

Chapter 38 – Pediatric Trauma

Episode Overview:

- 1) List 5 relevant anatomic/physiologic differences between children and adults in relation to trauma management
- 2) List 8 airway differences between pediatrics and adults with their relevant implications
- 3) List potential fluid therapies for hemorrhagic shock and their doses
- 4) List 3 ideal IO sites in pediatrics and describe the procedure
- 5) Describe the pediatric GCS
- 6) List 6 indications for laparotomy
- 7) List 6 signs of elevated ICP in infants and children
- 8) What is an impact seizure?
- 9) List the 5 layers of the scalp and describe 3 types of extra cranial bleeding in pediatrics
- 10) What is the difference between a linear and a diastatic skull fracture
- 11) Describe the typical presentation and etiologic cause of an epidural hematoma and a subdural hematoma
- 12) Describe the management of elevated ICP
- 13) List 10 anatomical differences between the pediatric and adult cervical spine
- 14) How can you discern between true subluxation and pseudosubluxation at C2/C3
- 15) List 2 ways to choose the size of chest tube in pediatrics
- 16) What are indications for ER resuscitative thoracotomy in chest trauma?
- 17) List pediatric specific cardiovascular and abdominal injury patterns

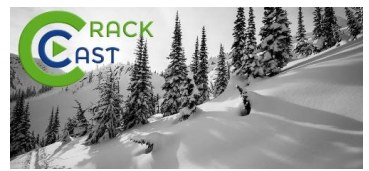
Rosen's in Perspective:

Principles of disease:

- children have:
 - proportionally larger abdominal organs
 - less subcutaneous fat
 - less protective abdominal muscles
 - proportionally larger kidneys
 - flexible cartilaginous ribs that can compress internal organs without showing fractures

Clinical features:

- very difficult to obtain complete history
- physical exam is plagued with difficulty
 - tachypnea
 - abdominal tenderness / bruising
 - shock
 - shoulder pain



- vomiting (late sign in child with duodenal hematoma or pancreatic injury)
- rectal exam is insensitive

- SERIAL exams are essential!

Circulation and Hemorrhage control:

- pediatric shock:
 - cool distal extremities, decreases in peripheral vs. central pulse quality, delayed cap refill
 - altered sensorium

FAST and family:

- ultrasound for blood
- allowing family to be present during the resuscitation
 - informing them of what happened
 - utilizing social work and child life specialists

Secondary survey:

- AMPLE history
- Tasks to complete
 - continuous repeated vitals signs
 - provision of analgesia
 - abx and tetanus
 - monitor urine output
 - post-intubation sedation and medication
 - don't forget adequate analgesia!

Physical examination:

- head to toe exam: pit to finger exam
- remove the kid off backboard
- many orthopedic injuries are missed

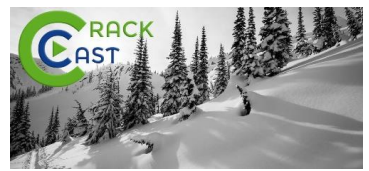
Diagnostic evaluation:

Labs:

- initial hemoglobin is usually unreliable: do serial measurements
- glucose level

Radiology:

- CXR
- pelvis x-ray unless:
 - age >3 and no complaint of injury
 - no impaired LOC



- no major distracting injury
- no complaint of pelvic pain
- no signs of fracture on inspection
- no pain on pelvic stressing
- no pain on hip rotation or flexion
- skeletal survey in young children suspected of having NAT

Formulas to know!

- Cuffed ET:
 - $\text{age in years}/4 + 3.5$
- Uncuffed ET
 - $\text{age in years}/4 + 4$
- Tube depth
 - $\text{age in years}/2 + 12$
 - Appropriate tube size X 3 = number of cm at the teeth that the ETT should be taped at.
- Chest tube size:
 - 2 x ETT size
- Femoral line: 3-6 F.

1) List 5 relevant anatomic/physiologic differences between children and adults in relation to trauma management

1) More widely distributed forces in a child = multiple injuries more likely to occur due to structural differences

- Brain is less protected: thinner cranial bones, less myelination
- More anterior inner organs with less muscle and fat: liver, spleen, and less protected spleen
- Pulmonary injuries occur without skeletal injuries due to elastic ribs
- Open growth plates = salter-type fractures with long term implications
- SCIWORA injuries occur due to an elastic vertebral column and tenuous blood supply

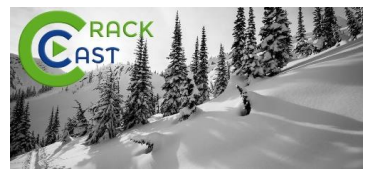
2) Larger surface area = prone to heat loss ---> hypothermia = negative effect on cardiac function, inotropy, LV contractility, platelet function, renal and hepatic drug clearance, metabolic acidemia

3) Higher, proportional requirements for free water, electrolytes, minerals due to higher metabolism

4) Higher O₂ consumption and glucose utilization per kg = need energy and calories sooner - due to increased metabolism

5) Great capacity to maintain BP despite 25-30% blood loss

- little role for inotropy: mostly dependent on chronotropy and SVR



- ****compensated shock (TachyC and slow cap. refill) are warnings that the kid is about to crash!****

2) List 8 airway differences between pediatrics and adults with their relevant implications

	Differences	Implications
Physiologic	Increased vagal response to laryngoscopy	Bradycardia - have atropine on hand!
Anatomic	Larger tongue	#1 cause of airway obstruction; need better head positioning +/- OPA/NPA
	Larger adenoidal tissues	Nasotracheal intubation and NPA's are tougher to insert
	Floppy epiglottis more U shaped	"use miller blade" (false dogma) and change in intubation technique - 'insert Miller blade into the esophagus and then SLOWLY withdraw until you see the glottis'
	Cephalad, anterior larynx	tougher to visualize the cords, need to angle 45 deg. forward to see them
	Cricoid ring the most narrow part of the airway (the first cricoid cartilage of the trachea)	May need uncuffed tubes in kids <8 yrs (or need to downsize slightly)
	Narrow tracheal diameter and distance between rings	Needle cric. for kids <12 yrs: not surgical airway rings
	SHORTER tracheal length; large airways more narrow	Right mainstem intubation (neck extension) and EASY dislodgement of tube (neck flexion) ; greater airway resistance

3) List potential fluid therapies for hemorrhagic shock and their doses

- standard trauma/resus room protocol : MOVIE
- 10-20ml/kg of crystalloid IV bolus repeated up to three times then:
 - PRBCs: 10 ml/kg
 - FFP: 25 ml/kg
 - Platelets: 10 ml/kg

4) List 3 ideal IO sites in pediatrics and describe the procedure

Need to use the mantra "1-2-IO" - get access ASAP

- IV access: if not do an IO
 - proximal medial tibia
 - proximal humerus
 - anterior distal femur



5) Describe the pediatric GCS

AVPU system / age appropriate GCS score

- **the problem with the peds GCS is that it DOESN'T help you prognosticate neurological outcome as the adult GCS score (no validation) and has poor inter-rater reliability**

Children with poor scores can have great outcomes

Signs of herniation might be indicated by:

- pupil size and reactivity
- extremity movement and tone
- posturing and reflexes

Treatment:

- mannitol 0.5 g/kg IV; maintain CPP of at least 50
- assess for spinal injury

Adult			Pediatric	
Spontaneously	4	Best Eye Opening	Spontaneously	4
To verbal stimuli	3		To verbal stimuli	3
To painful stimuli	2		To painful stimuli	2
No eye opening	1		No eye opening	1
Oriented	5	Best Verbal Response	Appropriate coo & cry	5
Confused	4		Irritable cry	4
Inappropriate words	3		Inconsolable crying	3
Incomprehensible	2		Grunts	2
No verbal response	1		No verbal response	1
Obeys commands	6	Best Motor Response	Normal spontaneous	6
Localizes pain	5		Withdraws to touch	5
Withdraws to pain	4		Withdraws to pain	4
Flexion to pain	3		Flexion to pain	3
Extension to pain	2		Extension to pain	2
No motor response	1		No motor response	1

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6) List 6 indications for laparotomy

- hemodynamic instability despite aggressive resuscitation
- free fluid on FAST and instability
- massive bleeding (intraperitoneal) despite blood
- pneumoperitoneum / intraperitoneal bladder rupture / grade V renovascular injury
- gunshot wound
- evisceration
- peritonitis



7) List 6 signs of elevated ICP in infants and children

Signs of increased ICP in infants - Rosen's Box 38-8

- full fontanel
- split sutures
- altered state of consciousness
- paradoxical irritability
- persistent emesis
- setting sun sign

Signs of increased ICP in children - 38-9 pg. 312

- headache
- stiff neck
- photophobia
- Altered mental status
- persistent emesis
- cranial nerve involvement
- papilledema
- hypertension, bradycardia, hypoventilation
- decorticate and decerebrate posturing

8) What is an impact seizure?

Principles of disease:

- important anatomic differences
 - larger, heavier cranial vault
 - high amount of torque on the C spine axis in toddlers and infants
 - malleable sutures
 - brain parenchymal damage without skull fractures

this highlights the principle that in kids: they get soft tissue damage WITHOUT showing fractures!

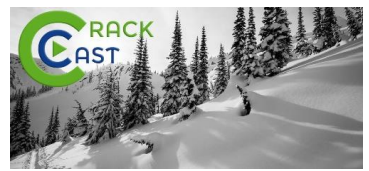
Less myelinated brain with higher water content

- more susceptible to shearing forces and further injury

Clinical features:

Key points on history:

- height of fall, method of landing, surface of impact, use of restraints, helmet use, LOC immediately after injury, signs of progressive lethargy/irritability/recurrent vomiting/etc.
 - vomiting is an unclear prognostic indicator : may just be a familial predisposition to vomiting vs. intracranial injury



- impact seizure: a seizure with immediate return to normal mental status after the postictal period: usually NOT associated with parenchymal injury.
 - seizures > 20 mins from injury portend greater possibility of TBI and need for CT and neurosurgery consult.

Physical exam:

- ABC's interventions
 - maintain oxygenation and perfusion
 - optimize glucose
 - euvolemia
 - $CPP = MAP - ICP$
- no matter what a child's neuro presentation in the ED try to resuscitate

9) List the 5 layers of the scalp and describe 3 types of extra cranial bleeding in pediatrics

Layers of the scalp – use the SCALP mnemonic:

S – Skin

C – Connective Tissue

A – Aponeurosis

L – Loose Connective Tissue

P – Periosteum

Caput succedaneum: hematoma, freely mobile and crosses suture lines

Cephalohematoma:

- blood UNDER periosteum = does NOT cross suture lines
- scalp bleeding can be profuse and lead to shock in infants

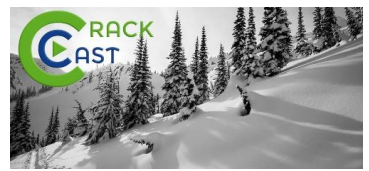
Cerebral contusions

- clearly demonstrable on CT scan as a brain parenchymal injury
- neuro features with altered MS

10) What is the difference between a linear and a diastatic skull fracture

Skull fracture factors associated with poor outcomes:

- 1) fracture over a vascular channel
- 2) a depressed fracture
- 3) a diastatic fracture
 - cross through/along suture lines and leptomeningeal cysts (growing fractures) may develop (>2mm of separation)
- 4) fracture extending over the area of the medial meningeal artery
- 5) rhinorrhea, otorrhea



11) Describe the typical presentation and etiologic cause of an epidural hematoma and a subdural hematoma

Epidural hematoma

- "head injury: lucid interval: followed by rapid deterioration"
- due to VENOUS bleeds in kids (adults = arterial bleed)
 - **delayed signs and symptoms**
- highly associated with overlying skull fractures

Subdural hematoma

- usually associated with rupture of bridging veins.
- most common in kids <2 yrs. of age
- may be chronic in the child
 - with "shaken baby syndrome" or NAT!
 - vague: vomiting failure to thrive, altered LOC, seizures.
- need fundoscopic exam to rule out retinal hemorrhage pathognomonic of NAT (non-accidental trauma)

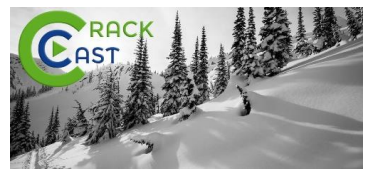
12) Describe the management of elevated ICP

Diagnostic strategies:

- serial exams are key
- absence of focal findings doesn't rule out injury
 - papilledema requires days to develop
- cushing's response is ominous
- monro-kellie doctrine
 - as ICP increases - brain perfusion/ability to autoregulate decreases
- herniation syndromes:
 - uncal herniation
 - unilaterally dilated pupil
 - compression of ipsilateral third nerve, contralateral hemiplegia, hyperventilation
 - "down and out pupil"
 - may progress to frank apnea and cardiac arrest

Treatment:

- **prophylactic treatment with anticonvulsants **not** recommended **
 - incidence of post-traumatic seizures is low
- treatment of Increased ICP: non-pharmacologic methods and pharmacologic methods
 - 1) Non-pharmacologic
 - elevate HOB >30 deg



- head in midline
- avoid hyperthermia
- mild hypothermia
- maintain euvolemia
- decompressive craniotomy
- 2) Pharmacologic
 - Mannitol (0.5 g/kg IV)
 - rapid osmotic diuresis
 - Hypertonic saline (0.1-1 mL/kg of 3% saline)
 - Pentobarbital / phenobarbital
 - lowers cerebral metabolism
 - Neuromuscular blockade
 - Sedation
 - Treat seizures aggressively
- Stop gap therapies:
 - hyperventilation for ACUTE increase in ICP (temporary fix)

13) List 10 anatomical differences between the pediatric and adult cervical spine

Spinal injury

- rare
- higher cord injuries are more common
- SCIWORA (Spinal Cord Injury without Radiography Abnormality) - found in 25-50% of spinal injuries

Principles of disease

- C-spine features approach adult patterns around age 8-10.
- Key differences in the peds: C spine:
 - higher fulcrum C2-3 (higher c spine injuries)
 - larger head size - greater flexion and extension injuries
 - smaller neck muscle mass
 - increase interspinous lig. flexibility
 - flatter facet joints
 - incomplete ossification at multiple bony sites
 - anterior surfaces of the vertebral bodies are more wedge shaped
 - Epiphytes of spinous processes tips mimic fractures
 - Narrow predontoid space
 - Pseudosubluxation of C2-3 seen on 40% of children 8-12 yrs
 - Pre vertebral space varies with respiration
 -

Clinical features

- need to consider MOI; standard trauma primary survey
- C-spine injury indicators



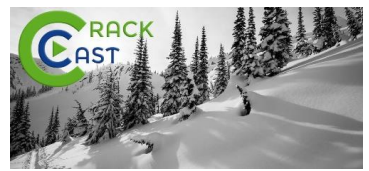
- tenderness in the body c-spine area
- paralysis or paresthesias
- ptosis
- priapism
- incomplete (some motor or sensory function below the level of the lesion) vs complete lesions
 - NOT a one-time assessment: to be continued until spinal shock resolves
- exam tests:
 - bulbocavernosus reflex
 - rectal or anal wink

Cord syndromes:

Central cord	Anterior cord	Brown_sequard	Complete
extension injury	flexion injury	hemisection of the cord	cutt
---arm tone < leg tone ----- distal symptoms > proximal **burning dysesthesias in fingers and hands***	---complete motor paralysis, loss of pain and temperature sensation ---position and vibration is preserved	--ipsilateral loss of motor function and proprioception at the level of transection ---contralateral loss of pain and temperature sensation one or two levels below the lesion	

Radiology

- NEXUS criteria
 - but very few kids in the study actually had SCI and no cases of SCIWORA
 - <1% of the kids in the study had an injury
 - most of the injured cases were older than 9 years
- CT c-spine is the imaging of choice
 - don't bother with x-ray if you're actually suspicious of a cervical injury
 - poor sensitivity of plain radiographs at detecting bony fractures
- Plain radiographic clearing requires:
 - imaging the C7-T1 interface
 - three views of the c spine
 - predental space < 6mm in kids less than 6 years
 - prevertebral space < 1/2-1/3 the vertebral body width
 - the four cervical radiographic lines:
- patients with persistent neck pain despite negative radiographs and CT should get an MRI
- flex / ext. views are rarely helpful

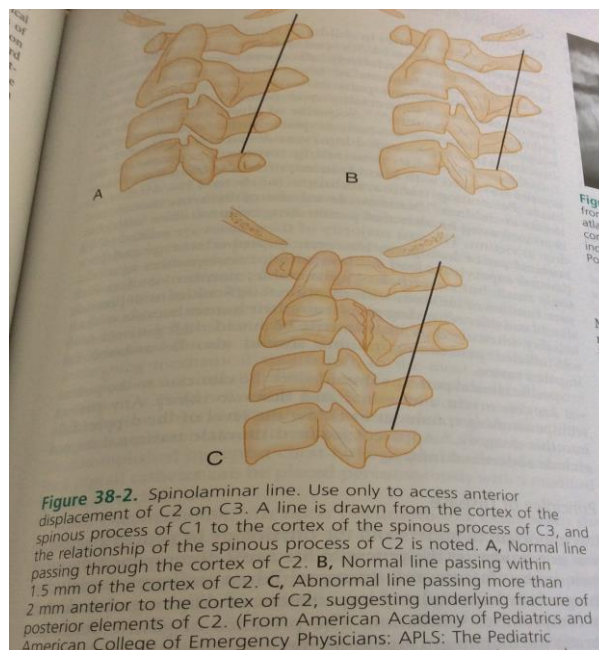


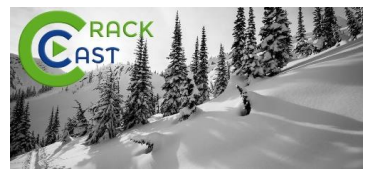
Management:

- Two phases of SCI
 - Direct injury : irreversible injury
 - due to ischemia, hypoxia, tissue death
- Spinal shock
 - Injury above T1:
 - lower extremity findings of SCI: flaccid paralysis of skeletal and smooth muscle leading to hypovolemia due to decreased SVR
 - resolves in hours to 1 day
- Neurogenic shock
 - injury above T6
 - loss of sympathetic tone and have UNOPPOSED parasympathetic tone: hypoTN and Bradycardia
 - trxt: atropine, ino-pressors, fluids are used
- Backboards should be removed ASAP: only use is for extraction

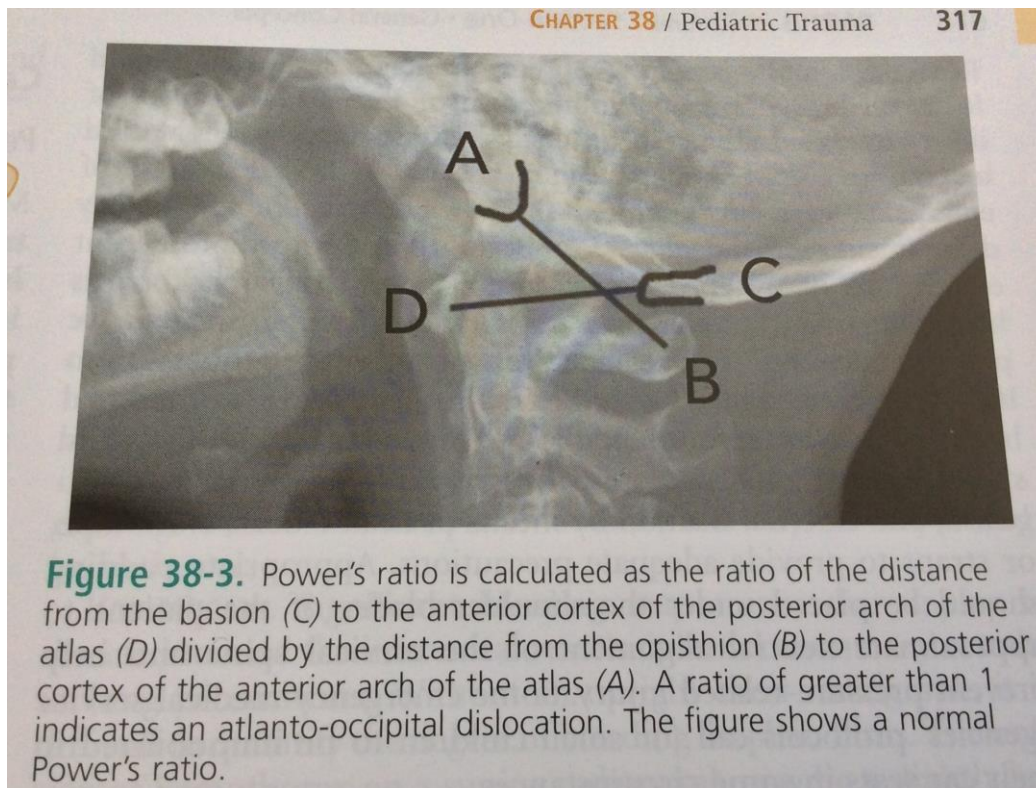
14) How can you discern between true subluxation and pseudosubluxation at C2/C3

- Pseudosubluxation of the c-spine at C2-3 is common in kids
 - Swischuk line
 - spinolaminar line of C1-3, If the line crosses C2's anterior cortical margin by **less than 2 mm**, (and no cervical soft tissue swelling and no fracture is seen) the image demonstrates pseudosubluxation





- **occipital cervical junction injuries:**
 - suspect in any child pedestrian vs. vehicle injury
 - with a big chin laceration
 - most of these injuries are immediately fatal
 - Power's ratio > 1 indicates atlanto-occipital dislocation
 - Normal = 0.77
 - distance from D to C / distance from A to B

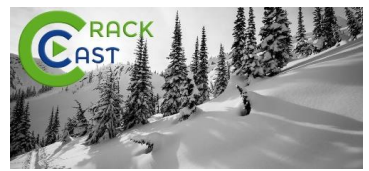


15) List 2 ways to choose the size of chest tube in pediatrics

- 2 X ETT size
- 4 X ETT size

16) What are indications for ER resuscitative thoracotomy in chest trauma?

- RARE
- same indications as adults (see episode on Major Trauma)
 - penetrating chest trauma with signs of life and less than 15 min of CPR
 - blunt trauma with signs of life and pericardial tamponade with <10 mins of CPR



17) List pediatric specific cardiovascular and abdominal injury patterns

Lap-belt injury
Handlebar injury
Sports-related injury

Principles of disease

- impairment of diaphragmatic breathing impairs ventilation
 - children's only way of improving ventilation is with increased RR
 - gastric distension impairs vital capacity
 - end-tidal CO₂ is helpful
- ribs are more compliant, so rib fractures are usually associated with massive trauma or in the setting of abuse: their absence doesn't rule out a serious injury

Specific disorders:

Pneumothorax:

- widespread transmission of breath sounds can mislead the clinician
 - ****listen in the axilla****
- <20% pneumothorax with no need for transport or ventilation may be watched
- Ultrasound highly sensitive and specific for detecting ultrasound

Open pneumothorax

- bidirectional flow of air
- significantly impairs oxygenation and ventilation
- Treatment:
 - three sided occlusive dressing
 - separate incision with chest tube

Tension pneumothorax

- one-way valve
- signs are often SUBTLE in pediatric patients

Hemothorax:

- difficult to identify on supine CXR
- rare; associated with big mechanism of injury
- need large tube drainage
- operating room thoracotomy if:
 - >15ml/kg of blood immediately exudes
 - continuous air leak

Pulmonary contusion:

- chest compliance in children puts them at increased risk of contusion even in the absence of external chest trauma



Traumatic diaphragmatic hernia

- associated with MVC's and lap belt use
- need to consider comorbid small bowel injury/hematoma and CHANCE fractures
- Trxt: insert NG tube to decompress the stomach; avoid BVM; intubation and surgery

Cardiac and vascular injuries:

- rare
- similar signs and symptoms as in adults
- watch for pericardial tamponade
 - need thoracotomy
- **commotio cordis**
 - sudden impact to the anterior chest which stops cardiac function or leads to a dysrhythmia
 - shock may persist despite resuscitation efforts
 - may need long term antiarrhythmic agents, pacemakers, and cardiac support

Abdominal injury

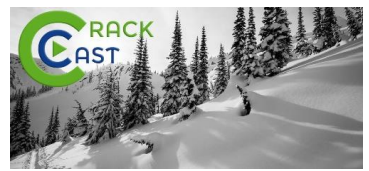
- most common cause of unrecognized fatal injury in children
- most often associated with MVC's

So now to answer the specific question:

- Three injuries assoc. with lap belt use:
 - small bowel injury/hematoma
 - pancreatitis
 - chance fractures
- bike handlebar injuries
 - duodenal hematoma
 - pancreatic transection/trauma
- sports related:
 - spleen, kidney, intestinal tract

Diagnostic strategies and management:

- abdominal distention is common due to ingested air
- early foley catheter helps decompress the bladder and assess U/O
- FAST ultrasound: If positive and patient stable --> on to CT +/- angiography
- indications for laparotomy:
 - hemodynamic instability despite aggressive resuscitation
 - free fluid on FAST and instability
 - massive bleeding intraperitoneal despite blood
 - pneumoperitoneum / intraperitoneal bladder rupture / grade V renovasc. injury
 - gunshot wound
 - evisceration
 - peritonitis



Spleen injury

- most common injury
- need hospital admission

Liver Injury

- most common cause of lethal hemorrhage
- need close hospital observation, serial exams and Hgb.

Penetrating injury:

- DPL : only performed in low resource settings

Disposition

ED role:

- resuscitation and stabilization and transfer to appropriate facility
- avoid extensive imaging if your centre can't deal with the results
- low threshold for admission with serial exams

Cessation of care:

- obvious if
 - livor mortis, rigor mortis, massive injuries
- attempts should be made if there are signs of life
- parental presence during resuscitation should be encouraged