	Any size
	Laceration	Skin and subcutaneous
	Fracture	<3 ribs, closed; nondisplaced clavicle, closed
II	Laceration	Skin, subcutaneous, and muscle
	Fracture	>3 adjacent ribs, closed Open or displaced clavicle Nondisplaced sternum, closed Scapular body, open or closed
III	Laceration	Full thickness, including pleural penetration
	Fracture	Open or displaced sternum Flail sternum Unilateral flail sternum (<3 ribs)
IV	Laceration	Avulsion of chest wall tissues with underlying rib fractures
	Fracture	Unilateral flail chest (>3 ribs)
V	Fracture	Bilateral flail chest (>3 ribs on both sides)



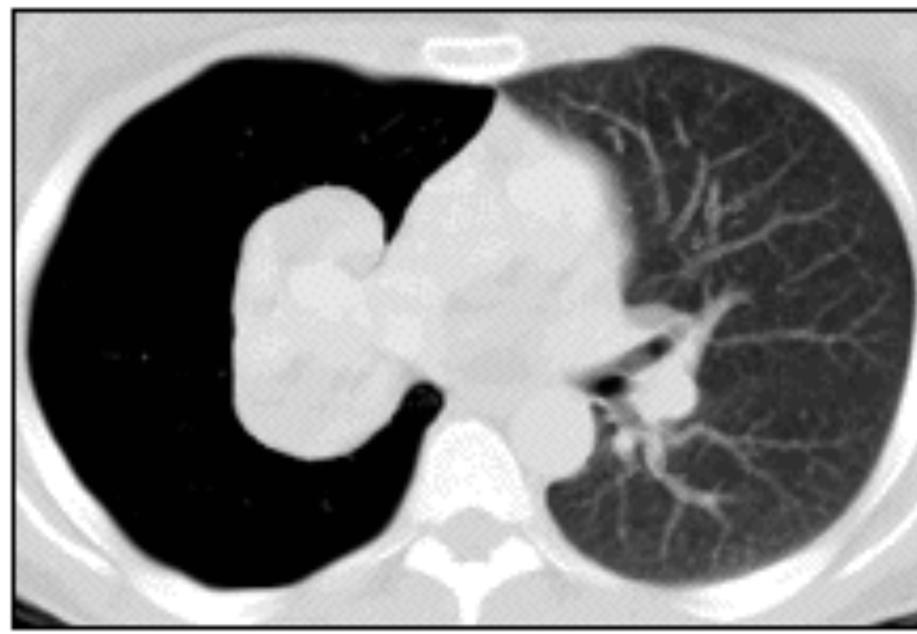
Lung Injuries

- Pneumothorax
  - 20% prevalence in thoracic trauma
  - Collection of air in pleural space
  - Causes
    - Sudden increase in intrathoracic pressure
    - Rib fractures displaced inward causing lung laceration
    - Deceleration that tear lung parenchyma
    - Blunt force can disrupt or rupture alveoli
  - Grading
    - 1cm=10%, 2cm=20%, 3cm=30%
  - 3 types
    - Simple
    - Open
    - Tension

Simple Pneumothorax

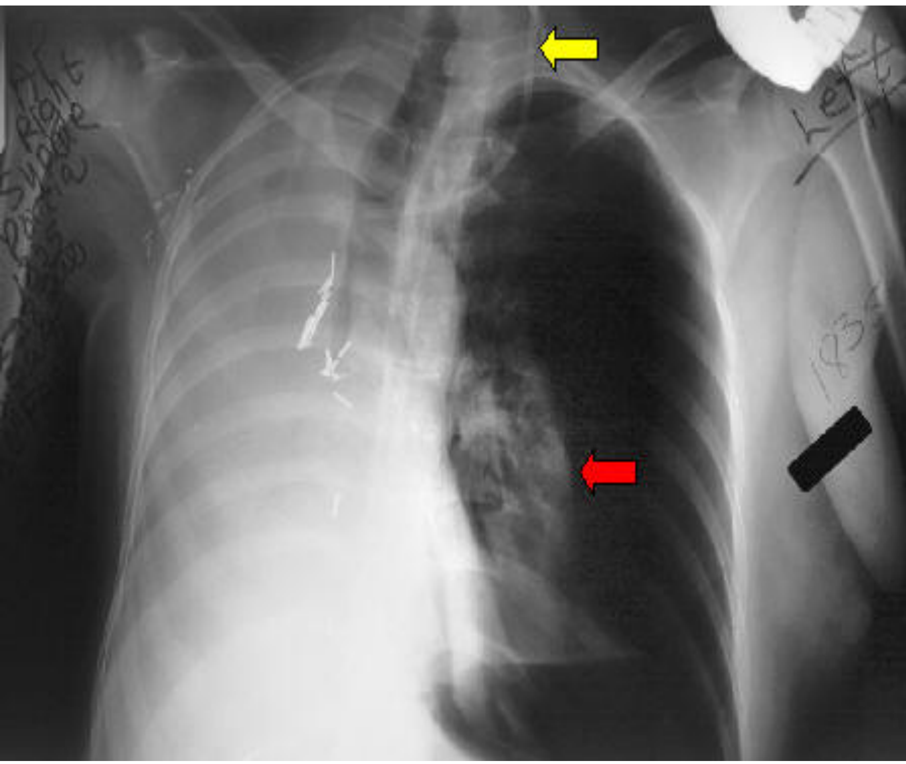


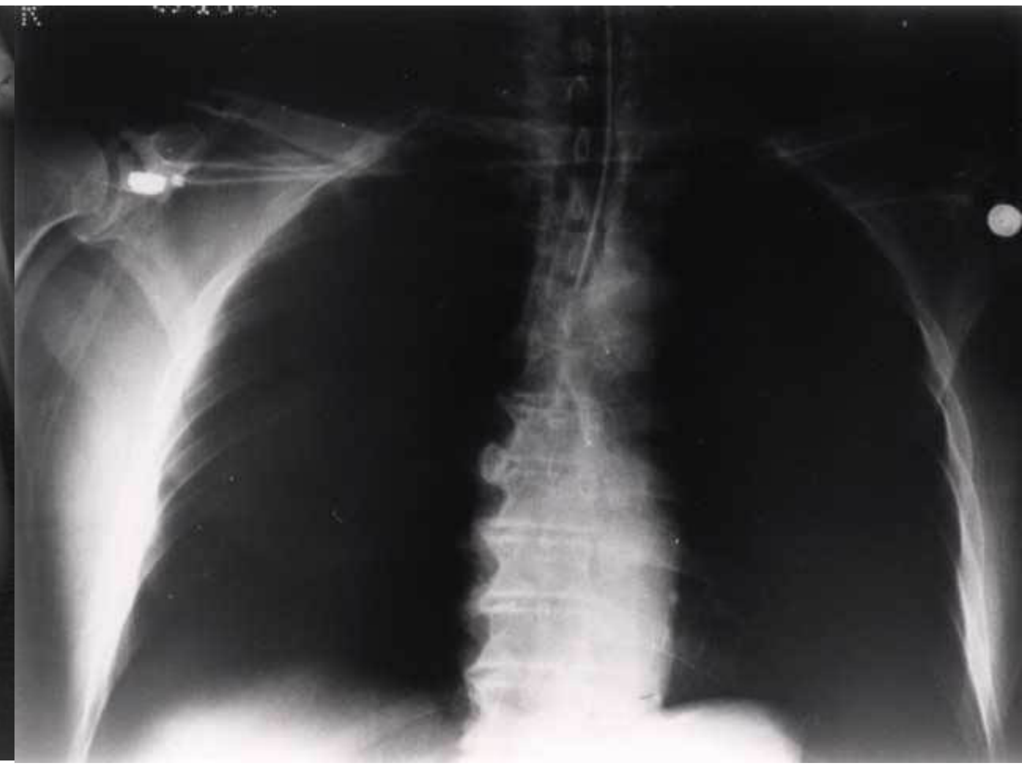
Right lung pneumothorax - Radiograph



Right lung pneumothorax - CT

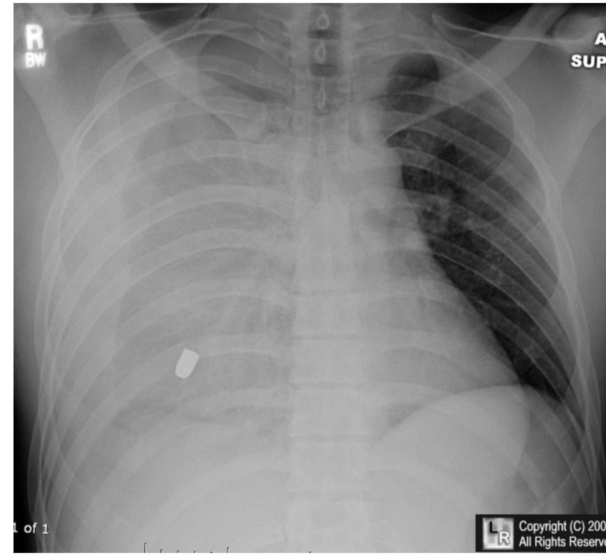
Tension Pneumothorax



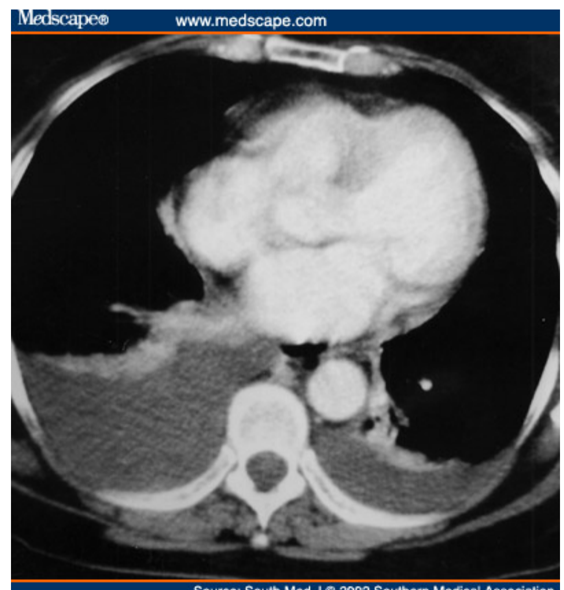


Post-Mortem Tension PTX

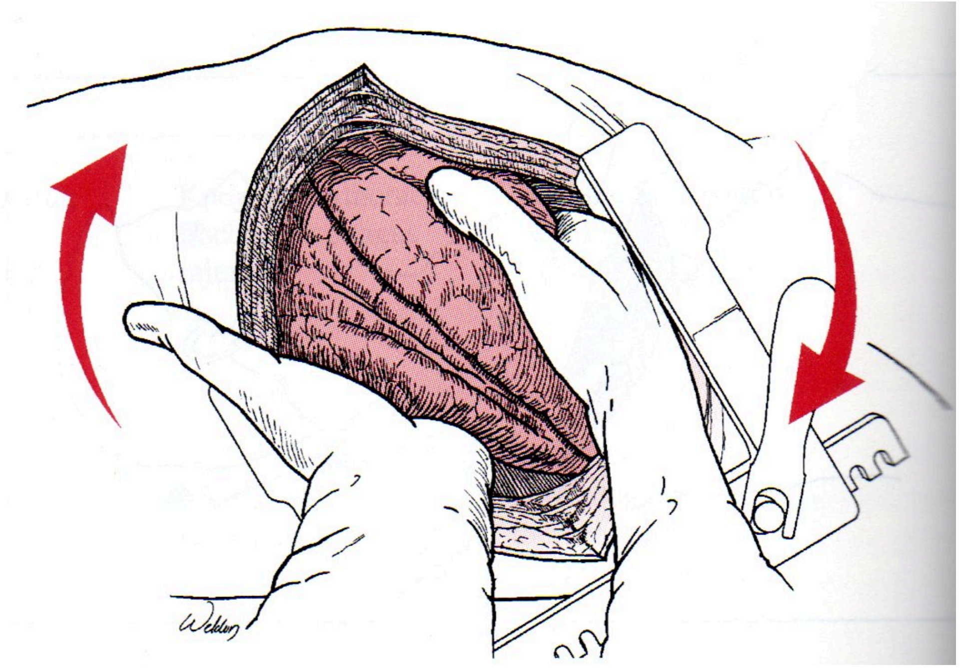
Hemothorax



- Bleeding in to the pleural space
- Causes
  - Lung parenchyma
  - Intercostal or internal mammary arteries
  - Heart or great vessels
  - Liver or spleen with diaphragm injury
- How much blood must be present to detect on CXR?
  - 200-300cc



Hemothorax

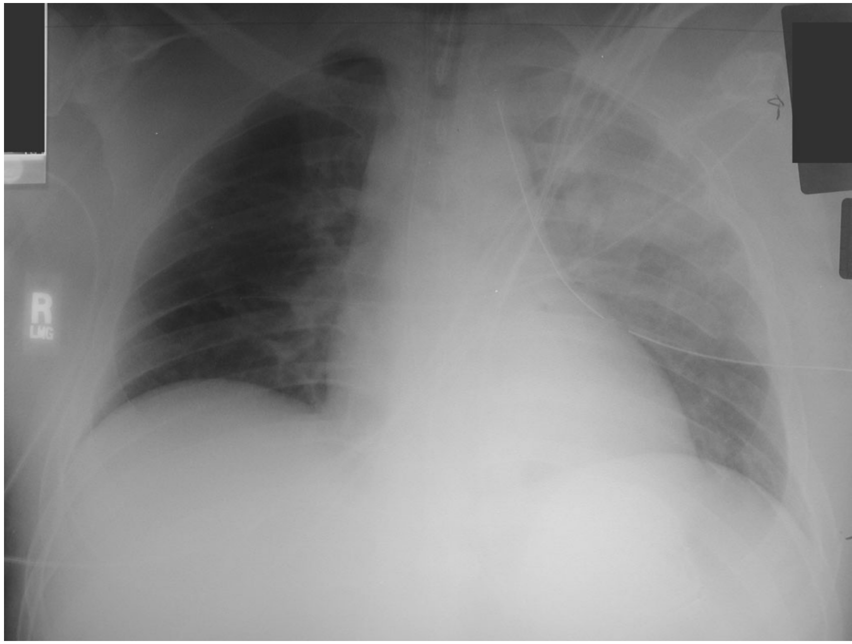


- Massive = > 1000cc
- Indications for thoracotomy
  - > 1000cc initially
    - 20cc/kg
  - > 300cc/hr
    - 3cc/kg
- Lung Laceration
  - Quick fix = Hilar twist

Tension Hemothorax

Pulmonary Contusion

- Alter V/Q matching
  - Leads to hypoxemia
- *The leading cause of dysoxia associated with a flail chest*
- CXR will “fluff out” 24-72 hours later
- Treatment
  - Supportive measures



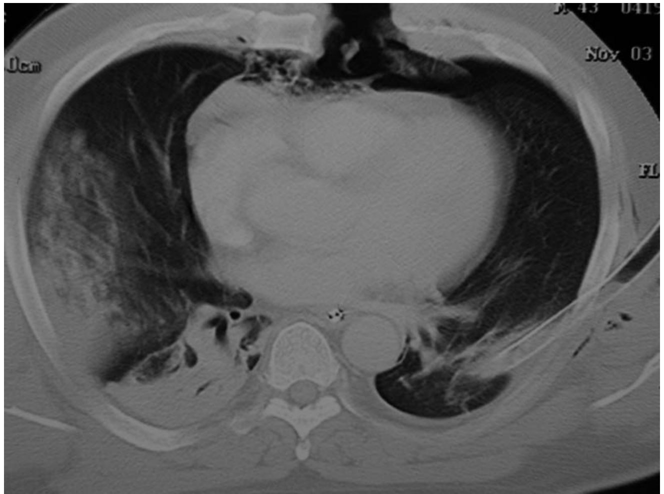


Table 2: Lung Injury Scale

Grade	Injury Type	Description of Injury
I	Contusion	Unilateral, <1 lobe
II	Contusion	Unlateral, 1 lobe
	Laceration	Simple pneumothorax
	Contusion	Unilateral, L1 lobe
III	Laceration	Persistent (>72 hours) air leak from distal airway
	Hematoma	Nonexpanding intraparenchymal
	Laceration	Major (segmental or lobar) air leak
IV	Hematoma	Expanding intraparenchymal
	Vascular	Primary branch intrapulmonary vessel disruption
V	Vascular	Hilar vessel disruption
VI	Vascular	Total uncontained transaction of pulmonary hilum

Complications

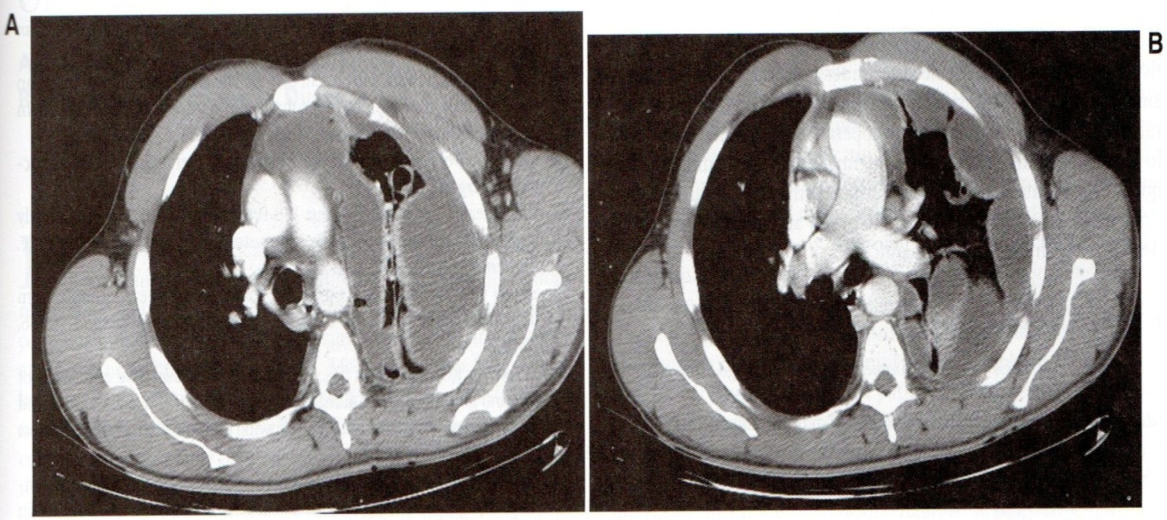
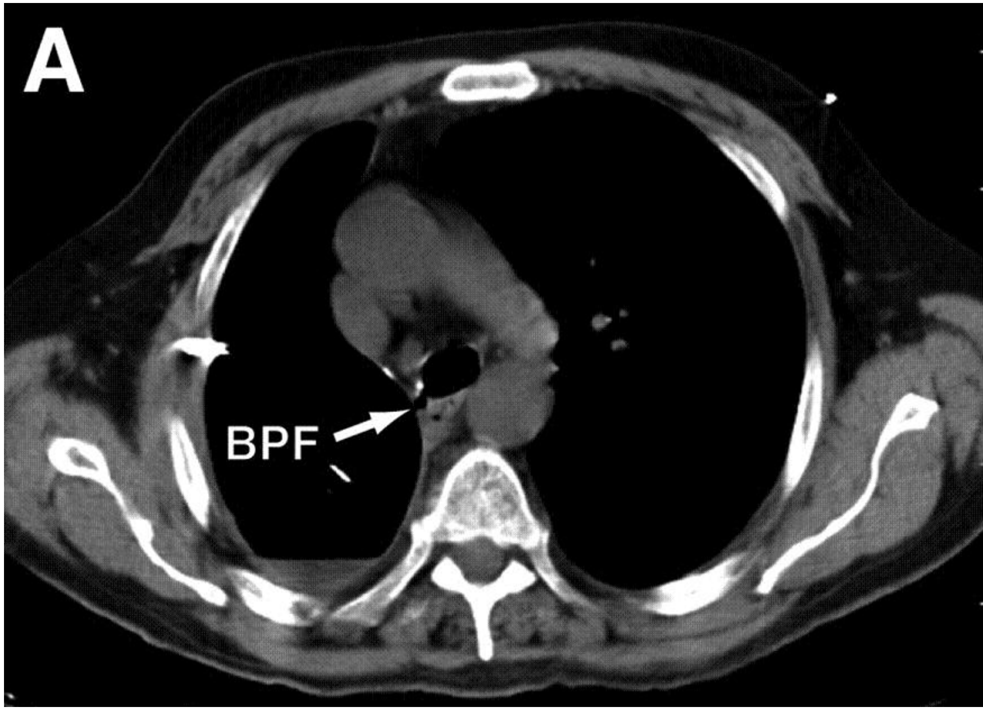


Figure 7 **(A, B)** Computed tomography scans of a loculated empyema of the chest in a patient 2 weeks following a gunshot wound to the chest and evacuation of a hemothorax. Note the enhancement around the collections. Patient was successfully treated with a thoracotomy and decortication.

- Empyema
  - Extraparenchymal infectious fluid collection
  - Causes
    - CT insertion
    - Penetrating trauma
  - S/S
    - Unexplained fever, elevated WBC, respiratory failure
  - Treatment
    - CT drainage
    - VATS
    - Thoracotomy with decortication
    - Abx, pulmonary toilet

Complications

- Bronchopleural Fistula and persistant air leaks
  - Communication between the pleural space and the bronchial tree
  - Causes
    - Bronchus injury
    - Small lung parenchymal injury
    - Mechanical ventilation
  - Treatment
    - VATS with pleurodesis



Cardiac Injuries

- Presentation
  - Hemodynamic stability to cardiac arrest
- Diagnosis
  - ECHO or FAST
    - Can show fluid in pericardium, valvular dysfunction, and parenchymal disruption
  - Subxiphoid window
    - If ECHO +
      - Blood = median sternotomy or thoracotomy
      - Fluid = observation

Blunt Cardiac Injury

- What is *comotio cordis*?
  - Sudden cardiac arrest from a sternal blow
- Diagnostic modalities
  - CXR
  - EKG
  - Cardiac enzymes
- PE findings
  - Pain or tenderness over anterior chest wall
  - Contusions
  - Ecchymosis
  - Anterior rib fractures

Blunt Cardiac Injury

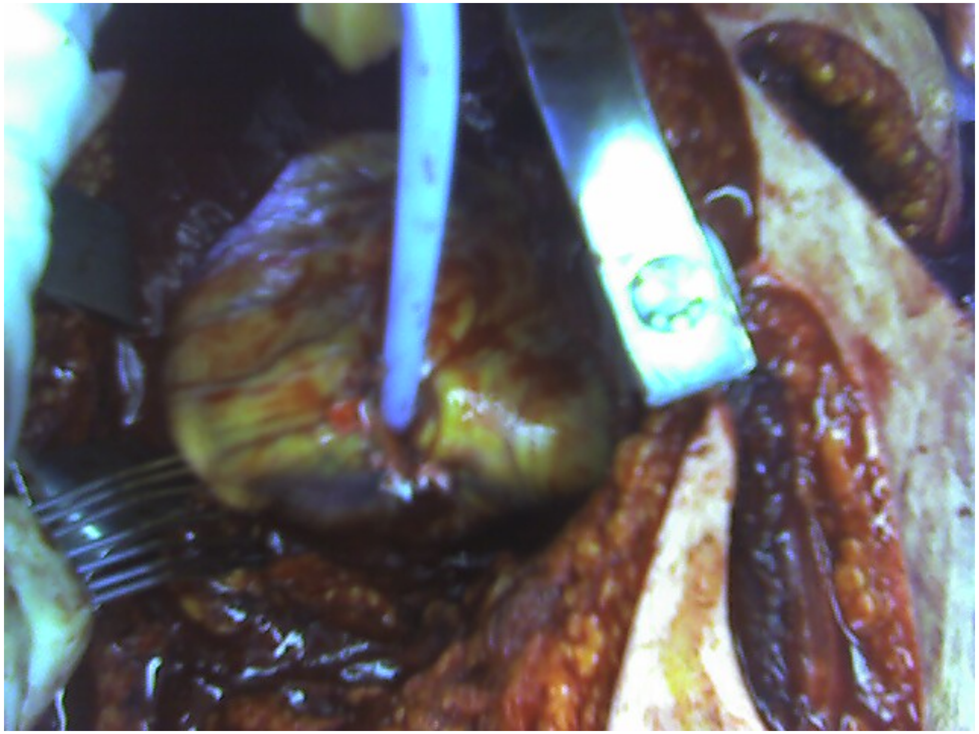
- Pericardial Injury
  - Heart can eviscerate out of pericardium causing great vessel torsion
- Valvular, Papillary Muscle, Chordae Tendinae, and Septal Injuries
  - Can be caused by rapid displacement of blood secondary to crush/compressive force
  - Aortic valve most common
  - PE
    - New cardiac murmurs, thrills, loud musical murmurs
  - Hypovolemia and decreased CO can mask these injuries

Blunt Cardiac Injury

- Blunt Coronary Artery Injury
  - Thrombosis of artery with intimal disruption
  - Presents as an AMI
  - LAD most common because it lies under sternum
- Cardiac Chamber Rupture
  - Often causes immediate death
  - Can cause delayed death by necrosis of contused portion of heart
  - Atrial > ventricular

Penetrating Cardiac Injury

- 2 main incisions
  - Median sternotomy
    - standard
  - Anterolateral thoracotomy
    - Patient *in extremis*
- Most common area of heart injured in penetrating trauma?
  - Right Ventricle



Atrial Injuries

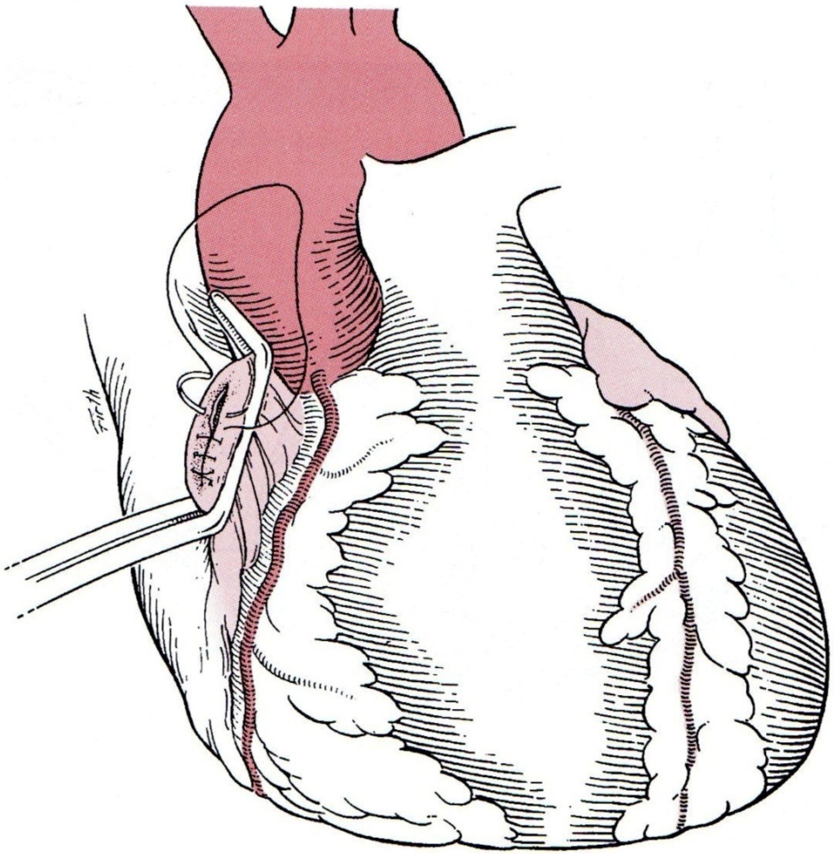


FIGURE 28-1. Satinsky partial occlusion clamp applied for right atrial repair.
(Reproduced with permission from Juan A. Asensio, MD, FACS, FCCM and Demetrios Demetriades, MD, PhD, FACS.)

- Incidence of left atrial injury very low due to recessed location
  - 2-12%
- Low pressure system makes repair easier
- Use 2-0 or 3-0 prolene

Ventricular Injuries

- Usually cause significant hemorrhage
- GSW can cause muscle fibers to retract and become more friable
  - Teflon to buttress suture line
- Use 3-0 or 4-0 prolene for primary repair
  - 2-0 prolene if using teflon strips

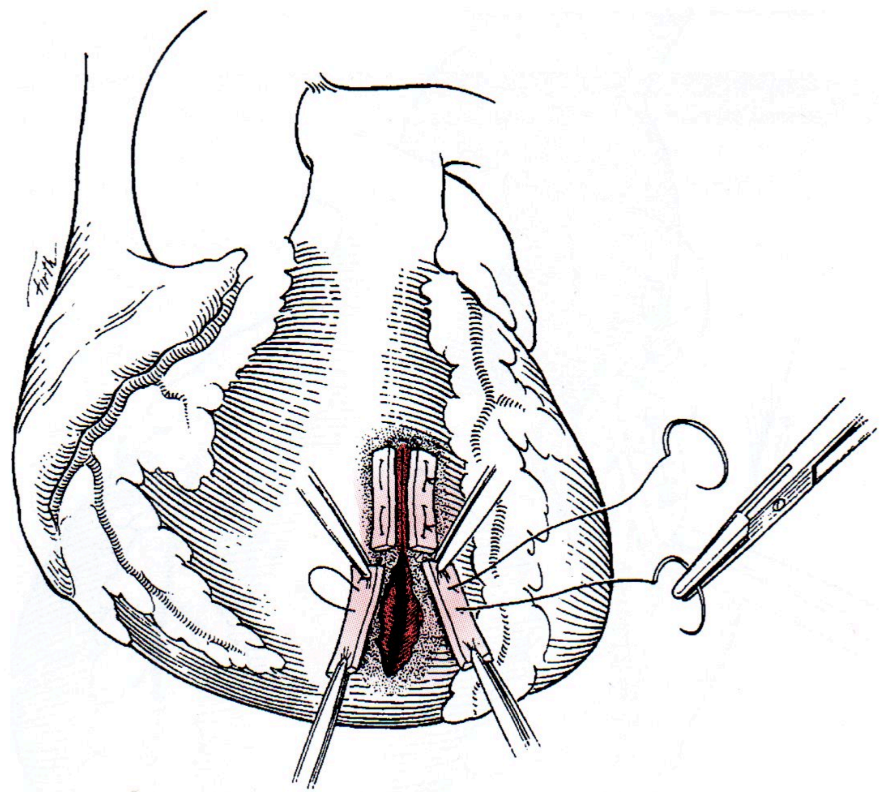


FIGURE 28-2. Method for repairing a complex left ventricular injury utilizing Teflon strips.
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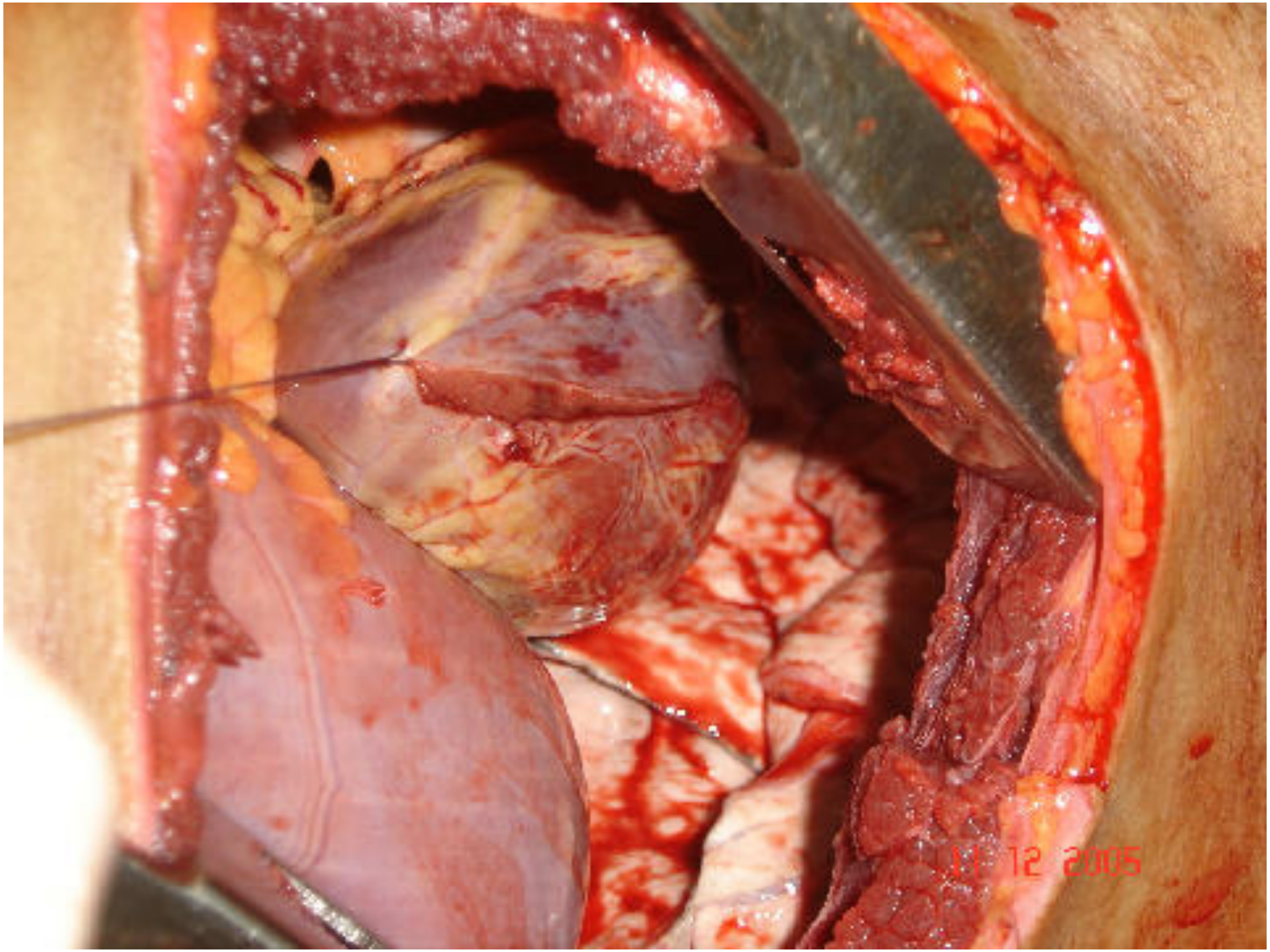
Cardiac Laceration



Coronary Artery Injuries

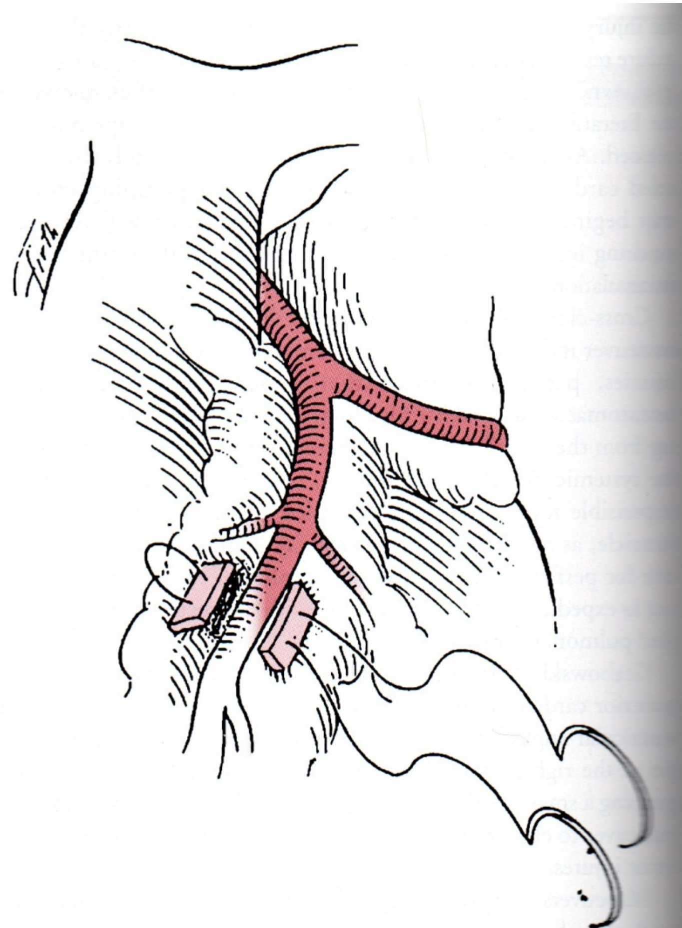


FIGURE 28-4. Technique depicting placement of sutures under the coronary artery bed. We recommend 2-0 polypropylene monofilament suture on a MH needle.
(Reproduced with permission from Juan A. Asensio, MD, FACS, FCCM and Demetrios Demetriades, MD, PhD, FACS.)

- Care must be taken not to narrow or occlude coronaries or branches when repairing lacerations
  - Suture under coronary bed with teflon strips
- Distal coronary injury
  - Ligation
- Proximal coronary injury
  - Revascularization

Pneumopericardium

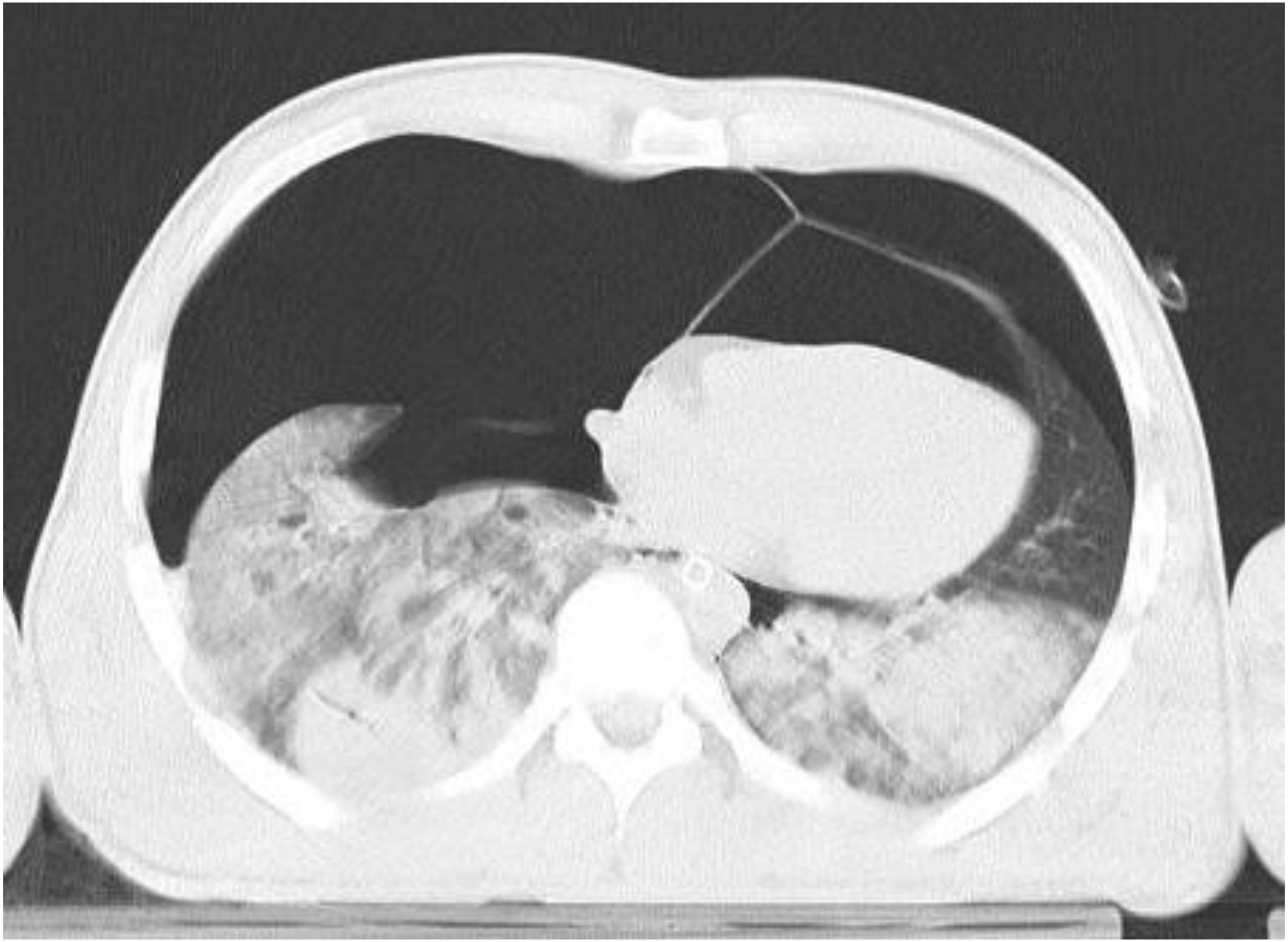


Table 3: American Association for the Surgery of Trauma, Organ Injury Scale: Cardiac Injury

Grade[a]	Injury Description
I	Blunt cardiac injury with minor electrocardiographic abnormality (nonspecific T or T-wave changes, premature atrial or ventricular contraction, or persistent sinus tachycardia). Blunt or penetrating pericardial wound without cardiac injury, cardiac tamponade, or cardiac herniation.
II	Blunt cardiac injury with heart block (right or left bundle branch, left anterior fascicular, or atrioventricular) or ischemic changes (ST depression or T-wave inversion) without cardiac failure. Penetrating tangential myocardial wound up to, but not extending through, endocardium, without tamponade.
III	Blunt cardiac injury with sustained (>5 beats per minute) or multifocal ventricular contractions. Blunt or penetrating cardiac injury with septal rupture, pulmonary or tricuspid valvular incompetence, papillary muscle dysfunction, or distal coronary arterial occlusion without cardiac failure. Blunt pericardial laceration with cardiac herniation. Blunt cardiac injury with cardiac failure. Penetrating tangential myocardial wound up to, but not extending through, endocardium, with tamponade.
IV	Blunt or penetrating cardiac injury with septal rupture, pulmonary or tricuspid valvular incompetence, papillary muscle dysfunction, or distal coronary arterial occlusion producing cardiac failure. Blunt or penetrating cardiac injury with aortic or mitral valve incompetence. Blunt or penetrating cardiac injury of the right ventricle, right atrium, or left atrium.
V	Blunt or penetrating cardiac injury with proximal coronary arterial occlusion. Blunt or penetrating left ventricular perforation. Stellate wound with <50% tissue loss of the right ventricle, right atrium, or left atrium.
VI	Blunt avulsion of the heart; penetrating wound producing >50% tissue loss of a chamber.

[a]Advance one grade for multiple penetrating wounds to a single chamber or multiple chamber involvement.
Modified from Moore EE, Malangoni MA, Cogbill TH, et al: Organ injury scaling IV: thoracic, vascular, lung, cardiac, and diaphragm. *J Trauma* 36:229–300, 1994, with permission.

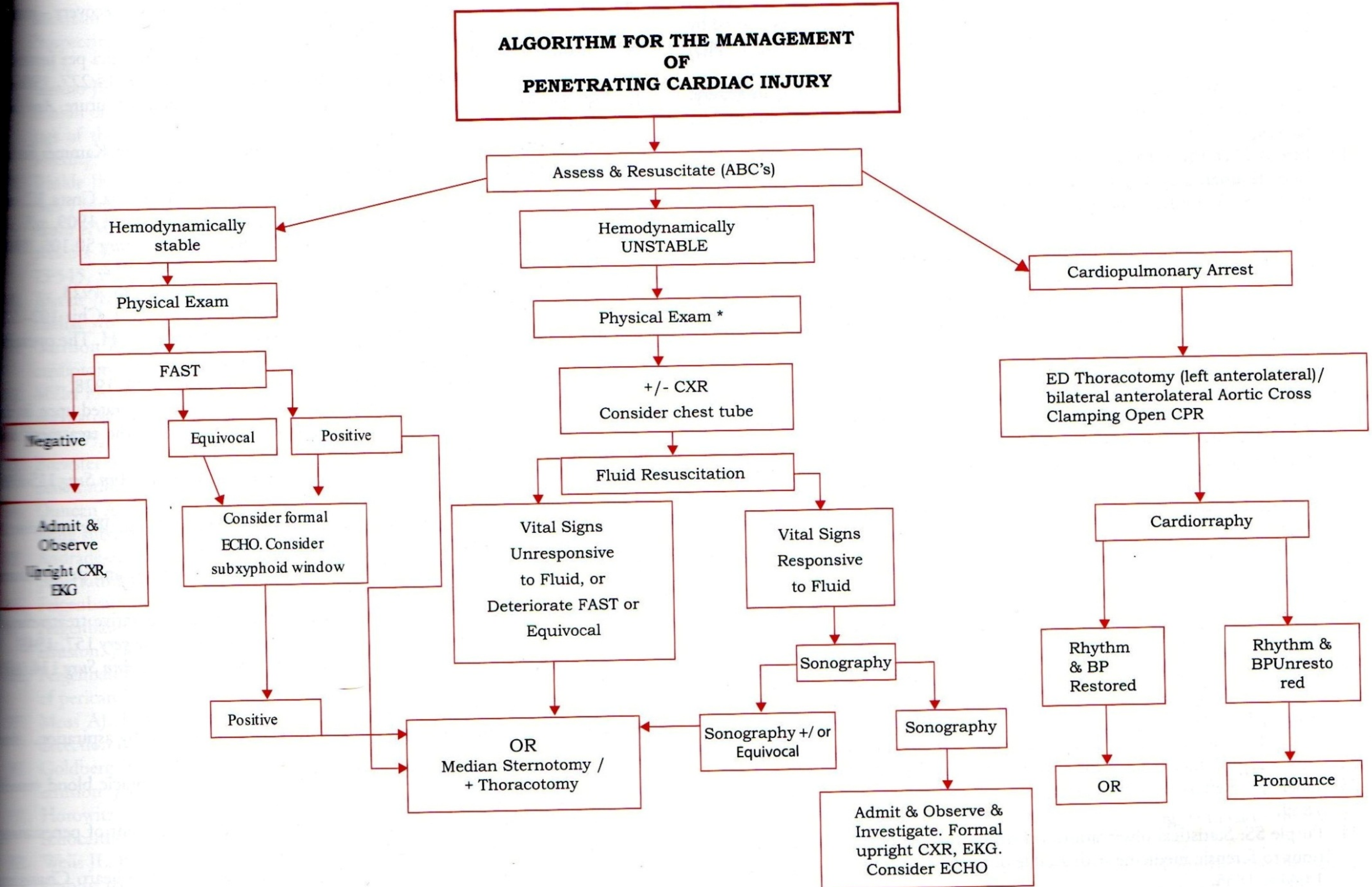
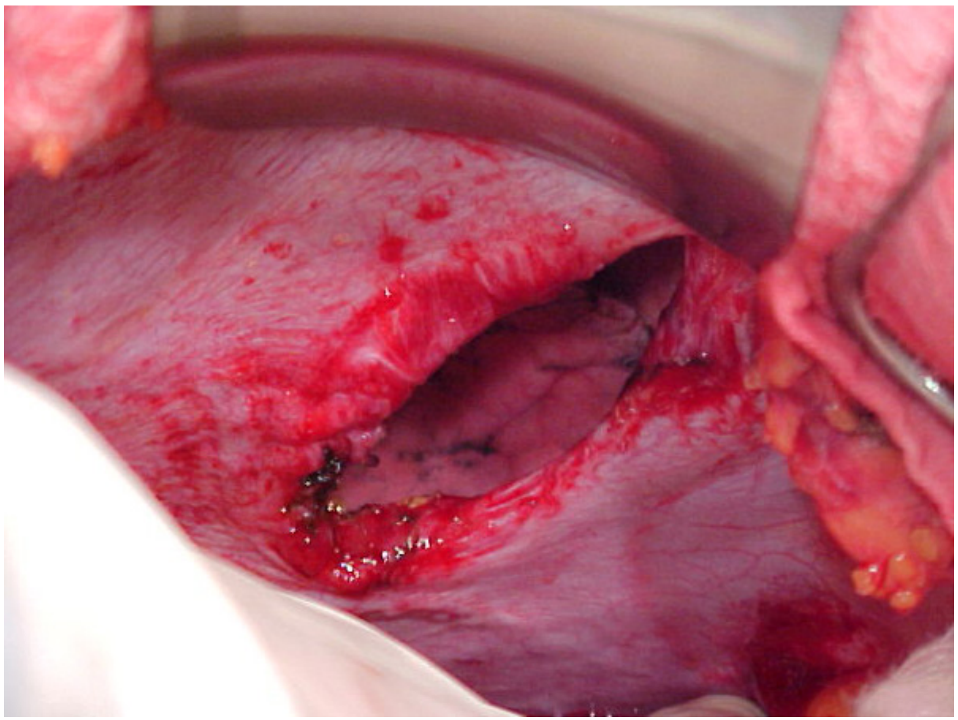


FIGURE 28-5. Algorithm for the management of penetrating cardiac injury.

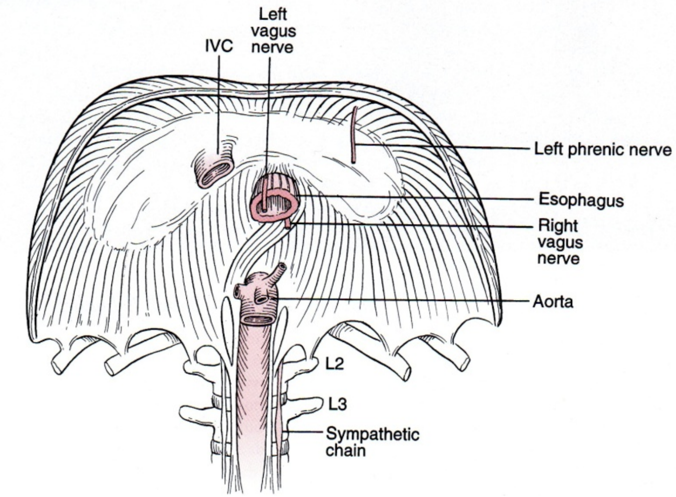
Diaphragm Injuries



- Difficult to diagnose
- Most are found intraoperatively
- ~25% mortality rate
- Incidence
  - Left > Right due to protective location of liver
- Associated injuries
  - Liver, spleen, and stomach
- Penetrating thoracoabdominal injuries should raise suspicion

Anatomy

- Bony attachments
  - Sternum, lower ribs, vertebrae
- Muscle fibers converge to form central tendon
  - No bony attachments
- Crura
  - Important for cross clamping aorta
- 3 openings
  - IVC – T8
  - Esophagus – T10
  - Aorta – T12



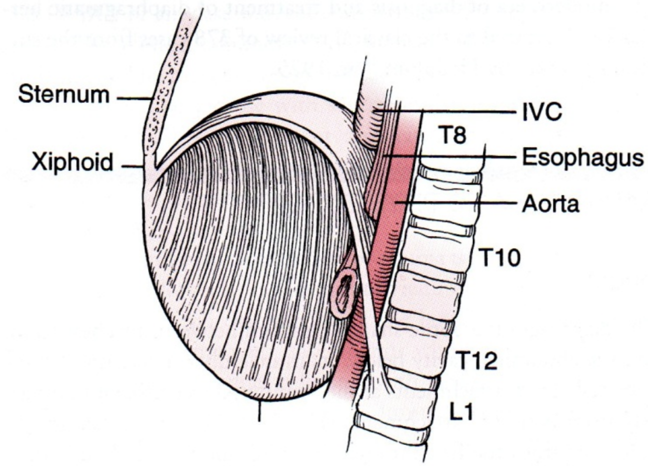
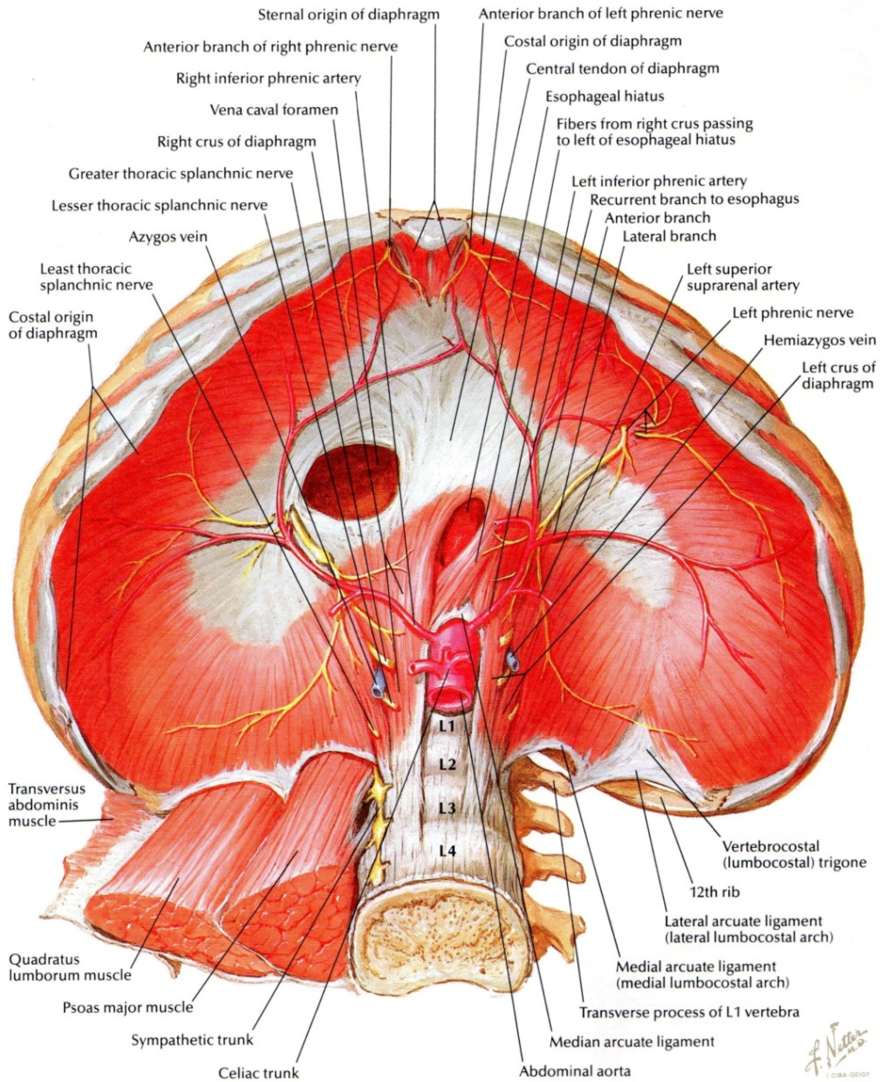


FIGURE 31-2. Side view of the diaphragm, showing its dome shape and anterior and posterior areas of attachment: the xiphisternal junction and the lumbar vertebral bodies. The level of the origin of each of the major apertures of the diaphragm are shown.

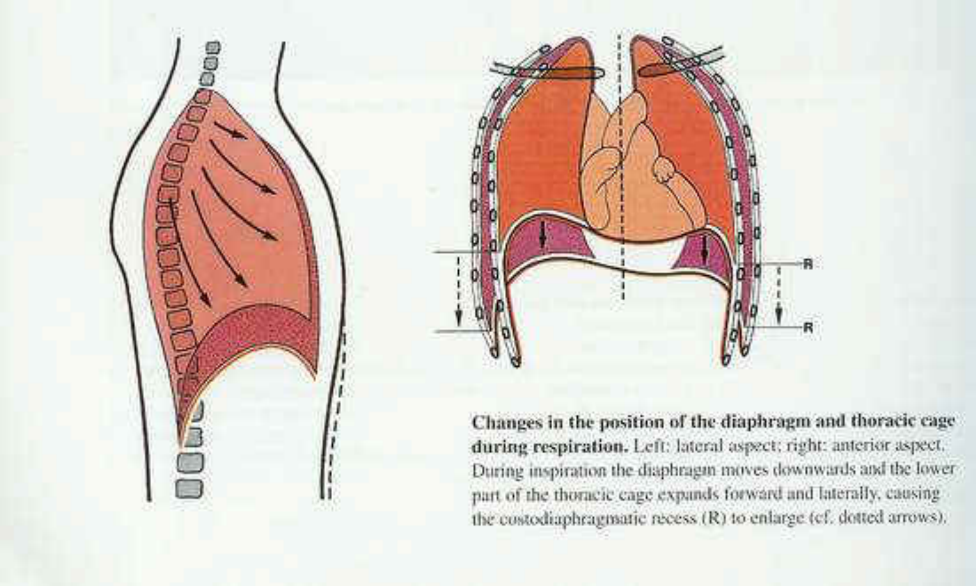
Anatomy



- Resitant to hypoxia
  - Phrenic and pericardiophrenic arteries
- Innervated by left and right phrenic nerves

Function

- 3-5cm motion during normal tidal volume
- Exhalation (anterior)
  - Right rises to 4th intercostal space
  - Left rises to 5th intercostal space
- Exhalation (posterior)
  - Both rises to 8th intercostal space

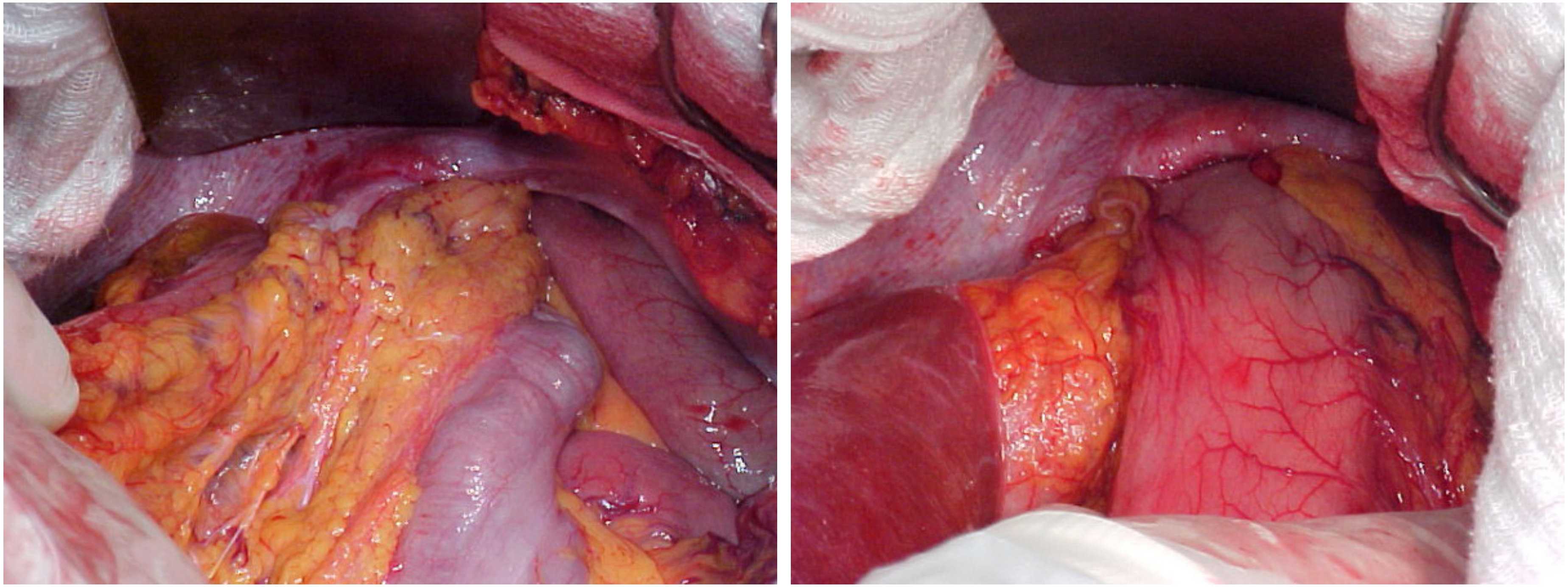


Changes in the position of the diaphragm and thoracic cage during respiration. Left: lateral aspect; right: anterior aspect. During inspiration the diaphragm moves downwards and the lower part of the thoracic cage expands forward and laterally, causing the costodiaphragmatic recess (R) to enlarge (cf. dotted arrows).

Diagnosis

- Physical exam
  - Dyspnea
  - Kehr's sign
  - Decreased breath sounds
  - Bowel sounds in chest
  - Scaphoid abdomen from visceral displacement
  - NGT position

Diaphragm rupture with stomach herniation



Grading

TABLE 31-3

Adapted from American Association for the Surgery of Trauma-Organ Injury Scale for Diaphragmatic Injuries

GRADE	INJURY DESCRIPTION
I	Contusion
II	Laceration ≤2 cm
III	Laceration 2–10 cm
IV	Laceration >10 cm with tissue loss ≤25 cm^2
V	Laceration with tissue loss >25 cm^2

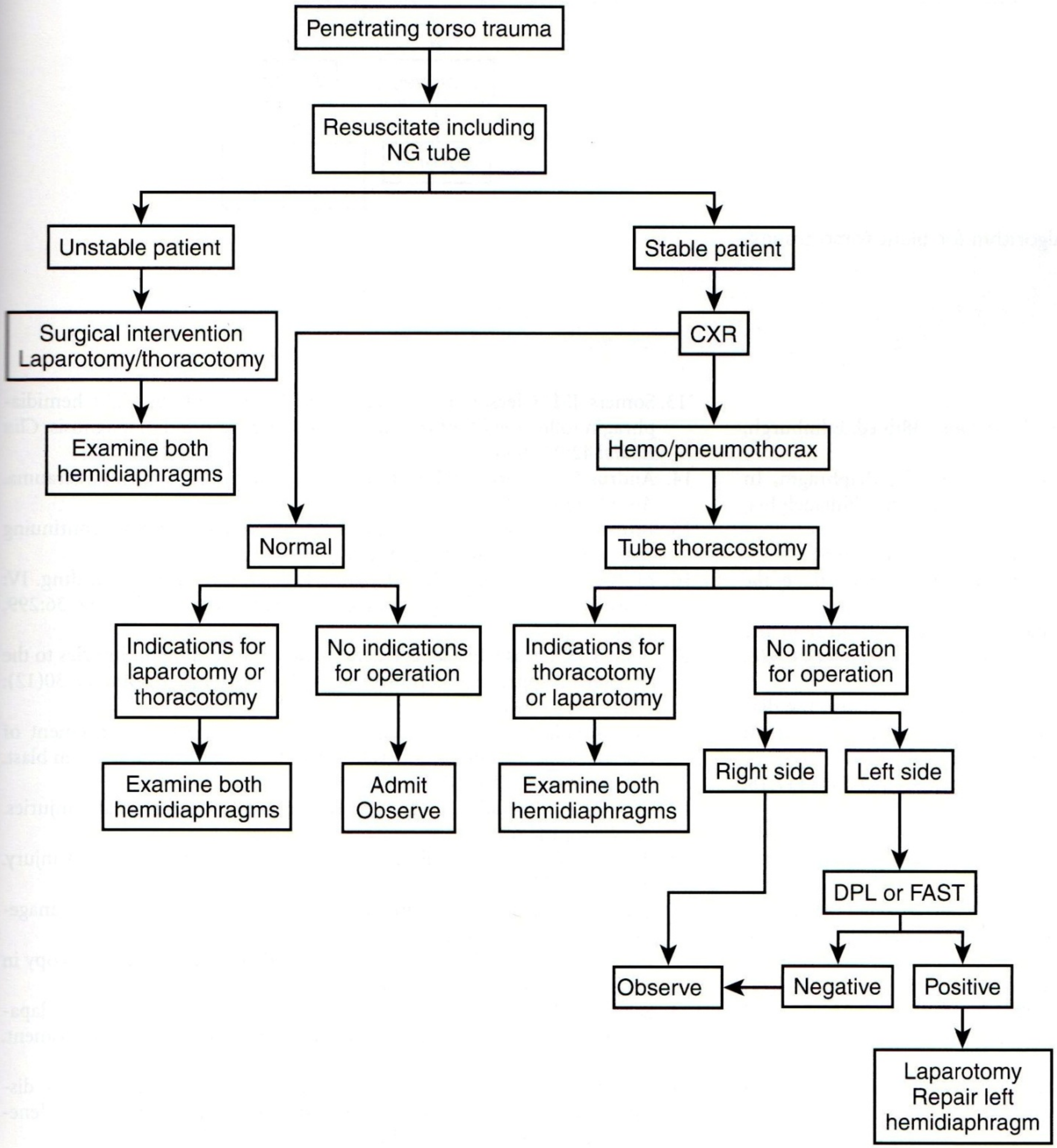


Figure 23 Algorithm for acute penetrating thoracoabdominal trauma.

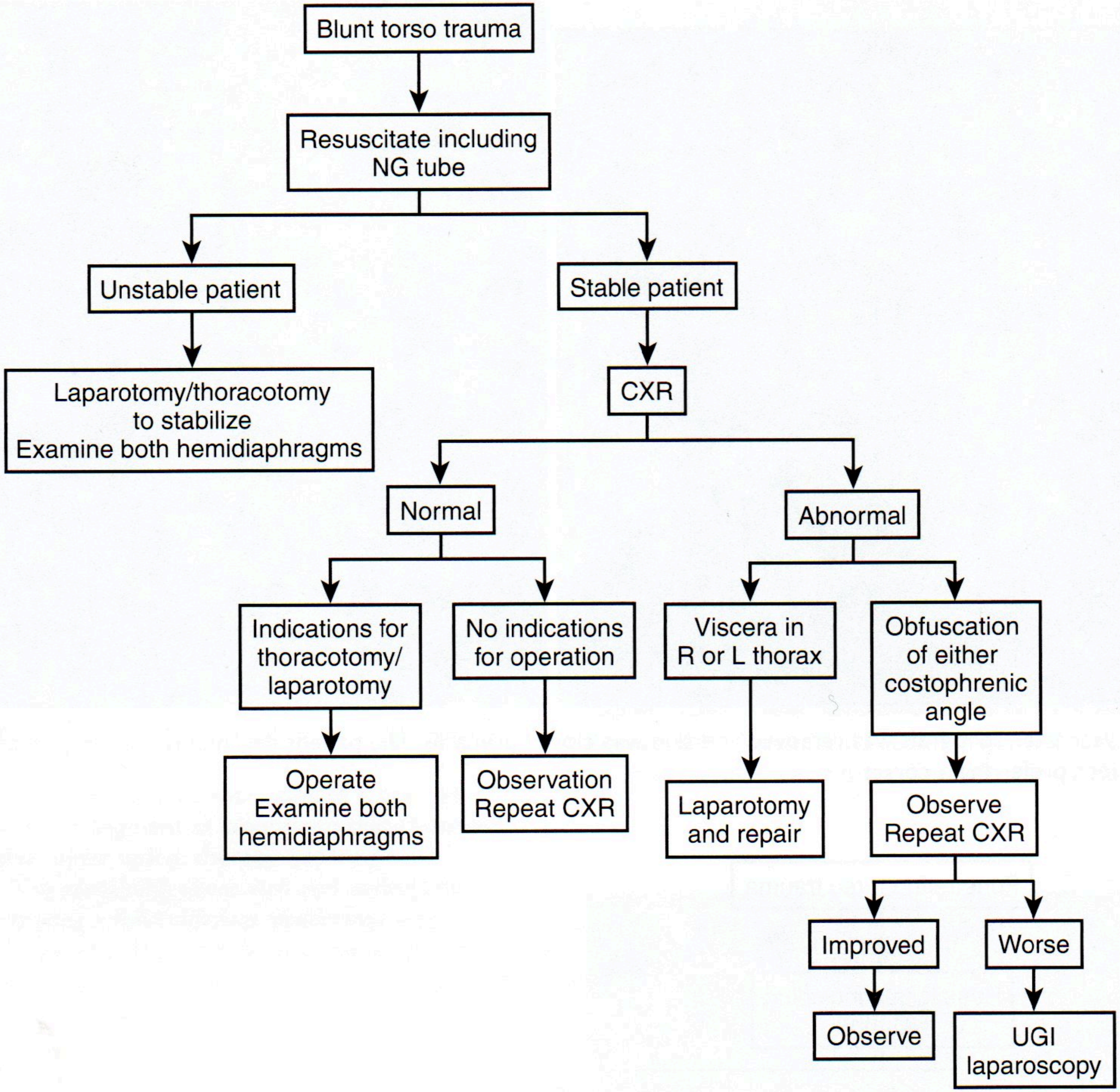
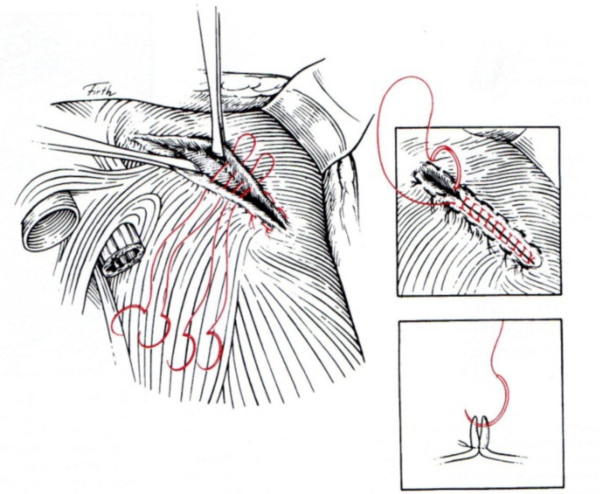


Figure 24 Algorithm for blunt torso trauma.

Surgical Repair

- Acute injury
  - Simple
    - Double layer primary repair with 0 or 1 prolene
  - Chest wall injury
    - Reattachment of diaphragm above injury
- Chronic Injury
  - Missed defects at initial injury can enlarge over time and present as hernia
  - Repair is often with synthetic mesh patches



GURE 31-11. Complex lacerations greater than 5 cm long may require a running suture for reinforcement. One may use 0 or 1 monofilament sutures of nonabsorbable material (polypropylene) or absorbable suture. An alternative means of repairing diaphragmatic injuries involves a continuous running suture. *(Reproduced with permission from Juan A. Asensio, MD, FACS, FCCM and Demetrios Demetriades, MD, PhD, FACS.)*

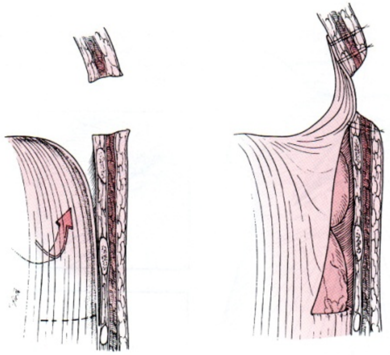


FIGURE 31-12. Immediate reconstruction of the chest wall following destructive types of injury may be accomplished by detaching the affected hemidiaphragm anteriorly, laterally, and posteriorly. The diaphragm is then resutured to the muscle of a higher intercostal space, thus effectively translocating it to a position above the full-thickness chest wall defect and converting such a defect functionally into an abdominal wall defect. The abdominal wall defect is then managed with local wound care in anticipation of further reconstruction with either split-thickness skin grafts or myocutaneous flaps at a later date.
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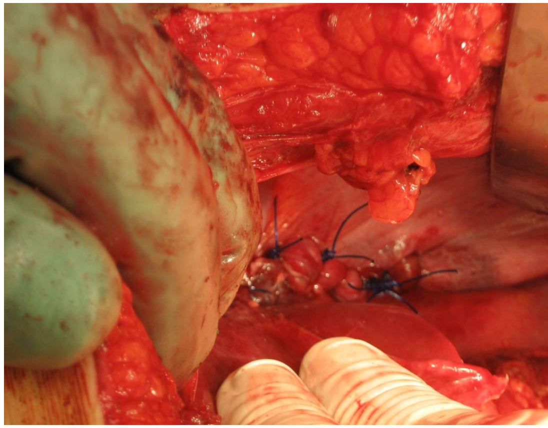


Traumatic Brain Injuries

Injuries

- Subdural Hematomas
- Epidural Hematomas
- Intracerebral Hematomas
- Subarachnoid Hemorrhages
- Intraventricular Hemorrhages
- Diffuse Axonal Injuries

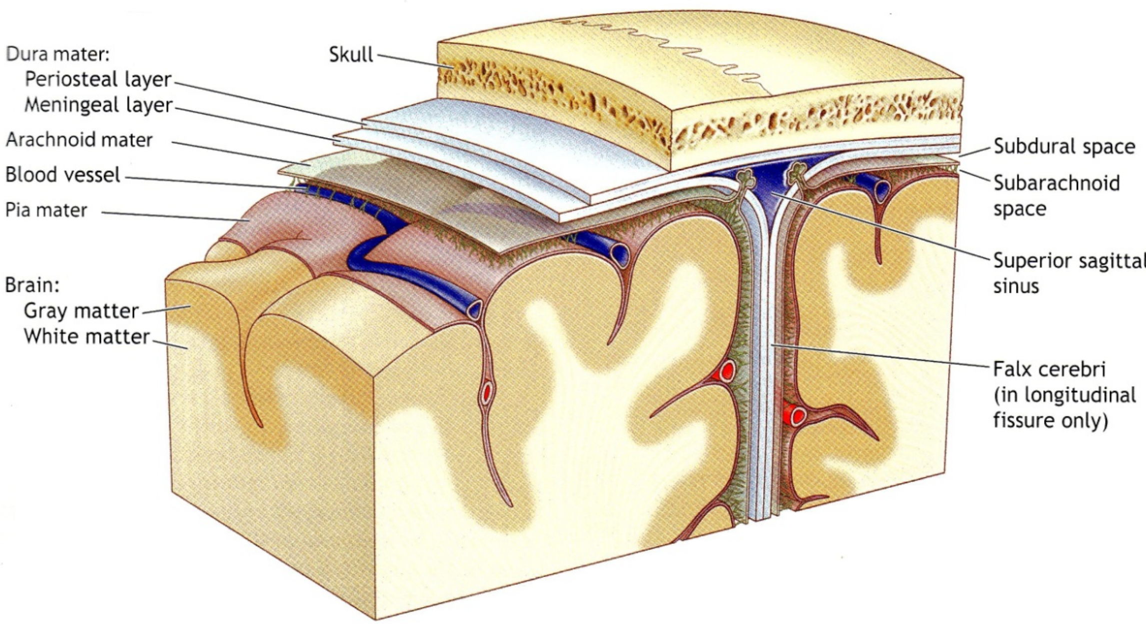
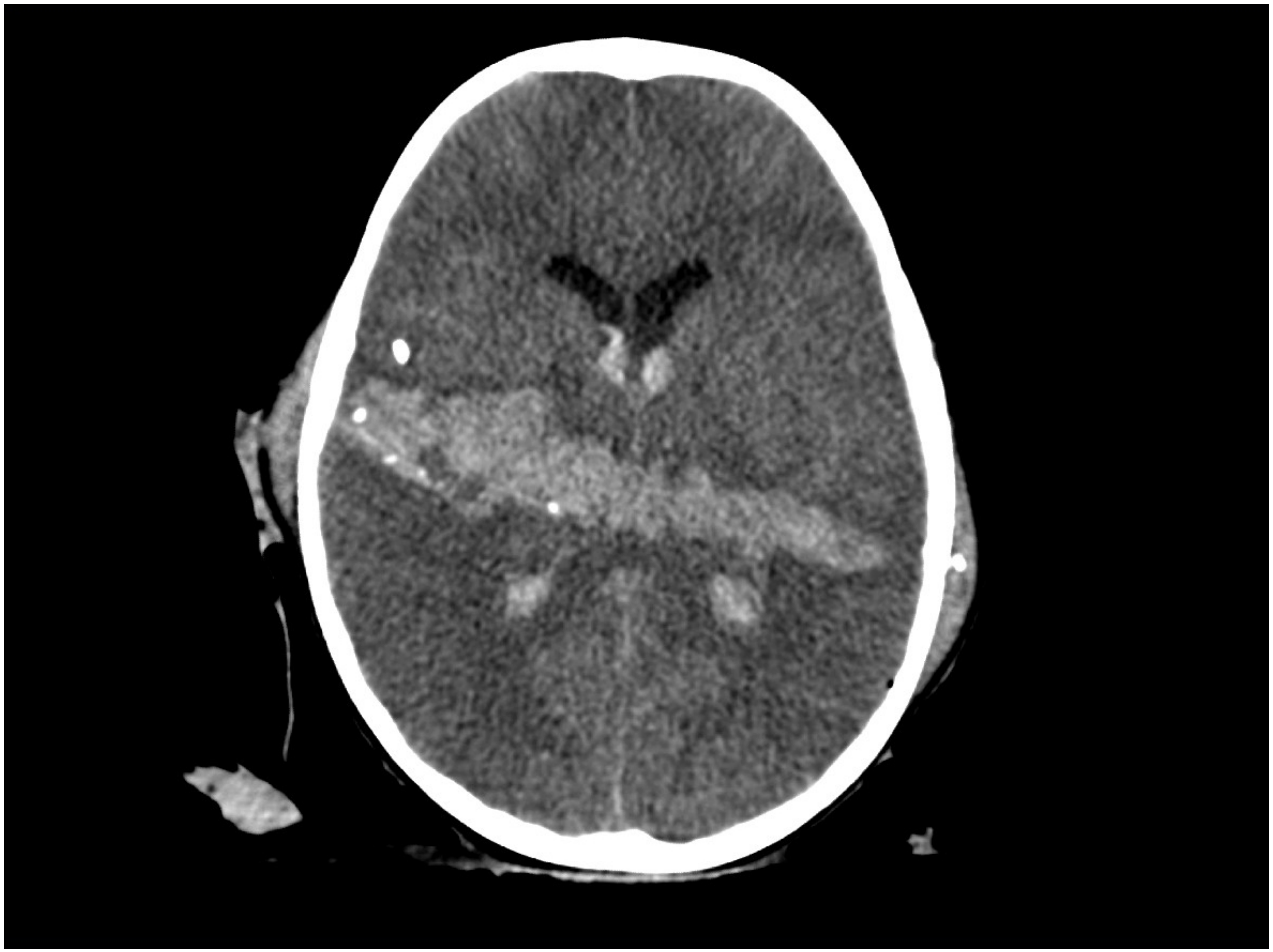


Figure 6-2 The Meninges. The meninges cover the brain and consist of three layers: the dura mater, arachnoid, and pia mater.

Transcranial GSW



Neuro Principles

- Monroe-Kelley Doctrine
  - Brain, Blood, CSF
- Cerebral Blood Flow
  - 50mL per 100g of brain
    - <25 - EEG flatline
    - <10 – cell death
- Cerebral Perfusion Pressure
  - MAP – ICP
- Glasgow Coma Score

Glascow Coma Score

- Add best score from each category
- Motor → V6
- Verbal → V(five)
- Eye → "4 eyes"

Table 9-1. Glasgow Coma Scale

Category	Points for a Given Response
	6: Obeys verbal command to move
	5: Localizes to pain
	4: Withdraws from pain
Motor	**3:** Stimulus causes flexure posturing
	2: Stimulus causes extensor posturing
	1: No response to stimulus
	5: Fully oriented
	4: Not fully oriented
Verbal	**3:** Intelligible but not organized
	2: Unintelligible sounds
	1: No vocalization
	4: Spontaneous
	3: Opens to speech
Eye opening	**2:** Opens to pain
	1: No eye opening

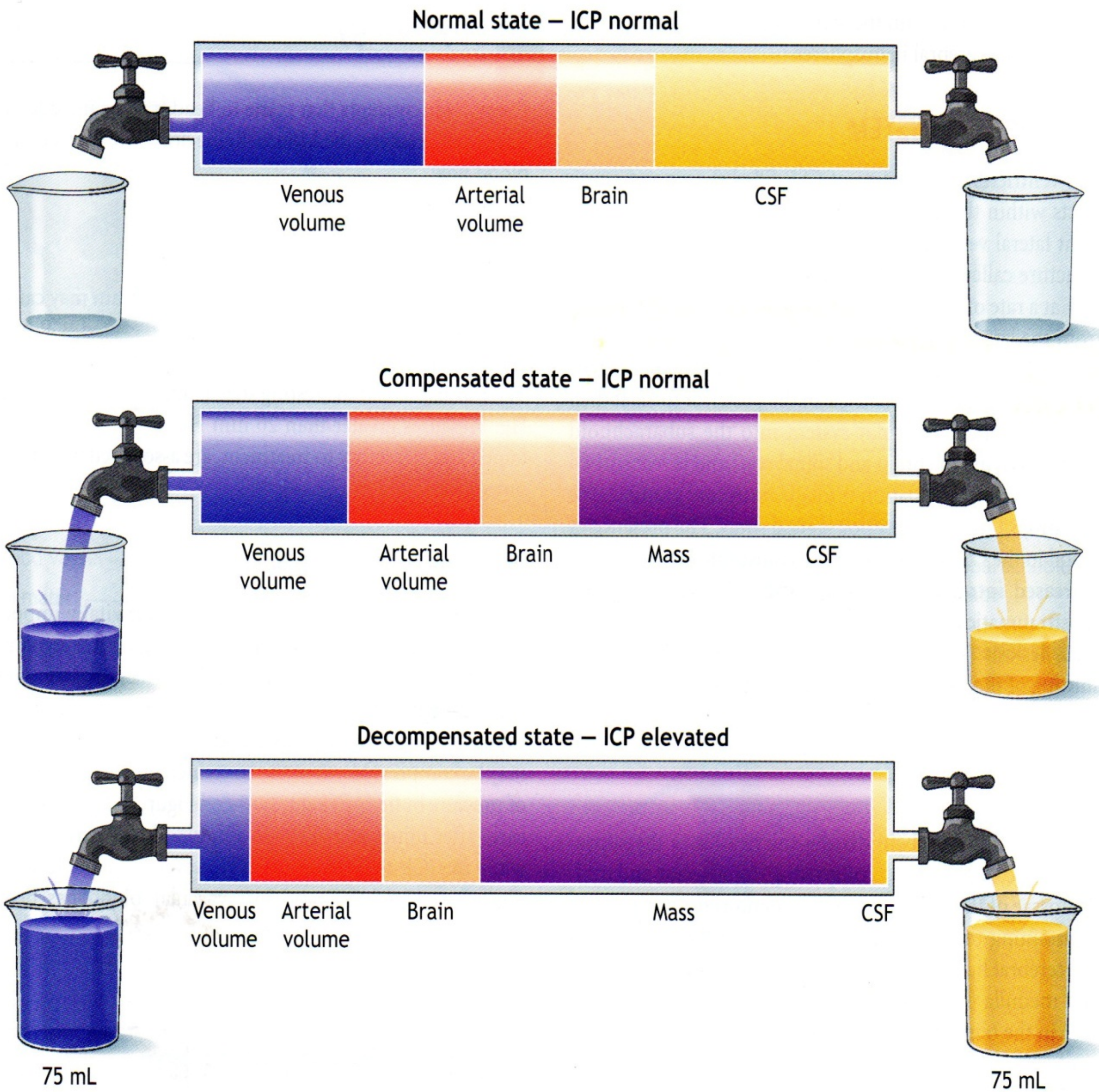
Glascow Coma Score

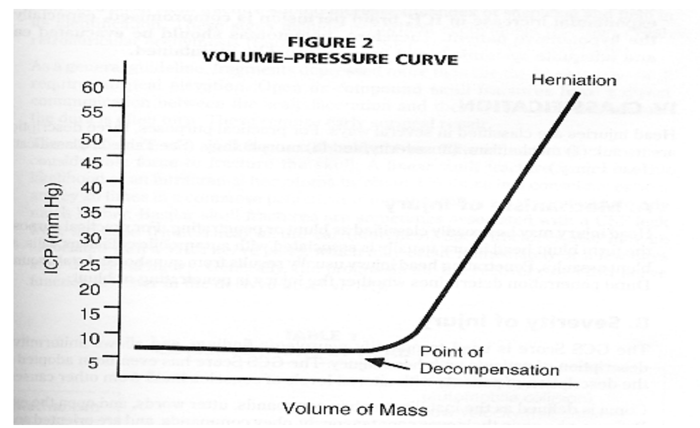
GCS Motor	Good Outcome, %
1	0
2	47
3	41
4	78
5	75

GCS	Mortality, %	Good Outcome, %
3	78.4	4.1
4	55.9	6.3
5	40.2	12.2

- At 6 hours post-injury
  - GCS 3 – 4 very poor outcome
  - GCS 5 – 7 ~ ½ self care or better
  - GCS ≥ 8 most self care or better

Monroe-Kelley Doctrine



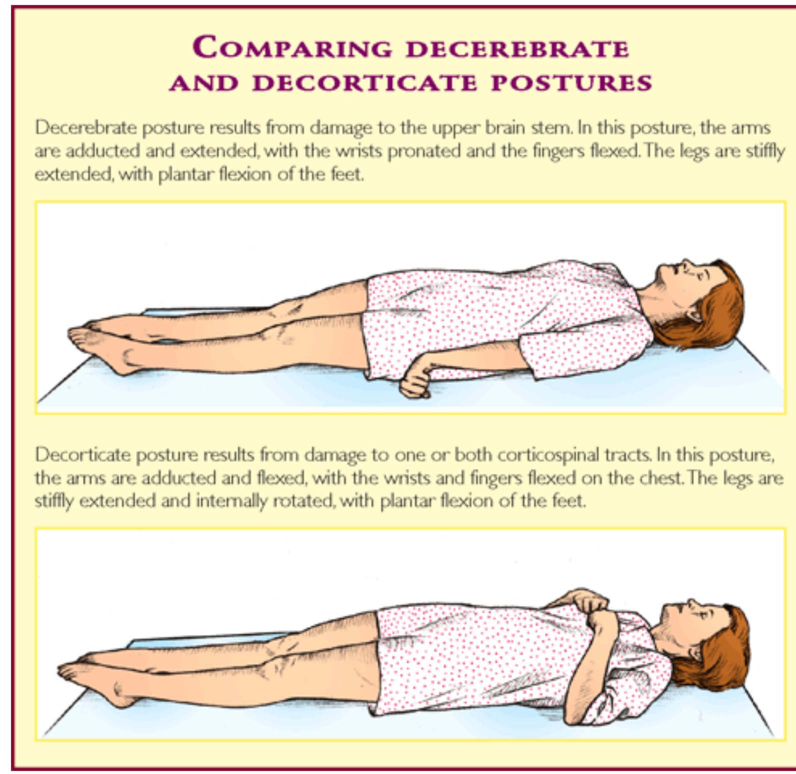


Evaluation of TBI

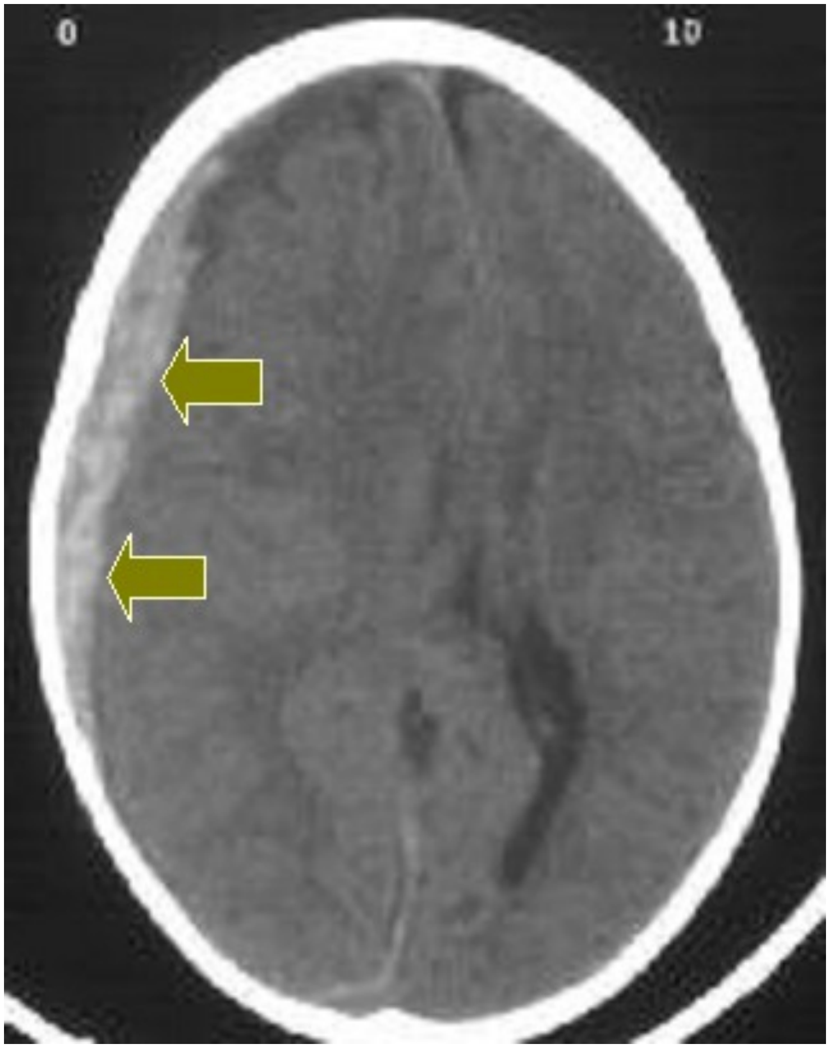
- Airway
  - Intubate with GCS < 9
- Breathing
  - Monitor for inadvertant hyperventilation
    - Decreases CO2 decreases perfusion to brain
- Circulation
  - Single episode if SBP<90 can increase mortality

Evaluation of TBI

- Pupillary Response
  - Look for asymmetry
    - >1mm difference
  - >4mm pupil = “blown”
    - Compression of what nerve??
- Posturing
- Head CT Non-contrast



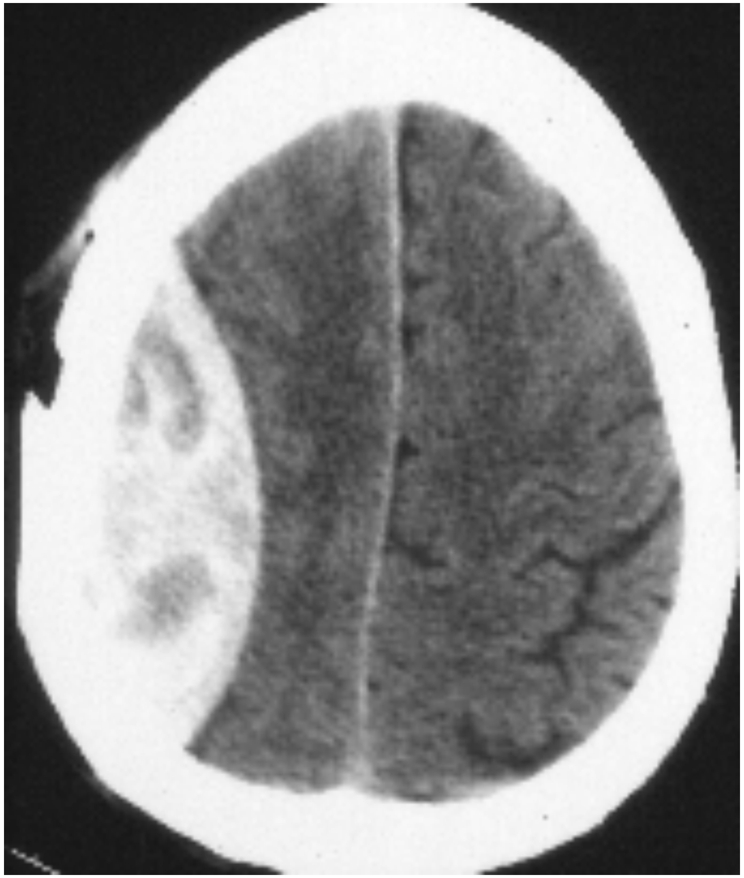
Subdural Hematoma



- Most common traumatic mass lesion
  - 20-40% of TBI
- Between dura and arachnoidal meningeal layer of brain
  - Injury to what vessels??
- Forms a crescent shape
- Treatment
  - Evacuation if:
    - Thickness >10mm
    - Midline shift >5mm
    - Blown pupil
    - ICP>20
    - Decline in GCS >2 points

Epidural Hematoma

- Occurs when dura is peeled off inner table of the skull
  - More a result of skull injury vs. brain injury
- High occurrence with temporal bone fracture
  - Injury to what vessel?
- Lucid interval prior to herniation
- Forms a lens shape
- Treatment
  - Emergent evacuation
  - Non-op management if:
    - Volume < 30cm2
    - Midline shift < 0.5mm
    - GCS>8
    - No focal deficits



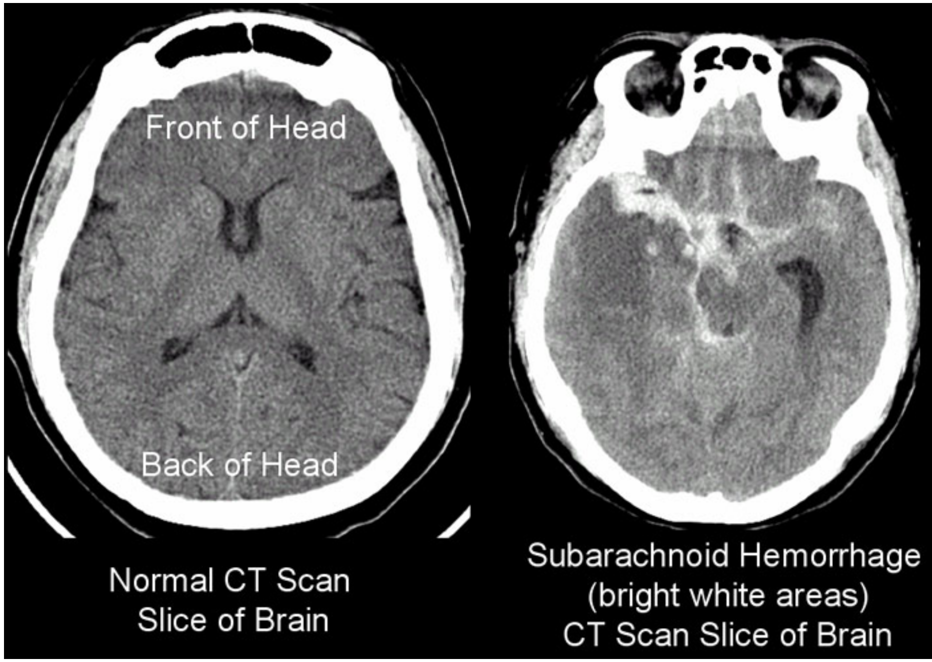
Bilateral Epidural Hematoma

Intraparenchymal Hematoma/Contusion

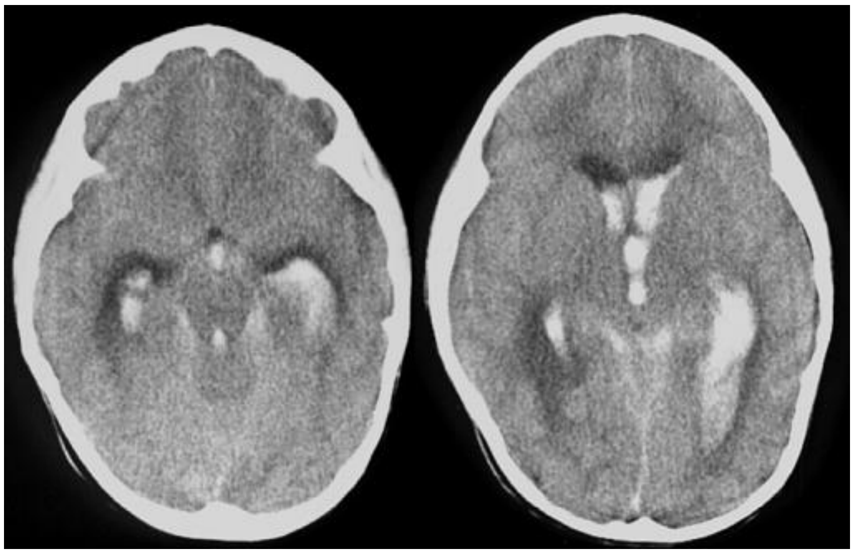
- Damage to brain itself
- Often occur on opposite side of force
  - Contracoup injury
- Take 12-24hr to appear
- Can progress as hematoma evolve
  - 10% to severe injury
- Treatment
  - Evacuation if :
    - Neurological deterioration
    - Medically refractory intracranial HTN
    - Signs of mass effect on CT
    - Volume is >50cm2

Subarachnoid Hemorrhage

- Most common cause is trauma
- Does not cause mass effect due to diffuse spreading
- Patients with SAH have increase chance for other space occupying lesions
  - 63-77% → cerebral CTN
  - 44% → SDH
- Increased risk for elevated ICP and IVH
- Can double mortality in brain inured patients
- Treatment
  - Observation



Intraventricular Hemorrhage



- Main significance is an indicator of the severity of trauma
- May predispose patient to post-traumtic hydrocephalus
- Treatment
  - Observation

Diffuse Axonal Injury

- Shearing of axons during sudden rotational force
  - Most of damage occurs 4hrs to days later by proteases that destroy the neurofilaments
- No treatment available
- Most patients are ether severely disabled or in a vegetative state

Herniation

- Occurs when an intracerebral mass or collection of fluid/blood forces brain parenchyma out of its normal position
- 3 types
  - Uncal
  - Subfalcine
  - Tonsillar

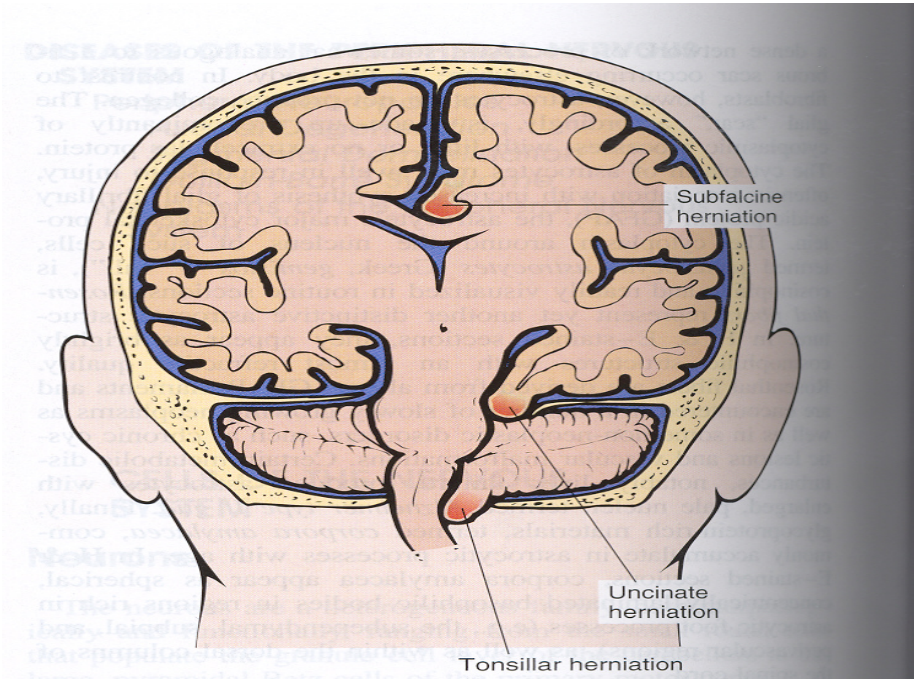
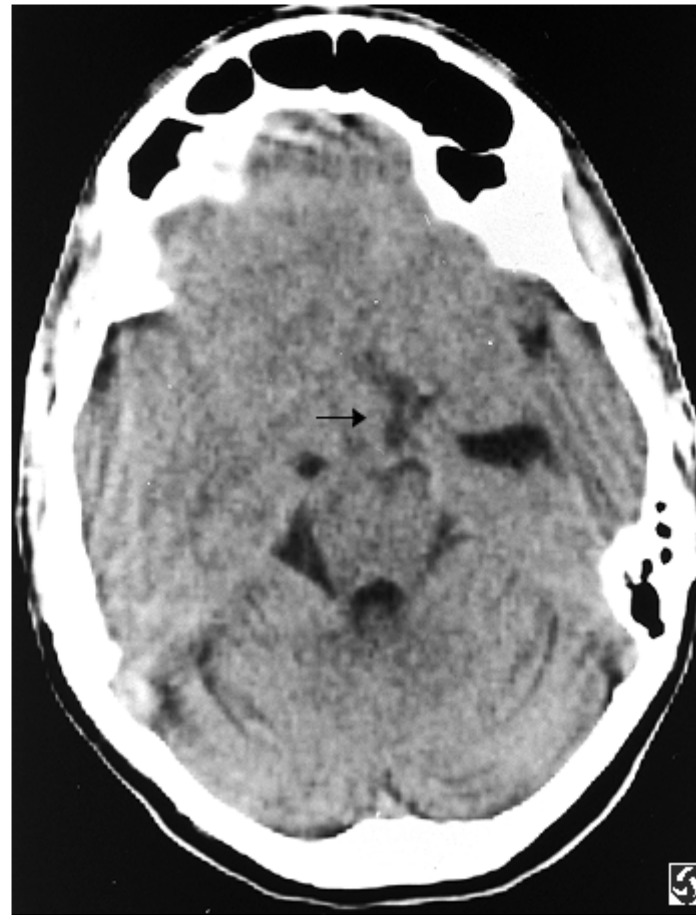


Figure 23–2

Patterns of brain herniation: subfalcine (cingulate), transtentorial (uncinate, mesial temporal), and tonsillar. (Adapted from Fishman RA: Brain edema. N Engl J Med 293:706, 1975. Adapted, with permission, from The New England Journal of Medicine.)

Uncal Herniation

- Herniation of the medial part of the temporal lobe (uncus) across the tentorial ridge
  - Compresses on CNIII and the cerebral peduncle
- PE
  - Blown pupil
  - Contralateral hemiparesis
  - Deterioration of GCS

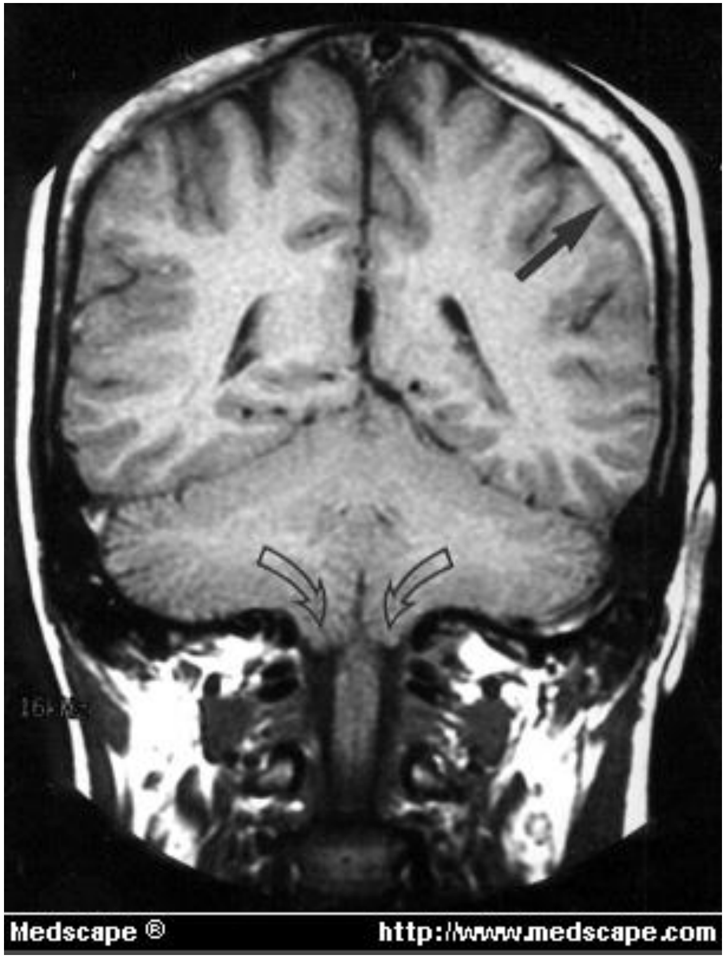


Subfalcine Herniation

- Most common type
- Occurs when singulate gyrus of one frontal lobe herniates below the falx cerebri
- Frequently believed to be a precursor to other types of herniation

Tonsillar Herniation

- Occurs when the cerebellar tonsils push through foramen magna



Management

- ICP management
  - <10 normal, >20 requires treatment, > 40 life threatening
  - CPP = MAP-ICP
    - >70 to ensure cerebral perfusion
- Ventriculostomy catheter
- Intraparenchymal catheter

Management

- Jugular Bulb Venous Oximetry
- Brain Tissue Oxygen Probes
- CVL
- Prevent hyperglycemia
- Prevent hypovolemia
- Permissive hypernatremia
- Hct > 30

What to do if increasing ICP??

- Increase HOB to 30 degrees
- Ensure no neck constriction
- Maintain CPP
- Hypertonic Saline
  - 3% NS
- Hyperventilation
  - decreasing CO_2 = cerebral vasoconstriction
- Sedation
  - Barbiturate can decrease cerebral metabolism up to 60%
- Mannitol
  - Increases serum osmolality to extract free water from brain
- Hypothermia
  - Core body temp decreased to 32-35 degrees < 48h
- Ventriculostomy
- Decompressive hemicraniectomy

Determining Brain Death

- Must return body to homeostasis
  - Normal temp, normal pH, normal BP, normal electrolytes
- No sedation or pain meds
- Brainstem evaluation
- Apnea evaluation
- Confirmatory tests if others are inconclusive

ALGORITHM 55.1 Approach to Determination of Death by Neurologic Criteria

Are homeostatic factors within the normal range?
- Core temperature >36°C
- Systolic blood pressure >90 mm Hg
- Normal serum electrolyte levels: Sodium >130 or <155 mmol/L potassium >2.7 or <6 mmol/L, magnesium >1 mEq/L
- Normal acid-base balance

- Elevate core temperature to >36°C with heating blankets
- Correct hypotension with fluids and vasopressors
- Correct electrolyte abnormalities
- Restore acid-base balance

Is the patient still comatose?

Does the history suggest drug effect?
- Recreation drug overdose
- Neuromuscular blockade
- Persistent effect of sedation or anesthetic agent

- Perform appropriate drug screens, if positive wait for 4–5 half lives of the offending agent to be eliminated
- Consider dialysis or other reversing agents

Examine brainstem reflexes
- Confirm deep coma and complete unresponsiveness to painful stimuli by applying supraorbital, temporomandibular, or nail-bed pressure on at least two locations
- Ensure pupils to be unresponsive to light in a dark room
- Lightly brush each cornea with a soft cotton tip or saline drops to confirm the absence of reflexive eye closing
- Ensure absent eye movements to caloric testing by tilting the head 30° up and irrigating each tympanum with a total of 50 mL of ice water
- Perform bronchial suctioning and confirm the absence of cough

Reflexes present

The patient does not meet criteria for brain death

All reflexes absent

Perform the apnea test
- Ensure temperature above 36.5°C and SBP >90 mm Hg. If patient requires high doses of vasopressors, high PEEP or FiO_2, use other confirmatory tests
- Preoxygenate with 100% FiO_2 for 10 minutes; check baseline pCO_2
- Disconnect the ventilator, insert a catheter through the ETT to the carina, deliver oxygen at 6 L/min
- Observe the chest and abdominal wall for respiration for 8–10 minutes while monitoring vital signs
- If pCO_2 is >60 mm Hg or increased by 20 mm Hg from the baseline value, apnea is confirmed

Are signs of spontaneous breathing present?
- Spontaneous chest or abdominal movements
- pCO_2 <60 mm Hg or less than a 20 mm Hg increase from baseline

Yes

Any ambiguity in the history or law requirement for confirmatory testing?

No
- Patient meets standard clinical criteria for brain death
- Notify organ-procurement agency immediately

Yes

Perform confirmatory testing
- Use method required by law or hospital

SBP, systolic blood pressure; PEEP, positive end-expiratory pressure; ETT, endotracheal tube.

TABLE 50.5 The Clinical Criteria of Brain Death in Adults

Instructions: When Steps 1, 2, and 3 are confirmed, the patient is declared brain dead.	**Check (✓) Item if Confirmed**	
Step 1: Prerequisite to Exam		
Evaluate and correct potentially reversible causes of the abnormal neurological examination. 1. Hypotension (mean arterial pressure <60 mm Hg, arbitrary) 2. Hypothermia (core temperature <32°C or <90°F) 3. Metabolic disturbances (i.e., glucose, electrolyte, acid-base, or endocrine) 4. Significant drugs or medications 5. Confounding diseases (e.g., locked-in syndrome, Guillain-Barré)	☐	
The cause of coma is known and sufficient to account for irreversible brain and brainstem death. Clinical history and/or neurological imaging are consistent with brain death.	☐	
Step 2: Absence of Brain and Brainstem Function This step involves two exams, usually performed 6 hours apart.	**First Exam**	**Second Exam**
Coma: Absent cerebral motor response in all extremities *and* face to noxious stimuli (nail-bed and supraorbital ridge pressure).	☐	☐
Absent Brainstem Reflexes:		
Pupils		
• Size: midposition to dilated (4 to 9 mm)	☐	☐
• Absent response to bright light	☐	☐
Absent corneal reflex (touch edge of cornea)	☐	☐
Absent gag reflex (stimulate pharynx)	☐	☐
Absent cough response (tracheobronchial suction)	☐	☐
Ocular Movement		
• Absent oculocephalic reflex (perform only if cervical spine is stable)	☐	☐
• Absent deviation of eyes with cold water stimulation of the tympanic membranes	☐	☐
Step 2a: Consider Confirmatory Test* if Steps 1 or 2 cannot be fully performed or adequately interpreted.		
Step 3: Absence of Respiratory Effort†		
Positive Apnea Test: Absent respiratory efforts when the arterial PCO_2 increases by more than 20 mm Hg above the patient's normal baseline.	☐	
Step 3a: Consider Confirmatory Test* if Step 3 cannot be fully performed or adequately interpreted.		

***Confirmatory Testing**

These conditions may warrant confirmatory tests: 1) significant levels of drugs (e.g., sedatives, neuromuscular blocking agents, anticholinergics, organophosphates, tricyclic

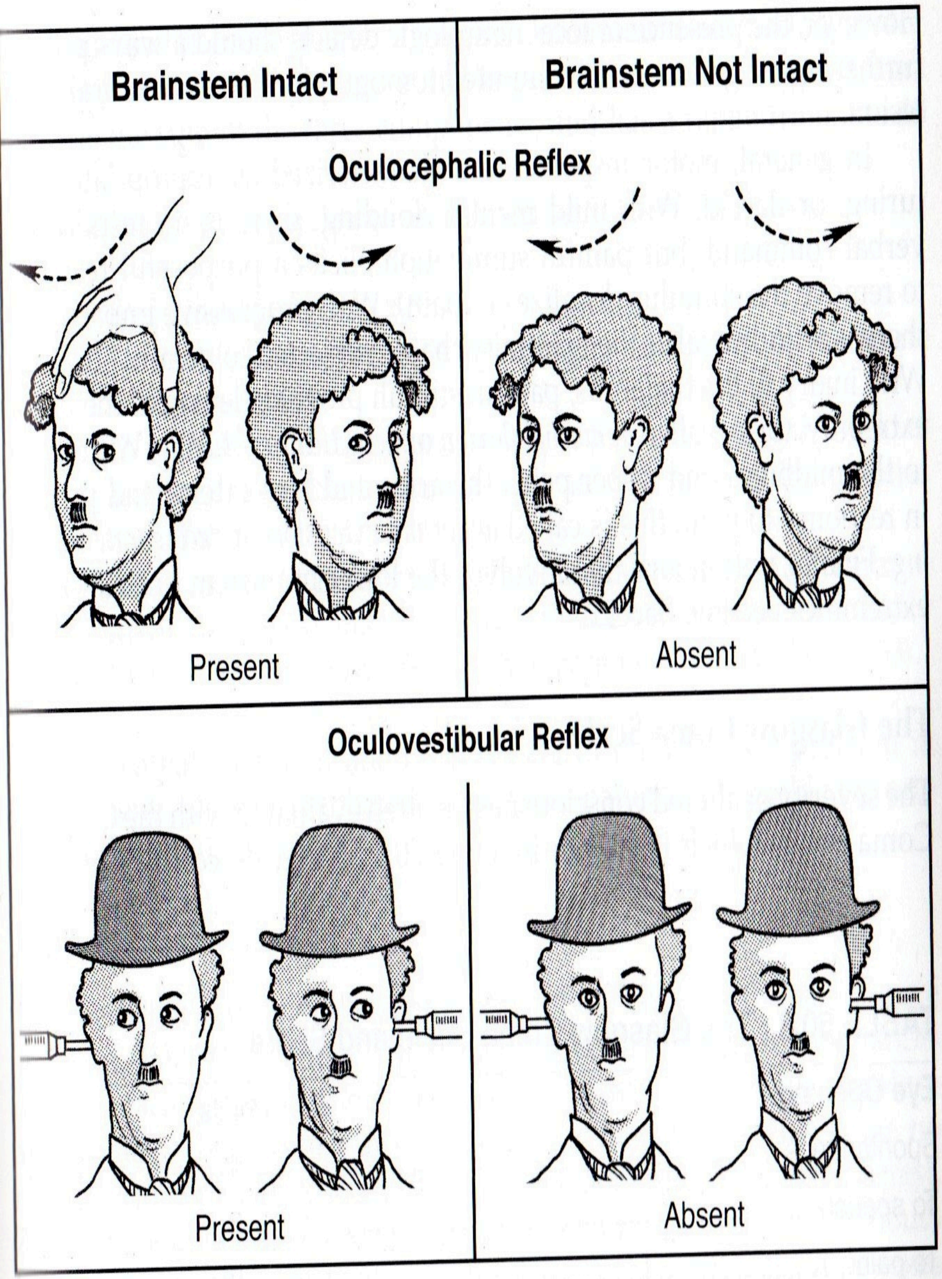


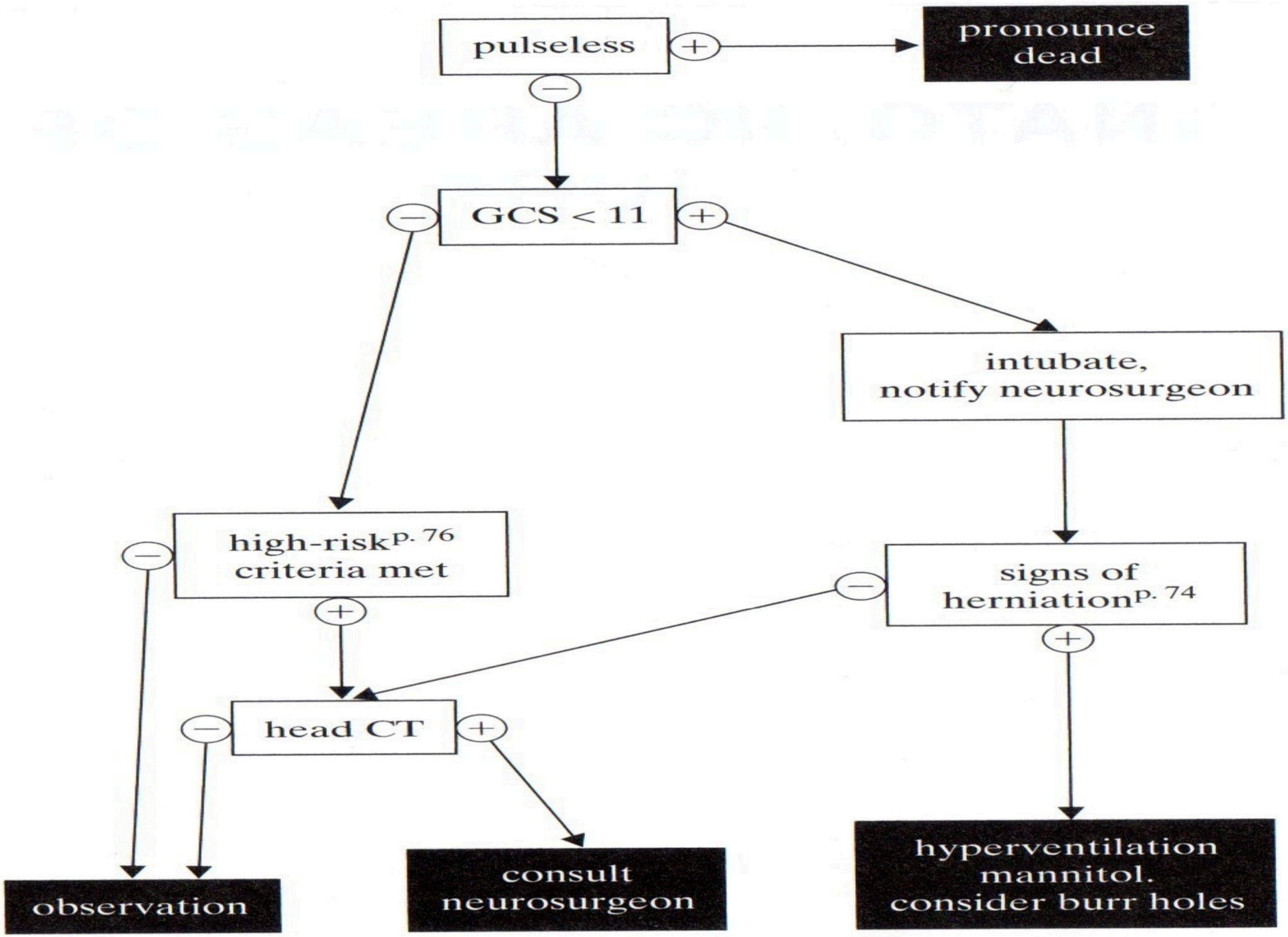
FIGURE 50.4 The ocular reflexes in the evaluation of coma.

TABLE 55.1 Confirmatory Tests Used to Declare Brain Death by Neurologic Criteria

Method	Pros	Cons
Electroencephalography	• Safe • Can be done at bedside	• Prone to artifacts in the ICU • No confirmation of brainstem failure • Prone to confounding factors (false-negative in drug verdose)
Cerebral DSA	High sensitivity and specificity	• Requires transportation • Contrast injection
Cerebral scintigraphy	• Safe • Can be done at bedside • High sensitivity and specificity	
Cerebral TCD	• Safe • Can be done at bedside	• Operator-dependent results • Inability to assess posterior circulation • Repeat studies may be needed

ICU, intensive care unit; DSA, digital subtraction angiography; TCD, transcranial Doppler ultrasonography.

Head Trauma


pulseless
+
pronounce dead
−
GCS < 11
−
+
intubate, notify neurosurgeon
high-risk p. 76 criteria met
−
+
signs of herniation p. 74
−
+
head CT
−
+
observation
consult neurosurgeon
hyperventilation mannitol. consider burr holes

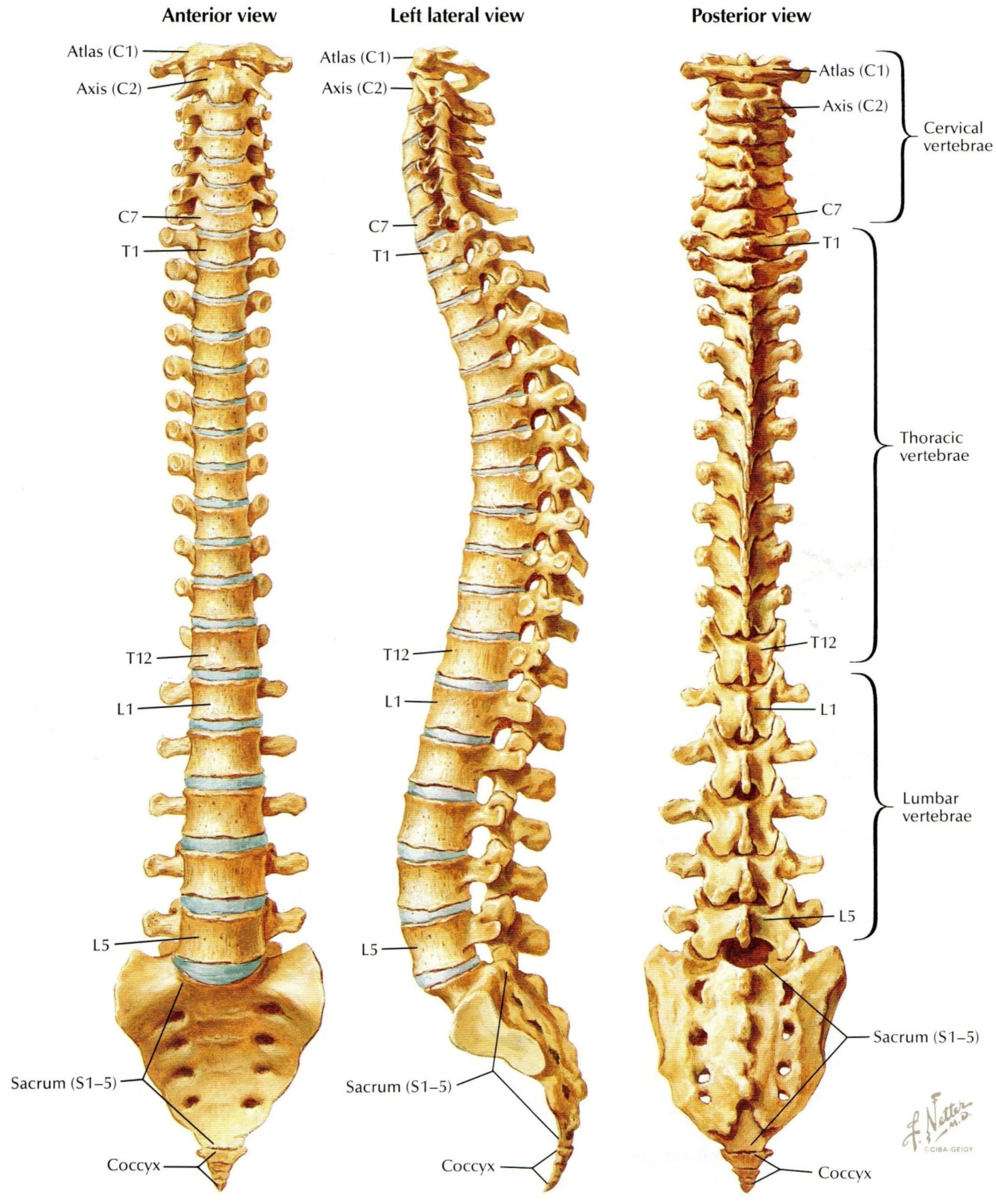
Vertebral and Spinal Cord Injuries

Introduction

- 4.3% incidence of cervical spine and 6.3% incidence of thoracolumbar spine injuries in all trauma patients
  - 1.3% of these patients have spinal cord injuries
    - 55% C-spine, 30% T-spine, 15% L-spine
- C-spine injuries
  - 25% occur in Oc-C2
  - 75% occur in C3-C7

Basic Principles

- Avoid progression of neurologic deficit
- Reduce unacceptable spinal deformity or malalignment to facilitate neurologic decompression and permit a functional ROM
- Maintain spinal alignment
- Achieve healing of the spine


Anterior view
Left lateral view
Posterior view
Atlas (C1)
Axis (C2)
C7
T1
T12
L1
L5
Sacrum (S1–5)
Coccyx
Atlas (C1)
Axis (C2)
C7
T1
T12
L1
L5
Sacrum (S1–5)
Coccyx
Atlas (C1)
Axis (C2)
Cervical vertebrae
C7
T1
Thoracic vertebrae
T12
L1
Lumbar vertebrae
L5
Sacrum (S1–5)
Coccyx
F. Netter M.D.
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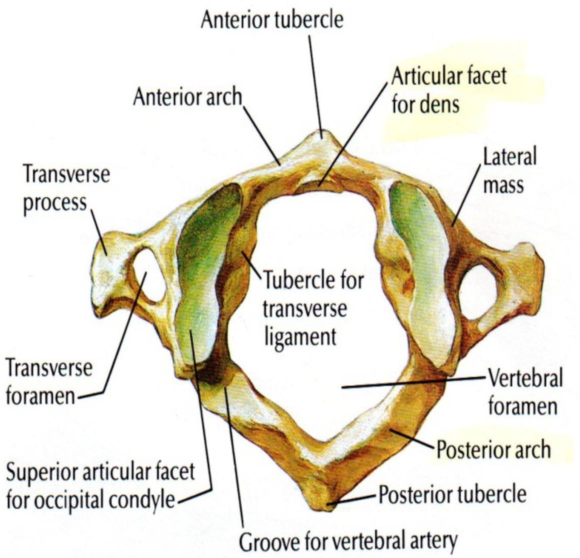
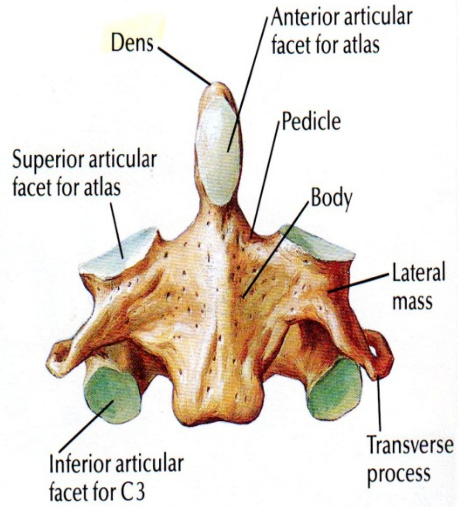
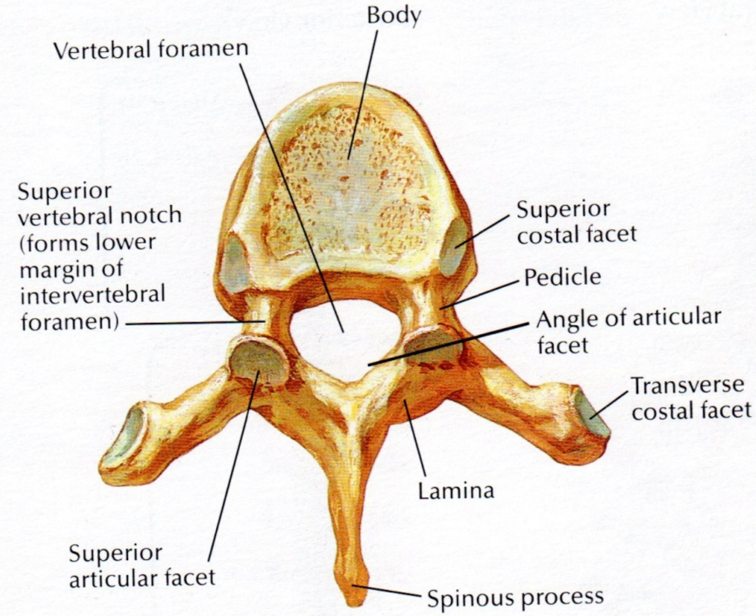


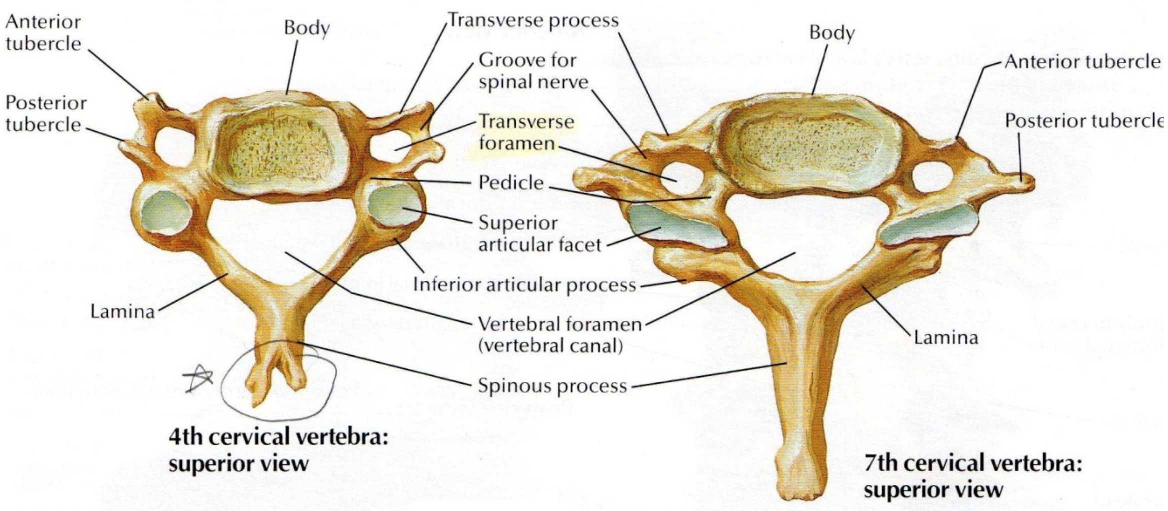
Atlas (C 1): superior view



Axis (C 2): anterior view

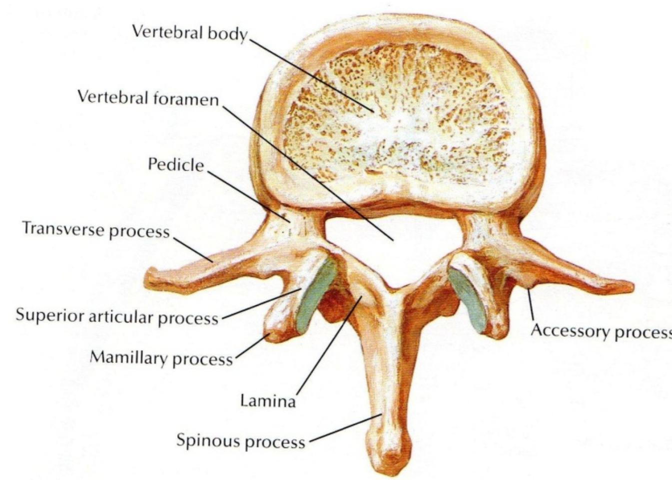


6th thoracic vertebra: superior view



4th cervical vertebra: superior view

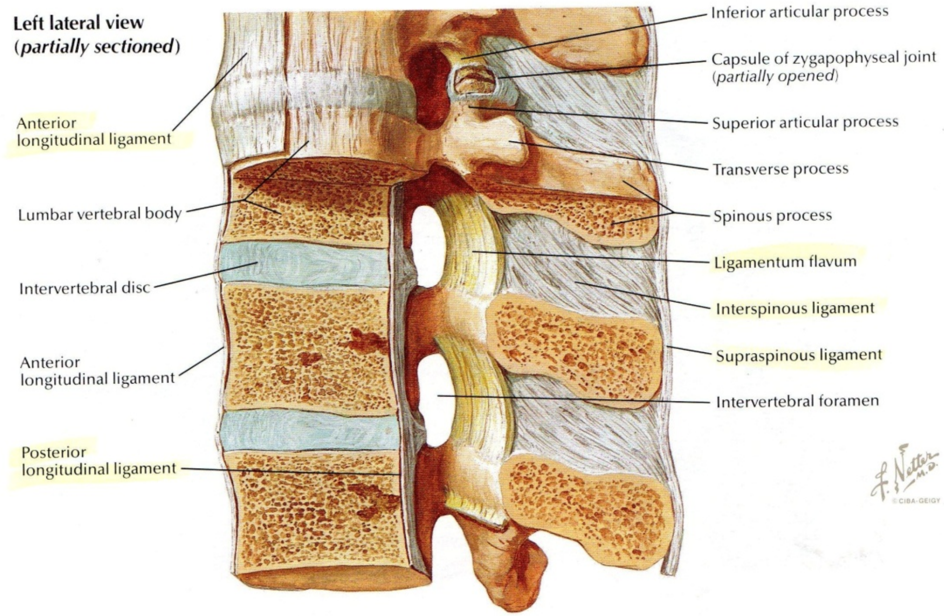
7th cervical vertebra: superior view



2nd lumbar vertebra: superior view

Acute Injury to Vertebral Column

- Instability
  - Loss of the ability of the spine to maintain its pattern of the displacement of its elements under physiologic loads
    - This can lead to subsequent damage or irritation to the spinal cord and roots
  - 3 columns of stability
    - Anterior
      - Anterior Longitudinal Ligament
    - Middle
      - Posterior Longitudinal Ligament
    - Posterior
      - Ligamentum Flavum
      - Interspinous Ligament
      - Supraspinous Ligament



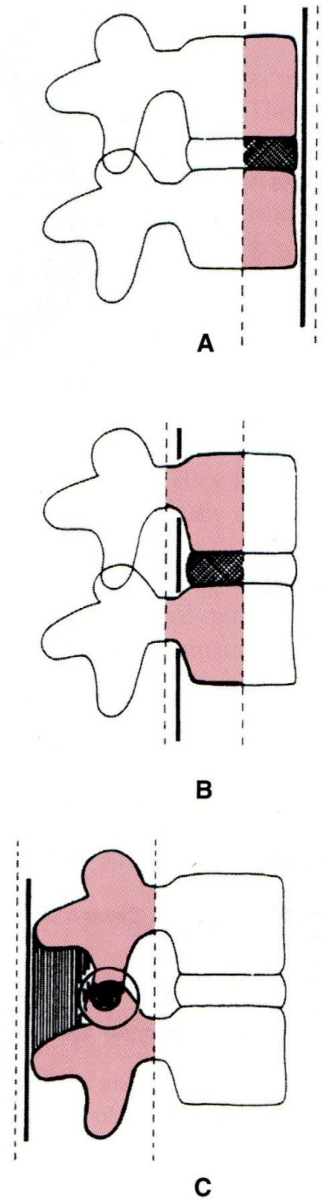


FIGURE 24-8. The three-column theory of the thoracolumbar spine distinguishes between the anterior **(A)**, middle **(B)** and posterior columns **(C)**. *(Reproduced with permission from Denis F. The three-column spine and its significance in the classification of acute thoracolumbar spinal injuries. Spine 8:817–831, 1983).*

Criteria for Instability

TABLE 24-2

Checklist for the Diagnosis of Clinical Instability of the Lower Cervical Spine (Total ≥ 5 Points = Unstable)

ELEMENT		POINTS
Anterior elements destroyed or unable to function		2
Posterior elements destroyed or unable to function		2
Radiographic criteria	Total	4
A. Sagittal displacement >3.5 mm	2	
B. Relative sagittal angulation >11°	2	
Positive stretch test		2
Spinal cord injury		2
Nerve root Injury		1
Abnormal disc narrowing		1
Dangerous loading anticipated		1

Adapted from: White, A.A.; Southwick, W.O.; Panjabi, M.M. Clinical instability in the lower cervical spine. *Spine* 1:15-27, 1976.

TABLE 24-4

Checklist for the Diagnosis of Clinical Instability of the Lumbosacral Spine (Total ≥ 5 Points = Unstable)

ELEMENT			POINTS
Anterior elements destroyed or unable to function			2
Posterior elements destroyed or unable to function			2
Radiographic criteria		Total	4
A. Flexion-extension radiographs:			
1. Sagittal translation	>4.5 mm or 15%	2	
2. Sagittal rotation	>15° at L1–L2, L2–L3, L3–L4	2	
	>20° at L4–L5	2	
	>25° at L5–S1	2	
B. Resting radiographs			
1. Sagittal displacement	>4.5 mm or 15%	2	
2. Relative sagittal angulation	>22°	2	
Cauda equina damage		3	
Dangerous loading anticipated		1	

Adapted from: White, A.A.; Penjabi, M.M. *Clinical Biomechanics of the Spine.* Philadelphia, JB

TABLE 24-3

Checklist for the Diagnosis of Clinical Instability of the Thoracic and Thoracolumbar Spine (Total ≥ 5 Points = Unstable)

ELEMENT		POINTS
Anterior elements destroyed or unable to function		2
Posterior elements destroyed or unable to function		2
Radiographic criteria	Total	4
A. Sagittal displacement >2.5 mm	2	
B. Relative sagittal angulation >5°	2	
Spinal cord or cauda equina damage		2
Disruption of costovertebral articulations		1
Dangerous loading anticipated		2

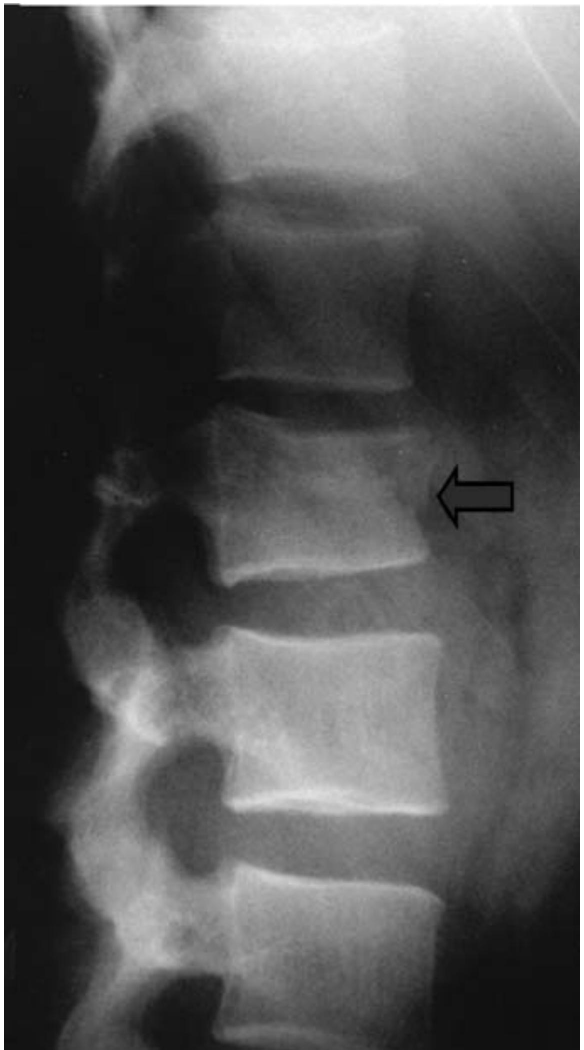
Adapted from: White, A.A.; Penjabi, M.M. *Clinical Biomechanics of the Spine.* Philadelphia, JB Lippincott, 1978, pp.236-251.

Mechanisms

- Flexion-Compression
  - Excessive flexion or biomechanical incompetence of VB (osteoporosis)
  - Wedge Fracture
  - Flexion Teardrop Fracture
    - Highly unstable
    - High incidence of neurologic compromise

C2 Teardrop Fx

Mechanisms

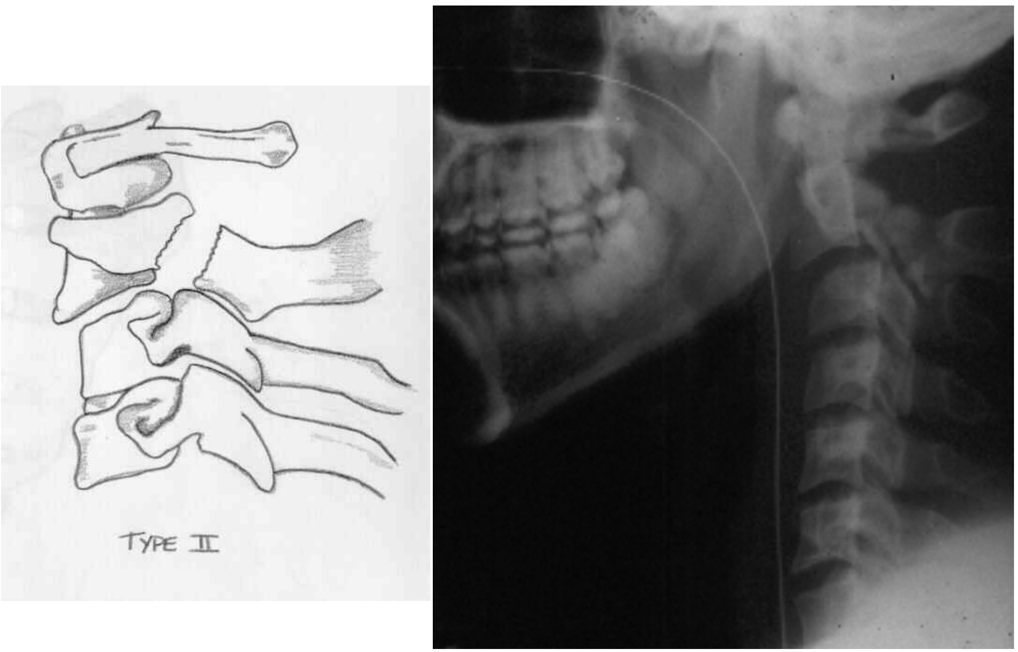


- Axial Compression
  - Results in burst fracture
  - Injury severity is determined by fracture comminution, degree of retropulsion with concomitant neurologic deficit, and residual deformity
  - What is this fracture?
    - Jefferson Fracture
      - 4 part burst fracture of C1

Mechanism

- Flexion-Distraction
  - Flexion with a pivot point anteriorly
  - Fracture with significant disruption of posterior stabilizing elements
  - Very unstable
  - Chance Fracture
    - Associated with seat belt restraints
    - Increased interspinous process distance on AP
    - Increased posterior height of VB on lateral

Mechanism



- Hyperextension
  - Disruption of anterior and middle columns in tension
  - Commonly associated with subluxation and dislocation
  - Unstable
  - Traumatic spondylolisthesis of C2 is called what?
    - Hangman's Fracture

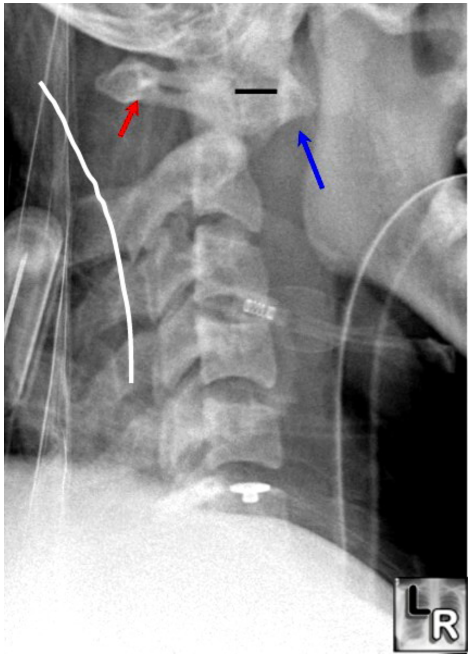
Mechanism

- Rotation
  - Flexion/extension injuries that include significant rotation component often result in subluxation, dislocation, and fracture dislocation of spinal facets
  - Unstable
  - Bilateral Facet Dislocation
    - Disruption of posterior ligaments with superior facets passing forward and upward, locking over inferior facets
    - Spinal cord injury common
      - 85% complete, 15% incomplete

C6 Dislocation with Cord CTN

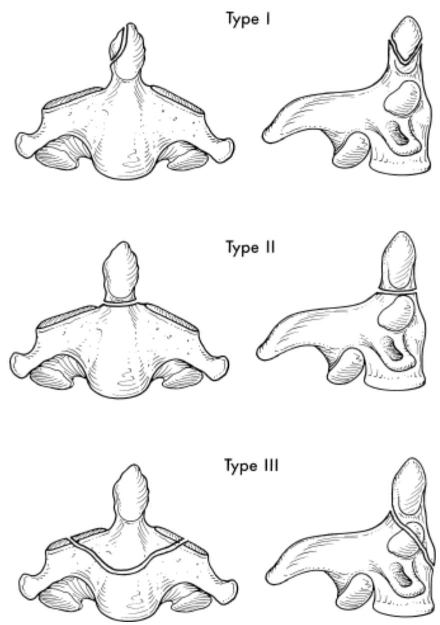
Rotational

- Atlanto-Occipital Dislocation
  - Tearing of all ligamentous connections between C1 and occiput
  - Almost always immediately fatal
  - Displacement of occipital condyles from superior articulating facets of C1
- Atlanto-Axial Dislocation
  - Rupture of transverse ligament drives odontoid into medulla
  - Increased predental space



Mechanism

- Avulsion
  - C7 spinous process fracture
    - Clay Shoveler’s Fracture
  - Odontoid Fractures
    - Type I
      - Avulsion at tip of dens
      - Stable
    - Type II
      - Trasnverse fracture at base of odontoid
      - Unstable, require surgery
    - Type III
      - Fracture through body of C2 involving superior facets
      - Can be unstable



Mechanism

- Shear
  - Produces failure of all three columns
  - Often associated with facet dislocation
- Direct Force
  - Transverse Process Fracture

Treatment

- HALO
  - Can be stabilizing and therapeutic
- TLSO Braces
- Surgical repair
  - Waiting up to 72 hours to allow for posttraumatic swelling to subside

Spinal Cord Injuries

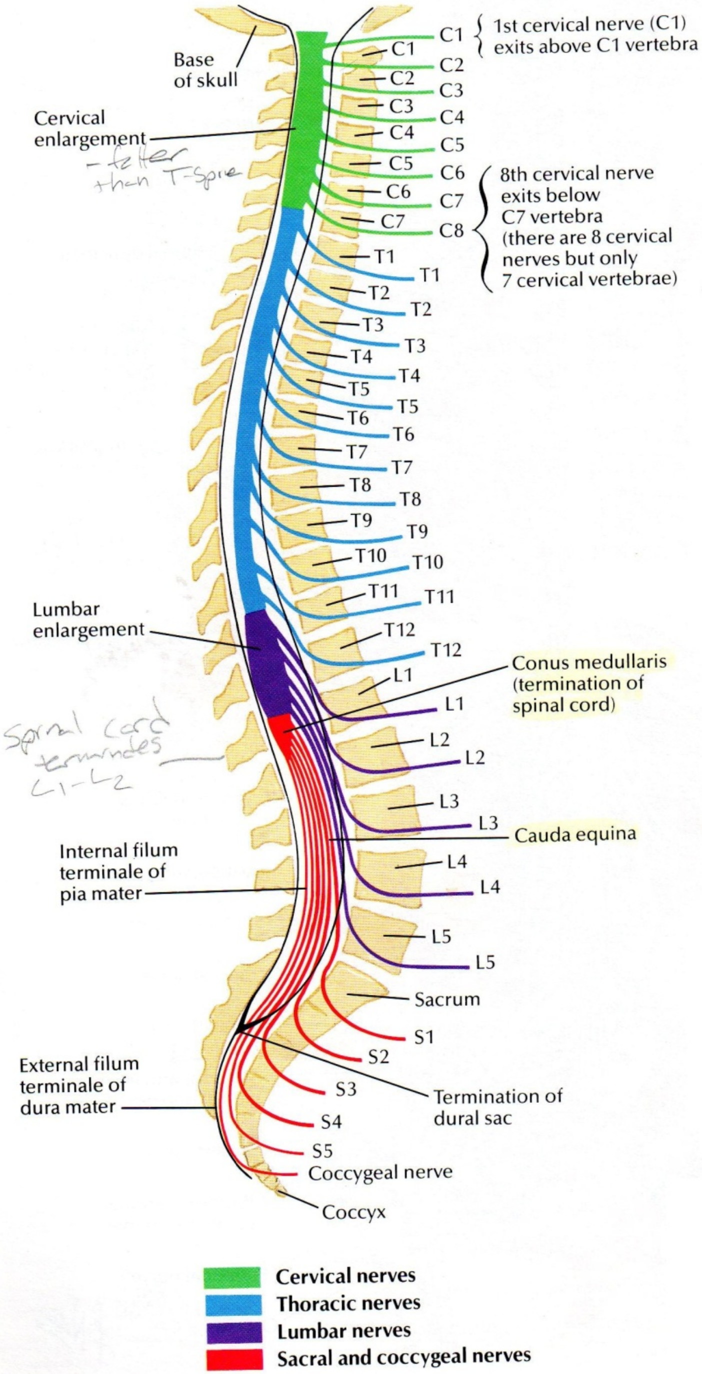
- 3 types of injuries
  - Direct space occupying lesions
    - Focal injury to neural elements at site of impact
      - High force concentrated on small area
  - Direct non-occupying lesion
    - Stretching, shearing, or compressive force applied to spinal cord via bony-ligamentous compression of spine
    - Small load distributed over large area of cord
    - Presents with more diffuse patterns of neurologic deficits
  - Secondary injury
    - Disruption of blood supply to spinal cord of passage of CSF

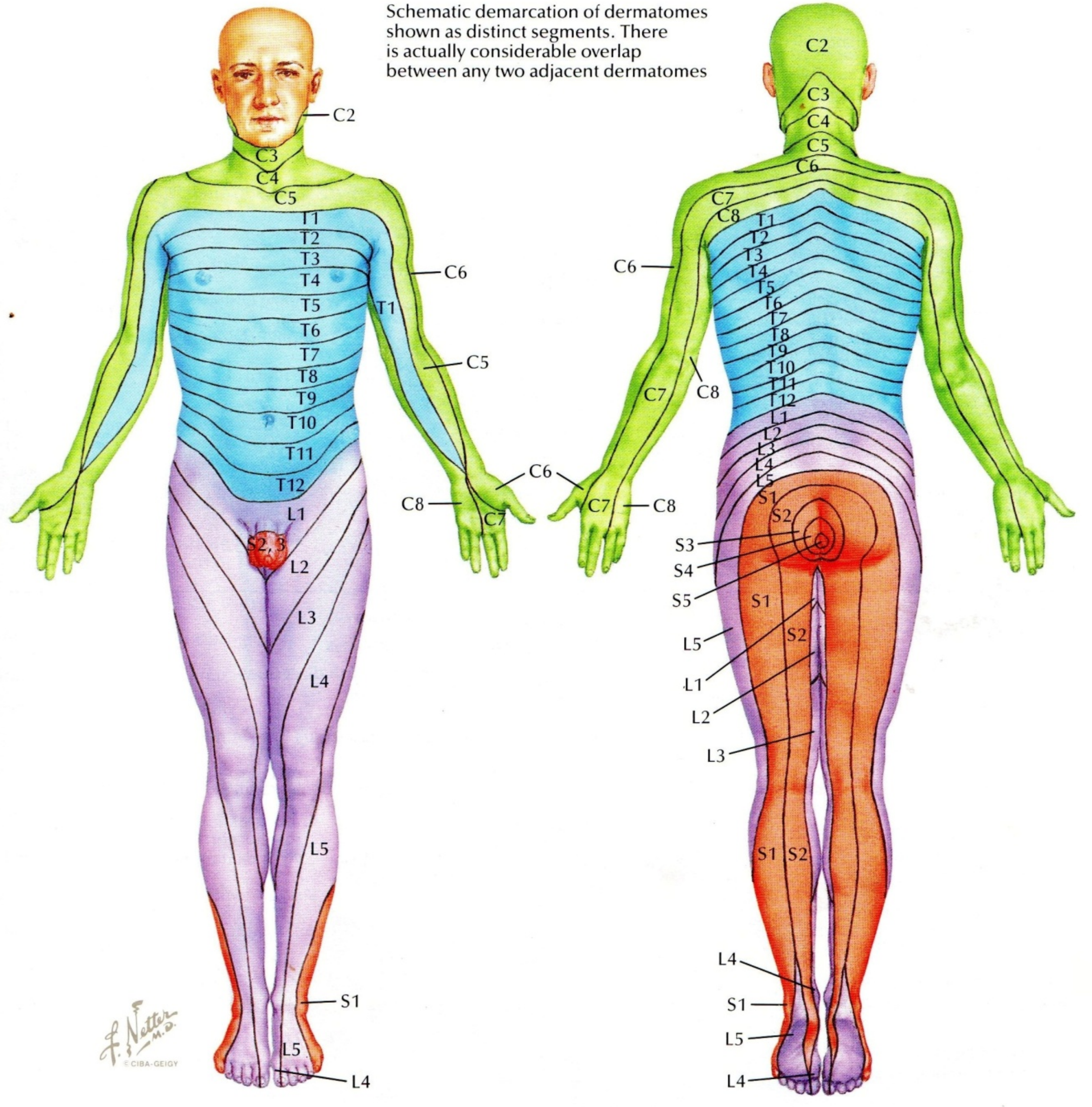
Damage following SCI

- Main damage
  - At/Near the site of injury
- Neighboring damage
  - Areas adjacent to the main damage
    - Hemorrhages, necrosis, edema
- Gray matter located in the central cord is most susceptible to injury
  - Higher metabolic rate and presence of repair mechanisms within the site of the injury
- Spinal cord may not show significant macroscopic or histopathologic changes until 6-24hrs after injury

Damage following SCI

- Initial traumatic events results in compression and contusion of spinal cord, with mechanical damage to nerve cells, axonal tracts, and blood vessels
- As a response to initial mechanical insult, hemorrhage, edema, and ischemia rapidly follow and extend into neighboring areas
- After the initial hemorrhage, inflammation proceeds in the central gray matter which leads to autonomic dysfunction, hypotension, and bradycardia which potentates ischemia





Levels of principal dermatomes

C5	Clavicles
C5, 6, 7	Lateral parts of upper limbs
C8, T1	Medial sides of upper limbs
C6	Thumb
C6, 7, 8	Hand
C8	Ring and little fingers
T4	Level of nipples
T10	Level of umbilicus
T12	Inguinal or groin regions
L1, 2, 3, 4	Anterior and inner surfaces of lower limbs
L4, 5, S1	Foot
L4	Medial side of great toe
S1, 2, L5	Posterior and outer surfaces of lower limbs
S1	Lateral margin of foot and little toe
S2, 3, 4	Perineum

STANDARD NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY

MOTOR

KEY MUSCLES

	R	L	
C2			
C3			
C4			
C5			Elbow flexors
C6			Wrist extensors
C7			Elbow extensors
C8			Finger flexors (distal phalanx of middle finger)
T1			Finger abductors (little finger)
T2			
T3			
T4			
T5			
T6			
T7			
T8			
T9			
T10			
T11			
T12			
L1			
L2			Hip flexors
L3			Knee extensors
L4			Ankle dorsiflexors
L5			Long toe extensors
S1			Ankle plantar flexors
S2			
S3			
S4–5			

0 = Total paralysis
1 = Palpable or visible contraction
2 = Active movement, gravity eliminated
3 = Active movement, against gravity
4 = Active movement, against some resistance
5 = Active movement, against full resistance
NT = Not testable

☐ Voluntary anal contraction (Yes/No)

TOTALS ☐ + ☐ = ☐ **MOTOR SCORE**

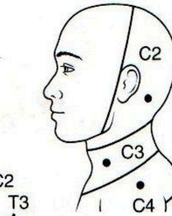
(MAXIMUM) (50) (50) (100)

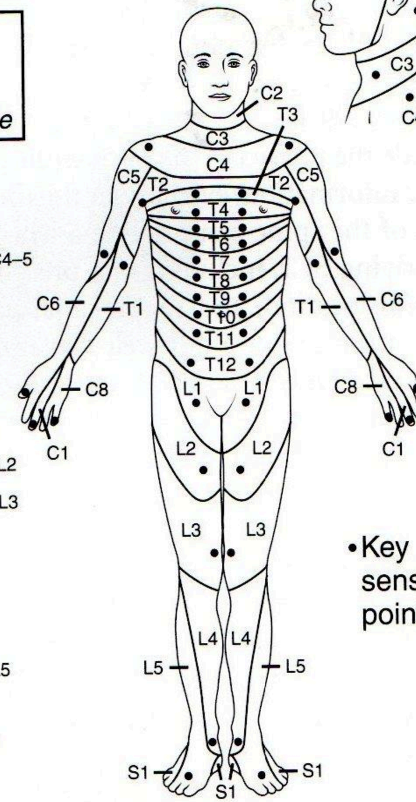
SENSORY

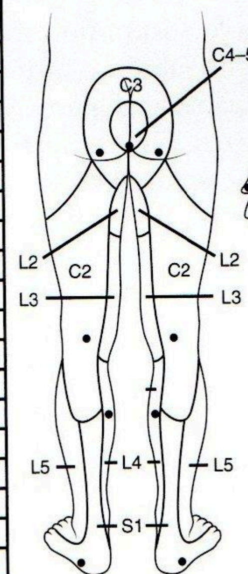
KEY SENSORY POINTS

	LIGHT TOUCH R	LIGHT TOUCH L	PIN PRICK R	PIN PRICK L
C2				
C3				
C4				
C5				
C6				
C7				
C8				
T1				
T2				
T3				
T4				
T5				
T6				
T7				
T8				
T9				
T10				
T11				
T12				
L1				
L2				
L3				
L4				
L5				
S1				
S2				
S3				
S4–5				

0 = Absent
1 = Impaired
2 = Normal
NT = Not testable







• Key sensory points

☐ Any anal sensation (Yes/No)

☐ + ☐ = ☐ **PIN PRICK SCORE** (max: 112)

TOTALS ☐ + ☐ = ☐ **LIGHT TOUCH SCORE** (max: 112)

(MAXIMUM) (56) (56) (56) (56)

NEUROLOGICAL LEVEL

The most caudal segment with normal function

	R	L
SENSORY		
MOTOR		

COMPLETE OR INCOMPLETE? ☐

Incomplete = Presence of any sensory or motor function in lowest sacral segment

ZONE OF PARTIAL PRESERVATION

Partially innervated segments

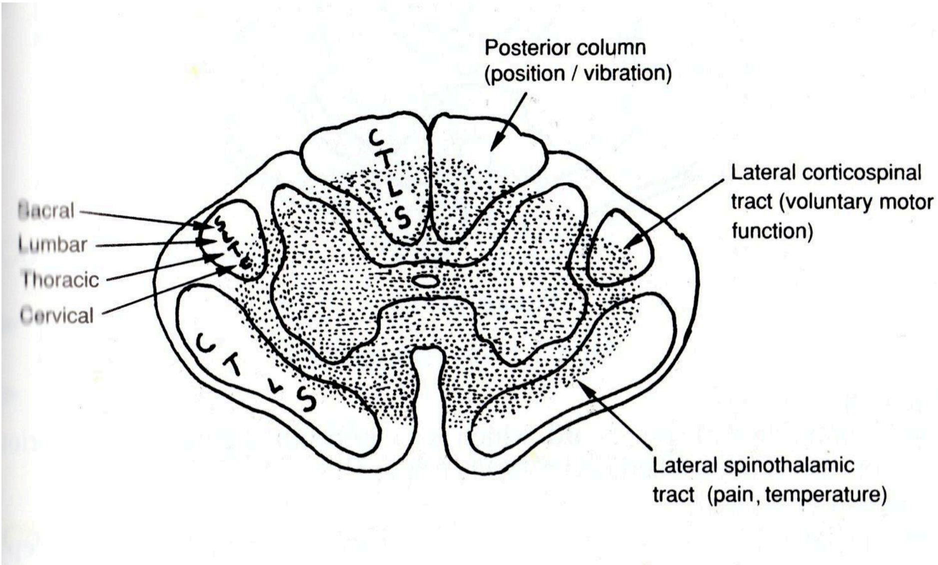
	R	L
SENSORY		
MOTOR		

Incomplete vs Complete

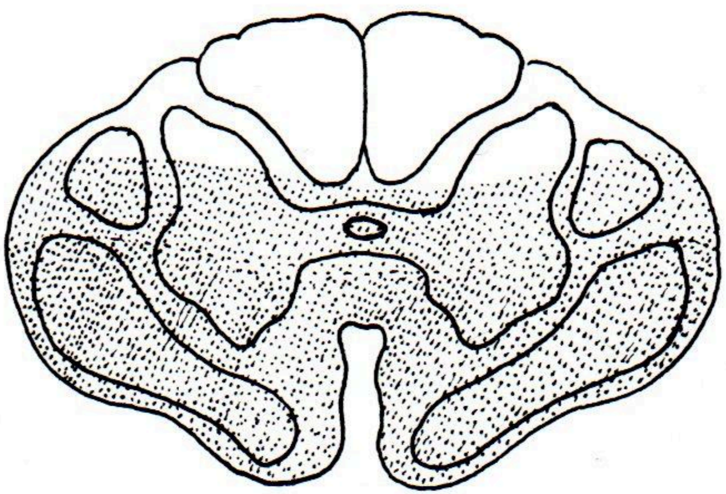
- Complete SCI
  - Complete loss of sensorimotor function below the level of injury
- Incomplete SCI
  - Sacral sparing
    - Perianal sensation
    - Rectal sphincter tone
    - Slight toe flexion
  - Central, Anterior, Brown-Sequard, Conus Medullaris, Cauda Equina

Central Cord Syndrome

- Hyperextension injury with pre-existing cervical spondylosis
  - Forward fall onto the face, hitting head on windshield without seatbelt in MVC
  - Ligamentum flavum buckles into the cord causing contusion
- LE strength > UE strength
- Can have bowel/bladder dysfunction
- 50% regain some function
  - LE strength, then bowel/bladder, the UE strength



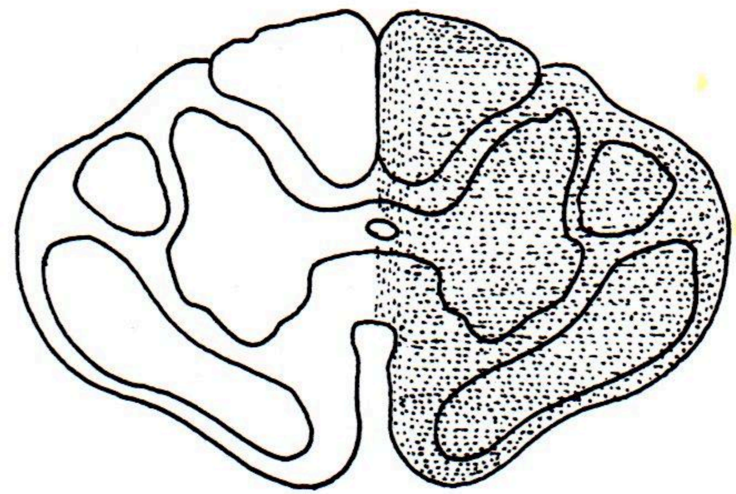
Anterior Cord Syndrome



- Flexion injuries with posterior protrusion of bony fragments or herniation causing direct damage to anterior cord
- Injury to anterior 2/3rd of cord, on the opposite site of spine injury
- Complete loss of motor function, temperature, and sharp pain, but retain proprioception, vibration, and deep pressure
- Poorest prognosis of all incomplete cord injuries
  – Most patients do not regain motor function

Brown-Sequard Syndrome

- Hemitransection of spinal cord with unilateral damage to corticospinal and spinothalamic tracts, with subsequent loss of ipsilateral motor, vibratory sensation, and proprioception, and contralateral loss of pain and temperature sensation
- Good prognosis



Conus Medullaris Syndrome

- Located at T11-L1 and is where the spinal cord terminates
- Sacral cord injury with involvement of the lumbar roots
- Variable sensorimotor loss in LE
- Loss of bowel/bladder control
  - No sacral sparing
- Poor prognosis

Cauda Equina Syndrome

- Extends from L1 to L5 and is composed entirely from lumbar and sacral nerve roots
- Usually due a large central lumbar disc herniation with injury to bilateral lumbosacral nerve roots
- Variable sensorimotor loss in LE
- Loss of bowel/bladder control
- Areflexic in LE

Management

- Prevent secondary injury to spinal cord
  - Prevent hypotension
    - MAP > 85
  - Prevent hypoxia
    - PaO2 > 80
  - Prevent inflammation
    - Solumedrol
      - 30mg/kg bolus over 15min
      - 5.4mg/kg/hr for 23hr

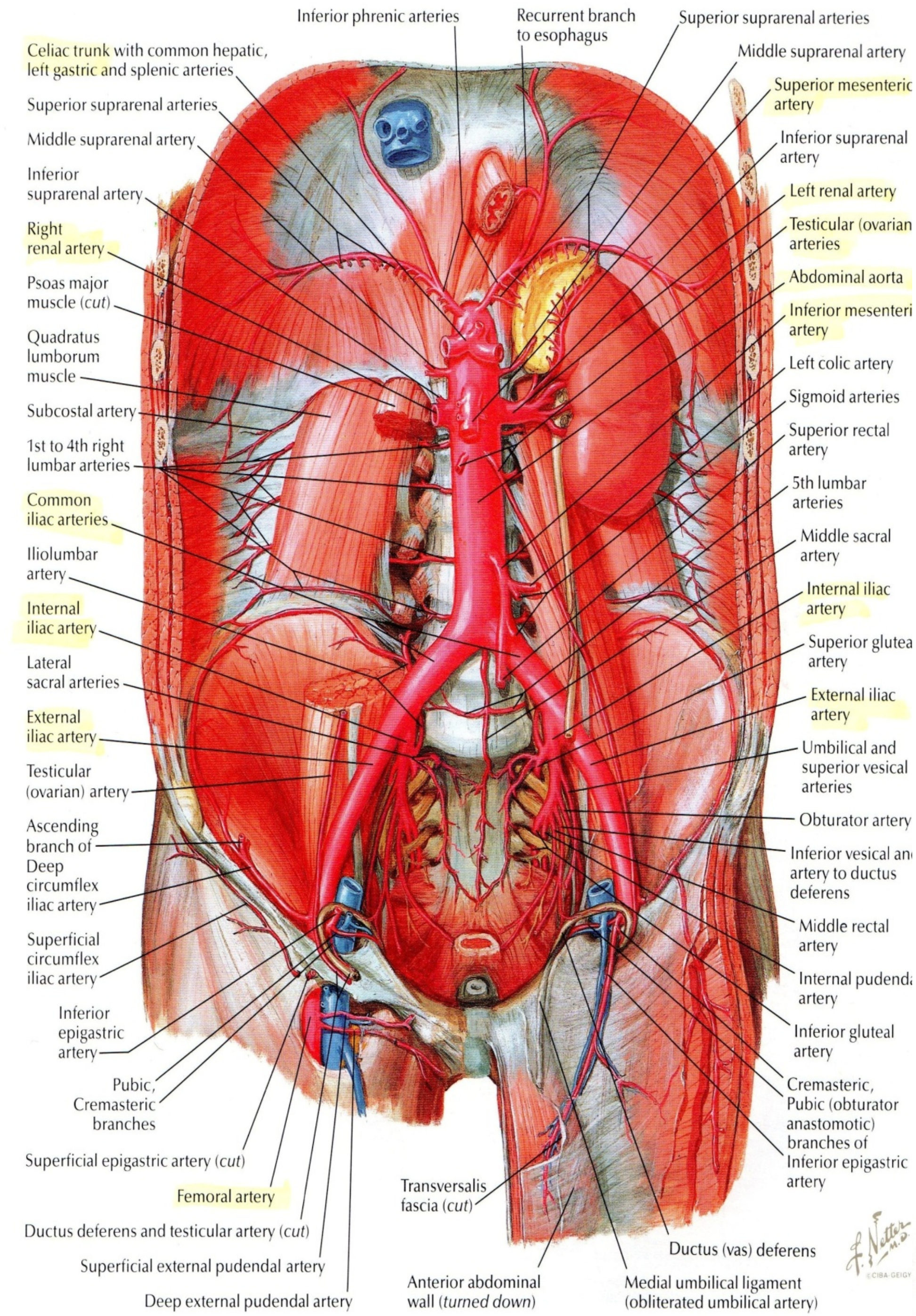
Complications

- Pulmonary
  - SCI above C4 compromises phrenic nerve function resulting in subsequent diaphragm dysfunction and need for permanent mechanical ventilation
  - Injury to lower cervical and upper thoracic levels can impair innervation to accessory muscles of respiration which leads to progressive loss of vital capacity, tidal volume, and negative inspiratory pressure
    - Abdominal binder
  - Impaired cough leads to increased risk of PNA

Complications

- DVT
  - IVC filter and anticoagulation
- GU
  - Elevated bladder pressures from incomplete voiding, increased risk for UTI, need for permanent catheterization
- GI
  - Increased risk for gastric ulcer from gastric capillary bed ischemia
  - Acalculous cholecystitis
- Integumentary
  - Increased risk of decubitus ulcers

Abdominal Vascular Injuries


Inferior phrenic arteries
Recurrent branch to esophagus
Superior suprarenal arteries
Celiac trunk with common hepatic, left gastric and splenic arteries
Middle suprarenal artery
Superior mesenteric artery
Superior suprarenal arteries
Middle suprarenal artery
Inferior suprarenal artery
Inferior suprarenal artery
Left renal artery
Right renal artery
Testicular (ovarian) arteries
Abdominal aorta
Psoas major muscle (cut)
Inferior mesenteri artery
Quadratus lumborum muscle
Left colic artery
Sigmoid arteries
Subcostal artery
Superior rectal artery
1st to 4th right lumbar arteries
5th lumbar arteries
Common iliac arteries
Middle sacral artery
Iliolumbar artery
Internal iliac artery
Internal iliac artery
Superior glutea artery
Lateral sacral arteries
External iliac artery
External iliac artery
Umbilical and superior vesical arteries
Testicular (ovarian) artery
Obturator artery
Ascending branch of Deep circumflex iliac artery
Inferior vesical an artery to ductus deferens
Middle rectal artery
Superficial circumflex iliac artery
Internal pudend artery
Inferior epigastric artery
Inferior gluteal artery
Pubic, Cremasteric branches
Cremasteric, Pubic (obturator anastomotic) branches of Inferior epigastric artery
Superficial epigastric artery (cut)
Femoral artery
Transversalis fascia (cut)
Ductus deferens and testicular artery (cut)
Ductus (vas) deferens
Superficial external pudendal artery
Anterior abdominal wall (turned down)
Medial umbilical ligament (obliterated umbilical artery)
Deep external pudendal artery
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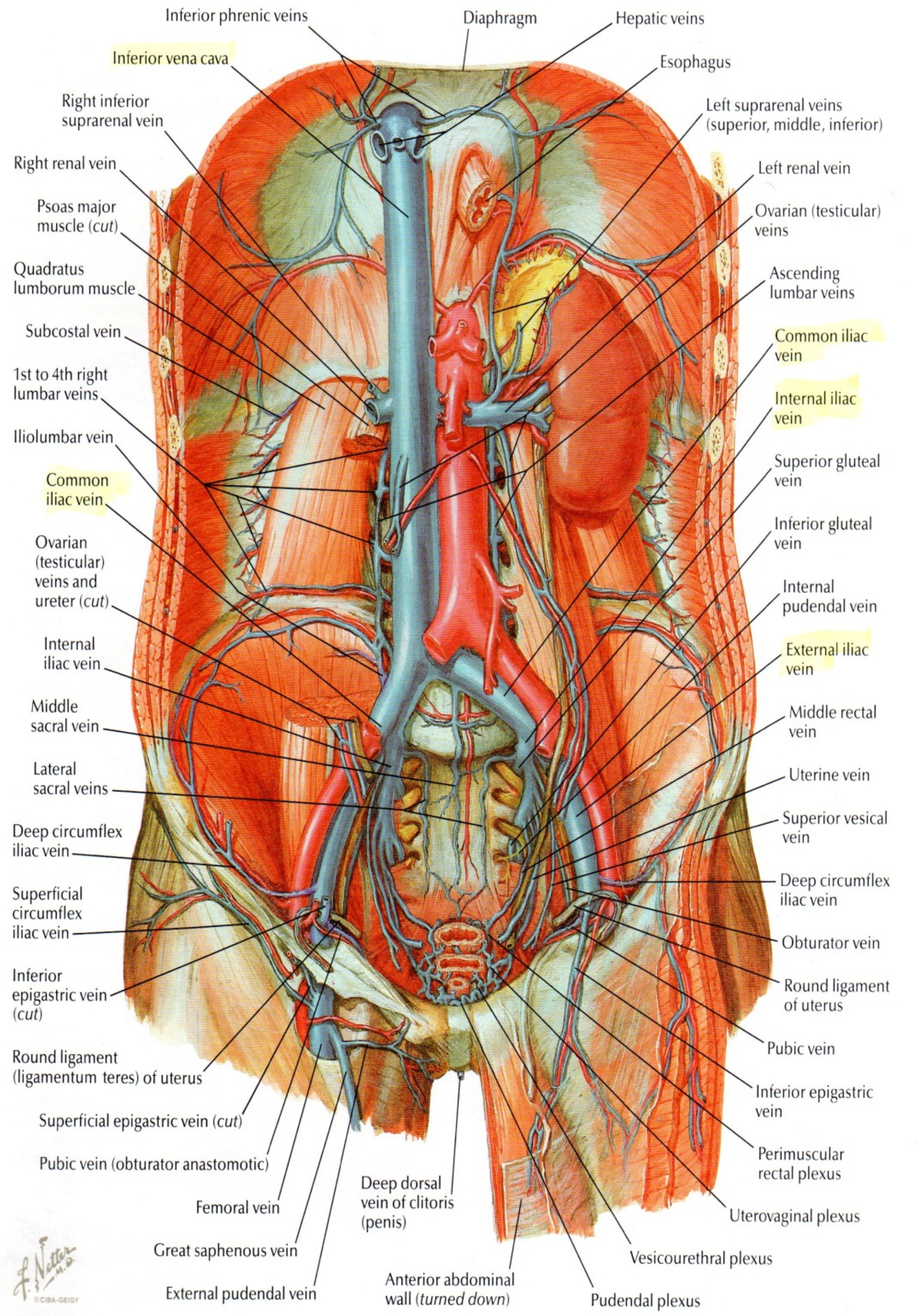
Inferior phrenic veins
Diaphragm
Hepatic veins
Inferior vena cava
Esophagus
Right inferior suprarenal vein
Left suprarenal veins (superior, middle, inferior)
Right renal vein
Left renal vein
Psoas major muscle (cut)
Ovarian (testicular) veins
Quadratus lumborum muscle
Ascending lumbar veins
Subcostal vein
Common iliac vein
1st to 4th right lumbar veins
Internal iliac vein
Iliolumbar vein
Superior gluteal vein
Common iliac vein
Inferior gluteal vein
Ovarian (testicular) veins and ureter (cut)
Internal pudendal vein
Internal iliac vein
External iliac vein
Middle sacral vein
Middle rectal vein
Lateral sacral veins
Uterine vein
Superior vesical vein
Deep circumflex iliac vein
Deep circumflex iliac vein
Superficial circumflex iliac vein
Obturator vein
Inferior epigastric vein (cut)
Round ligament of uterus
Pubic vein
Round ligament (ligamentum teres) of uterus
Inferior epigastric vein
Superficial epigastric vein (cut)
Perimuscular rectal plexus
Pubic vein (obturator anastomotic)
Deep dorsal vein of clitoris (penis)
Femoral vein
Uterovaginal plexus
Great saphenous vein
Vesicourethral plexus
External pudendal vein
Anterior abdominal wall (turned down)
Pudendal plexus
F. Netter M.D.
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Physiology

- Blunt Trauma
  - Rapid deceleration
    - Avulsion of small branches from major vessels
      - Intestinal branches off of SMA
    - Intimal tear with secondary thrombosis of the lumen
  - Crush Injury
    - Intimal tear or flap with secondary thrombosis
      - Seatbelt aorta
- Penetrating Trauma
  - Most common cause of abdominal vascular injury

Presentation

- Contained hematomas can present hemodynamically stable
  - CT with contrast, CT angio, angiography to diagnose injury
- Patients presenting with hypotension, + FAST exam, peritoneal signs spend 5min in ED getting lines and tubes before OR

Classification

- Zone I – Midline Retroperitoneum
  - Supramesocolic
    - Suprarenal aorta, celiac axis, proximal SMA, proximal renal artery, SMV
  - Inframesocolic
    - Infrarenal aorta and infrahepatic IVC
- Zone II – Upper Lateral Retroperitoneum
  - Renal vessels
- Zone III - Pelvic Retroperitoneum
  - Common, external, and internal illiac vessels

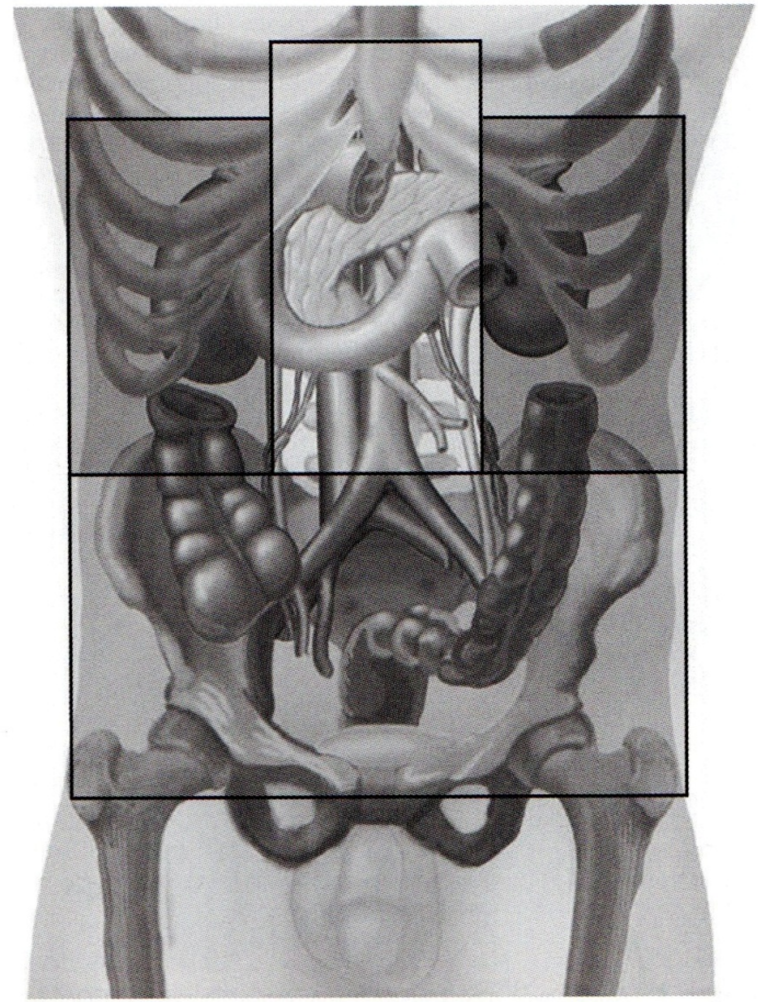
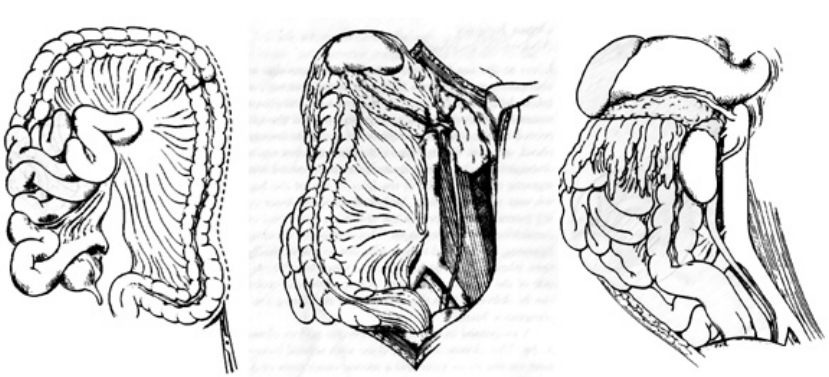


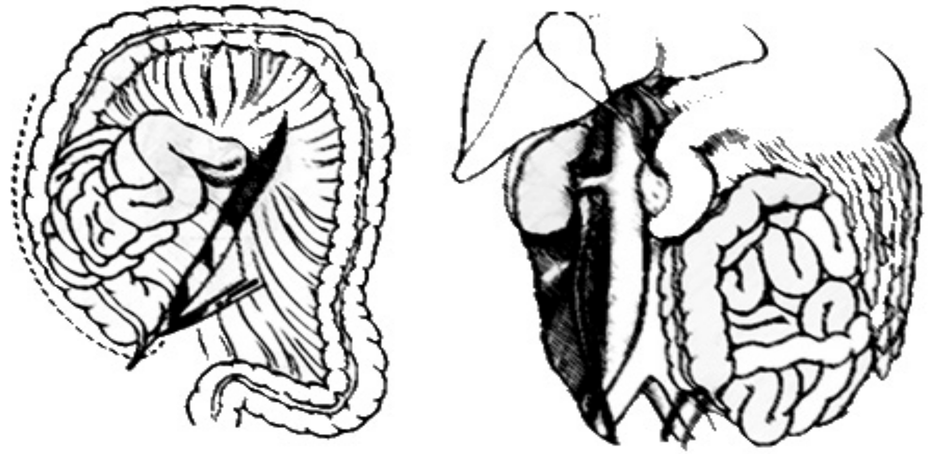
Figure 4 Retroperitoneal hematoma. Zone one: mandatory exploration. Zone two: explore in all penetrating injury and blunt injury with expanding or pulsatile hematoma. Zone three: explore in penetrating injury only. *(Courtesy of ATOM, L. Jacobs, MD, Cine-Med, 2004.)*

Exposure

Left Medial Visceral Rotation

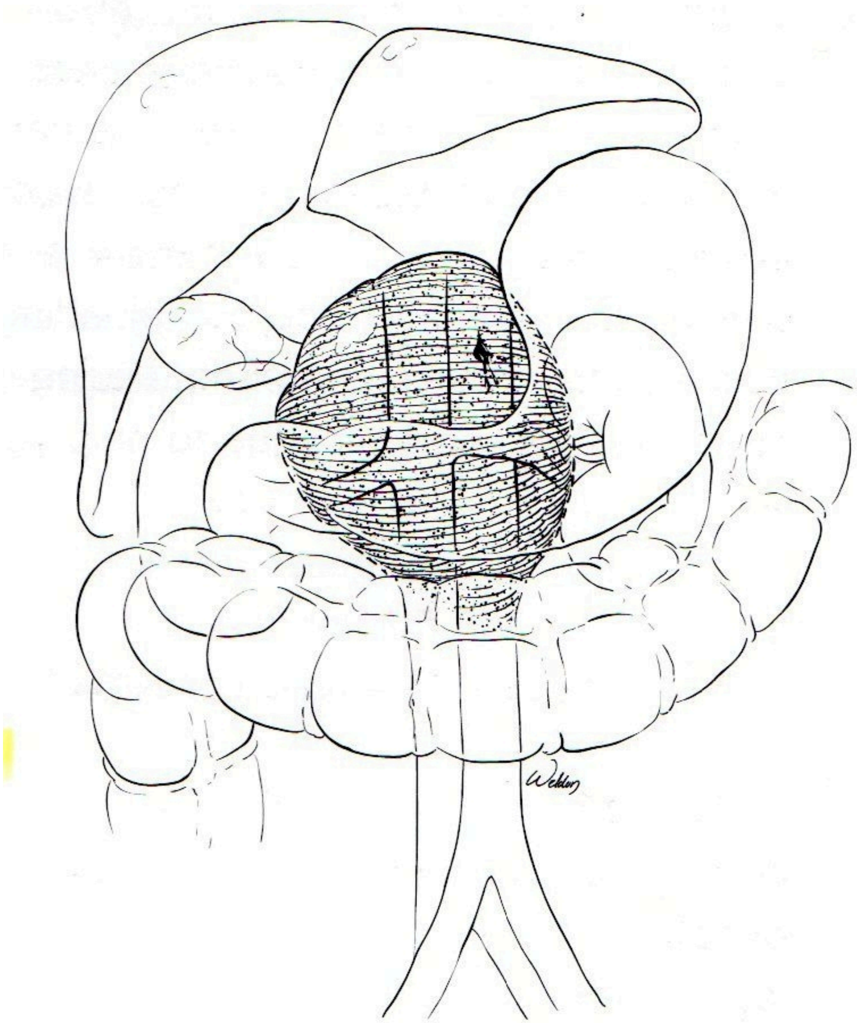


Right Medial Visceral Rotation



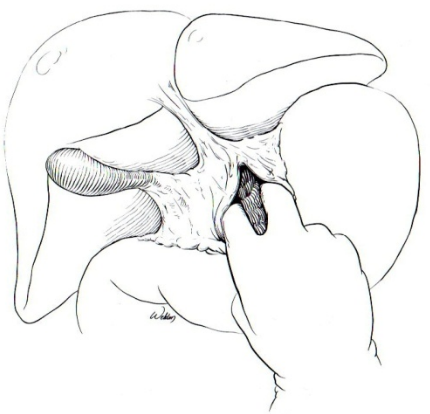
Cattell-Braasch Maneuver

Zone I - Supramesocolic



- Contained
  - Left sided medial visceral rotation (Mattox Maneuver) to visualize entire abdominal aorta and then cross clamp
- Active Hemorrhage
  - Go through lesser sac, separate two limbs of the right crus, and then cross clamp

Proximal Aortic Control



PROXIMAL AORTIC CONTROL

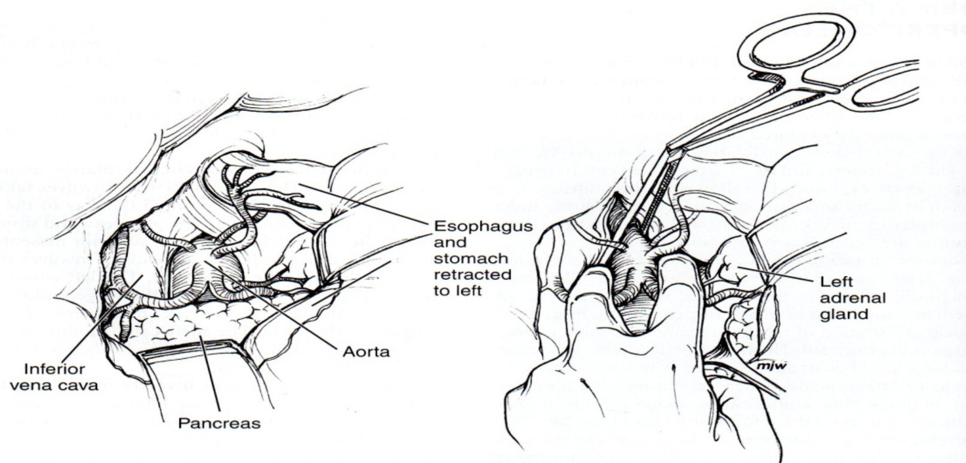


Figure 6 Proximal aortic control.

Repair

- Suprarenal aorta
  - 3-0 or 4-0 prolene suture closed in transverse fashion
  - If repair will narrow lumen too much or injury is too great, then a patch aortoplasty with PTFE is used
- Celiac Trunk
  - Large collateral supply
  - Injuries to the trunk or branches can be ligated

Repair

- SMA
  - Management is based on location of injury
    - If beneath pancreas
      - Divide the pancreas, prox/dist control, repair
      - Left medial visceral rotation, prox/dist control, repair
    - If beyond the pancreas
      - Unstable patient
        - » Arteriotomy with integral shunt
      - Stable patient
        - » Arteriotomy with graft placement on infrarenal aorta
- SMV
  - Divide neck of pancreas and repair with 5-0 prolene
  - Can be ligated, but will require massive fluid resuscitation

Repair of SMA injury

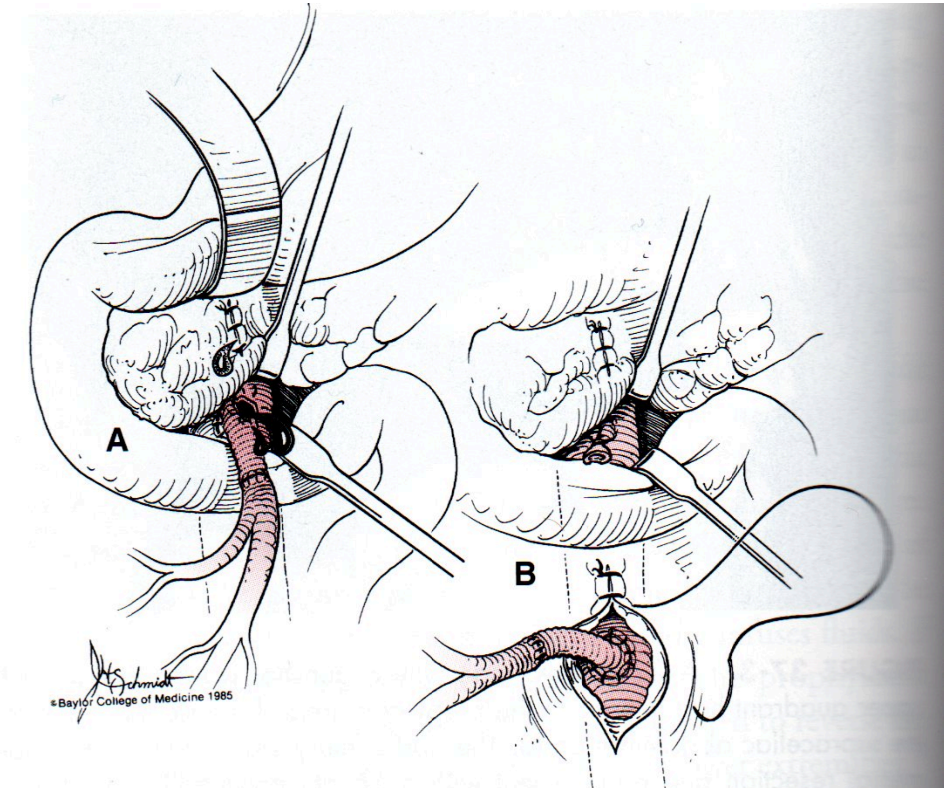


FIGURE 37-4. **(A)** When complex grafting procedures to the superior mesenteric artery are necessary, it may be dangerous to place the proximal suture line near an associated pancreatic injury. **(B)** The proximal suture line should be on the lower aorta, away from the upper abdominal injuries, and should be covered with retroperitoneal tissue. *(Reproduced with permission from Accola KD, Feliciano DV, Mattox KL, et al.: Management of injuries to the superior mesenteric artery. J Trauma 26:313, 1986.)*

Zone I - Inframesocolic

- Eviscerate small bowel to the right and pull transverse colon up
  - If hematoma is more left
    - Infrarenal aortic injury
  - If hematoma is more right
    - IVC
- Right medial visceral rotation for exposure

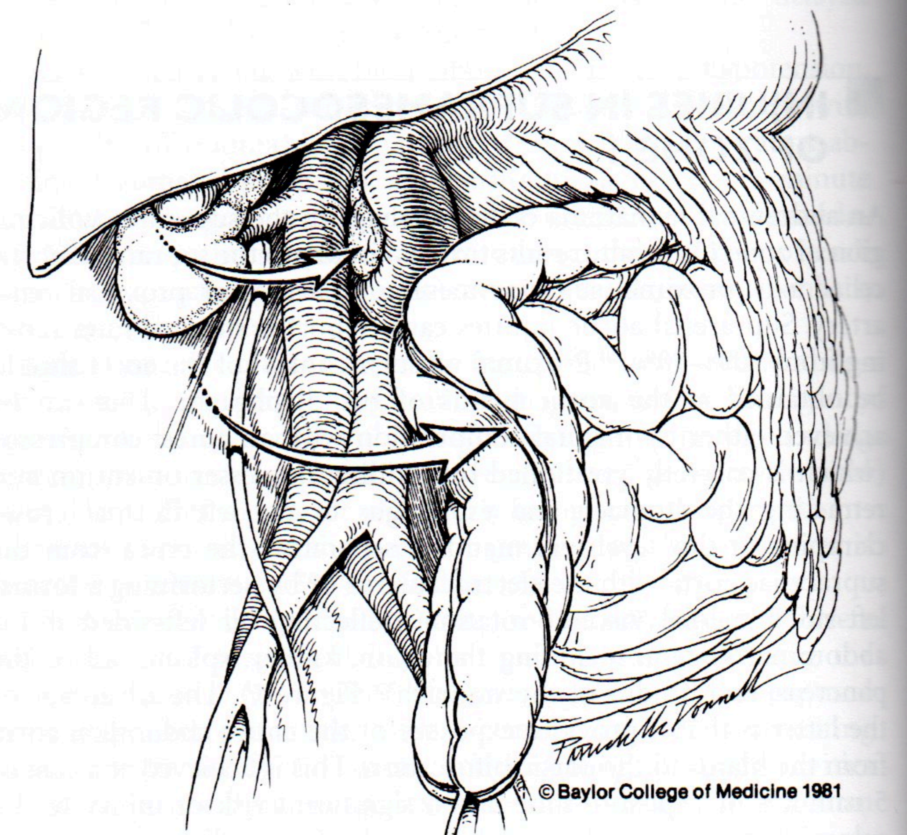
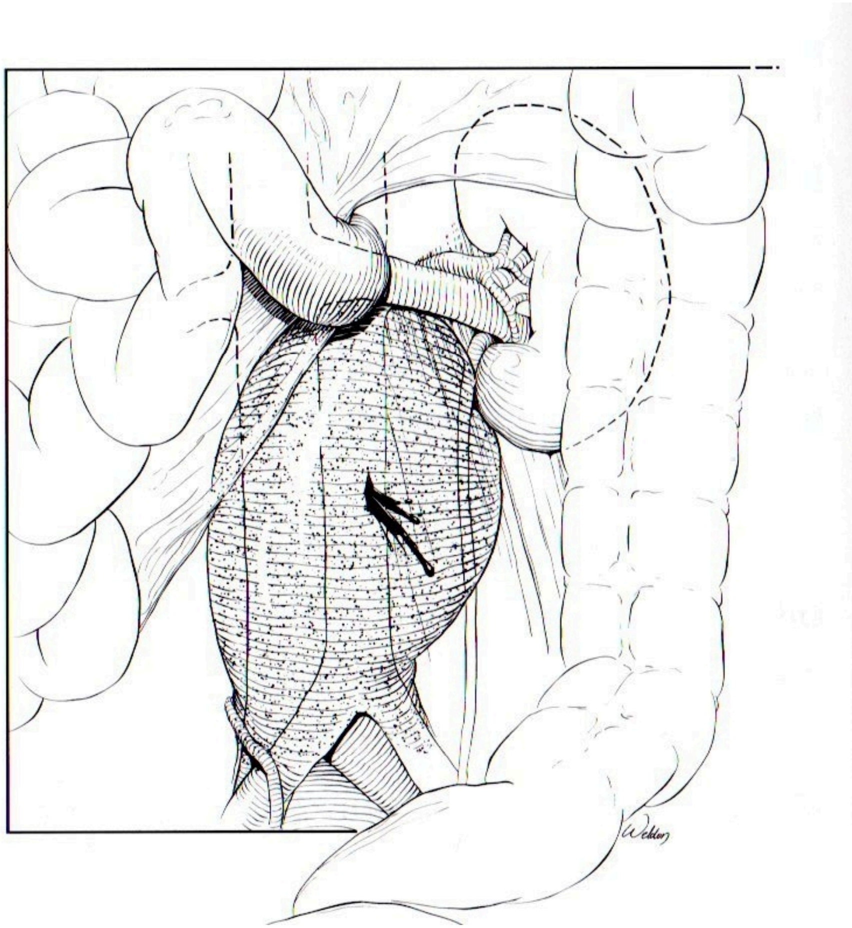


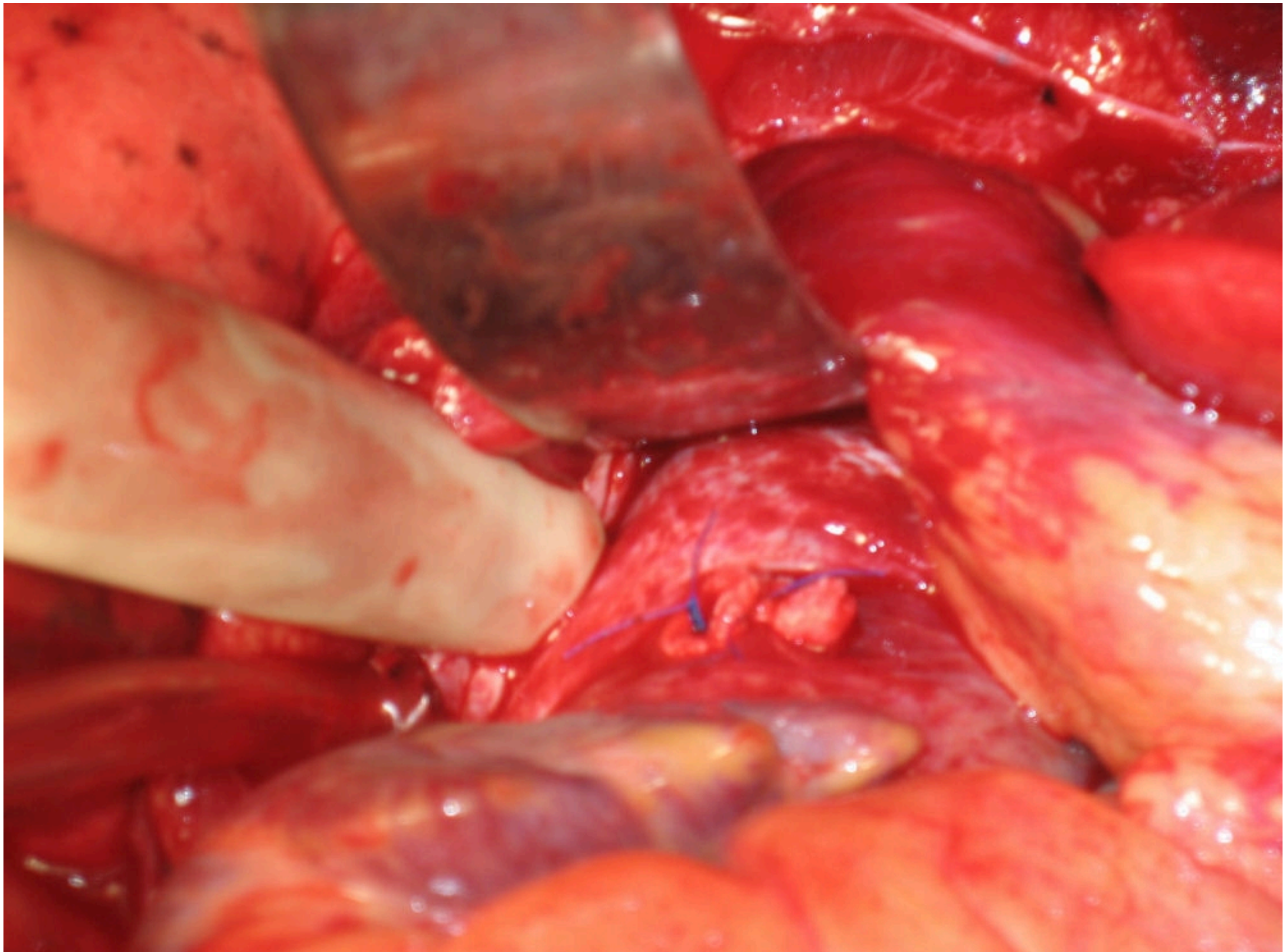
Figure 3 Right medial visceral rotation. Medial rotation of the right sided abdominal viscera (except the kidney) allows for visualization of the entire infrahepatic inferior vena cava. *(From Feliciano DV: Abdominal vascular injury. In Moore EE, Feliciano DV, Mattox KL, editors: Trauma, 5th ed. New York, McGraw-Hill, 2004, figure 36-5, p. 765. Copyright Baylor College of Medicine, 1981.)*

Zone I - Inframesocolic

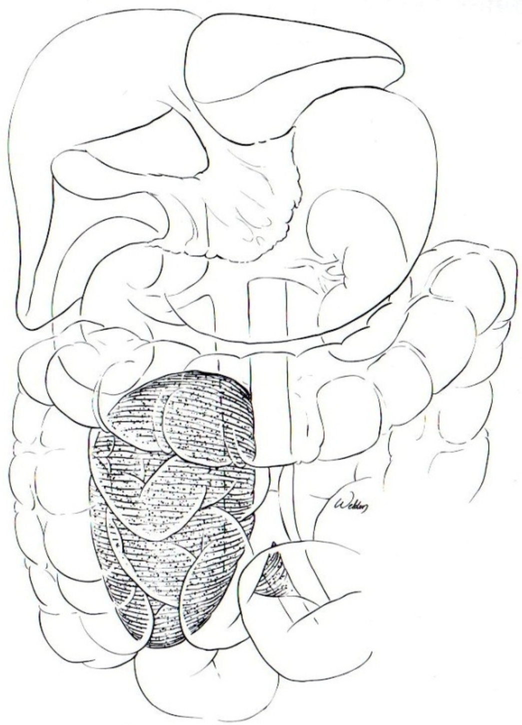


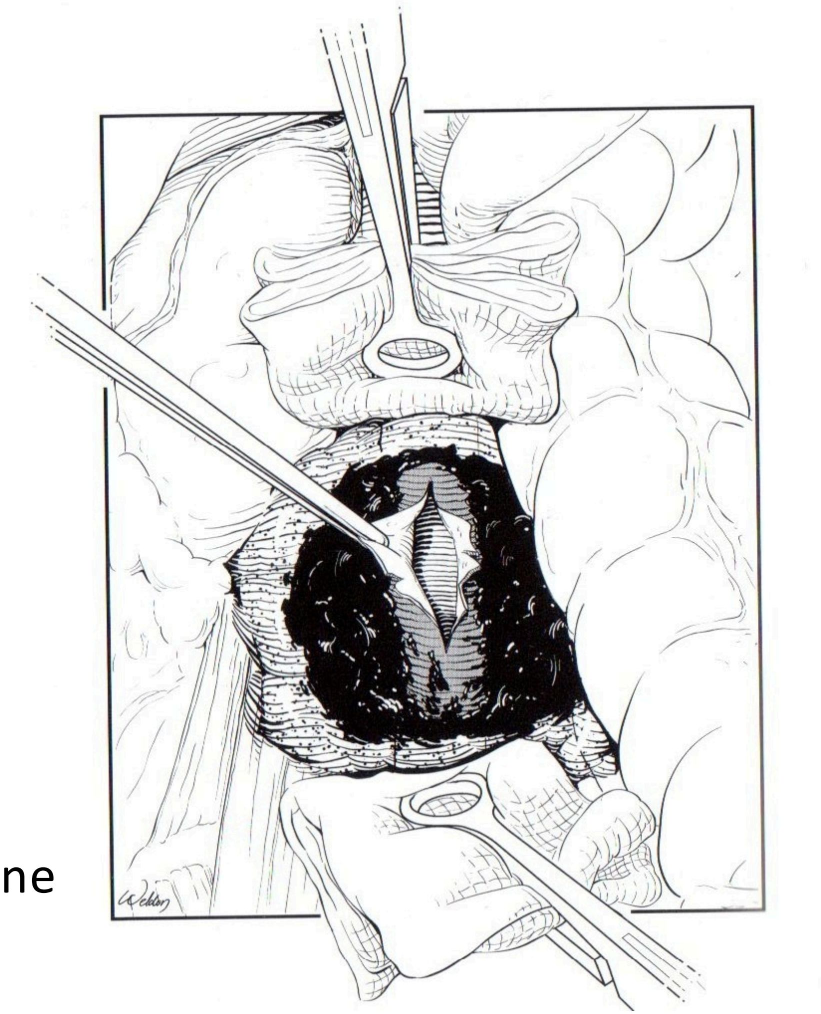
- Aortic Injury
  - Clamp at highest point of hematoma for proximal control
    - Mt. Everest Phenomenon
      - Injury is always at the highest point of hematoma
    - Be careful of LRV and IVC
      - Supraceliac clamp if unsure
  - 3-0 prolene suture, PTFE patch, or interpositional tube graft
  - Cover suture line and graft with gastrocolic omementum to avoid aortoduodenal fistula

Aorta Repair



Zone I - Inframesocolic

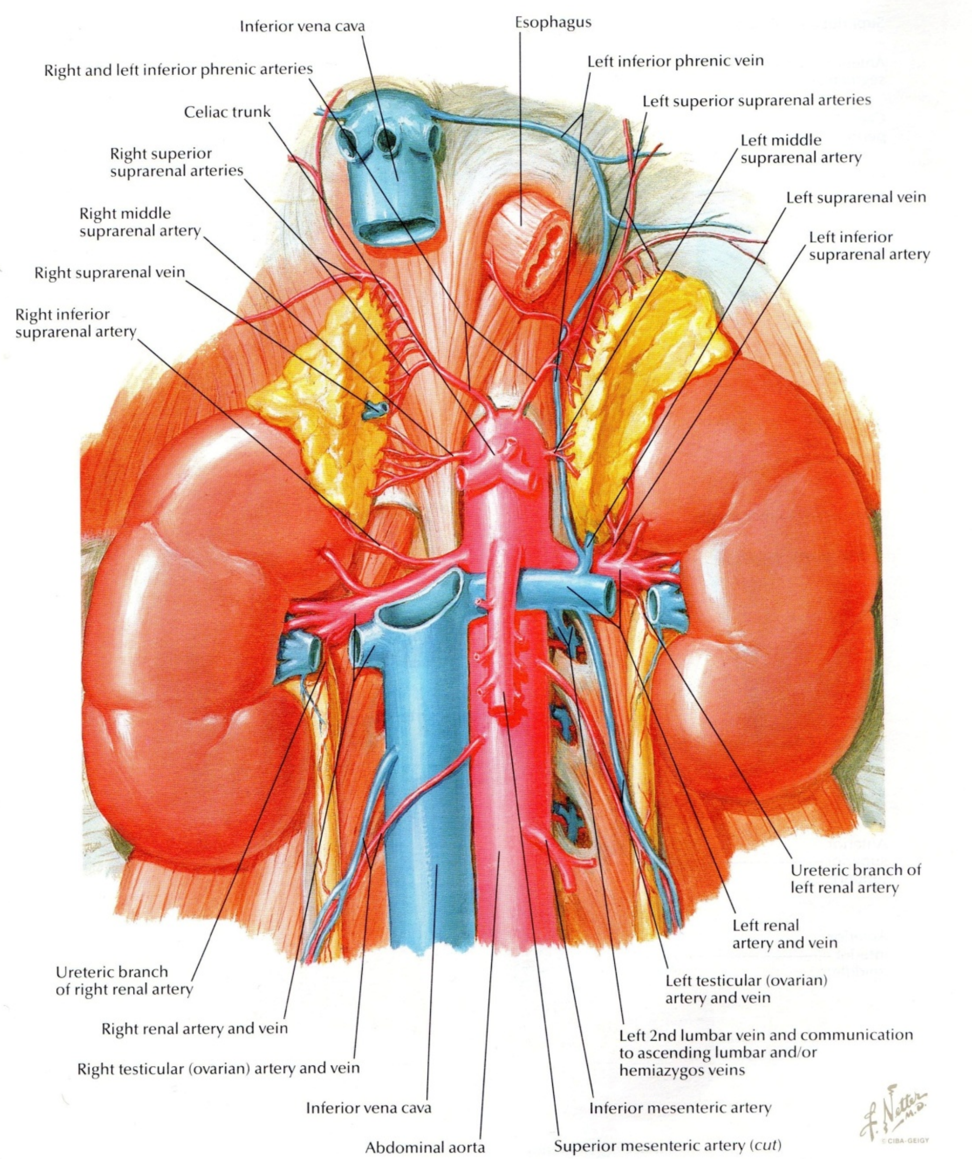




- IVC Injury
  - Unroof hematoma
  - Apply digital pressure against spine
    - Lap pads on ring clamps
  - Find edges of laceration
  - Suture the laceration

Zone II

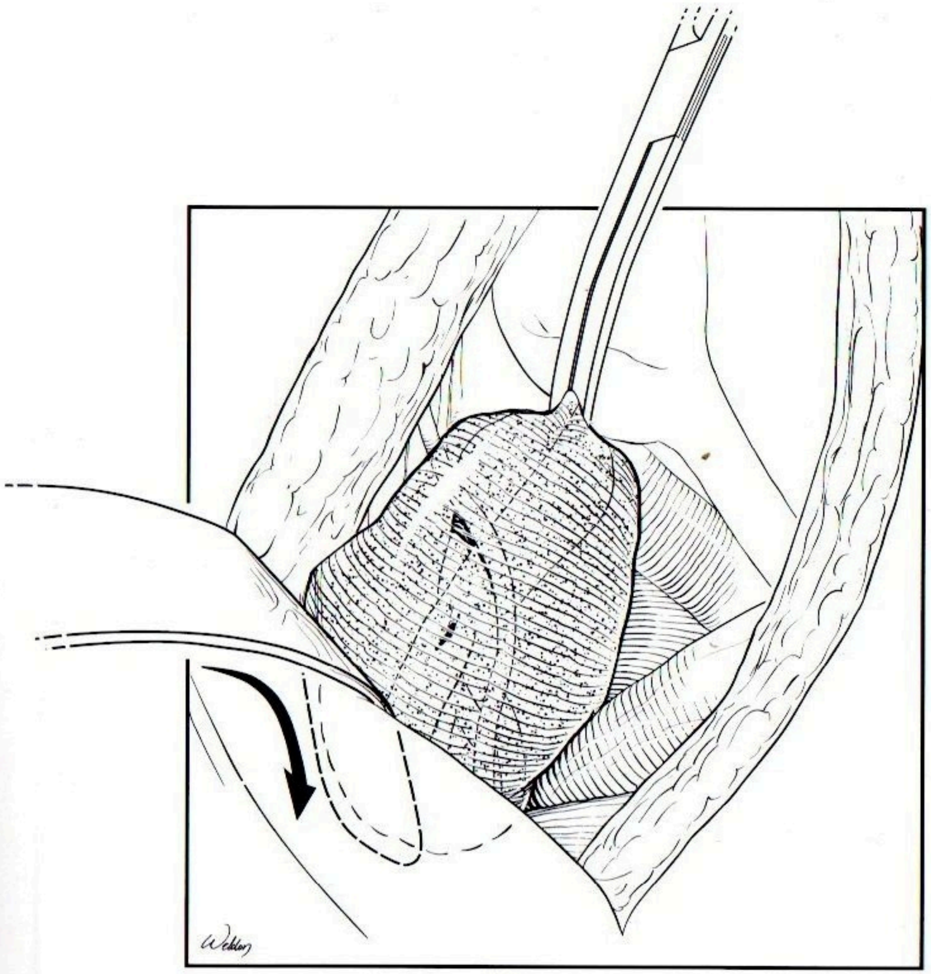
- Renal vascular injury
- If CT show injury, but patient is stable and hematoma is not expanding, no exploration is warrented



Zone II

- In the face of multi-trauma and a renal vessel injury, a nephrectomy is prudent
- In a stable patient with a renal vessel injury
  - Mobilize the kidney to midline, repair, PTFE graft, saphenous vein

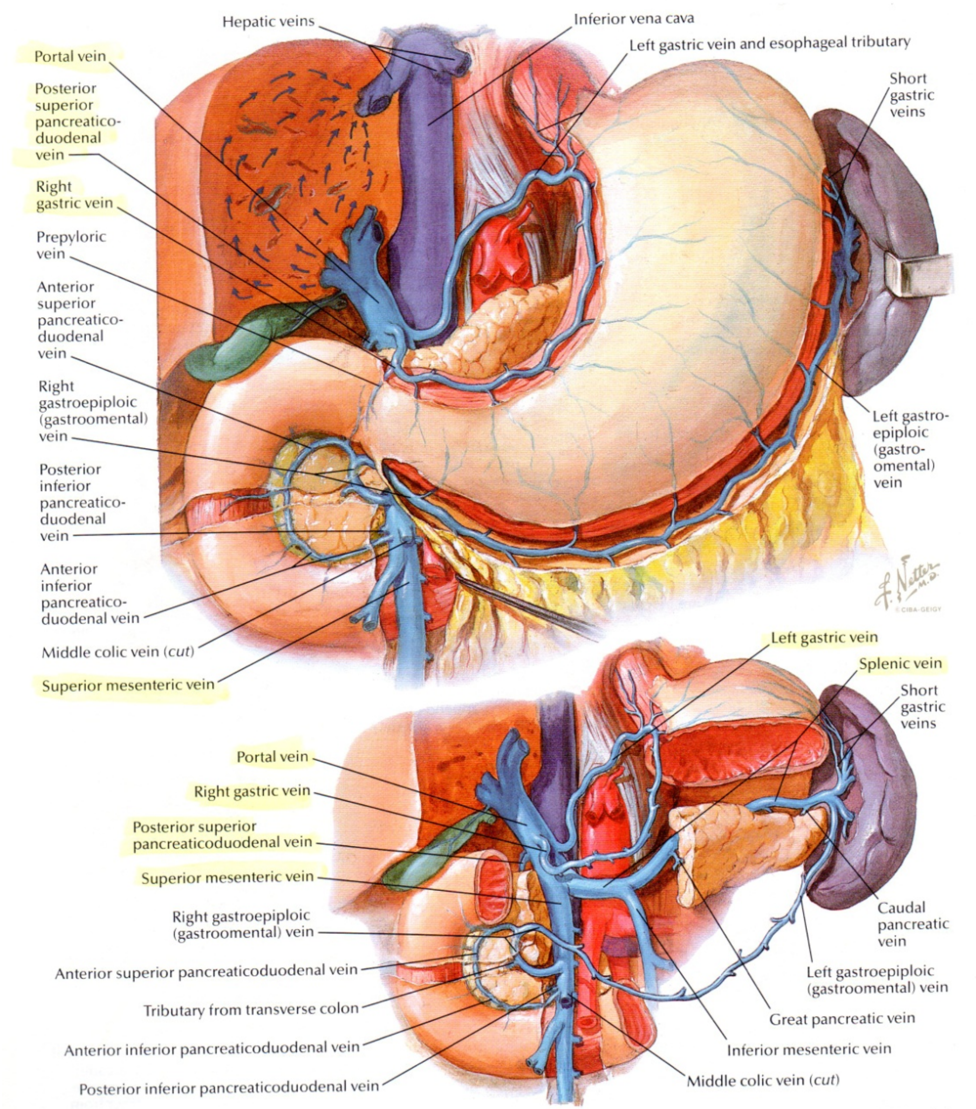
Zone III



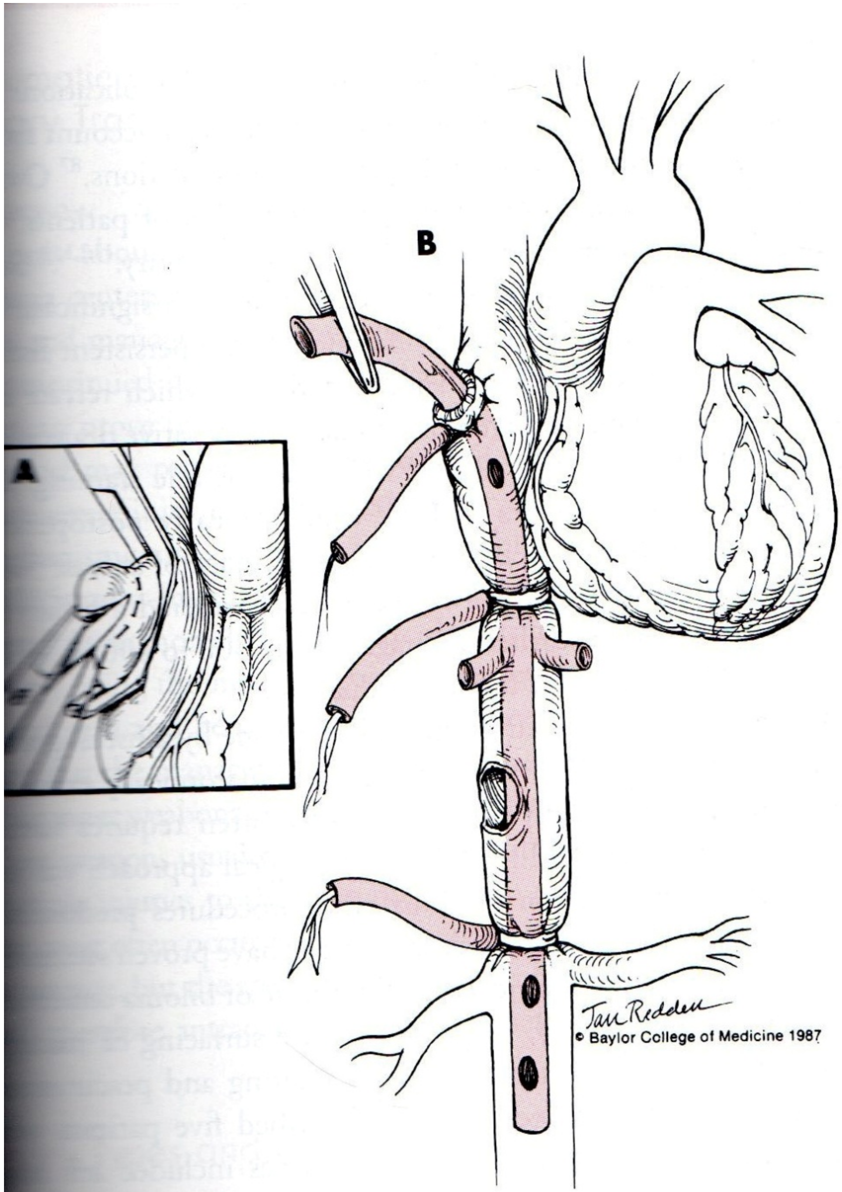
- Illiac vessels
- Blunt trauma
  - IR for embolization
    - Hematoma from pelvic fracture
- Penetrating Trauma
  - Repair
    - 4-0 prolene
    - PTFE graft
- "Walking the clamps"
  - Start distal to hematoma and clamp both artery and vein
  - Unroof hematoma and move clamps closer to injury until the laceration is found
- Ligate common illiac artery to gain access to common iliac vein

Portal Hepatis Injuries

- Hepatic Artery, Retrohepatic IVC, Portal vein
- Badness
- Difficult to expose and control



Portal Hepatis Injuries



- Hepatic artery
  - Ligate → cholecystectomy
- Portal vein
  - Repair with 4-0 or 5-0 prolene
- Retroheptic IVC
  - Atriocaval shunt with repair after stablization

Operative Approach to Retroperitoneal Hematoma

Hematoma	Explore? Penetrating	Explore? Blunt	Proximal control	Key maneuver
Midline supramesocolic	Yes	Yes	Supraceliac aorta	Mattox maneuver
Midline inframesocolic	Yes	Yes	Infrarenal aorta or IVC	Infrarenal aortic exposure or right-sided visceral rotation
Lateral perinephric	Selective	No	Hilar clamping or midline looping	Mobilize kidney
Pelvic	Yes	No	Distal aorta/ IVC	"Walking the clamps"

Table 1: Abdominal Vascular Injury Scale

Grade[a]	Description of Injury	ICD-9	AIS-90
I	Non-named superior mesenteric artery or superior mesenteric vein branches	902.20/.39	NS
	Non-named inferior mesenteric artery or inferior mesenteric vein branches	902.27/.32	NS
	Phrenic artery or vein	902.89	NS
	Lumbar artery or vein	902.89	NS
	Gonadal artery or vein	902.89	NS
	Ovarian artery or vein	902.81/.82	NS
	Other non-named small arterial or venous structures requiring ligation	902.90	NS
II	Right, left, or common hepatic artery	902.22	3
	Splenic artery or vein	902.23/.34	3
	Right or left gastric arteries	902.21	3
	Gastroduodenal artery	902.24	3
	Inferior mesenteric artery, or inferior mesenteric vein, trunk	902.27/.32	3
	Primary named branches of mesenteric artery (e.g., ileocolic artery) or mesenteric vein	902.26/.31	3
	Other named abdominal vessels requiring ligation or repair	902.89	3
III	Superior mesenteric vein, trunk	902.31	3
	Renal artery or vein	902.41/.42	3
	Iliac artery or vein	902.53/.54	3
	Hypogastric artery or vein	902.51/.52	3
	Vena cava, infrarenal	902.10	3
IV	Superior mesenteric artery, trunk	902.25	3
	Celiac axis proper	902.24	3
	Vena cava, suprarenal and infrahepatic	902.10	3
	Aorta, infrarenal	902.00	4
V	Portal vein	902.33	3
	Extraparenchymal hepatic vein	902.11	3 (hepatic vein), 5 (liver + veins)
	Vena cava, retrohepatic or suprahepatic	902.19	5
	Aorta suprarenal, subdiaphragmatic	902.00	4

[a]This classification system is applicable to extraparenchymal vascular injuries. If the vessel injury is within 2 cm of the organ parenchyma, refer to specific organ injury scale. Increase one grade for multiple grade III or IV injuries involving >50% vessel circumference. Downgrade one grade if <25% vessel circumference laceration for grades IV or V.

NS, Not scored.

From Moore EE, et al: Organ injury scaling. III: chest wall, abdominal vascular, ureter, bladder, and urethra. *J Trauma* 33(3):337–339, 1992.

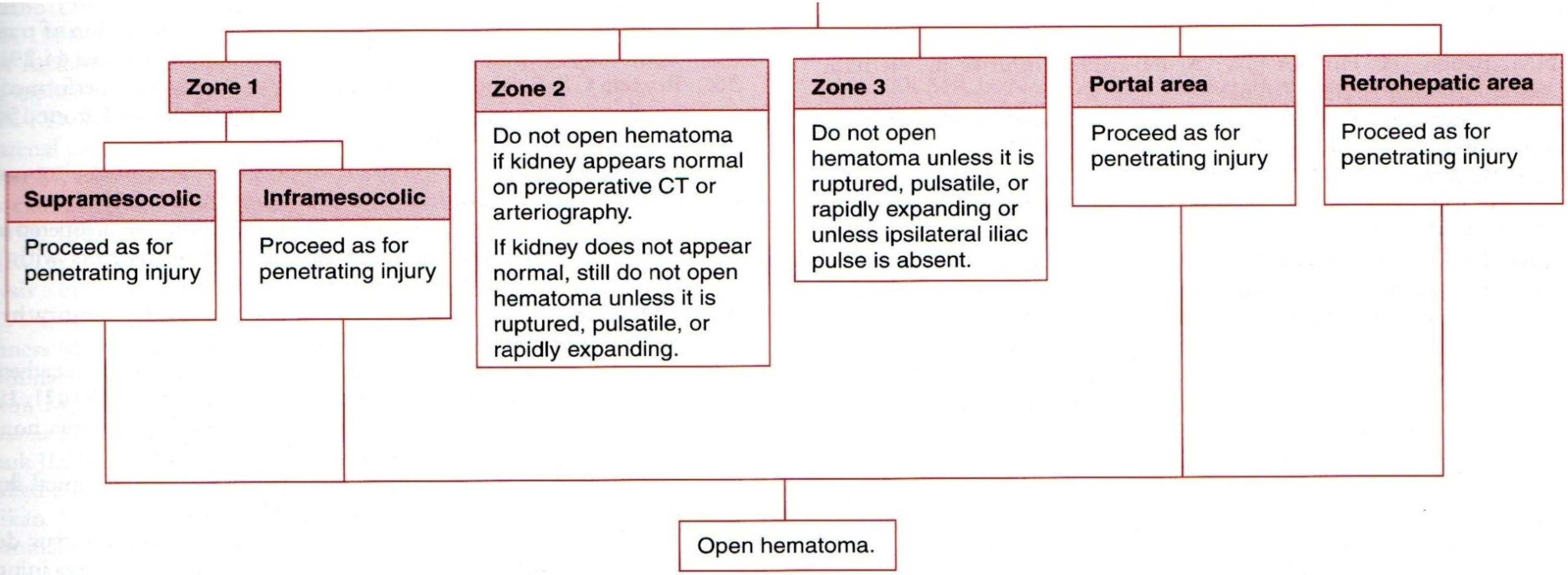


FIGURE 37-8. Patient with blunt abdominal trauma and intra-abdominal hematoma at laparotomy.

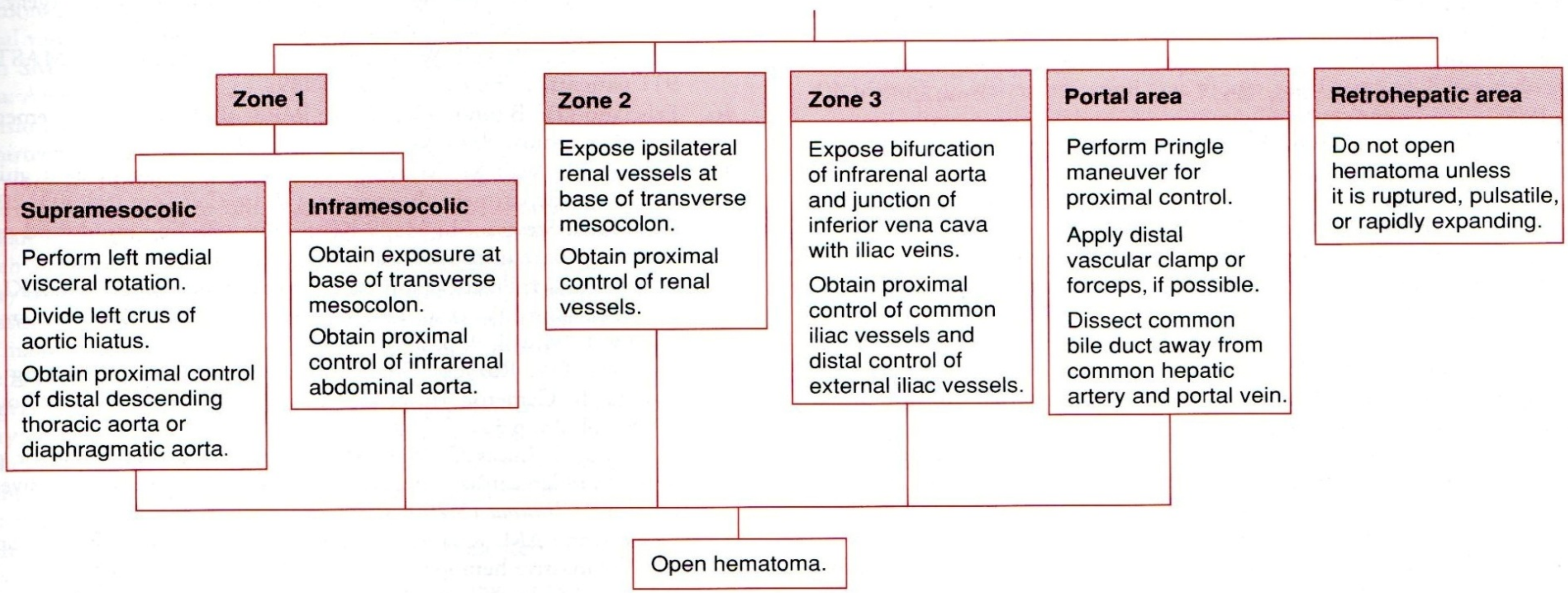


FIGURE 37-9. Patient with penetrating abdominal wound and intra-abdominal hematoma at laparotomy.

What you can ligate

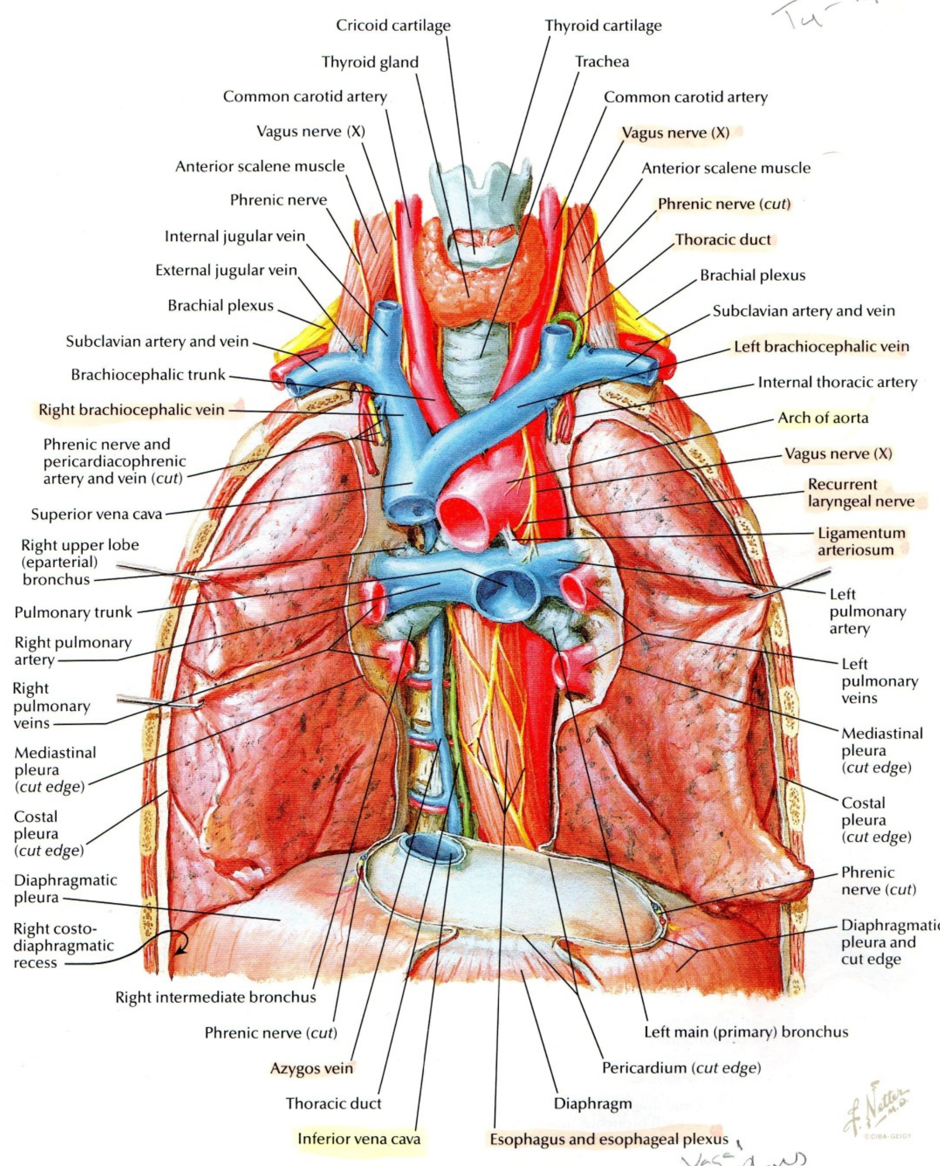
Table 2: Abdominal Vessel Ligation and Expected Complications

Vessel	Complication	Recommendations
Celiac axis	None	
Splenic artery	None if the short gastric vessels are intact	
Common hepatic artery	None if the portal vein is intact, possible gallbladder ischemia	Cholecystectomy (may be done at second look)
Superior mesenteric artery	Bowel ischemia	Second-look procedure
Superior mesenteric vein	Bowel ischemia	Second-look procedure
Portal vein	Bowel ischemia	Second-look procedure
Suprarenal inferior vena cava	Possible renal failure	Wrap and elevate legs, assess for compartment syndrome
Infrarenal inferior vena cava	Lower extremity edema	Wrap and elevate legs, assess for compartment syndrome
Left renal vein (proximal)	None	
Right renal vein	Renal ischemia	Nephrectomy
Common and external iliac artery	Lower extremity ischemia	Ipsilateral calf and sometimes thigh fasciotomies or extra-anatomic bypass
Common and external iliac vein	Lower extremity edema	Wrap and elevate legs
Internal iliac artery	None	
Internal iliac vein	None	

Thoracic Vascular Injuries

Great Vessel Injuries

- Aorta, Brachiocephalic vessels, Subclavian Vessels, Pulmonary vessels, Vena Cava, Azygos vein
- 90% are due to penetrating trauma
- Blunt mechanisms
  - Shear forces
    - Most common sites?
      - Ligamentum arteriosum
      - Atrial attachments of the pulmonary veins and vena cava
  - Compression of vessel between bony structures
    - Inominate artery between sternum and vertebrae
  - Profound intraluminal pressure during traumatic event



Diagnosis

- Physical Exam
  - Hypotension
  - Unequal blood pressures in upper and lower extremities
  - Evidence of major chest trauma
  - Expanding hematoma at thoracic outlet
  - Intrascapular murmur
  - Palpable fracture of sternum
  - Palpable fracture of thoracic vertebrae
  - Left flail chest
- Radiographical Evidence
  - Large hemothorax
  - Foreign bodies or trajectories in proximity to great vessels
  - Trajectory with confusing course
    - Migrating bullet
  - Missing missile in GSW to chest with no exit wound
  - Widened mediastinum > 8cm
  - Obliteration of aortic knob contour
  - Apical pleural hematoma
  - Displacement of trachea

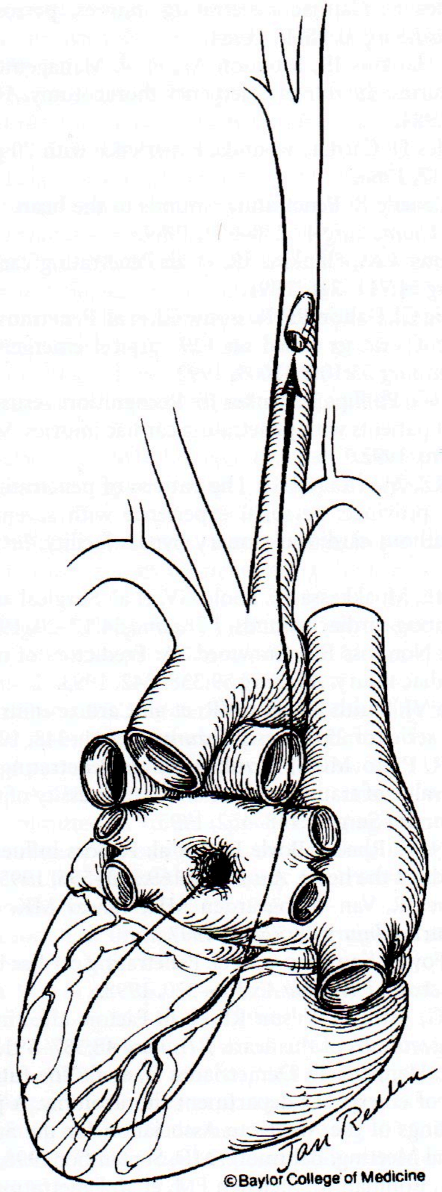
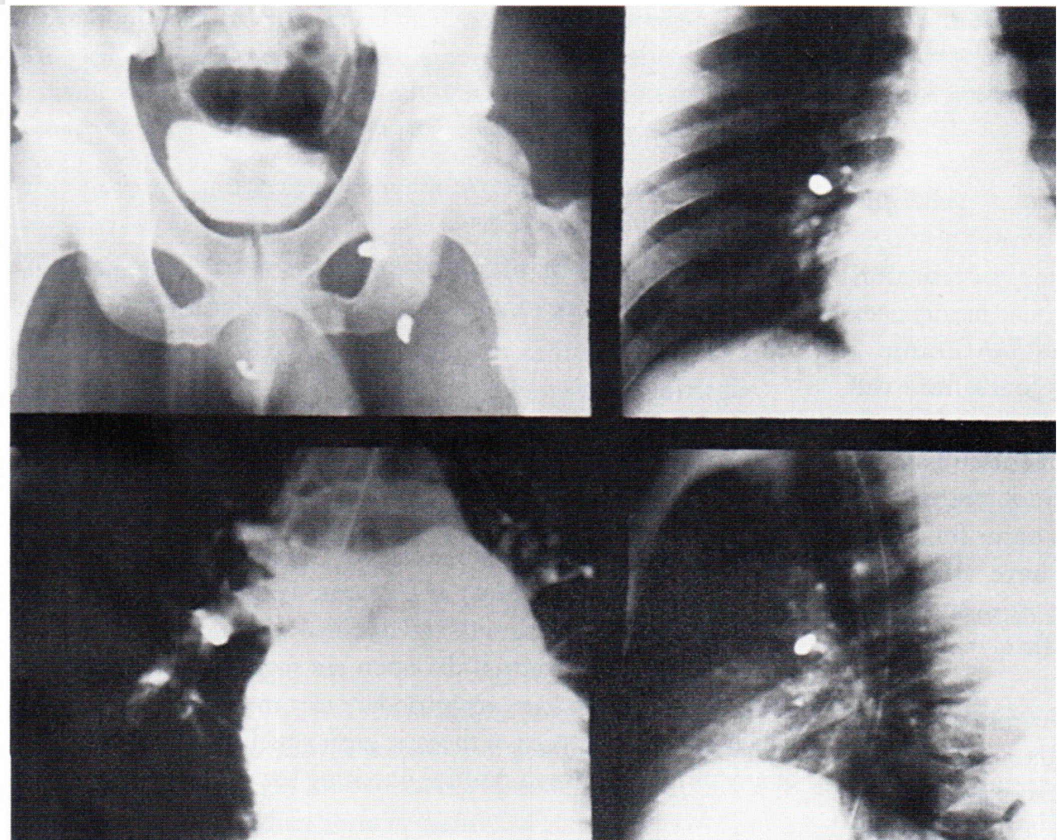


Figure 1 Bullet embolism from the left atrium to the left carotid artery. *(Courtesy Jan Redden, Baylor College of Medicine, 1980.)*



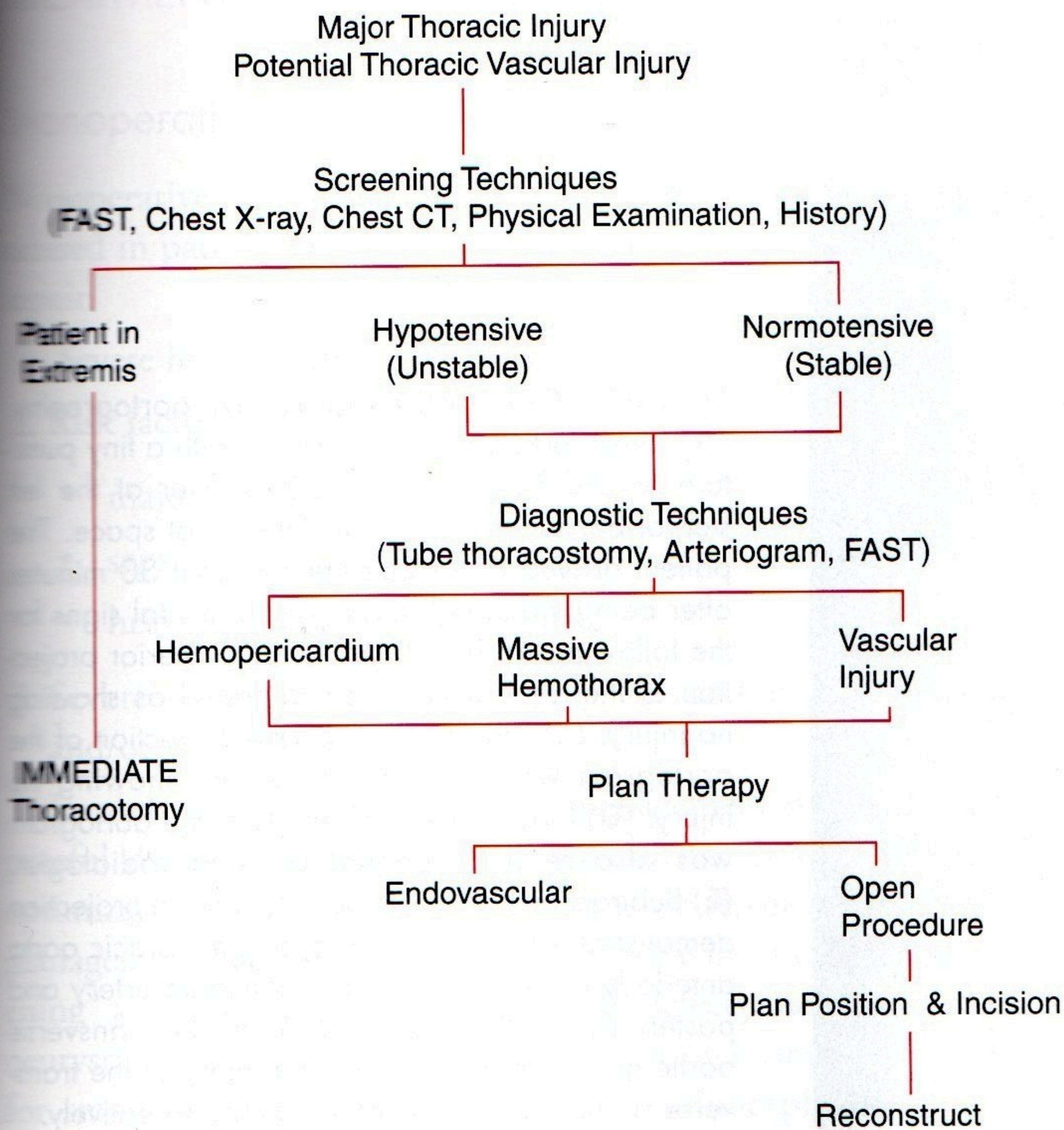


FIGURE 29-3A. Algorithm for an approach to patients with suspected thoracic vascular injury.

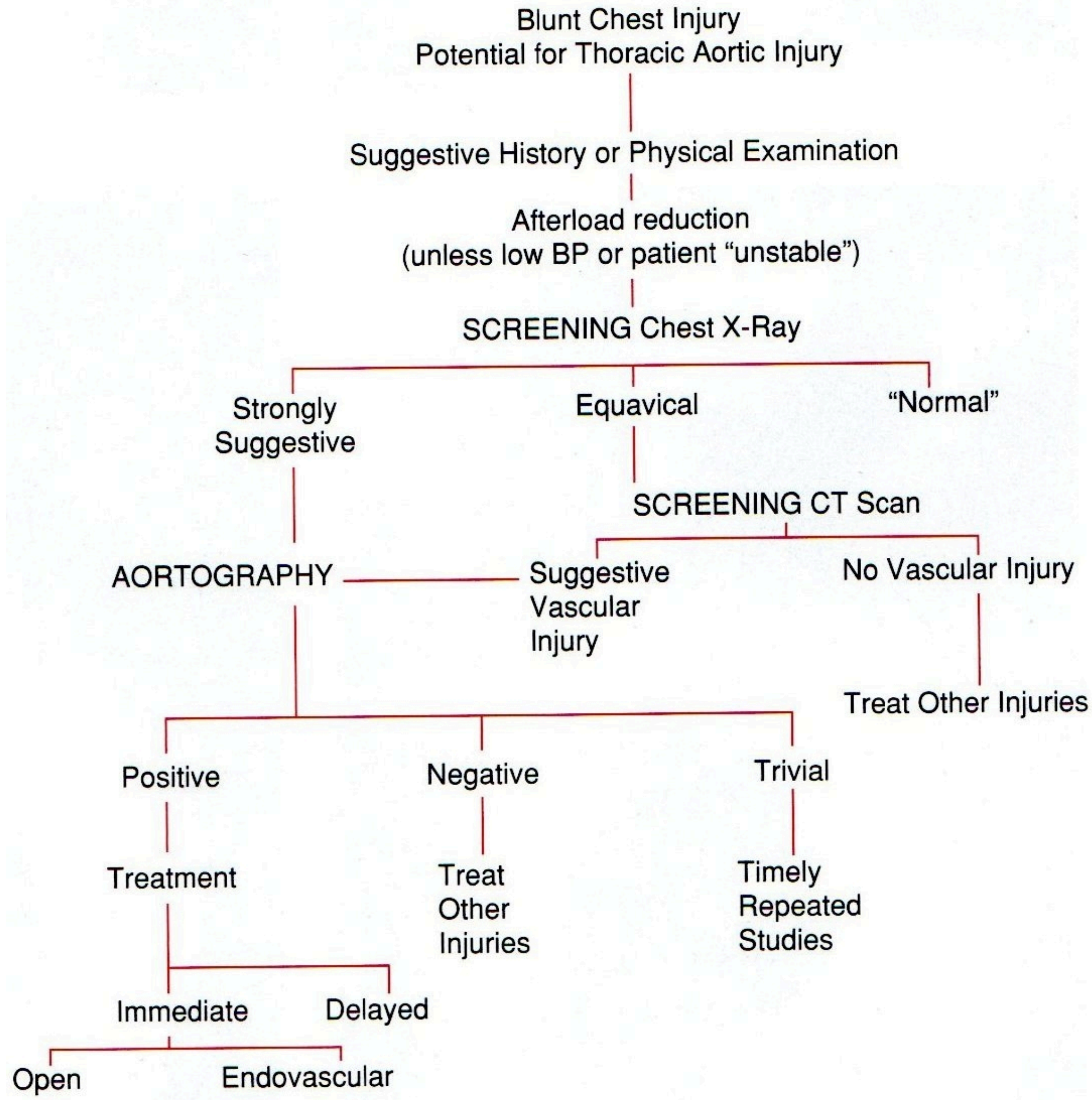


FIGURE 29-3B. Algorithm for the evaluation and treatment of a patient suspected of having a blunt injury to the thoracic aorta.

Diagnostic Studies

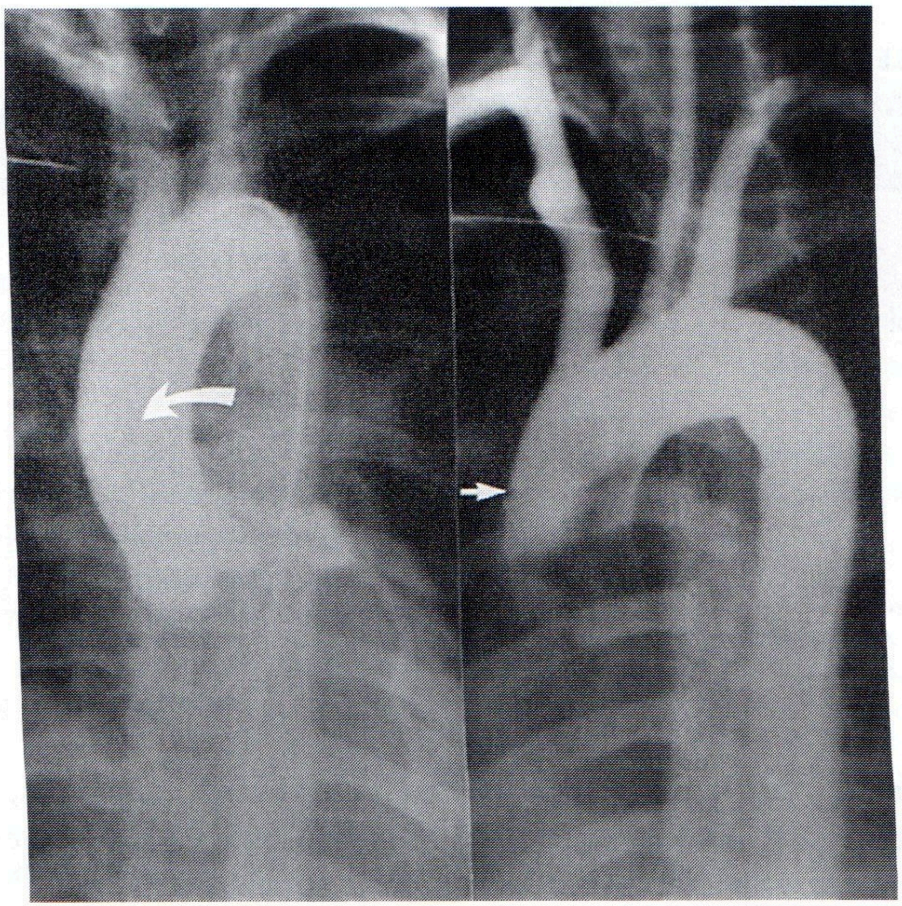


FIGURE 29-6. Aortogram of the patient in Fig. 28-7 demonstrating no apparent injury in the anteroposterior projection, but revealing a defect in the anterior aortic wall on the left anterior oblique projection (*arrows*).

- Arteriography
  - Indicated for suspected aortic, innominate, carotid, and subclavian artery injuries
  - Different injuries require different surgical approaches
  - Try to obtain tangential views

Classification

Table 3: American Association for the Surgery of Trauma, Thoracic Vascular Injury Scale

Grade[a]	Description of Injury
I	Intercostal vessels Internal mammary vessels Bronchial vessels Esophageal vessels Hemiazygos vein Unnamed vessels
II	Azygos vein Internal jugular vein Subclavian vein Innominate vein
III	Carotid artery Innominate artery Subclavian artery
IV	Descending thoracic aorta Intrathoracic inferior vena cava Pulmonary artery/vein, primary intraparenchymal branch
V	Ascending aorta Aortic arch Superior vena cava Main pulmonary artery trunk Pulmonary vein, main trunk
VI	Uncontained complete transaction of thoracic aorta or pulmonary hilar vessels

[a]Increase one grade for multiple grade III injuries or >50% circumference involvement in grade IV injuries. Decrease one grade for grade IV injuries if <25% circumference involvement.
Modified from American Association for the Surgery of Trauma (AAST).

Table 4: Indications for Operative Repair of Thoracic Great Vessel Injury

Initial loss of 1500 ml of blood from chest tube
Continuing hemorrhage >200 ml/hr from tube thoracostomy
Posttraumatic hemopericardium
Pericardial tamponade
Expanding hematoma at thoracic outlet
Exsanguinating hemorrhage presenting from supraclavicular penetrating wound
Imaging evidence of acute thoracic great vessel injury
Radiographic or other imaging evidence of chronic thoracic great vessel injury complications

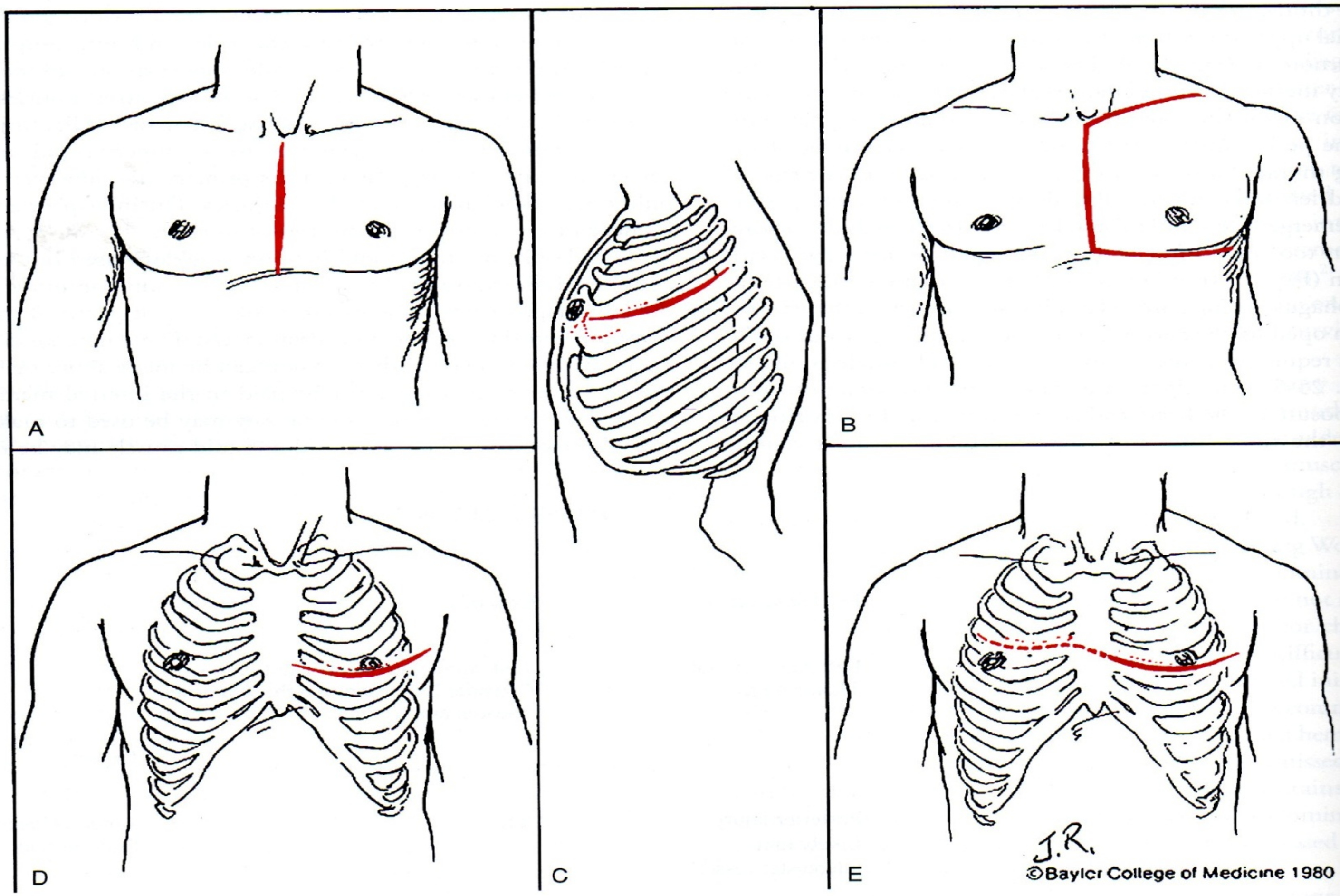
Surgical Considerations

- Neurological complications
  - Paraplegia, stroke, brachial plexus injuries
- Hypertension just as bad as hypotension
- Approach depends on the vessel injured

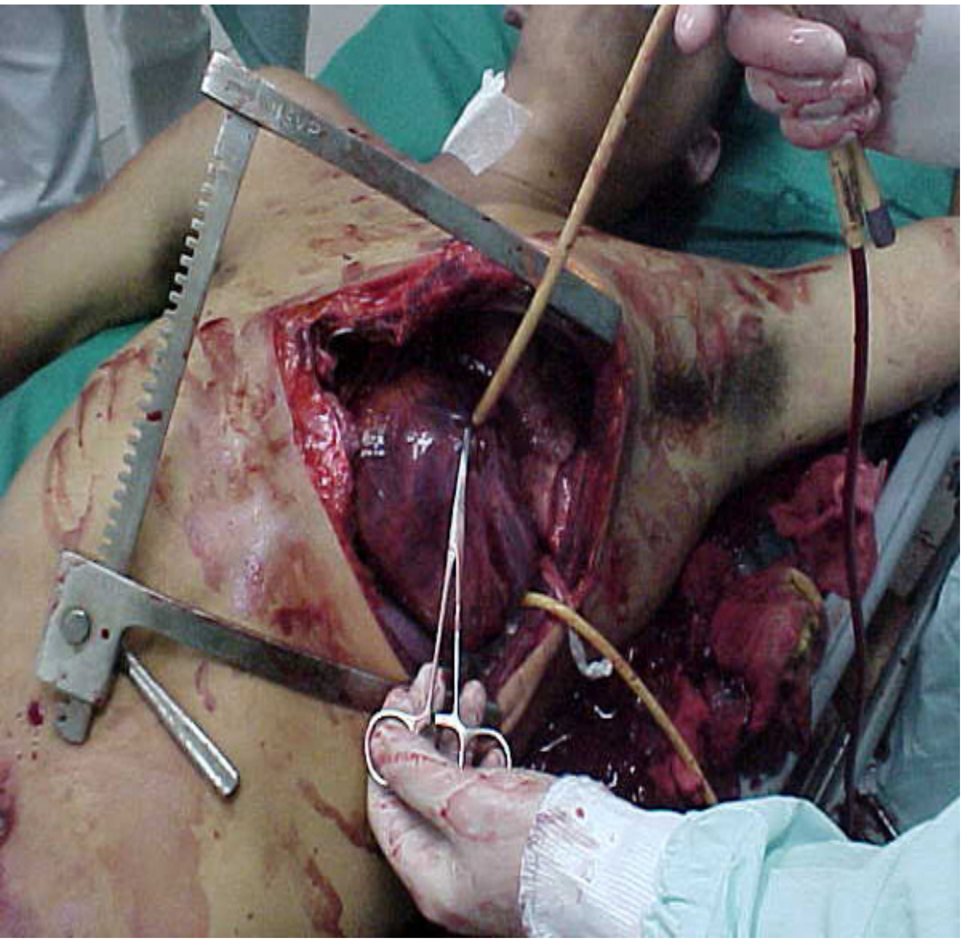
Thoracotomy

- Incision type depends on the suspected injury or patient condition
- Indications
  - Persistant severe hypotension (SBP<60)
    - Intrathoracic hemorrhage
      - CT output of 1500cc or 300cc/hr
    - Cardiac tamponade
    - Air embolism
  - Asystole after signs of life
  - Radiographic evidence of great vessel injury
  - Endoscopic or radiographic evidence of tracheo-bronchial injury
    - Massive air leak from chest tube

- Ascending aorta
Innominate artery
Right carotid/
Subclavian artery
Left carotid artery
  → Median sternotomy with neck/ supraclavular extension
- Left subclavian artery
  → Third interspace anterolateral thoracotomy with supraclavicular incision
- Known descending thoracic aorta
Intrathoracic left subclavian artery
  → Left posterolateral thoracotomy
- Known intrathoracic trachea/esophagus injury
  → Posterolateral thoracotomy
- Clotted hemothorax
VATS
  → Posterolateral thoracotomy



Anterolateral Thoracotomy



- Standard *in extremis* thoracotomy
- Allows exposure for opening pericardium, open cardiac massage, clamping of descending thoracic aorta, and treatment of many cardiac and left lung injuries

Posterolateral Thoracotomy

- Left side
  - Posterior mediastinum, left lung, hilum, decending thoracic aorta
- Right side
  - Pulmonary, tracheal, mid-esophageal injuries, superior and inferior vena cava, azygous vein

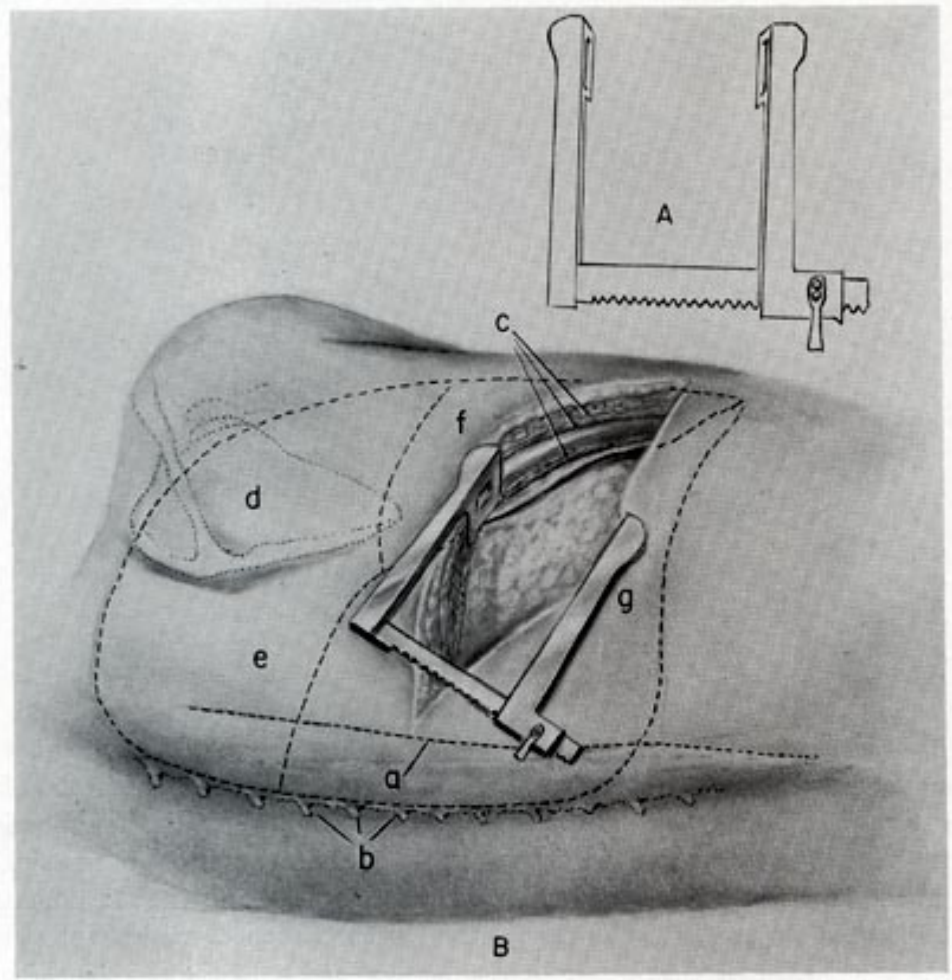


FIGURE 42.—Exposure of thoracic cavity with rib-spreader in posterolateral thoracotomy. A. Rib-spreader. B. Rib-spreader in situ, with gentle spreading of ribs, showing: Erector spinae muscle group (a), spinous processes (b), divided latissimus dorsi, serratus anterior, and intercostal muscles (c), scapula (d), right upper pulmonary lobe (e), right middle pulmonary lobe (f), and right lower pulmonary lobe (g).

Median Sternotomy

- Provides excellent exposure to cardiac and anterior mediastinal injuries, but provides no access to the esophagus and posterior thorax
- Very difficult to clamp descending thoracic aorta

Arterial Injuries

- Ascending Aorta
  - Rarely survive transport
    - 50% mortality even if vital signs stable at arrival
  - Median sternotomy
  - Need for bypass and insertion of Dacron graft
- Transverse Aortic Arch
  - Median sternotomy with extension to neck
  - May need bypass
  - Survival rates near 50%

Arterial Injuries

- Innominate Artery
  - Median sternotomy +/- right neck extension
  - Proximal injury more common in blunt trauma
  - Bypass Exclusion Technique
  - Patient with no original great vessel injury begins to have massive bright red blood coming out around a 3 month old tracheostomy. What is the concern?
    - Tracheo-innominate fistula
    - Overinflate cuff
    - Oral intubation past tracheostomy
    - Insert finger and pull up on tracheal against sternum

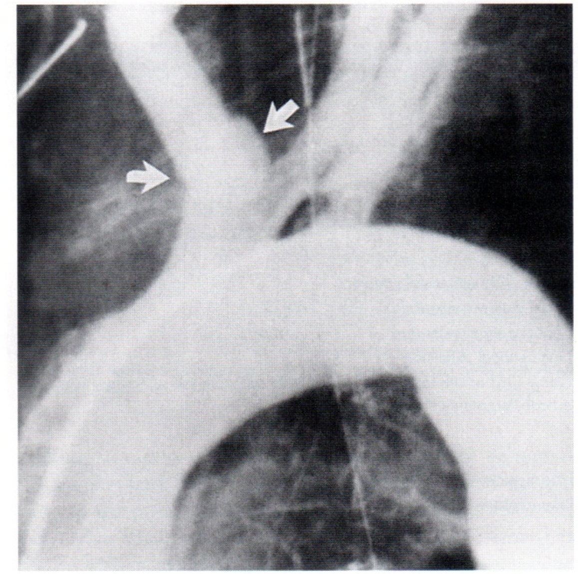


FIGURE 29-9. Aortogram of the patient in Fig. 28-1 demonstrating the tear involving the proximal innominate artery.

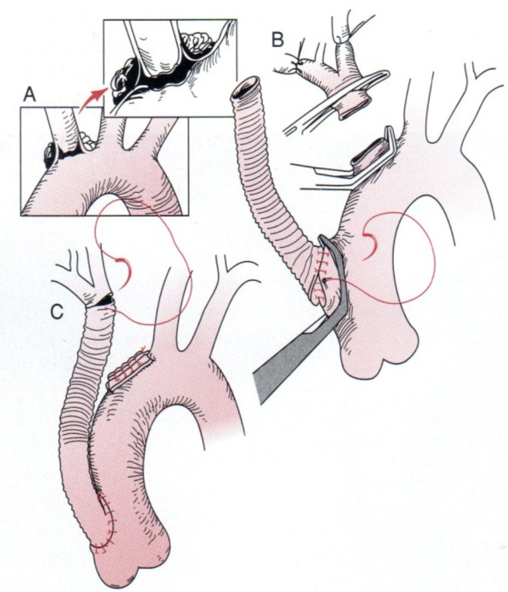
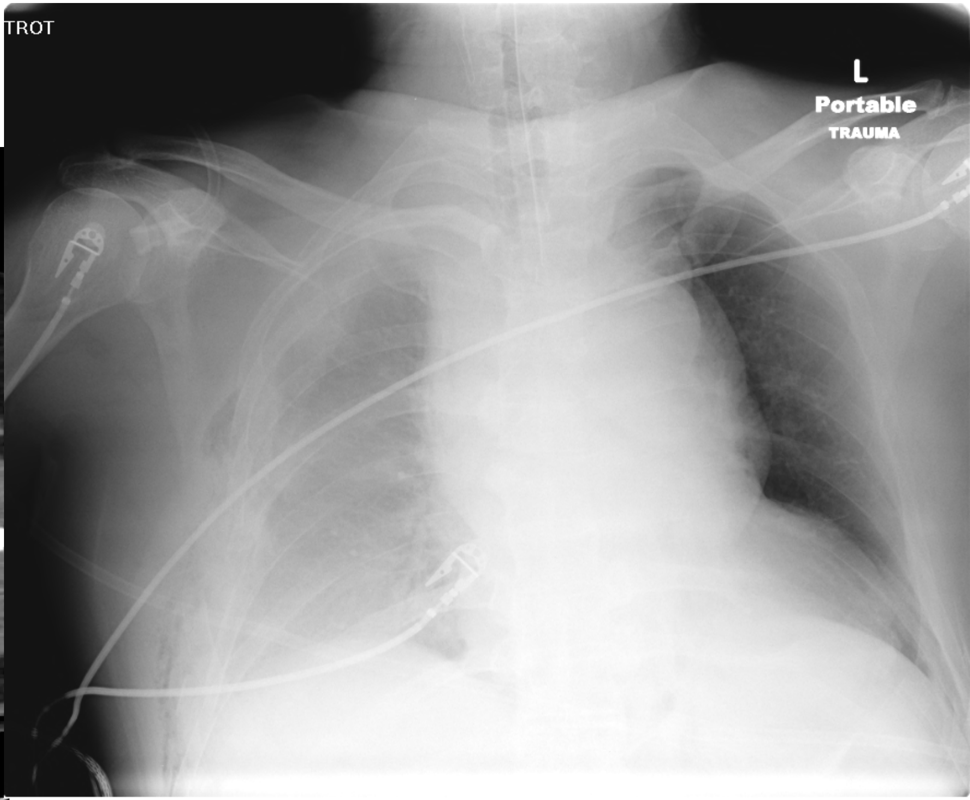


FIGURE 29-10. Drawing depicting the bypass exclusion technique employed in patients with innominate artery injuries. (*Copyright © Baylor College of Medicine, 1981.*)

Innominate Artery Injury



Arterial Injuries

- Descending Thoracic Aorta
  - 85% pre-hospital mortality
  - Majority of injuries located just distal to left subclavian artery and just proximal to diaphragm
  - 3 treatment options
    - Surgical – clamp and direct reconstruction
      - Posterolateral thoracotomy
      - Pharmacologic control of proximal hypertension
      - Passive bypass shunts
      - Pump-assisted bypass
        - » Traditional bypass
        - » Atrio-femoral bypass
    - Non-op and/or purposeful delay
    - Endovascular stenting
  - Complications
    - Paraplegia
      - 10%

Descending Thoracic Aorta

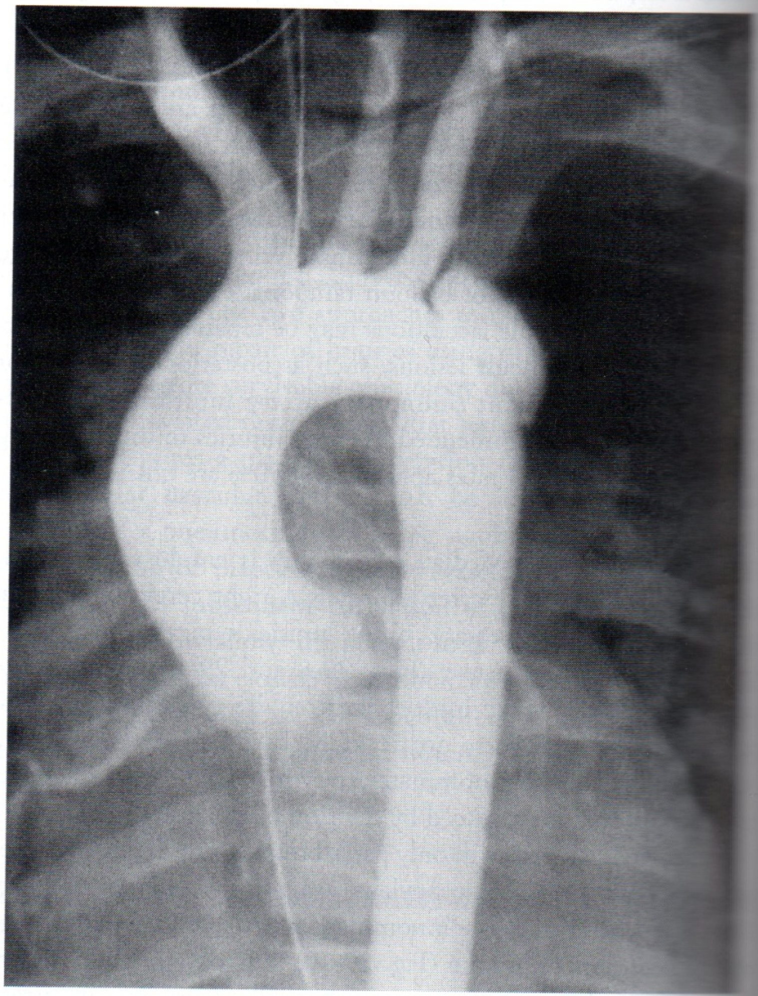


FIGURE 29-11. Aortogram demonstrating the classic intimal tear and traumatic pseudoaneurysm of the descending thoracic aorta.

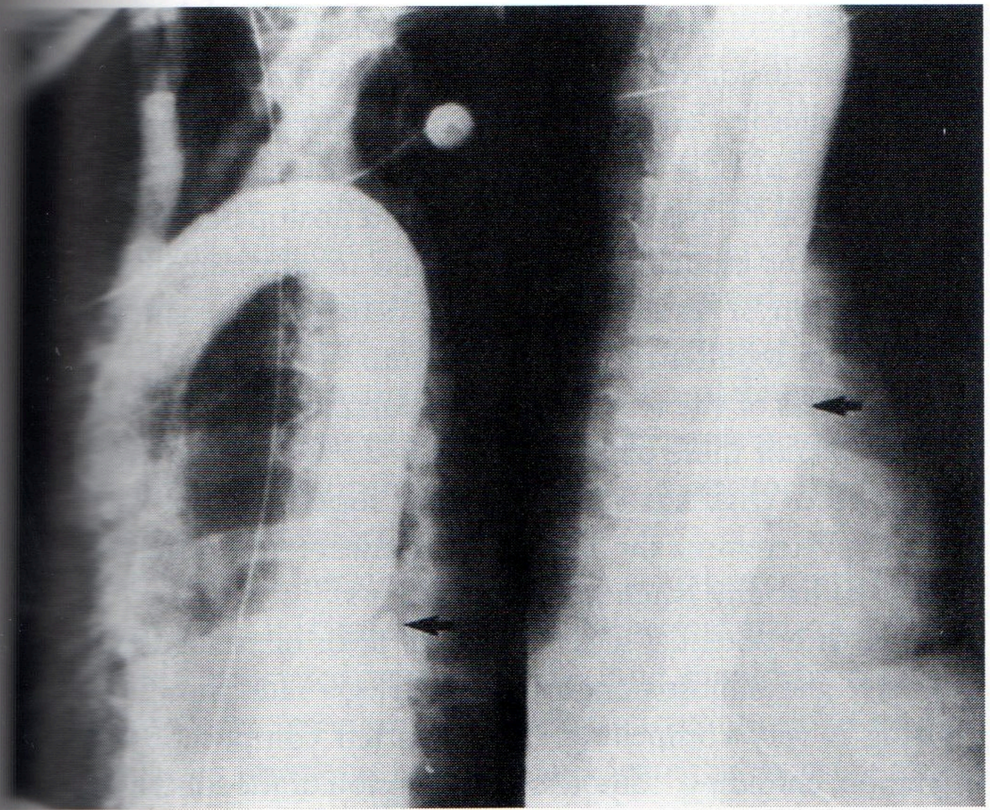
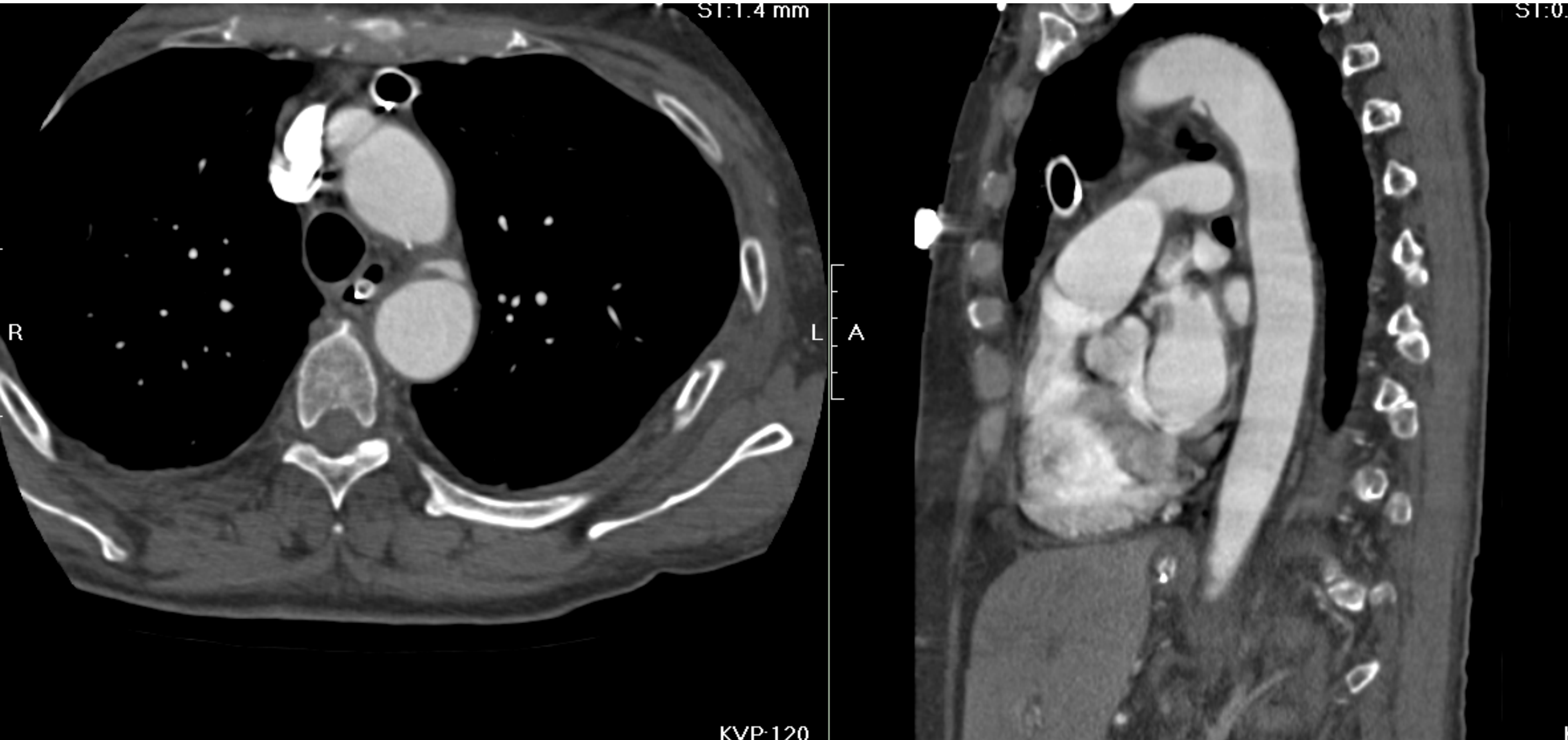


FIGURE 29-12. Aortogram in a patient with blunt chest trauma demonstrating an intimal tear of the descending thoracic aorta at the diaphragm.

Traumatic Aortic Rupture



Descending Thoracic Aorta

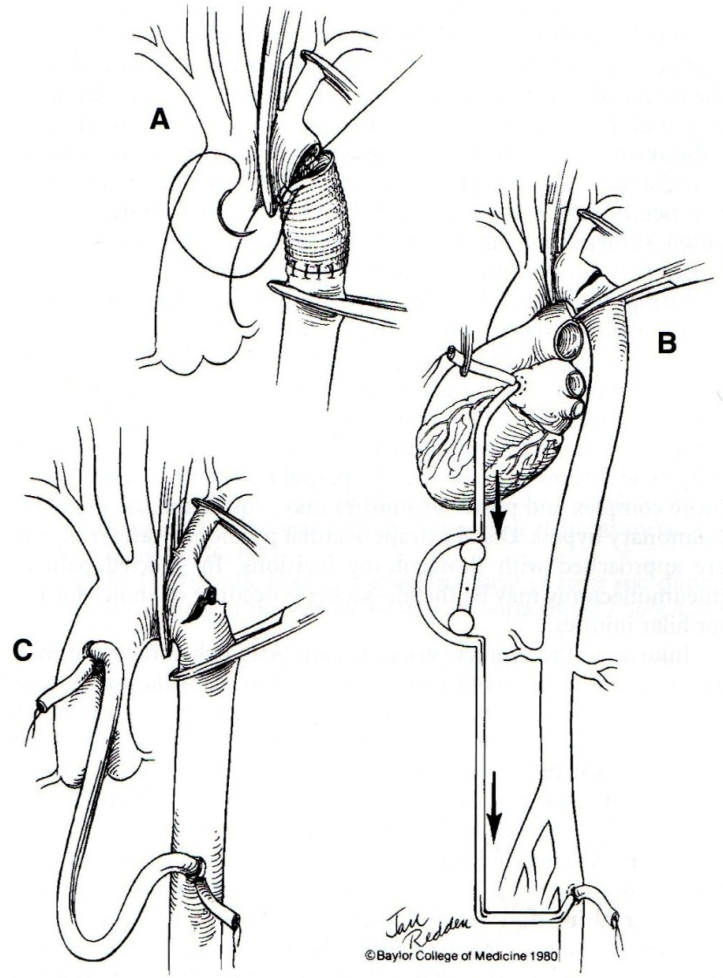


Figure 4 Adjuncts in the management of descending thoracic aortic injuries. **(A)** Simple clamp and sew technique with proximal and distal control using vascular clamps. **(B)** Active left atriofemoral bypass with partial left-heart bypass. **(C)** Passive ascending to descending thoracic aorta with shunt. *(Courtesy Jan Redden, Baylor College of Medicine, 1980.)*

TABLE 29-7

Possible Contributing Factors Related to the Multifactorial Development of Paraplegia Following Operations for Thoracic Great Vessel Injury

Injury Factors	Direct segmental artery injury
	Direct radicular artery injury
	Direct spinal artery injury
	Spinal cord contusion/concussion
	Spinal canal compartment syndrome
	Severity of aortic injury
	Specific anatomic location of aortic injury
Patient Factors	Location of arteri radicularis magma (?)
	Continuity of anterior spinal artery
	Caliber of individual segmental radicular arteries
	Congenital narrowing of spinal canal
	(?) Increased blood alcohol levels
	Total perispinal collateral blood supply
Operative Factors	Required occlusion of segmental arteries
	Pharmacological agents required
	(?) Declamping hypotension
	(?) Required cross clamp times (in combination with anatomic and injury factors cited in this table)
	Length of required interposition grafting or required exclusion
	(?) Level of systolic (or mean) proximal aortic blood pressure
	(?) Level of distal aortic mean blood pressure
	(?) "Flow" in the aorta distal to clamp
Postoperative Factors	Progressive swelling of the spinal cord
	Spinal canal compartment syndrome
	Delayed or secondary occlusion of injured or contused segmental, radicular, or spinal arteries
	Pharmacological induced spasm of spinal cord nutrient arteries

Arterial Injuries

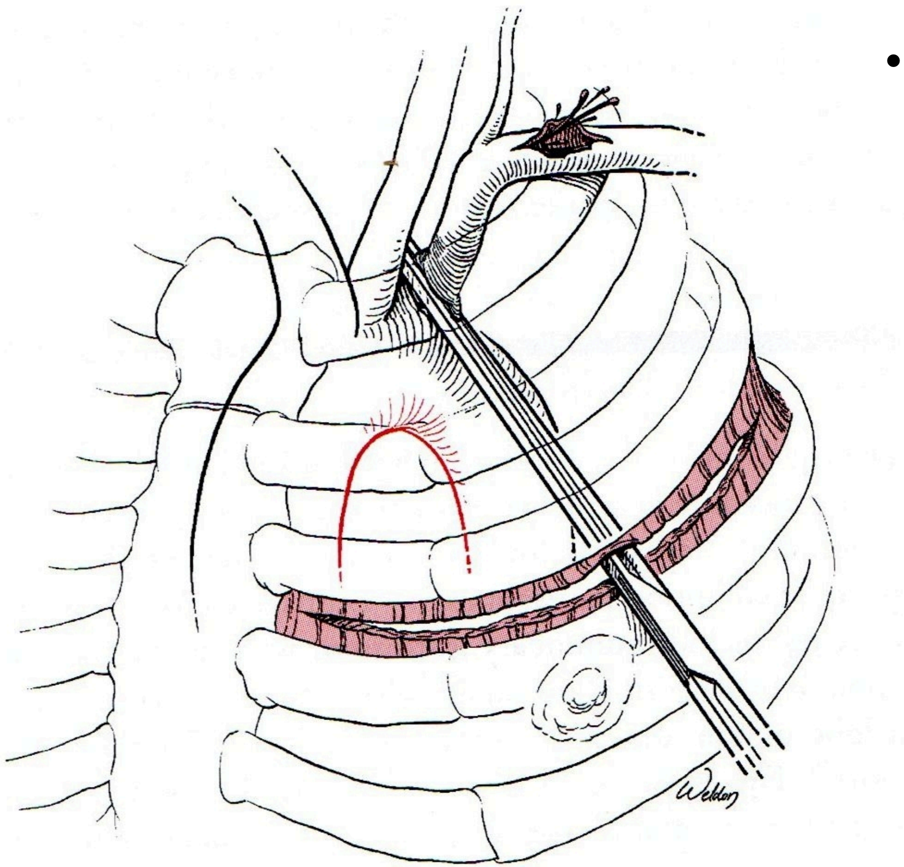


FIGURE 25-6. Proximal control of a left subclavian artery is obtained via a third interspace anterolateral thoracotomy. Definitive repair is then performed through a separate supraclavicular incision.
(Reproduced with permission from Baylor College of Medicine.)

- Subclavian Artery
  - Can occur in intrathoracic, thoracic outlet, cervical (zone I), and upper extremity
  - Right subclavian
    - Median sternotomy with right cervical extension
  - Left subclavian
    - Left anterolateral thoracotomy – proximal control
    - Supraclavicular incision – distal control
  - Document neurologic status prior to OR due to high incidence of phrenic nerve and brachial plexus iatrogenic injuries
  - Repair
    - Simple arteriorrhaphy or interpositional graft

Arterial Injuries

- Pulmonary Artery
  - Proximal Injuries
    - Median sternotomy
    - Mortality > 70%
  - Distal Injuries
    - Ipsilateral posterolateral thoracotomy
    - In massive exsanguination, pneumonectomy can be lifesaving
- Internal Mammary Artery
  - Capable of blood flow of > 300cc/hr
  - Mimics great vessel injury
  - IR embolization

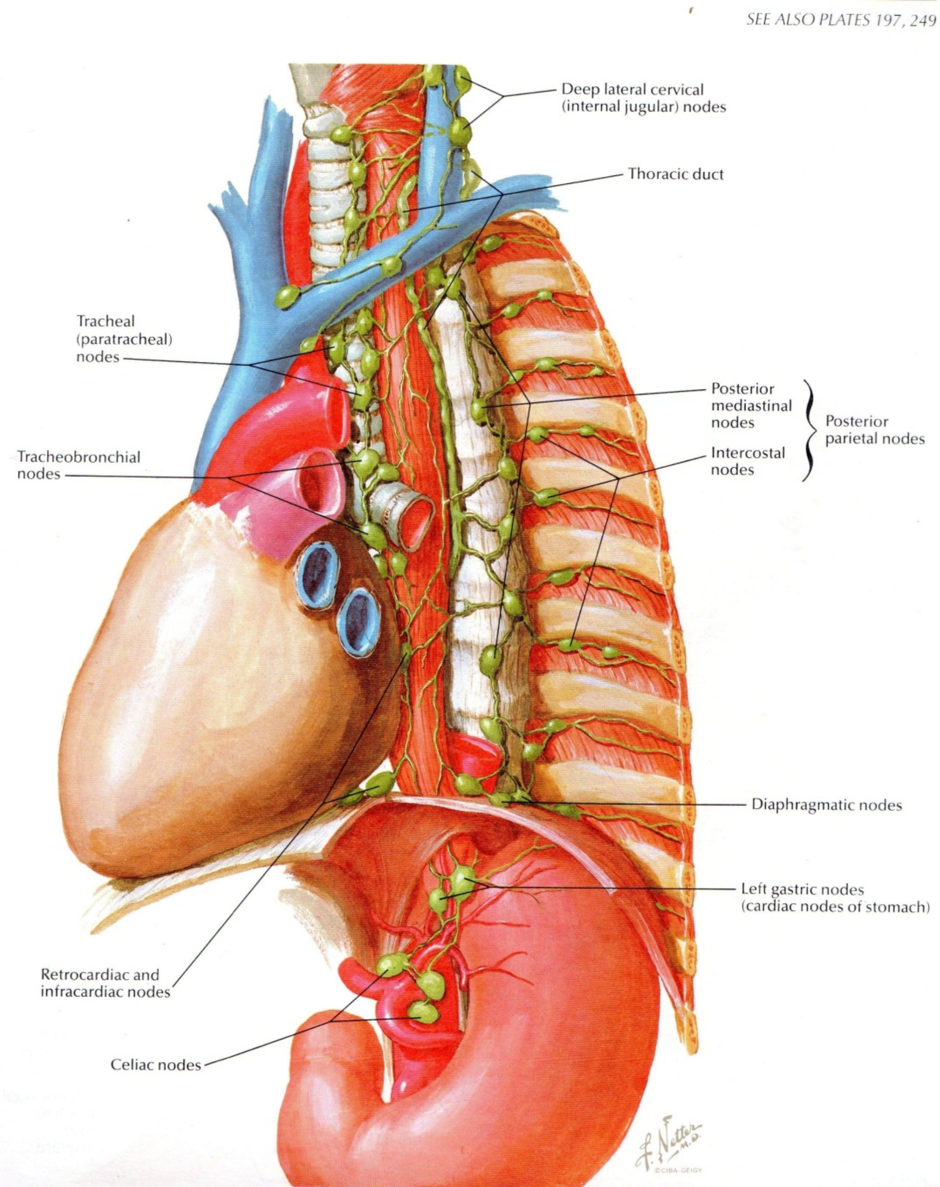
Venous Injuries

- Thoracic Vena Cava
  - High incidence of associated injuries
    - > 60% mortality
  - Exposure is extremely difficult unless patient is on bypass with inferior cannulation in groin in the abdominal IVC
  - Need to have intracaval balloon occlusion to avoid air embolism
  - Repair is achieved inside the vena cava through right atrium

Venous Injuries

- Pulmonary Veins
  - Posterolateral thoracotomy
  - If vein must be ligated, lobe needs to be resected
- Subclavian Vein
  - Same as artery
- Azygos Vein
  - Combined incisions are best depending on site of injury
  - Ligation above and below injury

Special Considerations



- Thoracic Duct Injury
  - Diagnosed by chylous drainage from chest tube
  - Treatment
    - Diet devoid of long chain fatty acids
      - Spontaneous closure in 1 month
    - Thoracotomy
      - Give fatty meal prior to surgery to help in identification of fistula

Special Considerations

- Air Embolism
  - Fistula between pulmonary vein and injured bronchiol
  - Pressure inside alveoli is greater than pulmonary vessel pressure

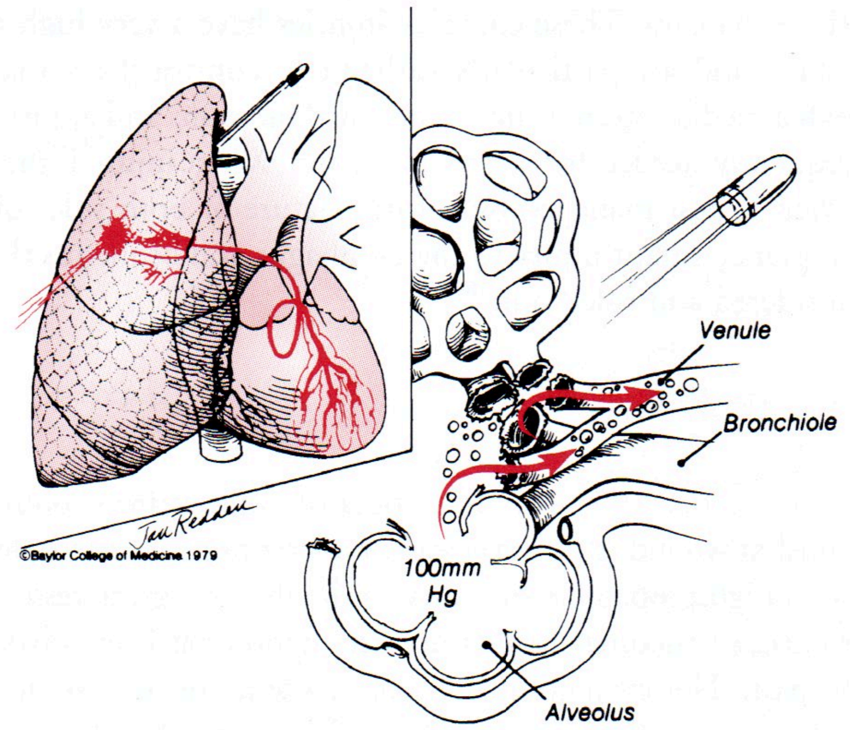


FIGURE 29-13. Drawing depicting the mechanism of systemic air embolism following a penetrating lung injury. (*Copyright © Baylor College of Medicine, 1979.*)

Pre-Op Management

- Some patients not able to be surgically repaired immediately
  - Shock, concomitant injuries
- As long as injury is stable and not enlarging, medical management can keep it stable
- BP and HR Control
  - SBP<120, HR<80
  - Esmolol gtt
    - Short acting, easily titratable, prevents rebound tachycardia
    - Max is 300 mcg/kg/hr
  - Nipride gtt
    - Add with esmolol for better BP control
    - What must you be concerned with?
      - Cyanide toxicity

Peripheral Vascular Injuries

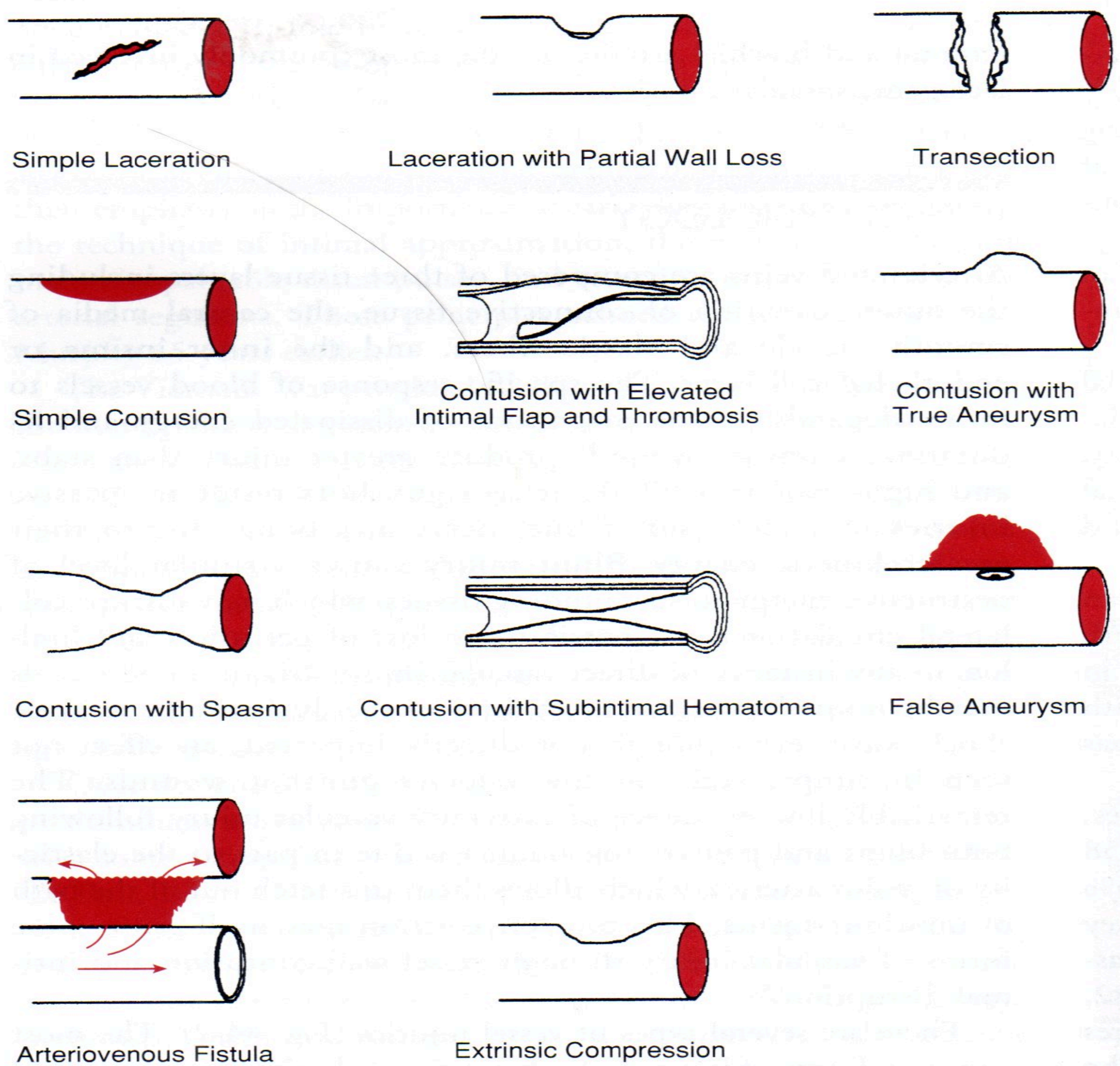
Introduction

- Peripheral vascular injuries have an incidence of 3.7% of all trauma
  - 6% of all penetrating trauma
  - <1% of all blunt trauma
- Femoral artery is the most common structure injured at 35%

Pathophysiology

- 3 layers of vascular structures
  - Adventia
    - Connective tissue
  - Media
    - Smooth muscle and elastic fibers
  - Intima
    - Endothelial layer
- Injury depends on magnitude of dissipated energy
  - Elasticity of the vessel allow it to flex out of the path of the shock wave or missile

Types of Injury



Diagnosis

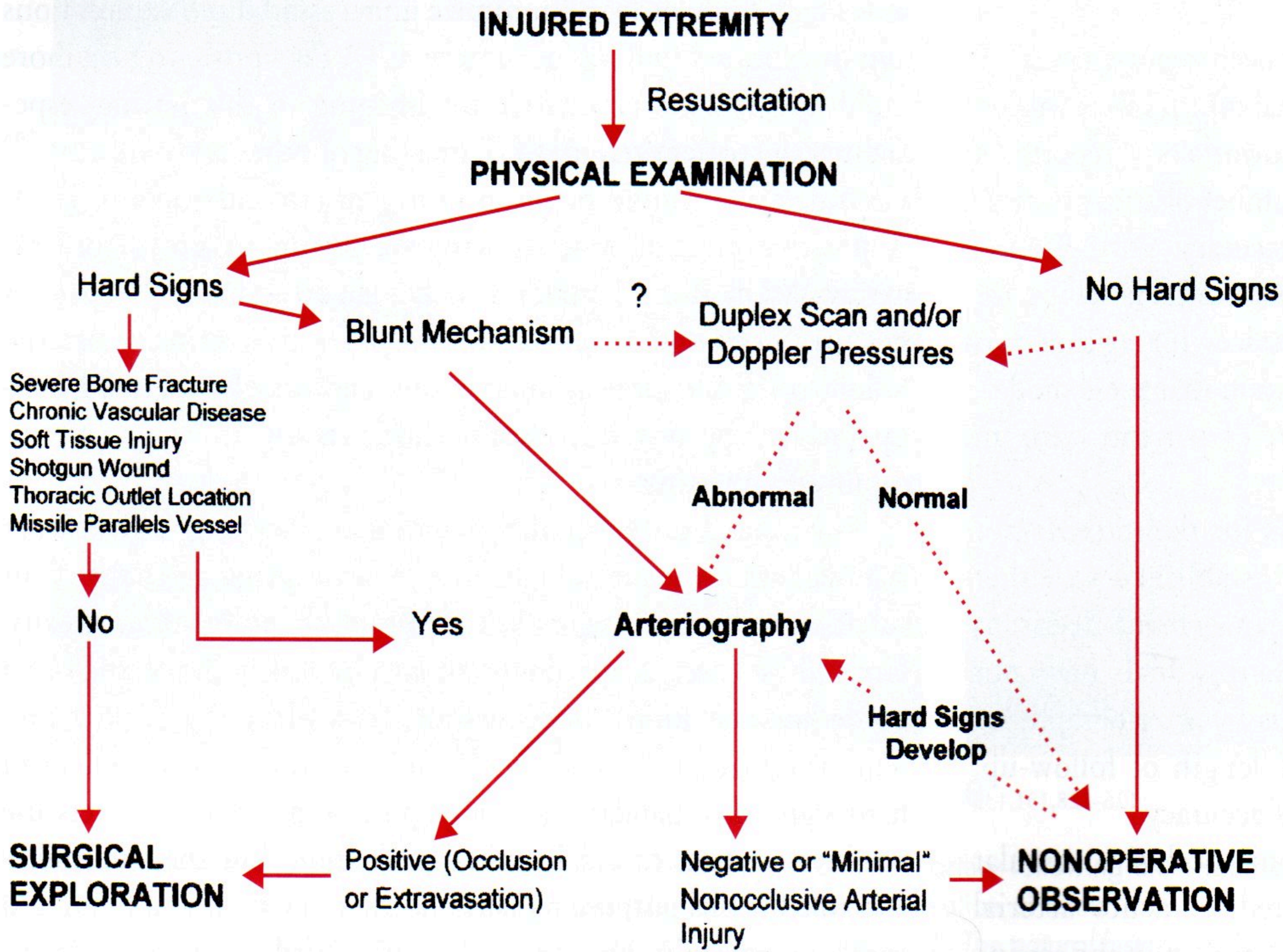
- Any penetrating trauma to an extremity has a vascular injury until proven otherwise
- PE
  - Hard signs
    - Large, expanding, pulsatile hematoma
    - Absent distal pulses
    - Distal ischemia
      - 6 P's
  - Soft signs
    - Small, stable hematoma
    - Injury to adjacent nerve
    - Unexplained hypotension
    - h/o hemorrhage at scene no longer present in hospital
    - Proximity to major vascular structures
  - ABI < 1.0
- Prompt diagnosis is key
  - Revascularization in < 6-8hrs shows a dramatic reduction in loss of limb

CT Angiography

- Only if patient is hemodynamically stable
- Reduces the number of negative surgeries
- Gives exact location of arterial injury
- Also allows for other scans
- Replacing arteriography in trauma

Management

- If active hemorrhage, apply pressure, do not clamp
  - Tourniquet as last result
- Prophylactic antibiotics if open wound, open fracture, or if prosthetic grafts are to be used
- If stable, CT Angio
- If unstable, to OR
- <u>*No definitive vascular repair until orthopaedic problems are fixed*</u>


INJURED EXTREMITY
Resuscitation
PHYSICAL EXAMINATION
Hard Signs
?
No Hard Signs
Blunt Mechanism
Duplex Scan and/or Doppler Pressures
Severe Bone Fracture
Chronic Vascular Disease
Soft Tissue Injury
Shotgun Wound
Thoracic Outlet Location
Missile Parallels Vessel
Abnormal
Normal
No
Yes
Arteriography
Hard Signs Develop
SURGICAL EXPLORATION
Positive (Occlusion or Extravasation)
Negative or "Minimal" Nonocclusive Arterial Injury
NONOPERATIVE OBSERVATION

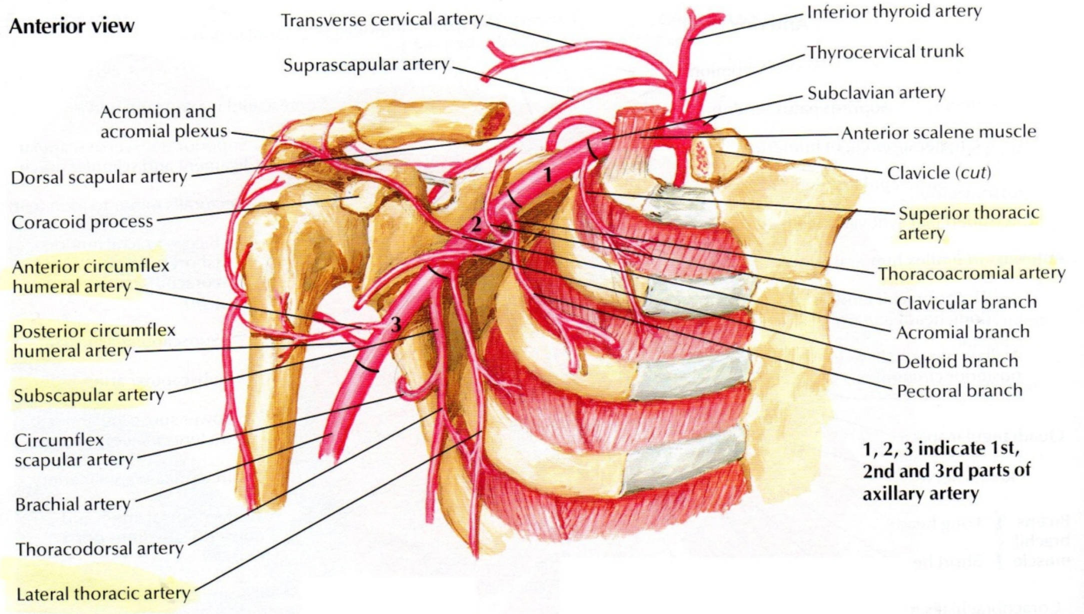
Operative Control

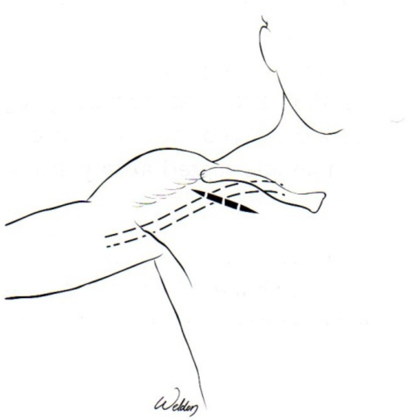
- Prep out a (contralateral) leg for saphenous harvesting if necessary
- Exposure of injured vessel is best obtained through uninjured tissue
  - Active extravasation limits this approach
- Obtain proximal and distal control
- Proximal and distal thrombectomy
- Heparinized saline instilled into proximal and distal segments
- Debride edges back to grossly normal vessel

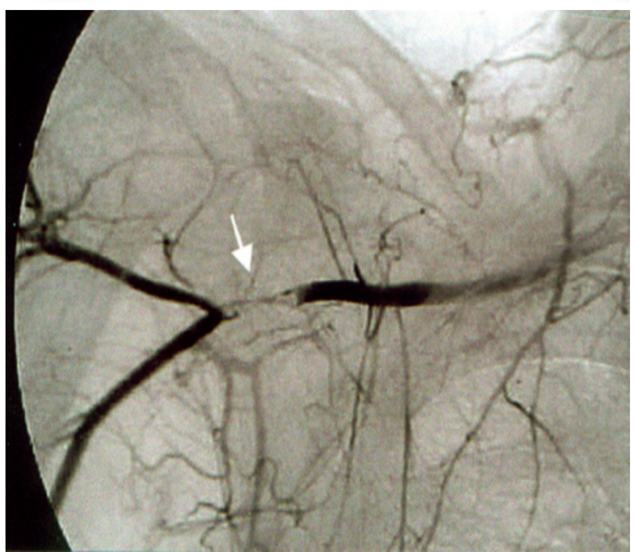
Repair

- Simple laceration repair
  - 5-0 prolene for larger vessels and 6-0/7-0 for smaller vessels
- End-to-end anastomosis
  - Autologous saphenous vein
  - Prosthetic grafts
- Intraluminal shunting
  - Damage control, unrepaired fractures

Surgical Approach



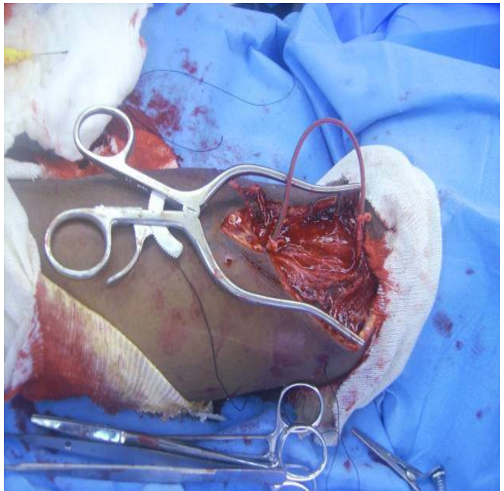


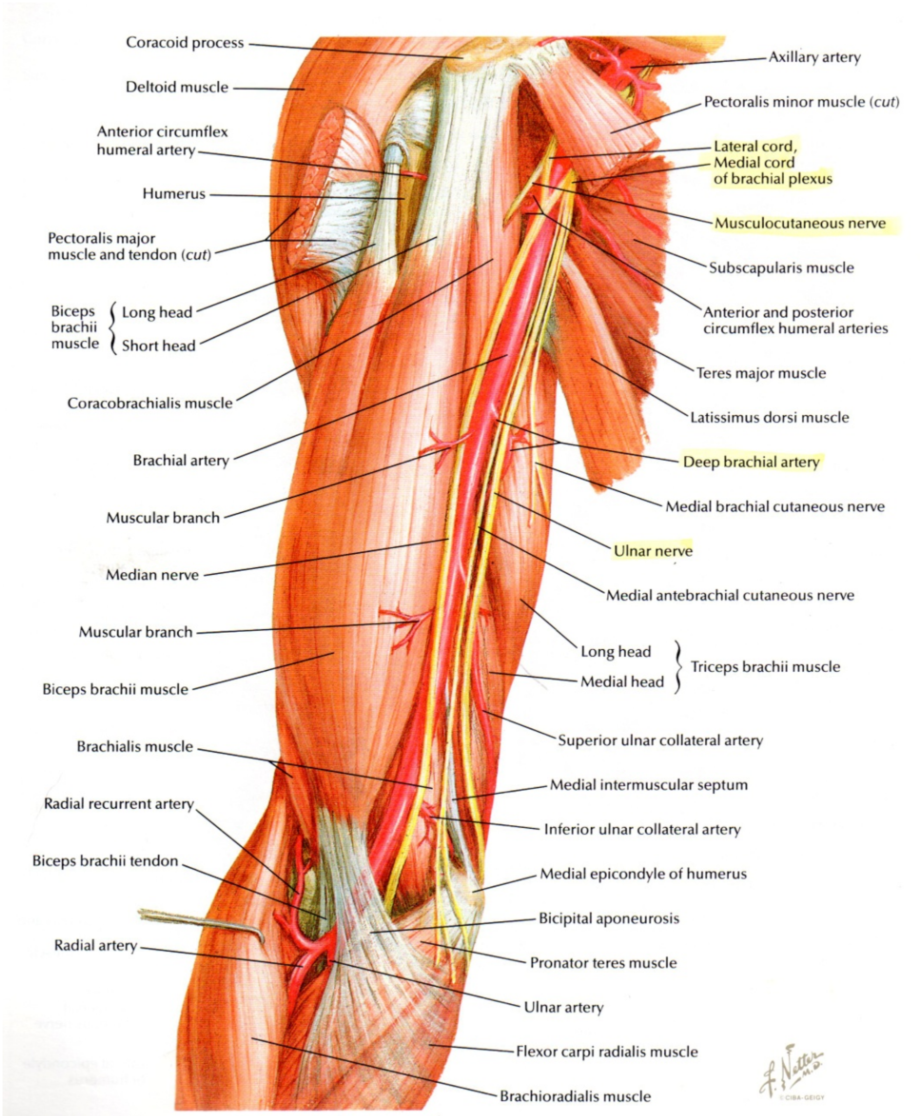


- Axillary Vessels
  - Infraclavicular incision extending from mid-clavicle to deltopectorial groove
  - Axillary vein is gatekeeper of the axilla
  - 1st portion
    - Medial to pec minor
  - 2nd portion
    - Detach pec minor from corocoid process
  - 3rd portion
    - Superficial after out from under pec minor

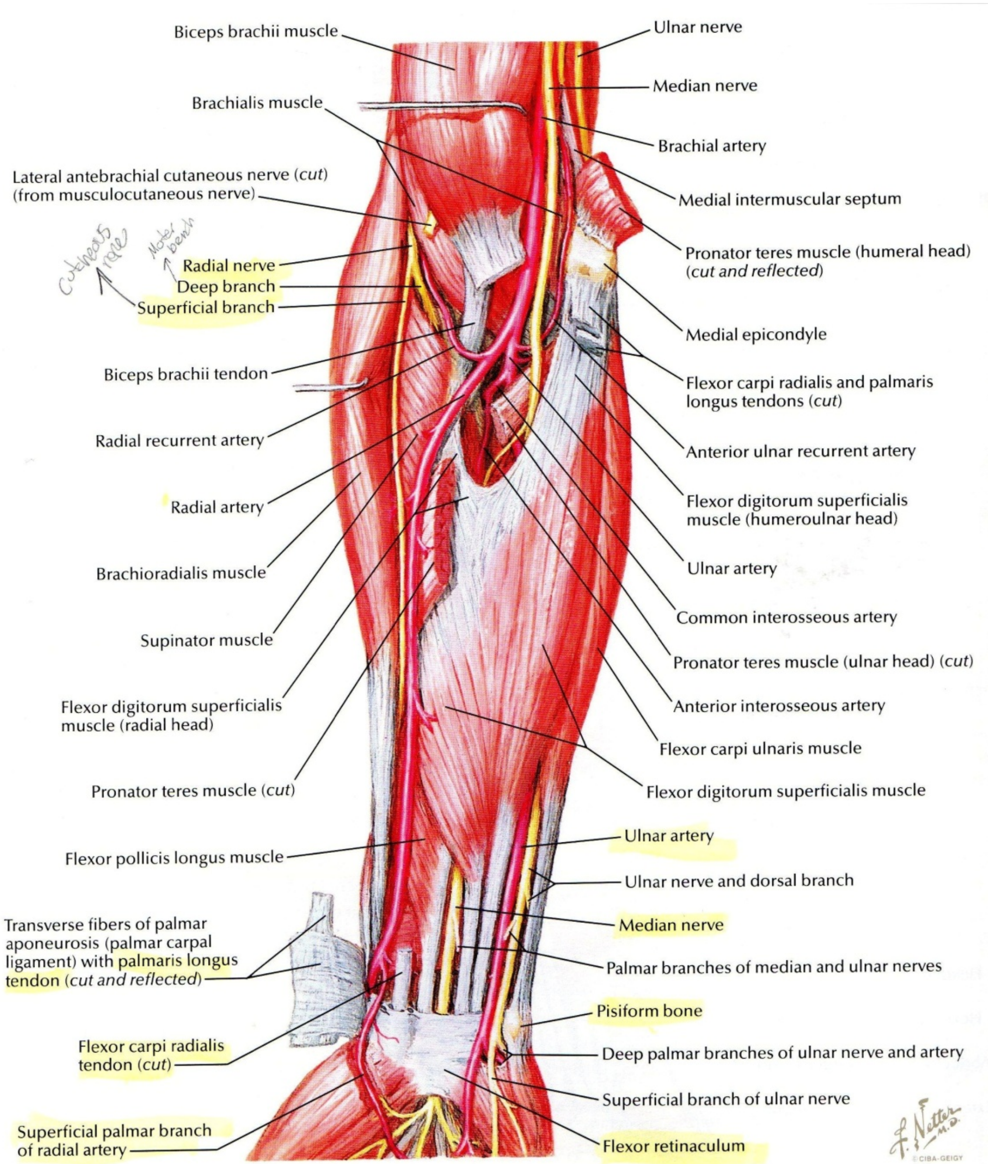
Surgical Approach

- Brachial Artery
  - Longitudinal incision along the course of the vessel just medial to bicipital sulcus





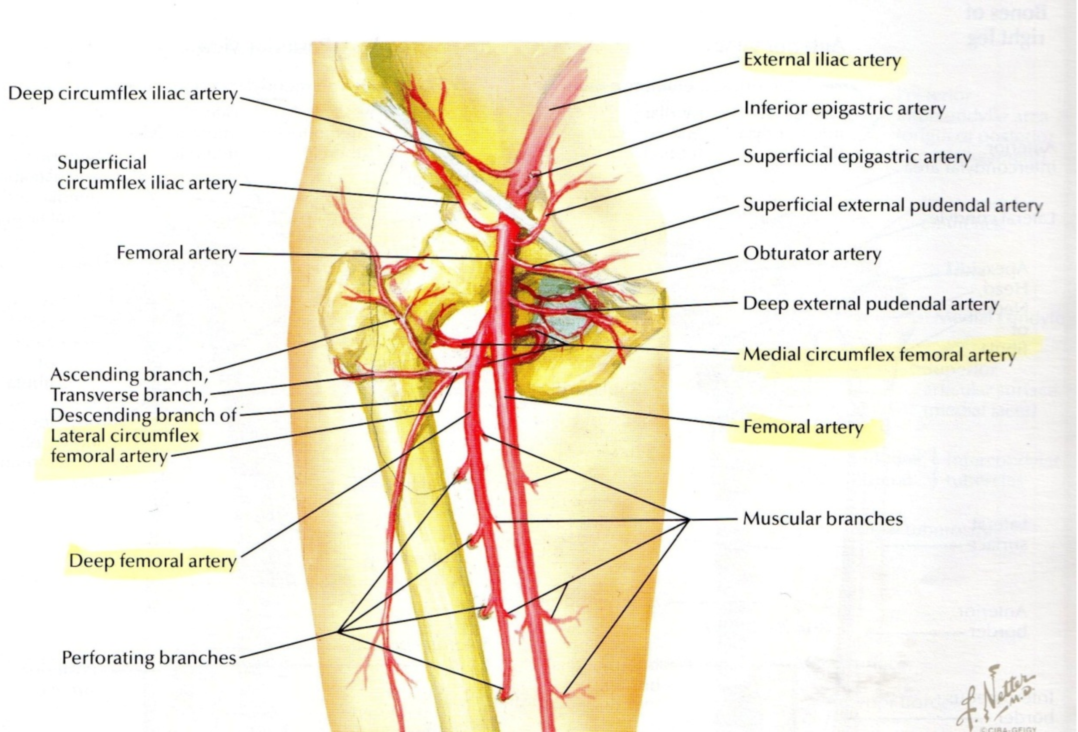
Surgical Approach

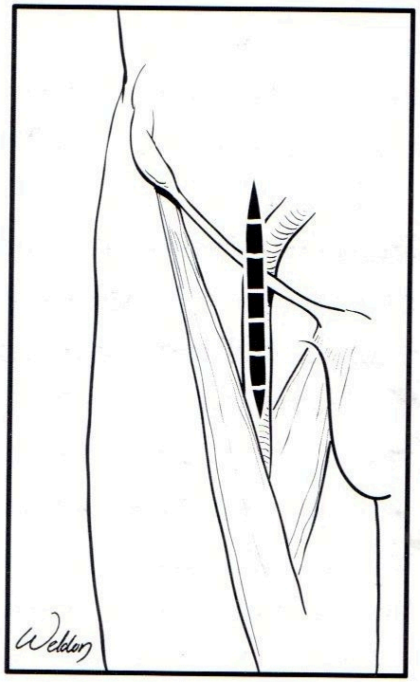


- Ulnar Artery
  - Longitudinal incision over medial volar aspect of forearm
- Radial Artery
  - Longitudinal incision on the medial aspect of the brachioradialis

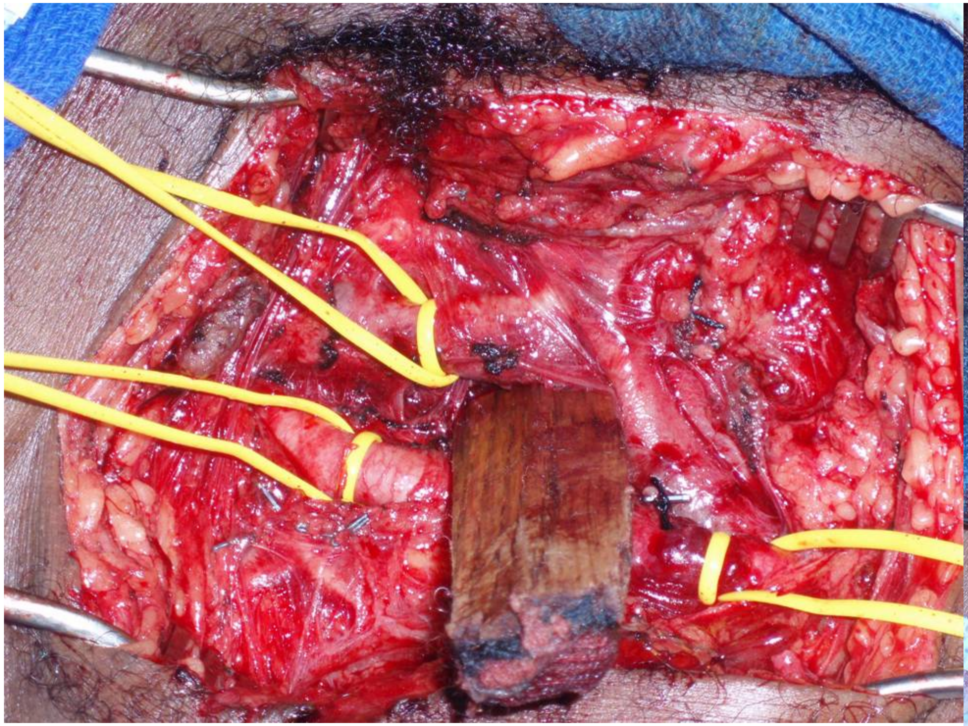
Surgical Approach

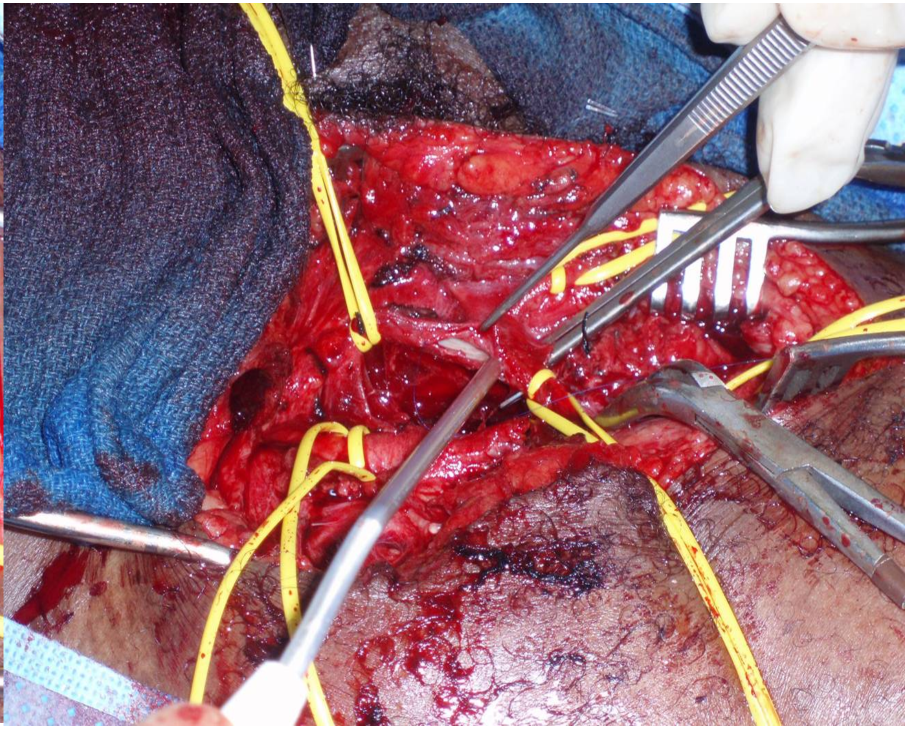
- Femoral Artery
  - Longitudinal incision over femoral pulse
  - Identify Deep femoral artery
    - Where artery makes abrupt change in diameter



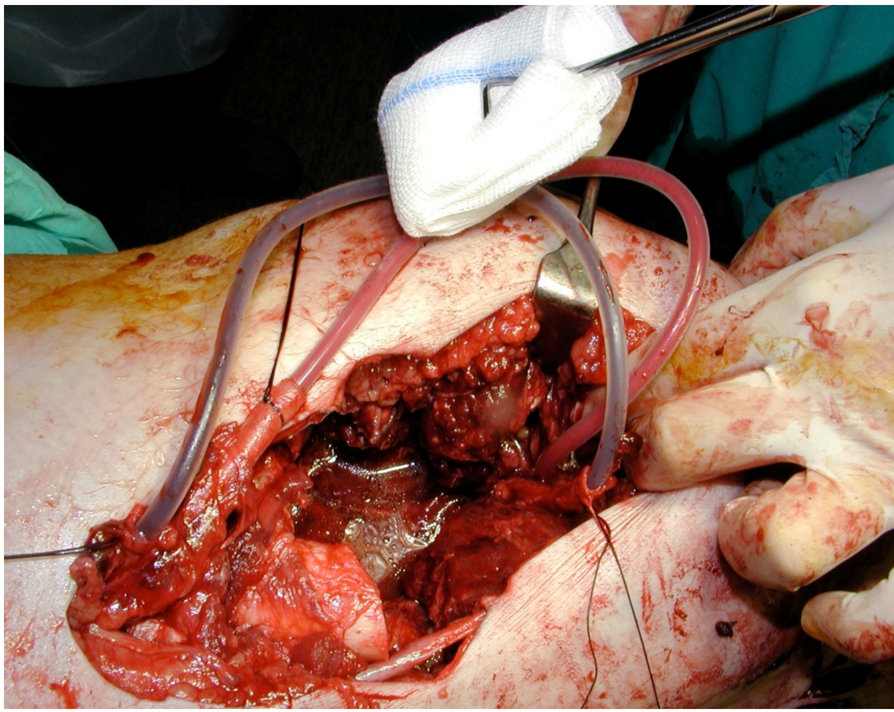


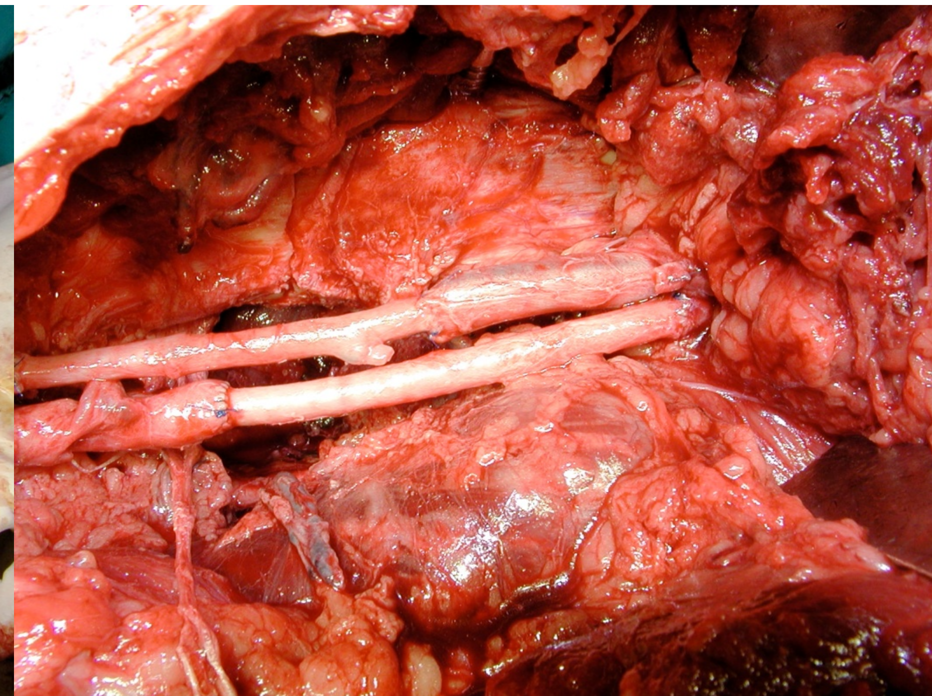
Femoral Vein Injury





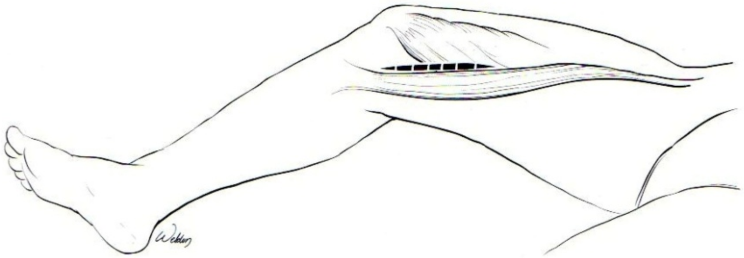
Femoral Artery and Vein Shunt

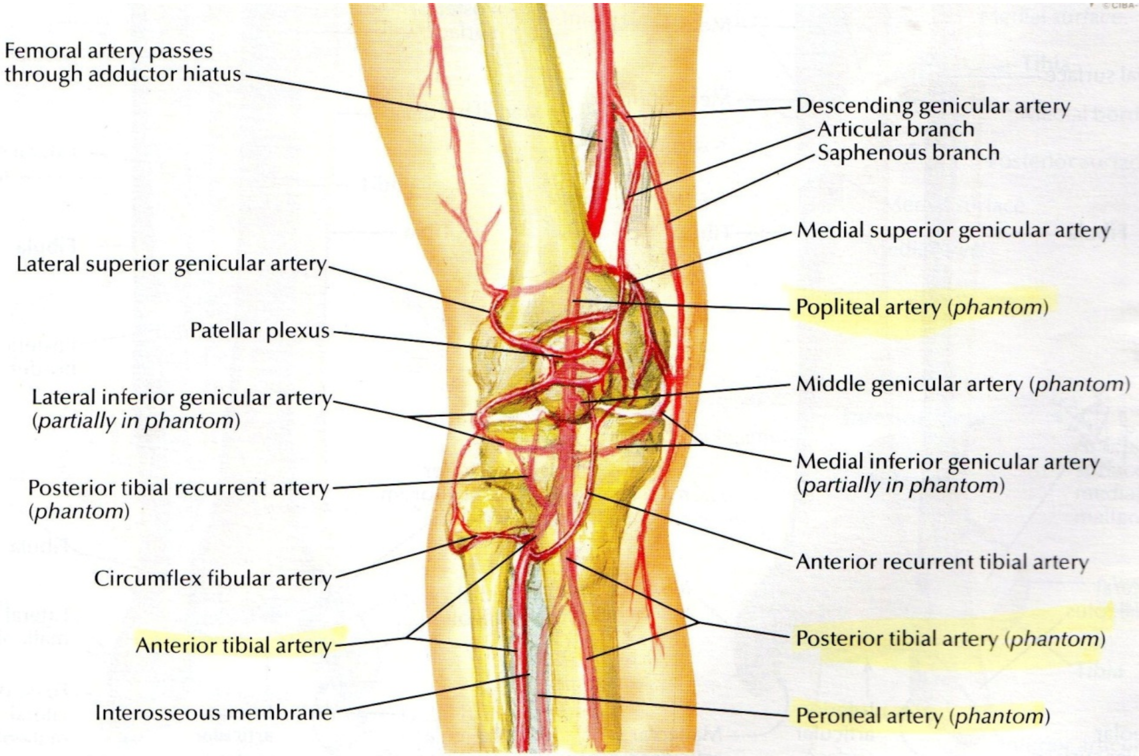




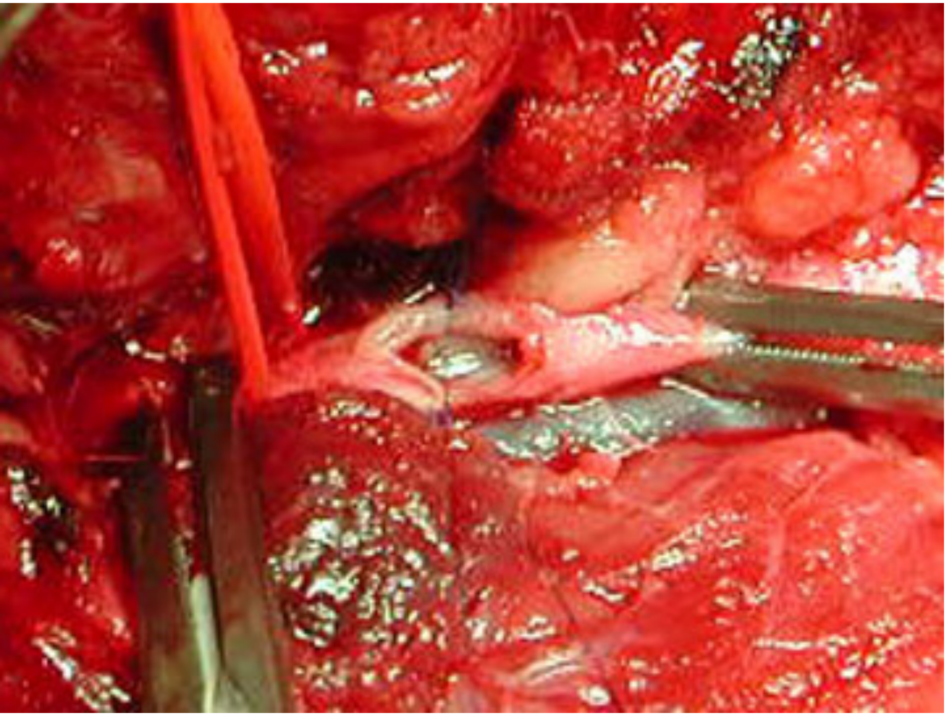
Surgical Approach

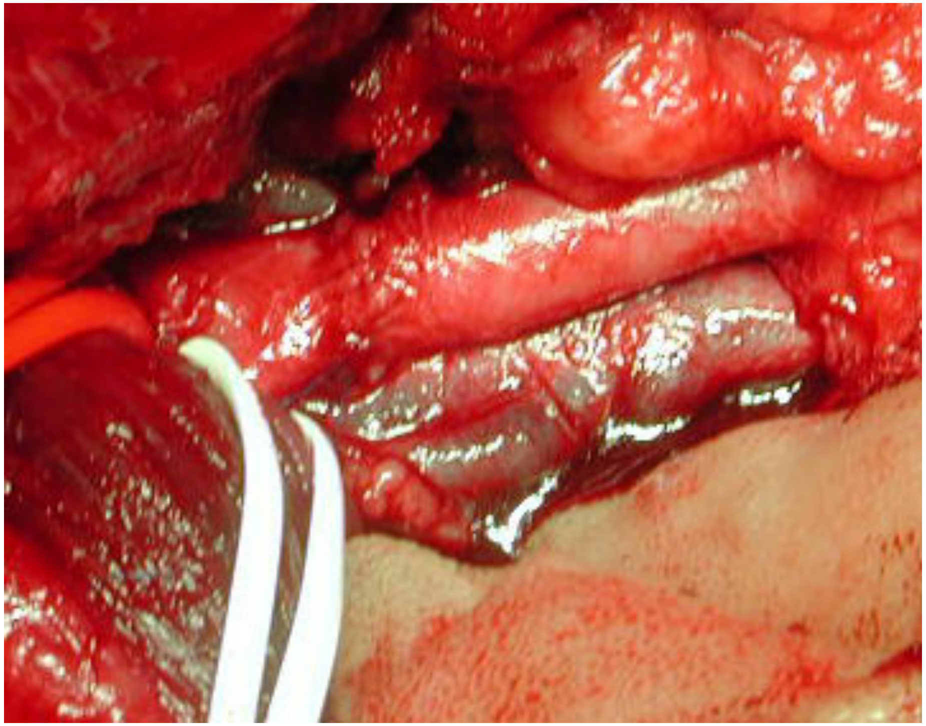
- Popliteal Artery
  - Medial incision
    - Incision is made in the lower thigh along the palpable groove between the vastus medialis and sartorius muscle



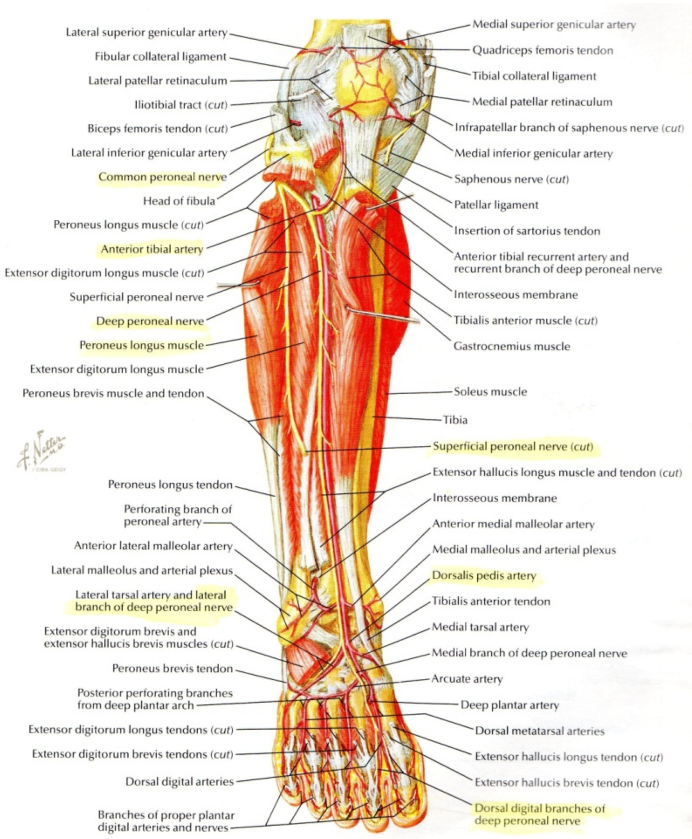


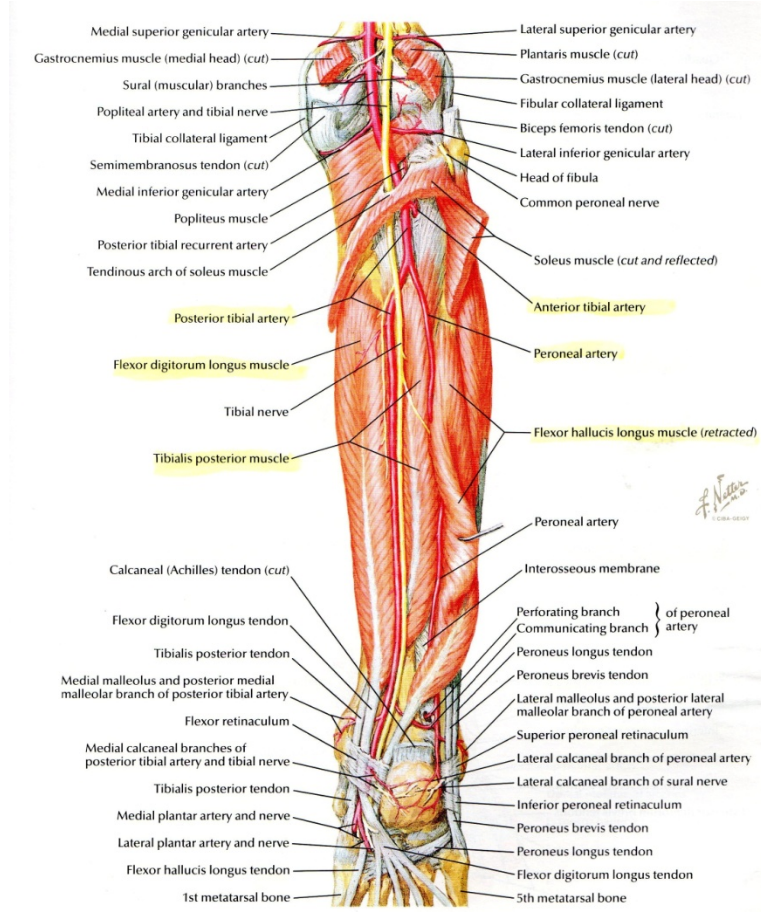
Popliteal Artery Injury





Surgical Approach





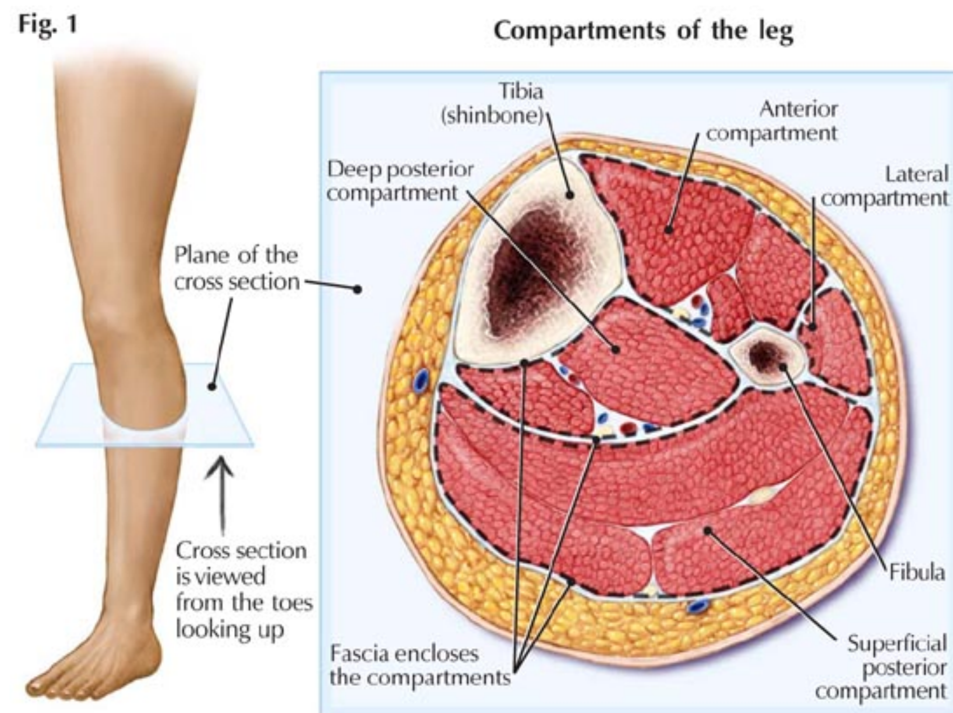
- Anterior Tibial Artery
  - Longitudinal incision on the lateral border of the tibia
    - ATV is a marker for the take-off of the ATA
- Posterior Tibial Artery
  - Medial incision behind the posterior border of the tibia

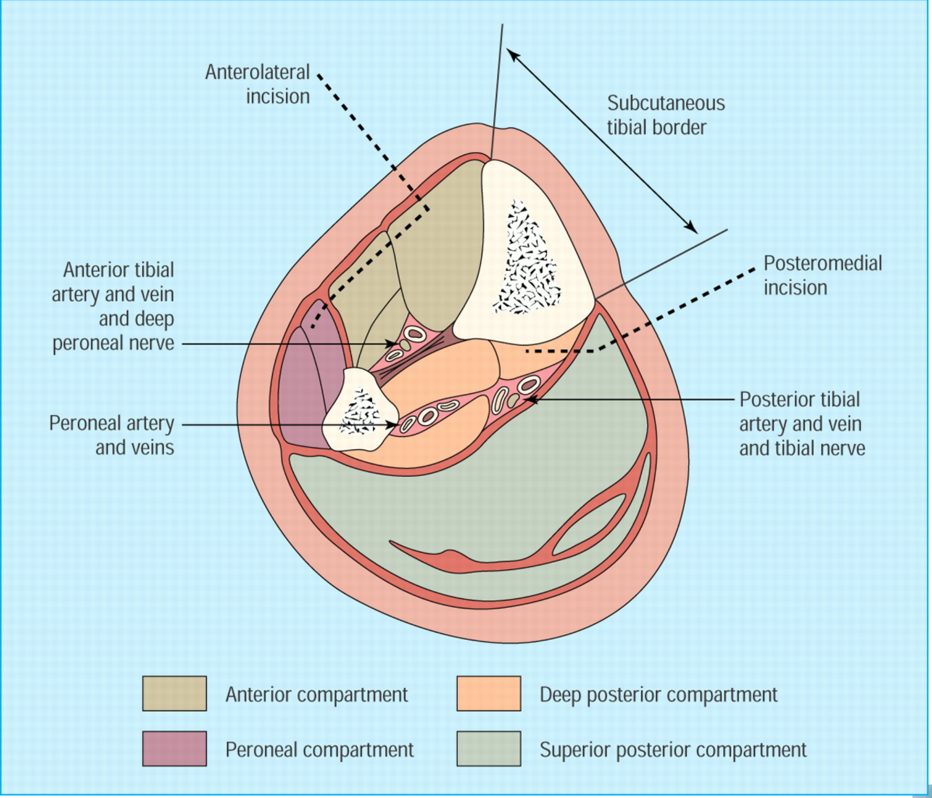
Post-Op

- Intraoperative arterography
  - Document patency
- Vascular checks every hour
- Re-scan 1-2 weeks later to check for pseudoaneurysm, AV fistula

Special Consideration

- Compartment Syndrome
  - Unrepaired injured vessel
  - Reperfusion injury
  - Ligation of major veins
  - Pressure > 25mmHg
  - Can lead to Rhabdo
  - 4 compartment fasciotomy




Anterolateral incision
Subcutaneous tibial border
Posteromedial incision
Anterior tibial artery and vein and deep peroneal nerve
Peroneal artery and veins
Posterior tibial artery and vein and tibial nerve
Anterior compartment
Deep posterior compartment
Peroneal compartment
Superior posterior compartment

When to amputate

- Attempts are made to stabilize skeletal trauma through ex-fix or traction
- Damage control if vascular injury
- Assess nerve damage
- Observe for 24-48 hours
- If no improvement or clinical picture worsens, amputation is best bet

TABLE 44-11

High-Risk Factors for Ultimate Limb Loss or Severe Dysfunction Following Combined Vascular and Skeletal Extremity Trauma
Gustilo III — C skeletal injuries
Transected tibial or sciatic nerve
Transection of 2 of 3 upper extremity nerves
Prolonged ischemia (>6–12 hours)
Shock and life-threatening associated injuries
Below-knee arterial injury
Extensive soft tissue loss
Crush injury
Multiple fractures
Elderly with medical comorbidity
Severe contamination
Patient preference

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