Eastern Association for the Surgery of Trauma

Advanced Practitioners in Trauma

January 16, 2014
Waldorf Astoria Naples
Naples, Florida

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American College of Surgeons
Division of Education

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Fundamentals of Trauma and Acute Care Surgical Radiology

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Topics

- Principles of Trauma Imaging
- What to know when ordering an image
- Interpreting Trauma Imaging
  - Plain radiographs
  - CT scans
  - Ultrasound
  - Angiography
  - MRI
  - Fluoroscopic imaging

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Principles of Trauma Imaging

- The selection of an imaging technique in the critically injured is driven by:
  - Patient stability
    - Unstable patients may not get any further imaging
    - Empiric surgical procedures serve both diagnostic and therapeutic purposes
  - Physical examination findings
    - Body area
    - Bruising / deformity / subjective patient complaint
  - Mechanism of injury
    - Blunt versus penetrating
    - High energy versus low energy
    - Mechanism of injury + Patient condition (preexisting or otherwise)

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Ideal imaging techniques….

- …Have the power to change what you are going to do for an injured patient
  - Otherwise why order it?
- …Are appropriate for the injury you are seeking to find
- …Can be rapidly performed in a minimum amount of time
- …Accomplish many goals with a single test
- ...Won't otherwise result in harm to the patient
- …*Ultimately demonstrates* ***VALUE***

$$\text{VALUE} = \frac{\text{Health outcomes (Improved or otherwise)}}{\text{Costs of delivering the outcomes}}$$

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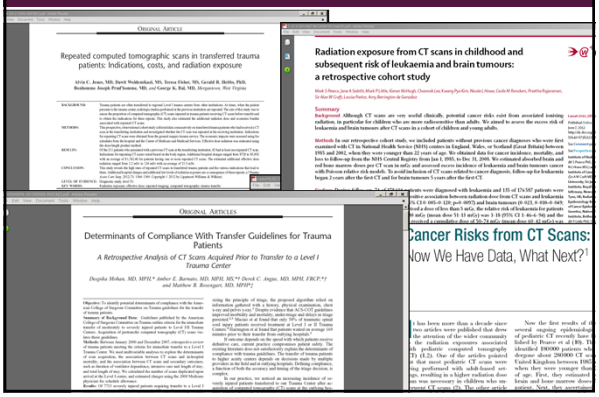
Imaging Risks and Costs



Repeated computed tomographic scans in transferred trauma patients: Indications, costs, and radiation exposure

Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study

Determinants of Compliance With Transfer Guidelines for Trauma Patients

A Retrospective Analysis of CT Scans Acquired Prior to Transfer to a Level I Trauma Center

Cancer Risks from CT Scans: Now We Have Data, What Next?

Radiation risk

- ***Risk of future malignancy increases with repeat radiation exposures***
  - Conclusions based largely on data from atomic bomb exposure but no large population level one epidemiologic evidence
  - Pearce et al: 1 CT of the head in the first decade of life may produce a single case of leukemia and a single case of brain cancer out of 10,000 patients within the first decade after exposure*
  - Malignancies not seen for years after exposure
- ***Risk theoretically increases in inter-hospital transfers***
  - Mohan** et al: 57% of 7713 transferred trauma patients received at least 1 CT scan. 82% of that cohort received a second CT scan.

*Pearce MS, Salotti JA, Little MP, McHugh K, Lee C, Kim KP, Howe NL, Ronckers CM, Rajaraman P, Sir Craft AW, Parker L, Berrington de Gonzalez A. **Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study.** Lancet. 2012 Aug 4;380(9840):499-505.

**Mohan D, Barnato AE, Angus DC, Rosengart MR. Determinants of compliance with transfer guidelines for trauma patients: a retrospective analysis of CT scans acquired prior to transfer to a Level I Trauma Center. Ann Surg. 2010 May;251(5):948-51

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Medical imaging costs

- In era of accountable care it is necessary to manage the benefit / cost ratio in future models of reimbursement (bundling / shared risk models)
- Jones et al*: Fees for CT scanning range from $728 to $5,892 per patient that had one or more repeated CT scans (using CMS data)
- Haley et al**: 53% of patients received at least one repeat study and resulting in $2,985 per patient with most charges from CT scans

*Jones AC, Woldemikael D, Fisher T, Hobbs GR, Prudhomme BJ, Bal GK. Repeated computed tomographic scans in transferred trauma patients: Indications, costs, and radiation exposure. J Trauma Acute Care Surg. 2012 Dec;73(6):1564-9

**Haley T, Ghaemmaghami V, Loftus T, Gerkin RD, Sterrett R, Ferrara JJ. Trauma: the impact of repeat imaging. Am J Surg. 2009

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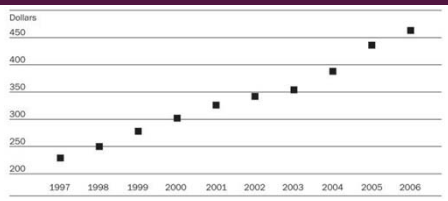
We are definitely ordering more, and paying more but probably getting less…



Annual Imaging Costs Per Health Plan Enrollee, 1997-2006*

- Between 2000 and 2005, medical imaging spending more than doubled from $6.6 billion to $13.7 billion
- ***No compelling data demonstrating that increasing the number of radiologic tests lead to an improvement in patient outcome…***

*From: Smith-Bindman R, Miglioretti DL, Larson EB. **Rising use of diagnostic medical imaging in a large integrated health system.** Health Aff (Millwood). 2008 Nov-Dec;27(6)

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Assessing medical imaging utility and accuracy

- ***Gold standard***
  - Defined as the best single test (or a combination of tests) that is considered the current preferred method of diagnosing a particular disease
  - All other tests for diagnosing the SAME disease are compared to the gold standard
  - Prime example in trauma: The gold standard for diagnosing blunt aortic injury is biplanar thoracic aortography. All other testing modalities (CT angiography, transesophageal echo) are compared against it
- ***Validity***
  - The extent to which a test measures what it is supposed to measure
  - Is determined by the ***sensitivity*** and the ***specificity*** of the test you are ordering

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Determining Sensitivity and Specificity

- ***Sensitivity*** is the ability of a test to correctly classify an individual as having a "disease"

$$\text{sensitivity} = \frac{\text{number of true positives}}{\text{number of true positives} + \text{number of false negatives}}$$

$$= \frac{\text{number of true positives}}{\text{total number of sick individuals in population}}$$

$$= \text{probability of a positive test, given that the patient is ill}$$

- ***Specificity*** is the ability of a test to correctly classify an individual as NOT having the "disease"

$$\text{specificity} = \frac{\text{number of true negatives}}{\text{number of true negatives} + \text{number of false positives}}$$

$$= \frac{\text{number of true negatives}}{\text{total number of well individuals in population}}$$

$$= \text{probability of a negative test given that the patient is well}$$

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Illustrative example of Sensitivity / Specificity

- **Sensitivity:**
  - 100 trauma patients are diagnosed with blunt aortic injury (BAI) as screened using "gold standard" biplanar thoracic aortography
  - Same 100 patients are then examined using CT angiography and only 97 are correctly found to have BAI

  Sensitivity is 97%, 3% of patients with BAI are missed (false negative)
- **Specificity**
  - 100 trauma patients screened using "gold standard" biplanar thoracic aortography found to NOT have BAI
  - Same 100 patients are then examined using CT angiography and 3 are incorrectly diagnosed with BAI

  Specificity is 97%, 3% of patients are wrongly diagnosed (false positive)

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Understanding Sensitivity and Specificity establishes…

- The **Positive Predictive Value (PPV)** of a test
  - The percentage of patients with a positive test *who actually have the disease*.
  - How many of test positives are *true positives*
  - If this number is as close to 100 as possible, then it is doing as good as 'gold standard.'

$$\frac{\text{\# of True Positives}}{\text{True Positives + False Positives}}$$

- The **Negative Predictive Value (NPV)** of a test
  - The percentage of patients with a negative test *who do not have the disease*
  - How many of the test negative are *true negatives*
  - If this number is as close to 100 as possible, then it is doing as good as the 'gold standard.'

$$\frac{\text{\# of True Negatives}}{\text{True Negatives + False Negatives}}$$

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CT scanning

- Axial tomograms obtained at set slice intervals
- Includes abdomen and pelvis, may be performed with IV and oral contrast or separately or with neither
- Unenhanced CT scan (no IV / oral contrast) of very low diagnostic yield
- With IV contrast: 150ml of IV contrast dye
- With oral contrast: 900ml of Readicat (barium) or 200ml of Gastroview
- Radiation dose varies with the thinness of slices (the thinner the slice, the higher the radiation). 30 kilogray is typical dose

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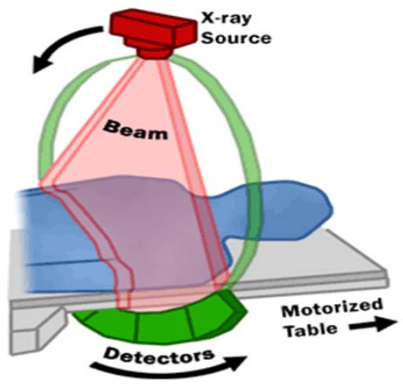

IV contrast in abdominal CT scans

- 150ml of Isovue usually administered IV
- Organically bound iodine
- Potentially nephrotoxic
- Essentially two CT scans are performed
  - First scan performed immediately after contrast bolus: **arterial phase**
  - Second scan performed 10-15 second delay after first: **porto-venous phase**
- Delayed images will give nephrograms (evaluate for renal parenchymal injury)

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Splenic injury (AAST grading)

- **Grade I**
  - Subcapsular tear <10% of surface area
  - capsular laceration <1 cm depth

Images from: http://radiopaedia.org/articles/splenic_injury_grading

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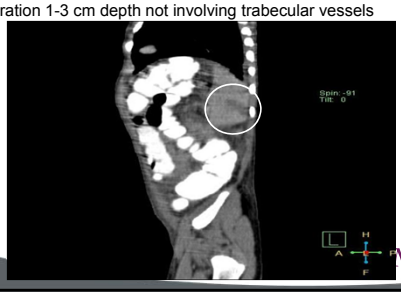
Splenic injury (AAST grading)

- **Grade II**
  - Subcapsular hematoma 10-50% of surface area
  - intraparenchymal haematoma <5 cm in diameter
  - laceration 1-3 cm depth not involving trabecular vessels



Images from: http://radiopaedia.org/articles/splenic_injury_grading

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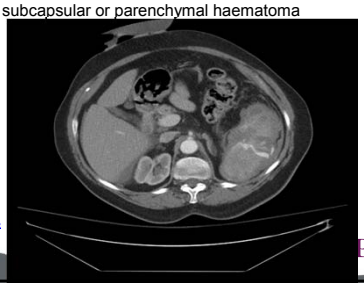
Splenic injury (AAST grading)

- **Grade III**
  - Subcapsular hematoma >50% of surface area or expanding
  - intraparenchymal haematoma >5 cm or expanding
  - laceration >3 cm depth or involving trabecular vessels
  - ruptured subcapsular or parenchymal haematoma



Images from: http://radiopaedia.org/articles/splenic_injury_grading

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Splenic injury (AAST grading)

- **Grade IV**
  - laceration involving segmental or hilar vessels with major devascularization (>25% of spleen)

Images from:http://radiopaedia.org/articles/splenic_injury_grading

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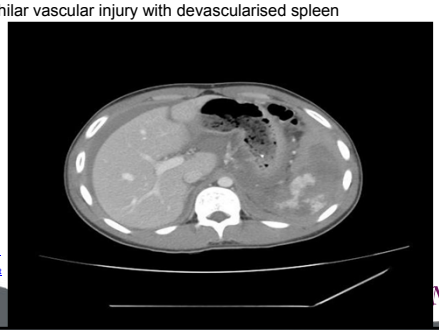
Splenic injury (AAST grading)

- **grade V**
  - shattered spleen
  - hilar vascular injury with devascularised spleen



Images from:http://radiopaedia.org/articles/splenic_injury_grading

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Liver injury (AAST grading)

- **grade I**
  - haematoma: sub capsular, < 10% surface area
  - laceration: capsular tear, < 1cm depth
- **grade II**
  - haematoma: sub capsular, 10 - 50% surface area
  - haematoma: intraparenchymal < 10cm diameter
  - laceration: capsular tear, 1 - 3cm depth, < 10cm length

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Liver injury (AAST grading)

- **grade III**
  - haematoma: sub capsular, > 50% surface area, or ruptured with active bleeding
  - haematoma: intraparenchymal > 10 cm diameter
  - laceration: capsular tear, > 3 cm depth

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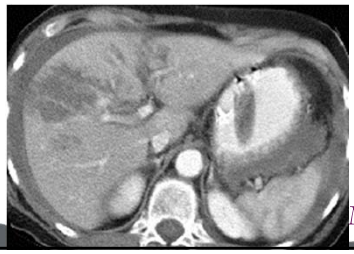
Liver injury (AAST grading)

- **grade IV**
  - haematoma: ruptured intraparenchymal with active bleeding
  - laceration: parenchymal distruption involving 25 - 75% hepatic lobes or
  - involves 1-3 segments (within one lobe)



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Liver injury (AAST grading)

- **grade V**
  - laceration: parenchymal distruption involving >75% helpatic lobe or
  - involves > 3 segments (within one lobe)
  - vascular: juxtahepatic venous injuries (IVC, major hepatic vein)
- **grade VI** - vascular: hepatic avulsion

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Renal laceration

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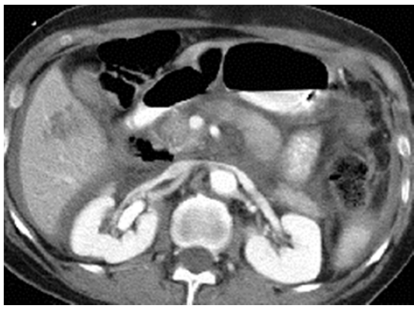
Mesenteric and peritoneal blood



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ARDS

- 34 year old garbage truck driver, falls off the back while making pick ups
- Knocked unconsciousness
- Vomits
- EMS arrives on scene, agonal respirations, sats: 85%
- Intubation attempted, failed due to large amount of vomitus over the cords.

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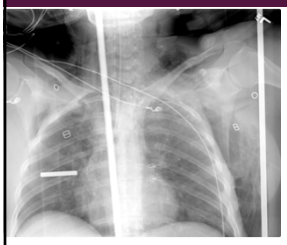
Massive Aspiration / ARDS



Arrival

Four hours later

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18 hours later

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ARDS

- Failed all ventilator strategies
  - Bilevel
  - Nitric oxide
  - Reverse I / E
  - Neuromuscular paralysis
- ABG: 6.9 / PCO2: 80 / PO2: 60 / bicarb: 10
- Started on arteriovenous ECMO

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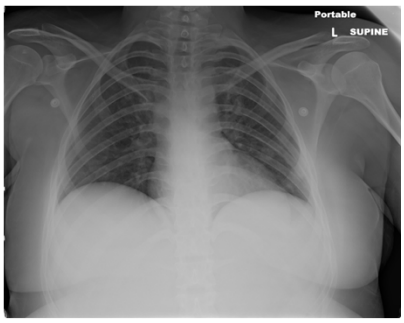

Day of discharge
(HD #50)

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Tension pneumothorax

- 19 year old male
- Single stab wound to left lateral chest
- Vital signs on EMS arrival: HR 85, BP 110/70, sats 100%, RR 20
- Vital signs 10 minutes later enroute: HR 140, BP 80/p, sats 85% on 100% NRB, RR 40
- Ambulance pulls over and patient is intubated
- Arrives in trauma bay

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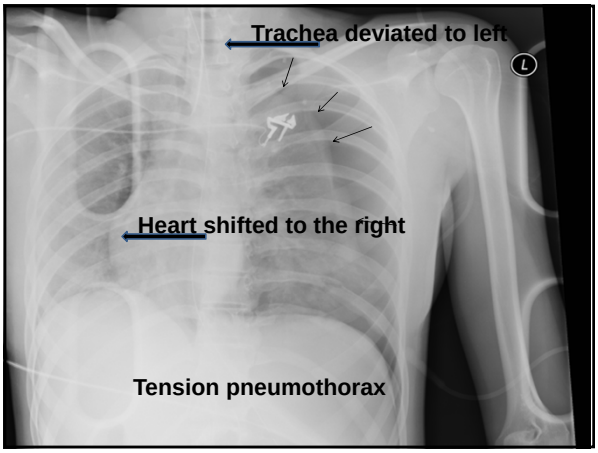
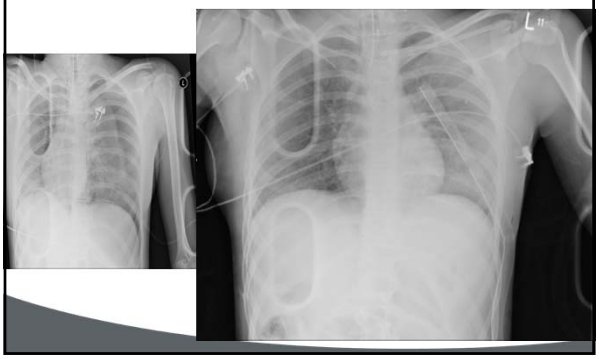
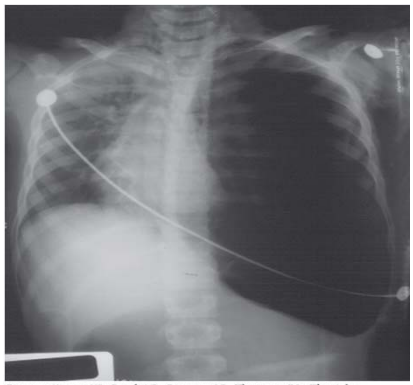
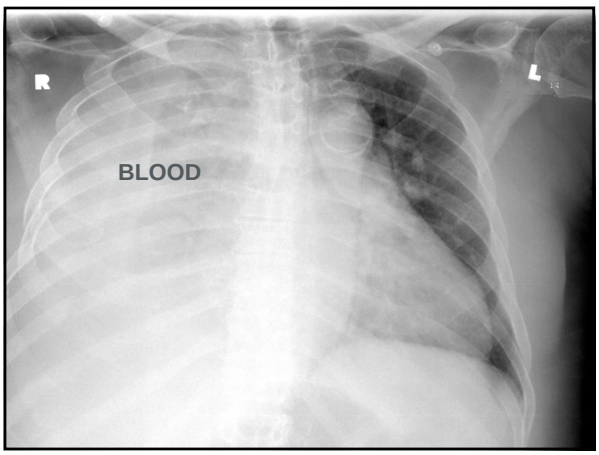


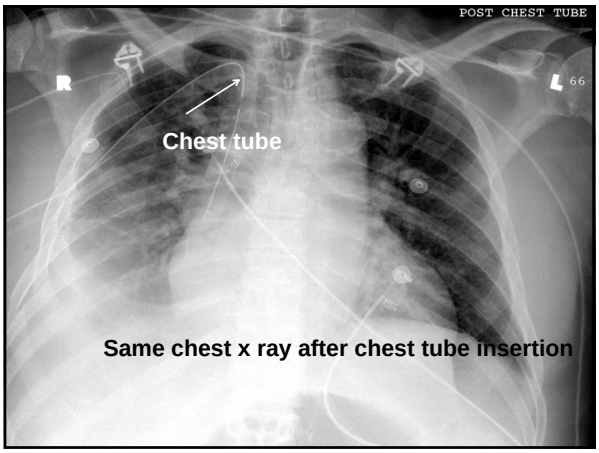
Tension Pneumothorax





Source: Knoop KJ, Stack LB, Storrow AB, Thurman RJ: *The Atlas of Emergency Medicine, 3rd Edition*: http://www.accessmedicine.com





FAST
Focused Abdominal Sonography for Trauma

- FAST only tells you whether or not there is fluid in the spaces in which you are looking
- In the context of appropriate mechanism and obvious shock, fluid seen on a FAST is assumed to be blood until ruled out by laparotomy
- Positive FAST = Fluid is present
- Fluid is BLACK (sonographically “anechoic”)

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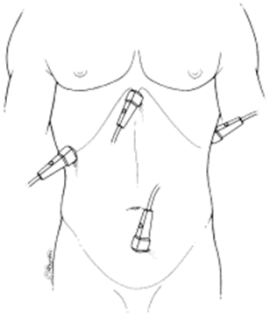
Focused *A*ssessment for the *S*onographic examination in *T*rauma
FAST

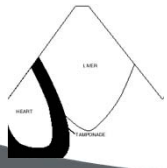
- Performed during the ATLS secondary survey
- 3.5 MHz probe
- Patient remains supine
- Aimed at the detection of free fluid
- FAST should *not* delay resuscitation or other interventions

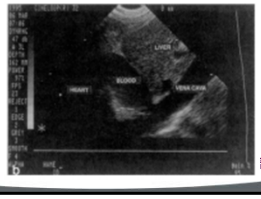
FAST in Trauma

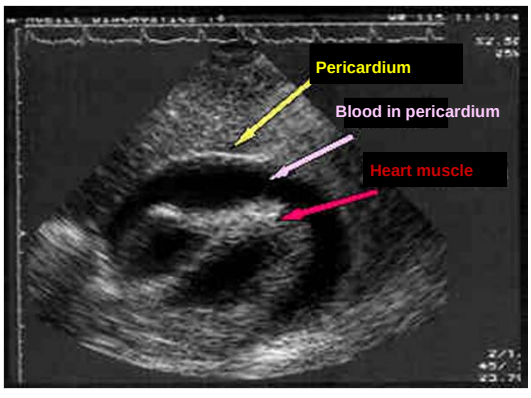
- The “4 P’s”
  - Pericardium
  - Perihepatic
    - Morrison’s Pouch
  - Perisplenic
  - Pelvic
    - Cul-de-sac



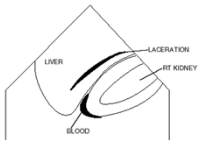
FAST- Pericardium







FAST – RUQ/Morrison's Pouch



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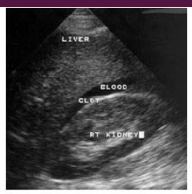
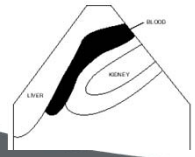
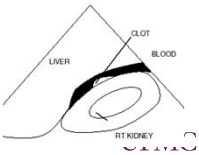
FAST – RUQ/Morrison's Pouch







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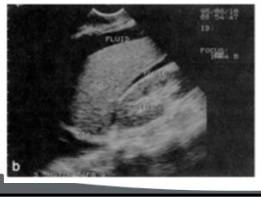
FAST – RUQ/Morrison's Pouch



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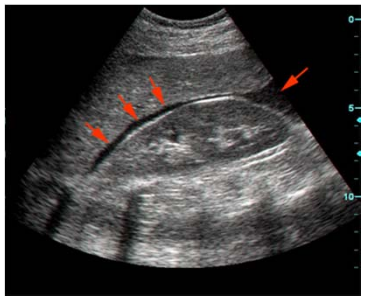
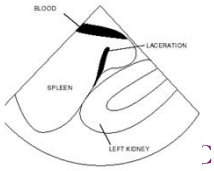


FAST – LUQ/Spleen



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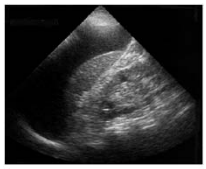
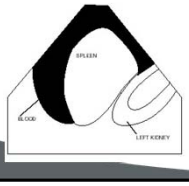
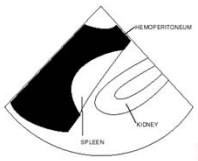
FAST – LUQ/Spleen







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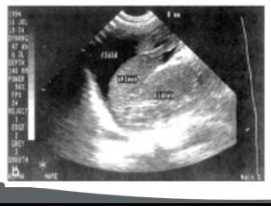
FAST – LUQ/Spleen



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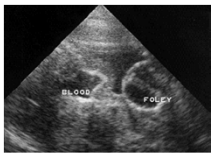
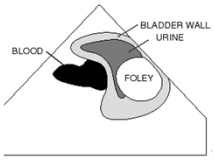
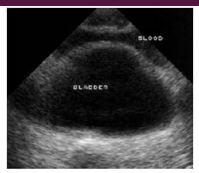
FAST – Pelvis/Cul-de-sac

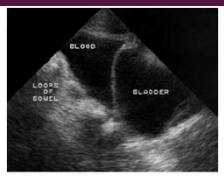


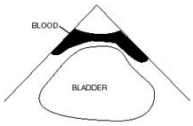


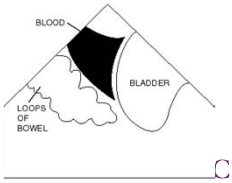
LIFE CHANGING MEDICINE

FAST – Pelvis/Cul-de-sac









LIFE CHANGING MEDICINE

Limitations of the FAST Exam

- FAST poorly evaluates the retroperitoneum
- FAST is not reliable in the evaluation of hollow viscus injuries
- Exams are generally low quality in very obese patients or those with large bowel gas
- Large hemothorax may cause false-negative pericardial FAST exam

UPMC LIFE CHANGING MEDICINE

Learning Curve for FAST

- Recommendation for "appropriate training" of clinicians of 50 – 400 proctored US exams
  - German Board of Surgery requires 300 exams
- No prospective data to support these numbers
- Surgeons trained as follows:
  - Didactic course, practice US on normal volunteers
  - US followed by standard dx studies (DPL, CT scan)
- Initial error rate of 17% fell to 5% after ten exams

UPMC LIFE CHANGING MEDICINE

Shackford SR et al. *J Trauma* 46:553-564. 1999.

Unusual case

- 25 yo F unrestrained driver versus pole
- Airbag deployed
- Self extricated, complaining of hip and foot pain
- Visibly intoxicated
- HR 73, BP 110/76Boarded, collared
- Taken to level 1 Trauma Center, but not as a Trauma activation
- CT scans ordered
- Trauma Consulted after scans

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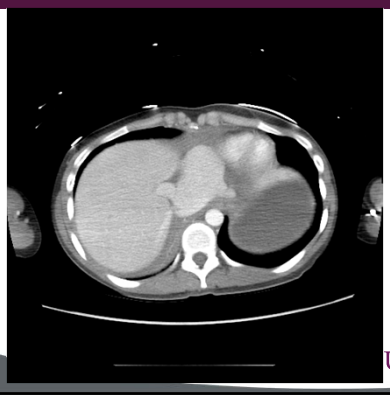
UPMC LIFE CHANGING MEDICINE



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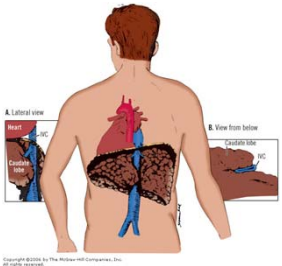
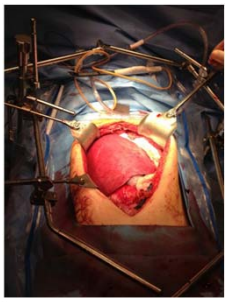
Contained Rupture of the Suprahepatic Vena Cava



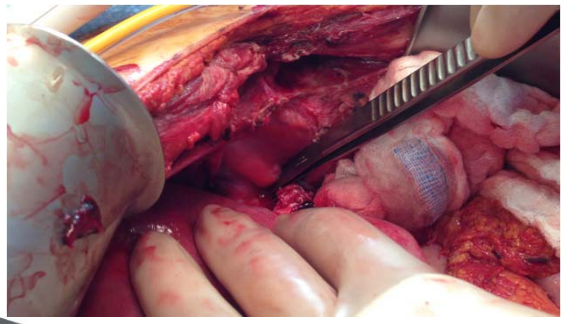
56

How do we approach this injury?



- We were able to control this by opening the diaphragm and clamping the vena cava within the pericardium from below the diaphragm
- The vena cava was found to be completely transected between the liver and the heart

57



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UPMC LIFE CHANGING MEDICINE

LW

- 22 year old male shot in the leg
- Pulses difficult to palpate
- Angiogram obtained to look for a vascular injury

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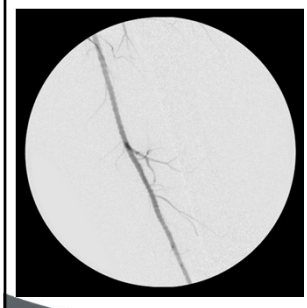
UPMC LIFE CHANGING MEDICINE

LW



- Femoral artery was intact
- Diffuse spasm of the artery
- Pulse improved with papaverine

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UPMC LIFE CHANGING MEDICINE

Case: LZ

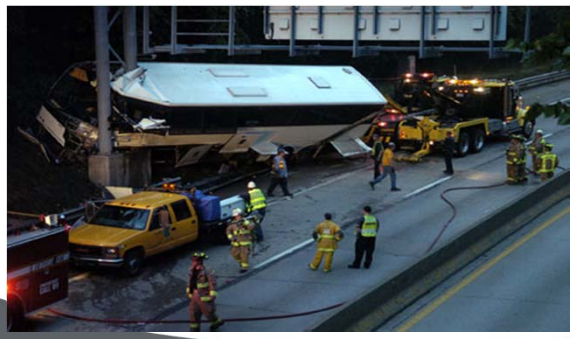
- Tour bus traveling from Chinatown, NYC to Pittsburgh
- Lost control, hit Jersey barrier, up hillside
- Struck traffic control sign embedding pole to the first passenger row
- Driver ejected, but relatively unhurt
- Entrapped first row passenger behind the driver

UPMC LIFE CHANGING MEDICINE

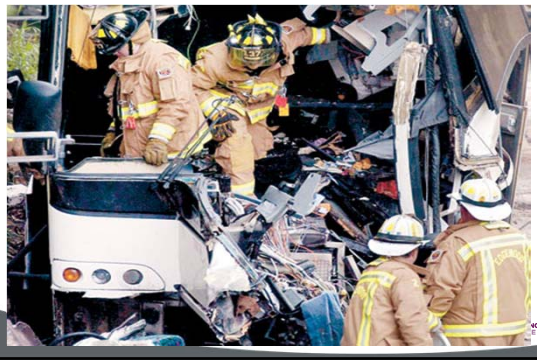
The Scene

LIFE CHANGING MEDICINE

The Scene



The Scene



The Scene

Technical problems

- Entangled between two seats bent over the patient and impinged by pole
- Difficulty stabilizing the bus
- ~One hour extrication time
- Poor ventilation
- Confined working space

Medical problems

- Hypotensive approximately 15 minutes into the incident
- Five liters of crystalloid given during extrication
- Unresponsive 30 minutes into incident
- Limited access to patient to control airway

UPMC LIFE CHANGING MEDICINE

Hospital Course: First 24 hours

- On arrival to trauma bay was hypotensive with positive FAST
- To OR for damage control laparotomy
  - Bilateral chest tubes
  - Splenectomy
  - Hepatorraphy
  - Pericardial window
- Taken to ICU in extremely critical condition
- Massive amounts of blood through both chest tubes. Back to OR for damage control thoracotomy on same day
- Nitric oxide, bilevel ventilation

UPMC LIFE CHANGING MEDICINE

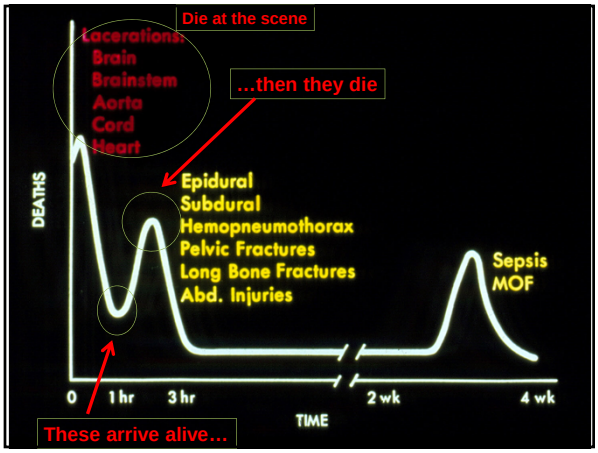
Chest x ray following damage control thoracotomy

UPMC LIFE CHANGING MEDICINE

Hospital course

- Refractory profound coagulopathy
  - "Blood like dilute Kool-Aid"
- Worsening lactic acidosis
- ARDS
- Bilateral lower and upper extremity ischemia
- Maximum vasopressor support
- Made CMO PTD 4

UPMC LIFE CHANGING MEDICINE

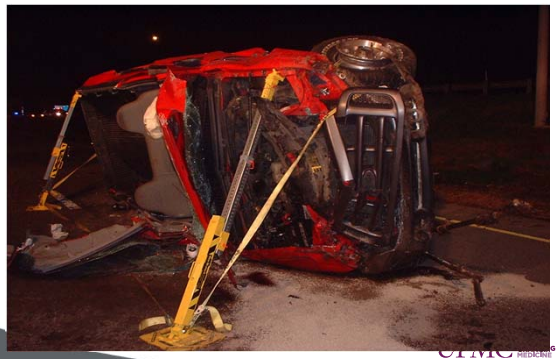


Case: KS

- 26 y/o male
- Rollover MVA at high speed
- Went through guardrail
- Up on it's side
- One victim ejected
- Struck another vehicle

UPMC LIFE CHANGING MEDICINE

The Scene



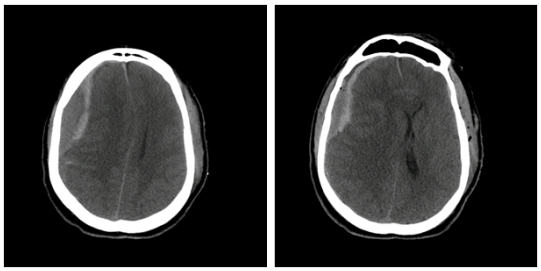
The Scene

UPMC LIFE CHANGING MEDICINE

The Scene

UPMC LIFE CHANGING MEDICINE

The Injury



UPMC LIFE CHANGING MEDICINE

Hospital Course

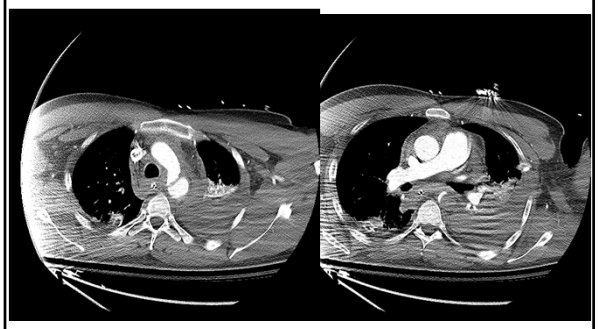
- Intubated in trauma bay
- To OR for decompressive craniectomy and evacuation of “hyperacute” epidural hematoma
- PEG on PTD 3
- EVD removed on PTD 5
- Extubated on PTD 6
- Discharged to TBI rehab on PTD 9
- Cranioplasty at the end of December
- Good functional recovery

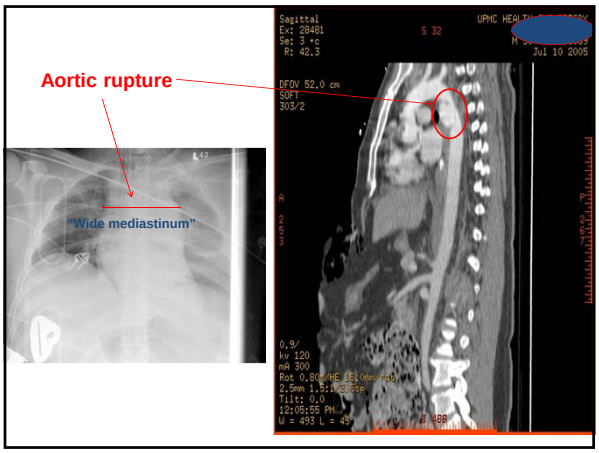
UPMC LIFE CHANGING MEDICINE

Case: K.K.

- 24 M restrained driver in a small pickup truck, (+) Airbag deployment
- Single car crash into a tree
- Legs entrapped under dashboard, emergency brake through left leg, pinned by steering wheel
- Twenty minute extrication

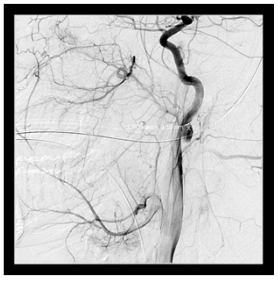
UPMC LIFE CHANGING MEDICINE





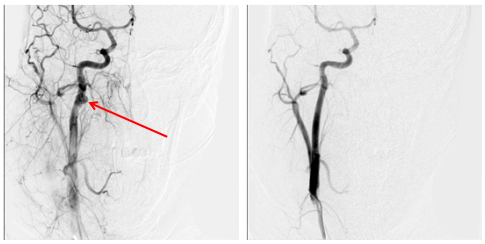
R.P.

- 32 year old male
- MVC, unrestrained with C4 fracture through foramen transversarium
- Cerebral Angiogram revealed a large carotid artery pseudoaneurysm
- Excluded with a covered stent



UPMC LIFE CHANGING MEDICINE

Stent Placement

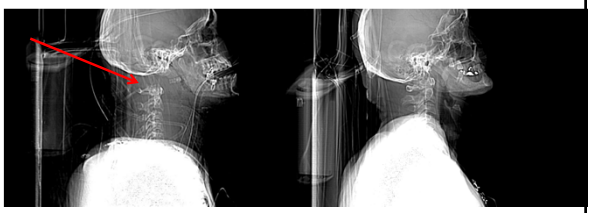


UPMC LIFE CHANGING MEDICINE

Attempted hanging

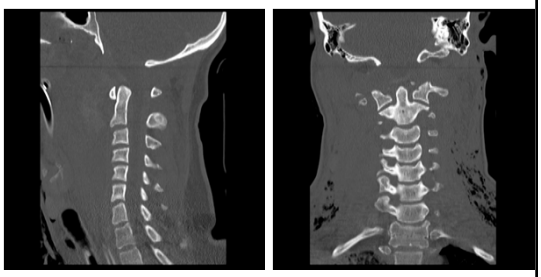
- 24 year old female two weeks post partum
- Endorsing depression, seen by psychiatrist
- Refused medications
- Found hanging in basement when husband returned from work

UPMC LIFE CHANGING MEDICINE



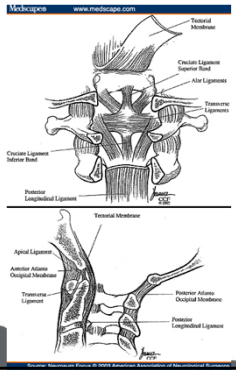
UPMC LIFE CHANGING MEDICINE

Atlanto-occipital Dissociation



UPMC LIFE CHANGING MEDICINE

Atlanto-occipital Dissociation



- "Internal decapitation"
- Mechanism of death typically by hanging

UPMC LIFE CHANGING MEDICINE

Ascending cholangitis

- 50 year old male
- Right upper quadrant pain, fever, icteric sclerae
- Total bilirubin: 4.5

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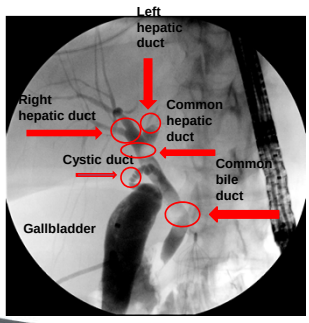
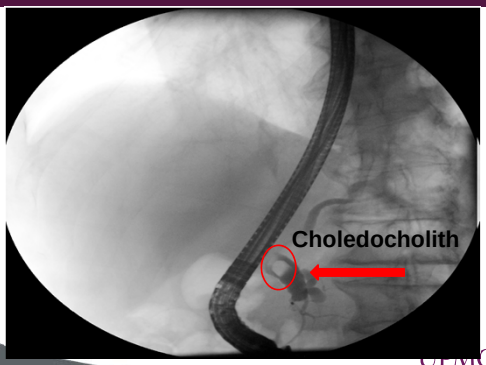
UPMC LIFE CHANGING MEDICINE

ERCP

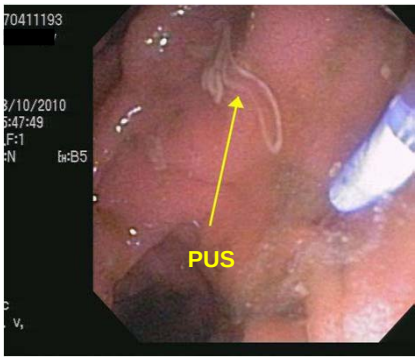


UPMC LIFE CHANGING MEDICINE

ERCP



UPMC LIFE CHANGING MEDICINE



Mesenteric infarction

- 70 year old male history of peripheral vascular disease (previous left sided fem-pop)
- Sudden onset of abdominal pain after eating
- Nausea / vomiting, dark red stools
- Pain unbearable, seen in ED.
- WBC 25K (15% bands), bicarb 12, lactate 10

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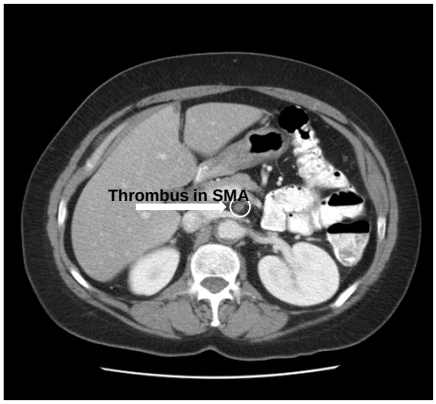
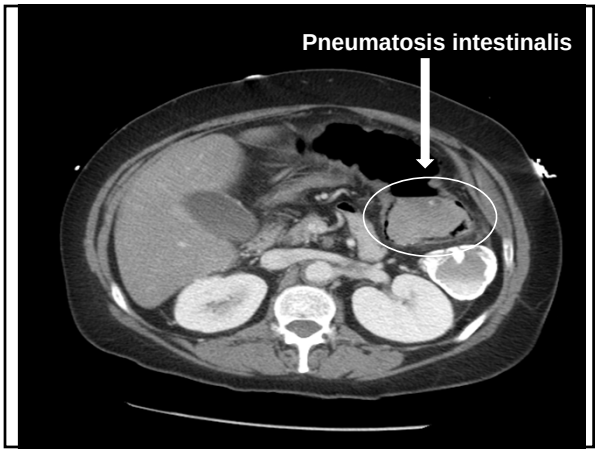
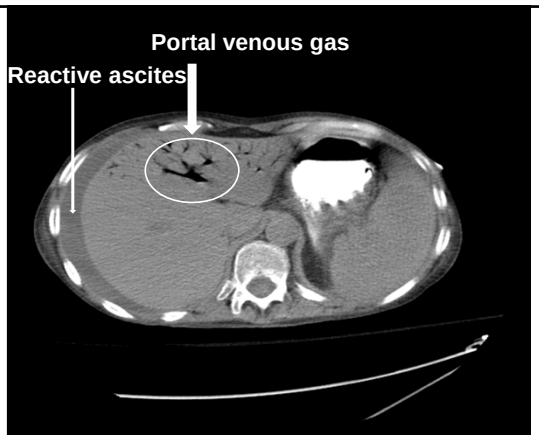
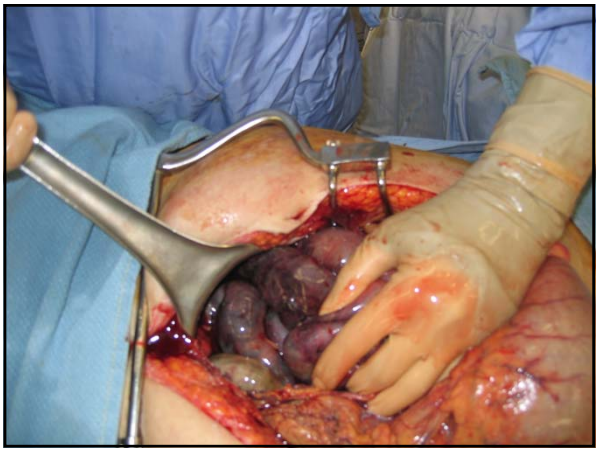
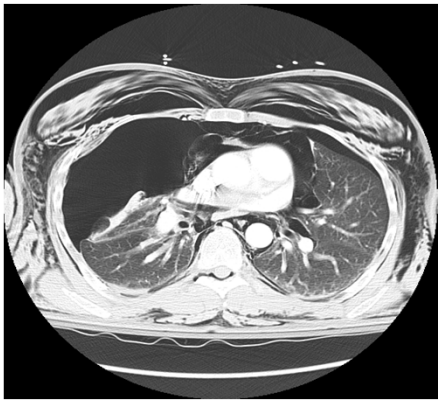
UPMC LIFE CHANGING MEDICINE






Portal venous gas
Reactive ascites

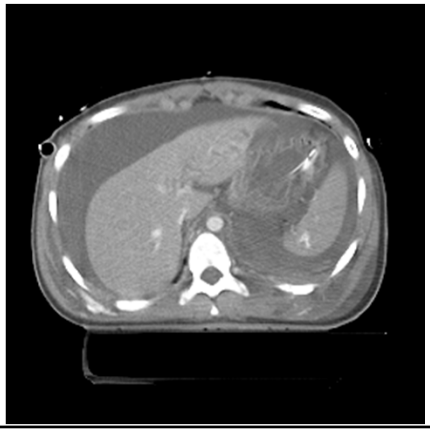




PC

- 43 year old male MVC, unbelted
- HR 120, BP 92/p, RR 25, sats: 95%
- Complaining of left upper quadrant pain

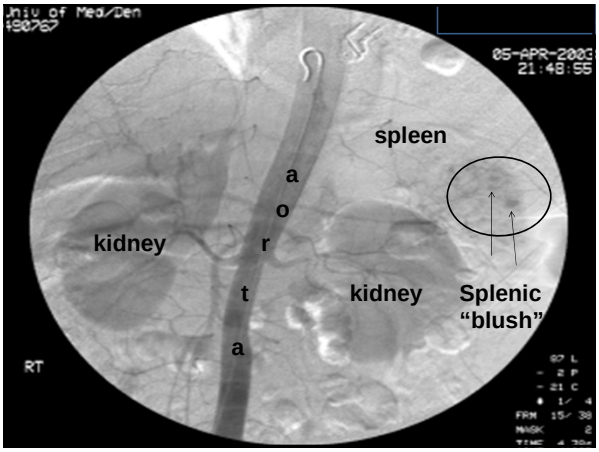
UPMC LIFE CHANGING MEDICINE

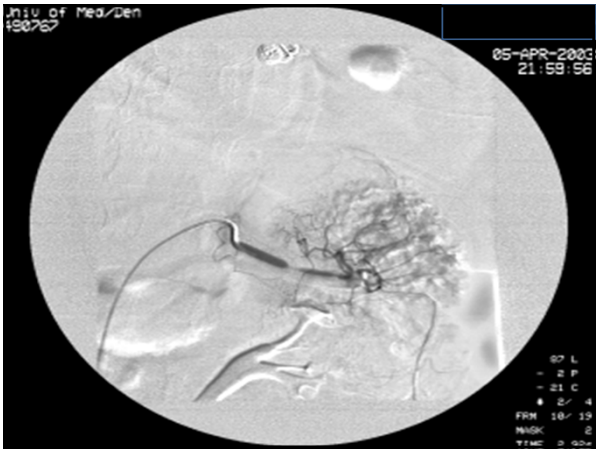


Visceral angiography

- Femoral artery accessed, catheter threaded up aorta
- Full biplanar or three dimensional aortogram and selective angiogram performed
- Diagnostic for arterial occlusion, arterial injury, aneurysm, pseudoaneurysm
- Therapeutic for stenting (across narrowing), embolization (stop hemorrhage), balloon dilation, administration of papaverine (spasm).

UPMC LIFE CHANGING MEDICINE





UA

- 45 year old female
- History of ongoing right upper quadrant pain associated with fatty meals
- Sudden onset of right upper quadrant pain this morning after breakfast
- Worsened to unbearable
- Nausea and vomiting

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UPMC LIFE CHANGING MEDICINE

CT of acute cholecystitis

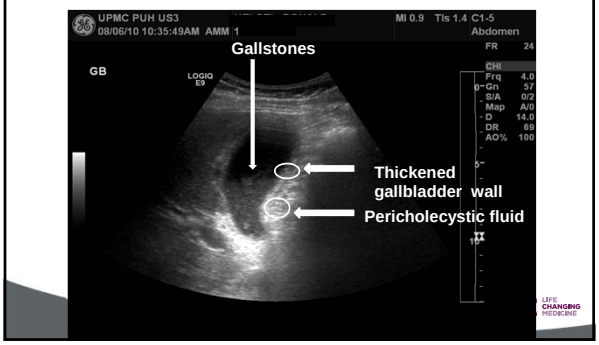
UPMC LIFE CHANGING MEDICINE

Abdominal ultrasound

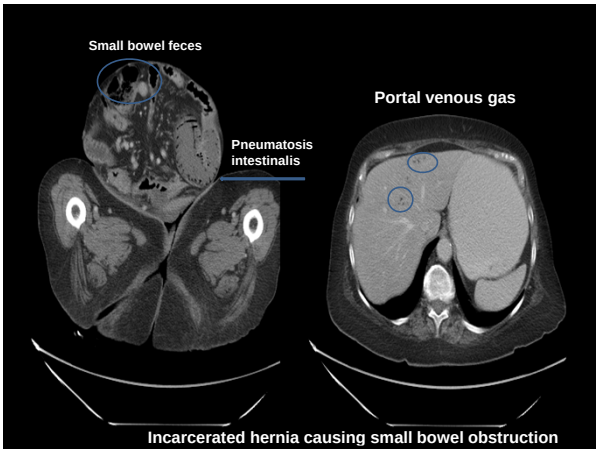
- Noninvasive, good for looking at liver, gallbladder, spleen, pancreas, kidneys and aorta
- Advantage over CT scans when doppler used
- Can be performed quickly if necessary, usually best performed when patient NPO for at least 8 hours
- Quality impaired by amount of adipose tissue or gas filled bowel loops

UPMC LIFE CHANGING MEDICINE

Ultrasound of acute cholecystitis



Large bowel obstruction CT

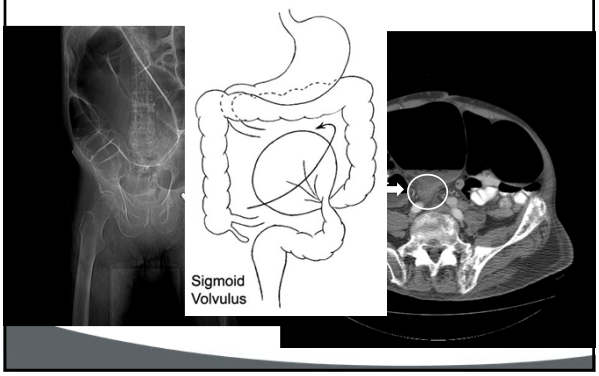


JM

- 89 year old male
- Sudden onset of abdominal pain
- Cessation of flatus, bilious emesis
- Pain localizes into the left lower quadrant

UPMC LIFE CHANGING MEDICINE

Volvulus

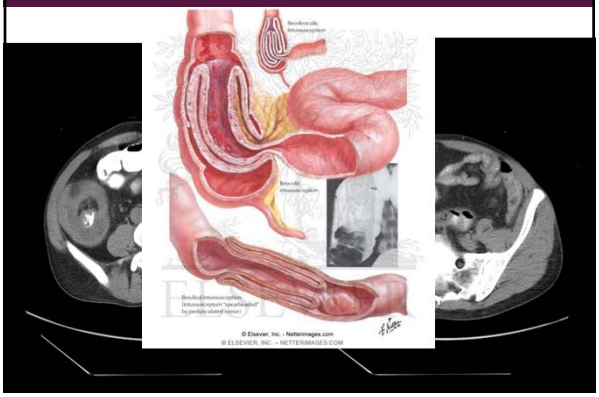


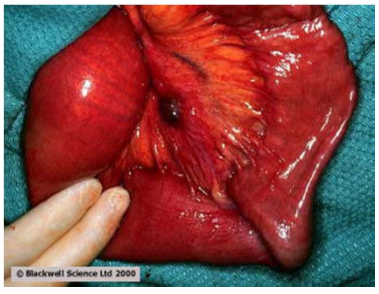
YN

- 34 year old male with Chron's disease
- History of previous small bowel resections
- Still has ileocecal valve
- Right lower quadrant pain followed by reddish / maroon stools
- Nausea and vomiting

UPMC LIFE CHANGING MEDICINE

Intussception





DA

- 20 year old male with cystic fibrosis now POD #16 after double lung transplant
- Prolonged ileus due to ongoing high narcotic requirement
- Home medications not restarted (pancreatic enzymes, bowel regimen)
- Abdominal pain, bloating, cessation of flatus, vomiting

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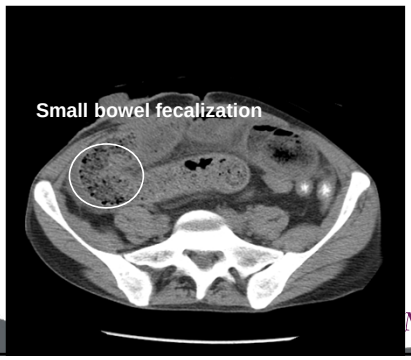
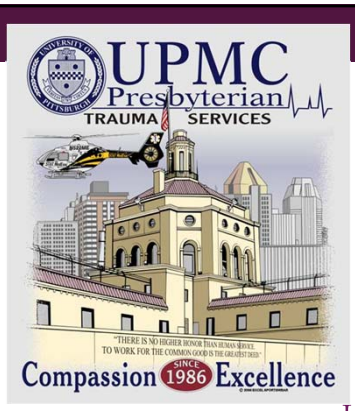
Distal intestinal obstruction syndrome





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Selecting imaging studies in trauma

William M. Bowling, MD FACS

14 January 2014

Objectives

- Evaluation of imaging studies
- Principles of testing
- Screening criteria
- Confirmatory tests

Basic charcteristics

- Sensitivity p$(T+|D+)$
- Specificity p$(T-|D-)$
- Positive predictive value (PPV) p$(D+|T+)$
- Negative predictive value (NPV) p$(D-|T-)$
- Accuracy

Biases in evaluation of diagnostic studies

- Verification bias
- Spectrum bias
- Incorporation bias
- Context bias

Testing principles

- Selection
  - Who is tested
- Screening
  - Usually very sensitive
- Confirmation
  - Usually more specific

Utility of screening

- Test result correlated with outcome
- Intervention alters outcome

Trichotomous decision space

- Disease very likely
  - Treat without further testing
- Disease moderately likely or unlikely
  - Further testing is helpful
- Disease very unlikely
  - No further testing

CTA for BCVI

- Prevalence 1-2%
  - unselected
- Sensitivity 74%
- Specificity 86%
- PPV 9.7%
- NPV 99.4%
- Accuracy 85.8%

		Disease		
		present	absent	
Test	positive	148	1372	1520
	negative	52	8428	8480
		200	9800	10000

CTA for BCVI

- Prevalence 34%
  - Biffl criteria
- Sensitivity 74%
- Specificity 86%
- PPV 73.1%
- NPV 86.5%
- Accuracy 82%

		Disease		
		present	absent	
Test	positive	148	1372	1520
	negative	52	8428	8480
		200	9800	10000

Pan-scan for trauma

Pro

- Faster vs. image quality
- Earlier disposition
- Missed injuries
- Changed management

Con

- Scan already indicated
- Image quality vs. time savings
- Benefit of early disposition
- Clinically significant injuries
- Significant change in management
- Radiation dose
- Cost

Pan-scan for trauma

Screening criteria

- Head
- C-spine
- Blunt carotid/vertebral injury
- Chest (aorta)
- Abdomen/ pelvis
- Thoraco-lumbar spine
- Extremities

Indications for head CT

- Canadian CT Head rule
- Minor blunt head trauma
  - Witnessed LOC, witnessed disorientation or definite amnesia
  - GCS 13-15
- Age ≥ 16 years
- Excluded
  - Anti-coagulation
  - Seizure

Canadian CT head rule

High risk

- GCS < 15 2h post-injury
- Suspected open or depressed skull fracture
- Suspected basilar skull fracture
- Vomiting ≥ 2 episodes
- Age ≥ 65 years

Medium risk

- Retrograde amnesia > 30 minutes
- Dangerous mechanism
  - Pedestrian vs. MVA
  - Ejection
  - Fall
    - » > feet
    - » > 5 stairs

Canadian CT head rule

- High risk criteria (neurosurgical intervention)
  - Sensitivity 100% (92-100%)
  - Specificity 68.7% (67-70%)
- Medium risk criteria (positive CT)
  - Sensitivity 98.4% (96-99%)
  - Specificity 49.6% (48-51%)

Cervical spine injury

- NEXUS criteria
- Canadian C-spine rule

NEXUS

- No focal neurologic deficit
- No midline tenderness
- No distracting injury
- No intoxication
- No altered level of alertness

NEXUS

- Prospective observational study
  - 34,069 patients at 21 centers
  - 578 clinically significant injuries (2.4%)
- Plain radiography ± CT
- All patients undergoing C-spine imaging
- Criteria not explicitly defined

NEXUS

- Clinically significant injury
  - Sensitivity 99.6% (98.6-100%)
  - Specificity 12.9% (12.8-13.0%)
- Utilization
  - Avoid imaging in 4,309 (12.6%)

Canadian C-spine rule

- High risk criteria
  - Mandate imaging
- Low-risk criteria
  - Any one allows ROM testing
- Range-of-motion
  - 45˚ left & right, regardless of pain

Canadian C-spine rule

High risk

- Age ≥ 65 years
- Dangerous mechanism
  - Fall > 1 m/5 stairs
  - Axial load
  - High speed (> 60 mph), rollover, ejection
  - Motorized recreational vehicle
  - Bicycle collision
- Parasthesias

Low Risk

- Simple rear-end MVA
- Sitting position in ED
- Ambulatory at any time
- Delayed onset of pain
- Absence of midline tenderness

Canadian C-spine rule

- Prospective cohort study
- Age ≥ 16 years at risk of blunt C-spine injury
- Normal vital signs and GCS 15
- Imaging
  - Plain X-rays 98.6%
  - CT 4.9%

Canadian C-spine rule

- 8,924 patients at 20 institutions
- Inter-rater reliability assessed (n=150)
- Variables chosen based on correlation AND reliability
- Two methods of derivation
- Jackknife validation

Canadian C-spine rule

- 151 clinically significant injuries (1.7%)
- Performance for clinically significant injury
  - Sensitivity 100% (98-100%)
  - Specificity 42.5% (40-44%)
- Utilization
  - Avoid imaging in 3,103 (37.4%)

NEXUS vs. Canadian C-spine rule

- Prospective cohort study in 9 Canadian centers
- 8,283 patients with 169 injuries (2.0%)
- By creators of the Canadian rule

	Sensitivity	Specificity	Imaging done
NEXUS	90.7%	36.8%	66.6%
Canadian C-spine rule	99.4%	45.1%	55.9%

Blunt carotid/vertebral artery injury

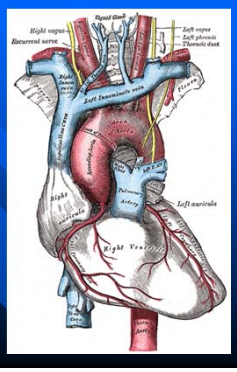
- High energy and mandibular or LeFort II or III fracture
- Neurologic abnormality not otherwise explained
- Fracture through foramen transversum or lacerum
- Seat belt sign
- Vertebral body fracture or subluxation
- Near hanging with anoxic brain injury
- Ischemic stroke on repeat head CT

Blunt carotid vertebral artery injury

- Duplex US with Doppler
  - Best sensitivity 86% for carotid alone
- Magnetic resonance angiography (MRA)
  - Sensitivity ≈ 50%
- CT angiography
  - 16 or greater slice
- Digital subtraction angiography
  - Gold standard

Blunt aortic injury

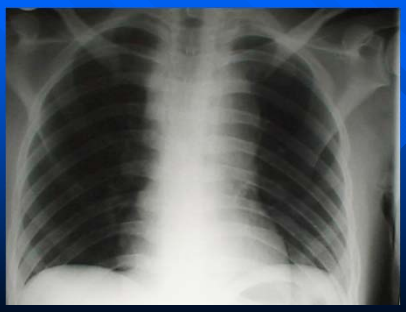
- Almost always in proximal descending aorta
- Annual incidence 0.1%
- Usually immediate death
- CXR best screening test



CXR findings

- Widened mediastinum
- Obscured aortic knob
- 1st rib fracture
- Apical cap
- Depressed left mainstem bronchus
- NGT deviation

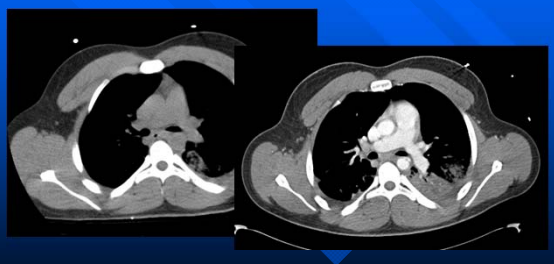
Widened mediastinum



Apical cap

Blunt aortic injury

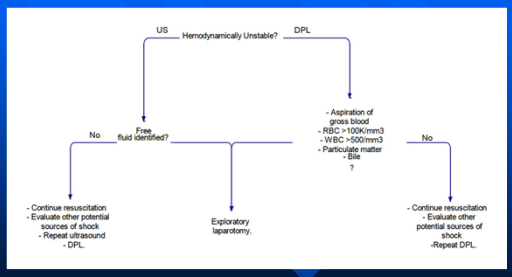
Blunt aortic injury



Abdominal trauma

- Little data to support algorithms
- Contradictory data
- CT necessary if unable to examine or severe associated injuries

Abdominal trauma



Abdominal trauma

- Reliable physical exam?
  - Abdominal pain or tenderness
- High risk signs?
  - Seatbelt sign
  - Lower rib fractures
  - Pelvic fracture
  - External signs of trauma

Abdominal trauma

- Associated injuries
  - Pelvic fracture, Chance fracture
    - » Cystogram
- Imaging results
  - Pelvic fracture
  - Chance fracture
  - Free fluid on CT

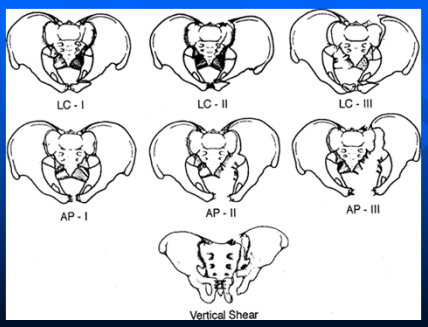
Pelvic imaging

- Physical exam reliable
- Additional imaging
- Hypotension & pelvic fracture

Hypotension & pelvic fracture

- FAST positive
  - Laparotomy
- Unstable fracture pattern
  - Stabilize pelvis
  - Angiography vs. pelvic packing
- Angiography vs. OR
  - Depends on institutional resources and surgeon skill

Pelvic fracture classification



Thoracolumbar spine injuries

- A reliable physical exam can exclude injury
- EAST guidelines recommend CT for screening
  - Reformatted or not?
- Limitations of studies
  - Included transverse & spinous process fractures
  - Intervention included orthotics

Thoracolumbar injuries

- High thoracic
  - CT necessary
- Middle thoracic
  - Can be seen well on plain X-rays
- Lower thoracic
  - Usually seen on abdominal CT
- Lumbar
  - Better seen than thoracic on plain X-ray
  - CT superior?

Extremity imaging

- Based on physical exam findings
- Missed injuries related to thoroughness of exam

General principles

- Get patient off back board first!
- Don’t send for imaging if hemodynamically abnormal
- Don’t delay transfer to image
- Every patient still needs a tertiary survey

Ultrasound in Trauma

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George Washington University

Disclosures

- None

Objectives

- Fundamentals of Ultrasound
- Evidence Basis of Ultrasound
- Real World Case Examples

How Does It Work

- Probe transmits sound at 1-5 mHz and also measures "listens" to its echo
  - Electricity applied to crystals cause vibration and sound
  - Echo hitting crystal generates electrical pulse
- Picture is comprised of: distance to tissue/echo and intensity of echo

How Does It Work

- User Input: change amplitude, frequency, and duration of each pulse to alter picture
- Shape of probe determines field of view
- Frequency determines depth and resolution

Common Probes

- Curvilinear
- Phased array
- Linear

Curvilinear Probe

- Most commonly used probe in trauma
- Low frequency = good depth
  - Morrison's Pouch, Bladder, Splenorenal recess
  - IVC size
  - Bad for PTX and heart

Linear Probe

- High frequency = excellent resolution, poor penetration
  - Pleural views
  - Not bad for heart

Ultrasound in Trauma

- Focused
- Assessment with
- Sonography in
- Trauma

FAST

- Europe 1980s
- 1st report in US: 1992
- Replaced DPL by 2000

Basis for FAST

- Hemorrhage remains most common cause of preventable death
  - Abdomen = the hidden man
- Early detection improves survival
  - MTP activation, TXA, OR, IR, ETC….
  - Vital signs: not sensitive
  - Scoring systems are cumbersome
    - TASH: SBP, pulse, Hg, abd fluid, long bone fx, pelvic fx, base deficit, gender

Basis for FAST

- EAST PMG: FAST may be considered as the initial diagnostic modality to exclude hemoperitoneum (Level II)

FAST: Sensitivity/Specificity

Table 1 Reported results of focused assessment with sonography for trauma (abdomen)

Author	Year	*n*	End point	Injury type	Sensitivity	Specificity	Accuracy
Rozycki *et al.* [9]	1995	295	Fluid	Blunt	78.6	100	98
		76	Fluid	Penetrating	83.8	97.4	90.7
Rozycki *et al.* [10]	1998	1227	Fluid	Blunt	78.3	99.8	98.5
Boulanger *et al.* [11]	2001	72	Fluid	Penetrating	67	98	89
Udobi *et al.* [12]	2001	75	Fluid	Penetrating	46	94	68
Soffer *et al.* [13]	2004	177	Fluid	Penetrating	48	98	85
Kirkpatrick *et al.* [14]	2004	38	Fluid	Penetrating	71.4	95.8	86.8
Friese *et al.* [15]	2007	96	Fluid	Blunt	26.1	96.3	65.6
Natarajan *et al.* [16••]	2010	2105	Injury	Blunt	43	99	94.1

FAST, focused assessment with sonography for trauma.

1. Sensitivity inversely proportional to stability
2. Sensitivity directly proportional to probability of injury
   --- Better for Penetrating Trauma

Matsushima, Frankel. Curr Opin Crit Care. 17:606-12; 2011

FAST Interpretation

- Positive = positive
- Negative = May false (low sensitivity)
  - True Negative can rule out injury 99% cases
- Indeterminate = positive
  - Obesity
  - Subcutaneous emphysema
  - Very large clot burden
  - Retroperitoneal hematoma

EAST PMG: Abdominal FAST

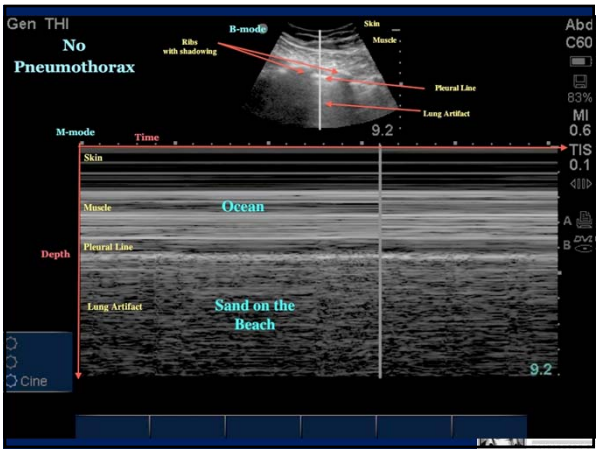
- A negative FAST should prompt follow-up CT for patients at high risk for intraabdominal injuries (e.g., multiple orthopedic injuries, severe chest wall trauma, neurologic impairment).

Negative FAST, Unstable Pt

- "DPA": Diagnostic peritoneal aspiration
- Ex lap – beware of severe TBI as the cause of the hypotension

eFAST vs CXR

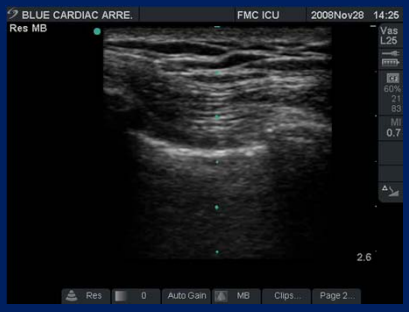
- Faster
- More sensitive and accurate
- Indicators of PTX:
  - Lead point
  - Absence of sliding
  - Absence of comet tails



Pleural FAST (eFAST)

- 2nd ICS, MCL
- Linear Probe is ideal
- Solid line = pleural interface “sliding”

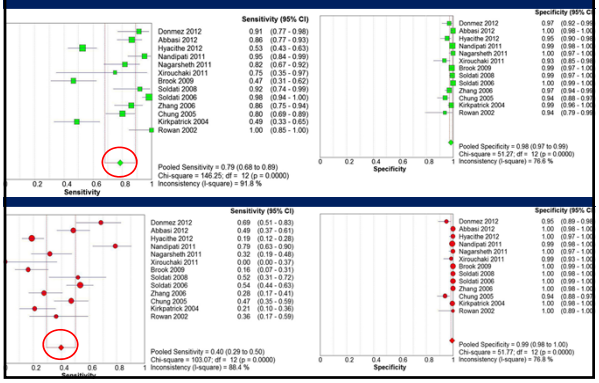
Normal Sliding = No PTX



Pleural FAST (eFAST)

- Comet tail: hyperechoic artifact (linear white line) in lung

Sens/Spec of CXR v Ultrasound for PTX



eFAST vs CXR for HTX

- 20cc vs 175cc
- Sens 98% v 93%
- Specificity 99% in both

Cardiac FAST

- Accuracy 100% in 2 studies
- Indeterminate view in both sub-xyphoid and parasternal = clot in pericardium
- False negative rare with anterior/lateral wounding

FAST for volume status

- Dynamic IVC collapse
- No validating studies in:
  - Spontaneous breathing
  - Hemodynamically stable
- No definition on degree of collapse to define hypovolemia

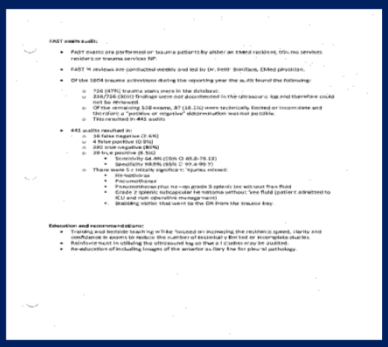
Limitations of Ultrasound

- User dependent
- Hollow viscera, retroperitoneum missed
- Intraparenchymal lesions (intrahepatic contusion) missed

PI of FAST

- Most centers do not routinely PI FAST
  - Image capture
  - Chart review against CT scan or Surgery
  - Expert Review of images
  - Feedback to user

FAST PI Report



Real World Example 1

- 55 yo female, MCC ejected, not helmeted
  - 80/40, P 150, GCS 3 despite IVF
  - RSI on arrival
- FAST: negative x 2
- CXR: negative

Real World Example 1

- Options:
  - Chest tubes (which side(s))?
  - DPA
  - Ex lap
  - CT scan of head
  - CT scan of chest/abdomen/pelvis

Babak's Mistake

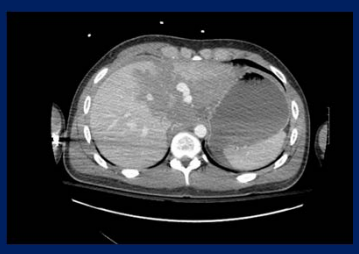
- Ex lap = "yep, that FAST sure was right"
- Bilateral chest tubes = "yep, that CXR was right too"
- Head CT scan = herniated PTA, brain dead
- Should have used DPA to confirm FAST and avoided the OR

Real World Example 2

- 25 year male crushed by falling cinder wall
  - A&O, GCS 15 c/o epigastric pain
  - 120/80, 110, RR 18, sat 100%

Real World Example 2

- Next move?



Real World Example 3

- 35 year MCC, ejected
  - GCS 15, c/o left chest pain. RR 25, Sat 92% RA

Real World Example 4

- 19 yo male, car-surfing, fell and dragged
  - Cardiac arrest at OSH, recovered
  - Cardiac arrest upon arrival to GW
  - Left (ED) thoracotomy with ROSC – NO HTX
  - Right chest tube – NO PTX/HTX
- FAST negative x 2
- Critically Unstable

Real World Example 4

- Next move??
  - CT scan of head – devastating brain injury
  - DPA in OR: negative.
  - Pt allowed to die in OR

Questions?

Radiologic Zebras in Trauma

Martin D. Zielinski, MD
Mayo Clinic
EAST/STN AP Workshop
January 16, 2014

If it looks like a horse,

And it sounds like a horse,

It must be a…

ZEBRA!

ZEBRA - **ze·bra**

- /ˈzibrə; British also ˈzɛbrə/
- noun, plural ze·bras
  - 1. any of several horselike African mammals of the genus Equus, each species having a characteristic pattern of black or dark-brown stripes on a whitish background.
  - 2. a word formerly used in communications to represent the letter Z.
  - 3. Football Slang. an official, who usually wears a black and white striped shirt.
  - 4. Medical Slang. Arriving at an exotic medical diagnosis when a more commonplace explanation is more likely.
  - Synonym - fascinoma

ZEBRA aka "fascinoma"

"When you hear hoofbeats, think of horses not zebras."

- Dr. Theodore Woodward
  University of Maryland

"In making the diagnosis of the cause of illness in an individual case, calculations of probability have no meaning. The pertinent question is whether the disease is present or not. Whether it is rare or common does not change the odds in a single patient. If the diagnosis can be made on the basis of specific criteria, then these criteria are either fulfilled or not fulfilled."

- Dr.'s A. McGehee Harvey, James Bordley III, and Jeremiah Barondess
  Johns Hopkins University

east

ZEBRA

"Uh-oh, that sounds bad…"

"…what do we do?"

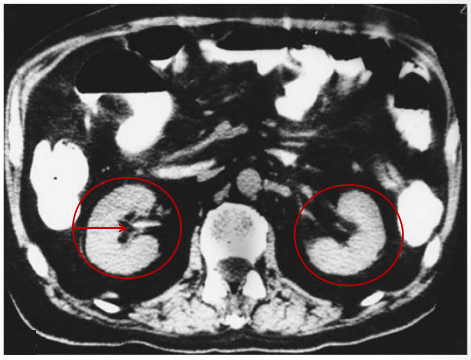
east

CASE REPORTS???

east

38 Male MVC

- Hemodynamically stable
- Seat-belt sign
- c/o abdominal pain
- Oral contrast CT



"But wait, we didn't give him IV contrast…"

38 Male MVC w/ Renal Contrast

- Bilateral
  - Recent CT with IV contrast
  - Active Crohns or Ulcerative Colitis
- Unilateral
  - Kidney stone
  - Purulence
  - Fungus

OR…

Intestinal Perforation

38 Male MVC Intestinal Perforation

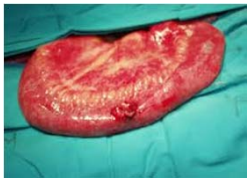
- Water soluble enteric contrast
  - Hyperosmolar
  - Gastrografin
  - Urografin
- Peritoneal absorption
- Renal excretion

- Enteric contrast relative contraindication for trauma

Enteric Renal Contrast

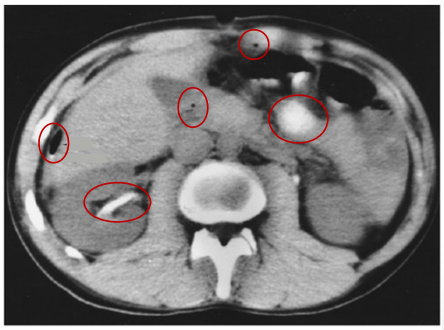
- Treatment?

Exploration!



Enteric Renal Contrast

Enteric Renal Contrast



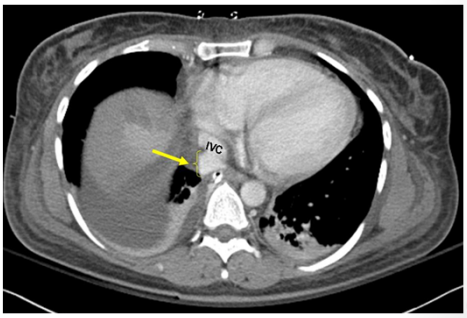
east

21 Female MVC

- Highway speeds
- Boyfriend concurrent causality
- Prolonged extrication
- Intubated for respiratory distress
- Hemodynamically stable

east

21 Female MVC



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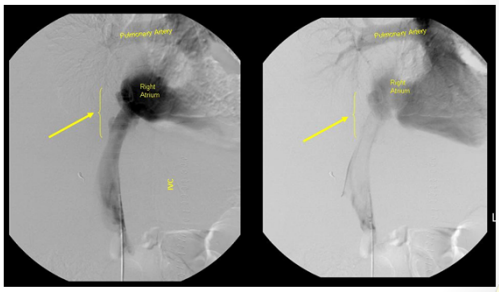
21 Female MVC

east

IVC pseudoaneurysm



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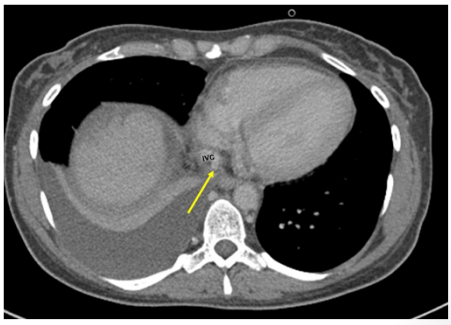
IVC pseudoaneurysm

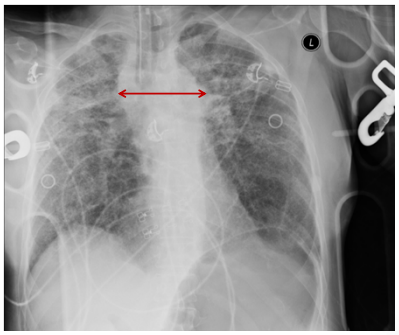


east

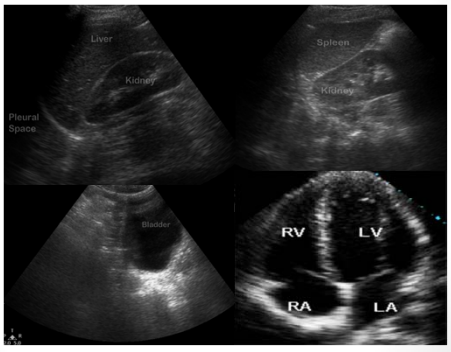
63 Female MVC vs Deer

- Hx of lymphoma
- Persistent hypotension and tachycardia
- GCS 3
- Intubated
- 8-cm scalp laceration – bleeding
- Massive transfusion initiated

63 Female MVC vs Deer



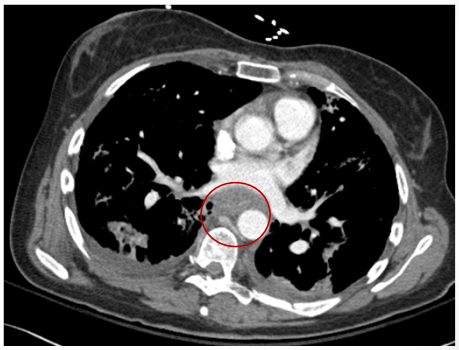
63 Female MVC vs Deer



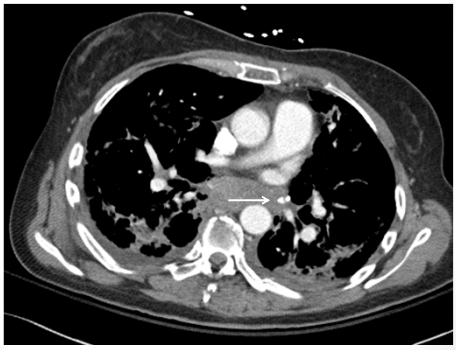
63 Female MVC vs Deer

- Raney clips
- Bilateral chest tubes – minimal output
- "Stable"
- 10 units RBC/plasma/platelets
- CT…"gulp"

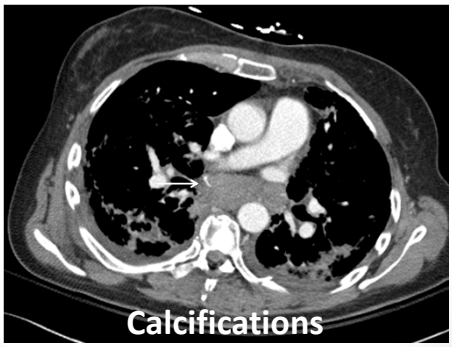
63 Female MVC vs Deer



63 Female MVC vs Deer



63 Female MVC vs Deer



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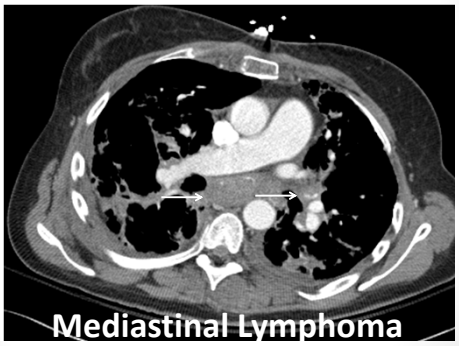
63 Female MVC vs Deer



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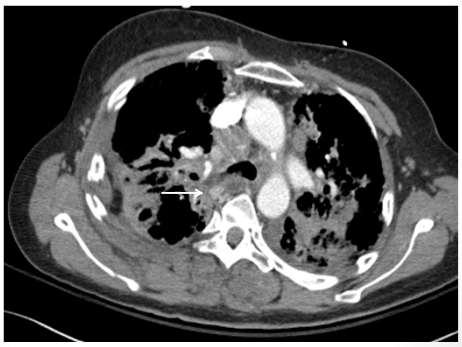
63 Female MVC vs Deer



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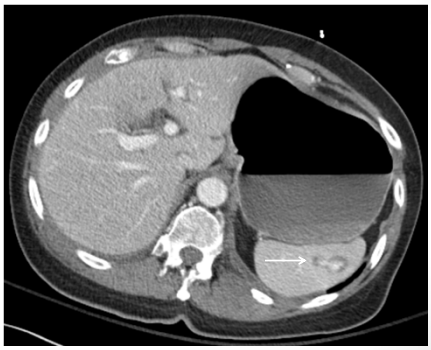


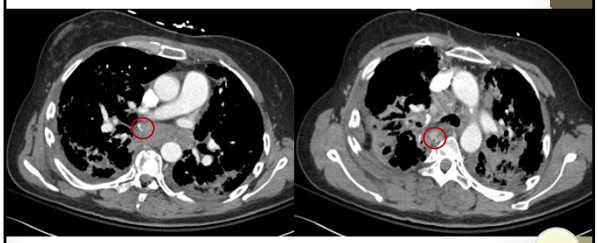
63 Female MVC vs Deer

- Splenic angioembolization
- Anatomic locations to bleed to death
  - Abdomen/pelvis
  - Retroperitoneum
  - Pleural cavities
  - Thighs
  - External

Mediastinal Masses

- Differential Dx
  - 5 T's
    - Teratoma
    - Thyroid tumors
    - Thymoma
    - Thoracic aorta
    - "Terrible" Lymphoma
  - Hematoma
    - Fractures – ribs/sternum/vertebrae
    - Major vasculature disruption
    - Lymph node tumor hemorrhage

63 Female MVC vs Deer



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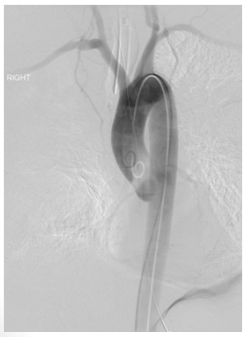
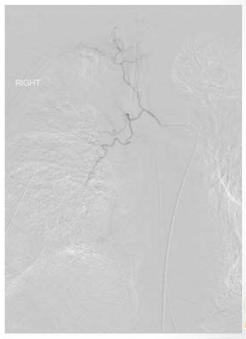
63 Female MVC vs Deer





east

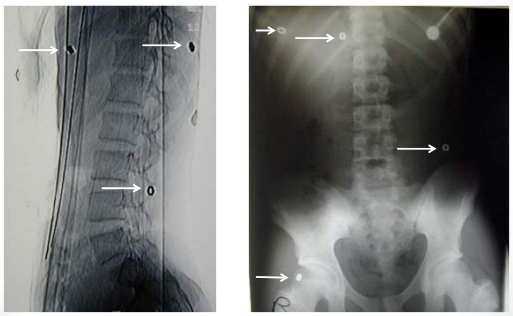
63 Female MVC vs Deer

east

Suicide Bomber Victim #1

- 15 year old male
- Multiple shrapnel penetrations
- Minor head, chest, abdomen & limb injuries

Suicide Bomber Victim #1



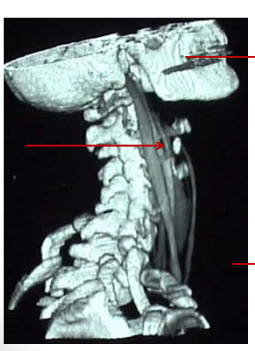
Suicide Bomber Victim #1

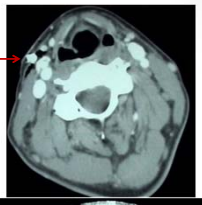
Suicide Bomber Victim #1

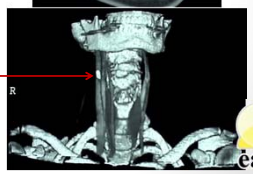
Suicide Bomber Victim #2

- 20 year old female
- Multiple shrapnel penetrations
- Head & neck

Suicide Bomber Victim #2







Suicide Bomber Victim #2

- **Proven By DNA Testing**
- **Terrorist Hepatitis B+**
- **HBV Immunization**
- **One Terrorist – HIV +**

east

43 Male GSW

- Right anterior thoracoabdominal
- Unstable
- Chest tube placed
- Intubated
- Massive Transfusion initiated
- OR (angiography capable)

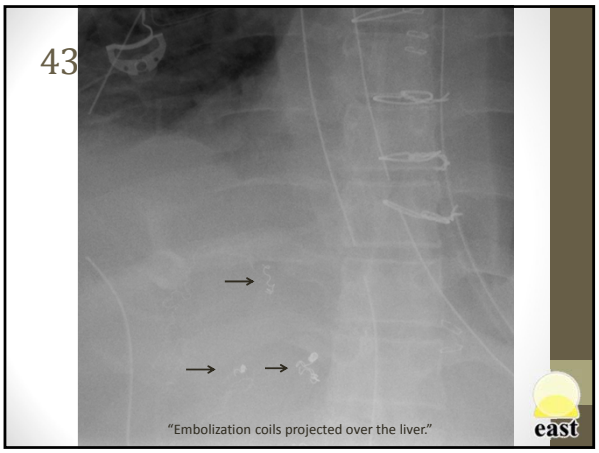
east

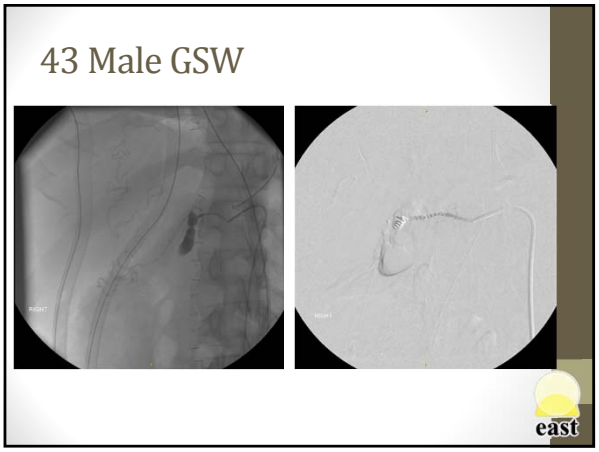
43 Male GSW

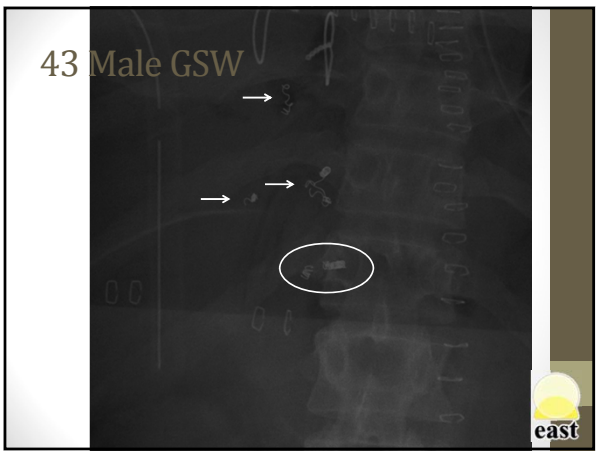
- Hepatic laceration
- Uncontained retrohepatic hemorrhage
- Right diaphragm laceration
- Thoracic hemorrhage through diaphragm
- Quick Clot placed*

*No Disclosures

east


43
"Embolization coils projected over the liver."
east


43 Male GSW
east


43 Male GSW
east

43 Male Missed RFO

43 Male Missed RFO

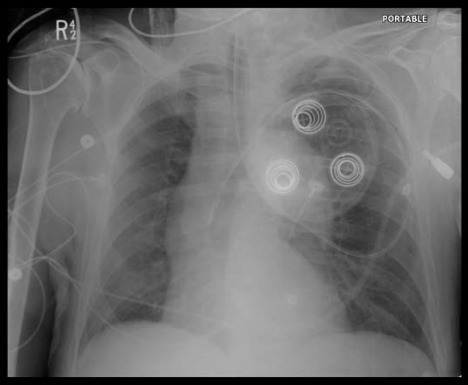
43 Male Missed RFO

- Sponges account for 48% of all RFOs
- 76% of counts are “correct”
- 40 patients = $2,072,319
  - $51,807 per patient
- Abdominal X-ray (needles)
  - 74% accurate
  - 69% sensitivity
  - 80% specificity

east

Trauma Imaging Jeopardy

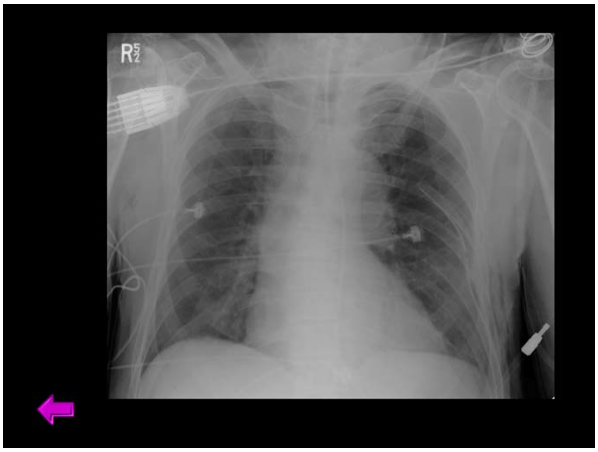
What's That Doing There?	Head and C-spine	True Blood	My Chest Hurts	Found Down!
10	10	10	10	10
20	20	20	20	20
30	30	30	30	30
40	40	40	40	40
50	50	50	50	50



Left main stem intubation with dobhoff feeding tube.

Now what?

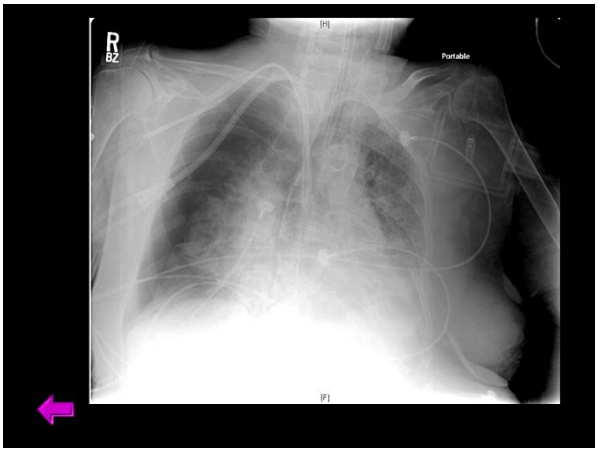

L 4 2 PORTABLE

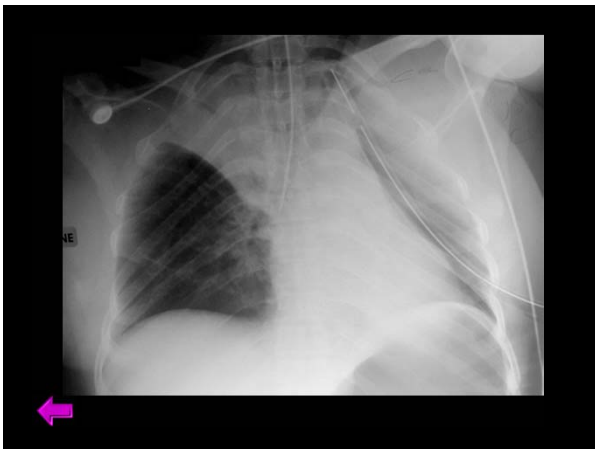

R 5 2


Portable
L

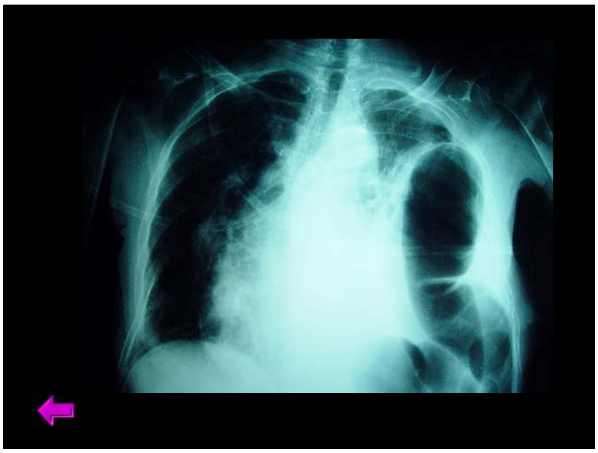
Right main stem intubation with dobhoff feeding tube.

What's different?

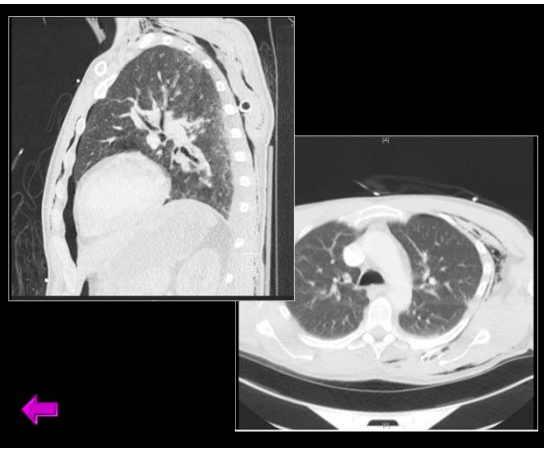




Right main stem intubation.



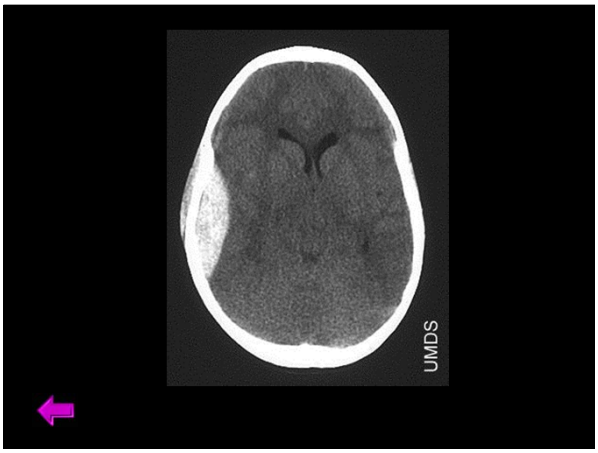
Left sided diaphragmatic rupture with herniation of colon to the left chest.



Small anterior pneumothorax with extrathoracic chest tube.

Transcranial gunshot wound.

What's the prognosis?



Epidural hematoma.

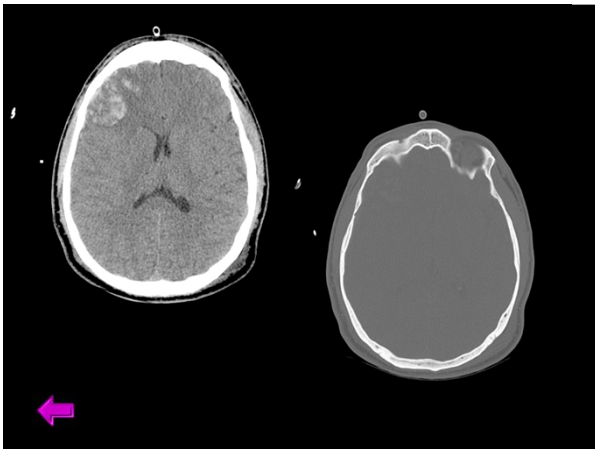
What's the classic clinical presentation?

Subdural hematoma with midline shift and sulcal effacement.

Would you rather have this injury at 18 years of age or 78?

Posterior dislocation of C-6 with C-6 vertebral body fracture.

What neurologic deficits do you expect?

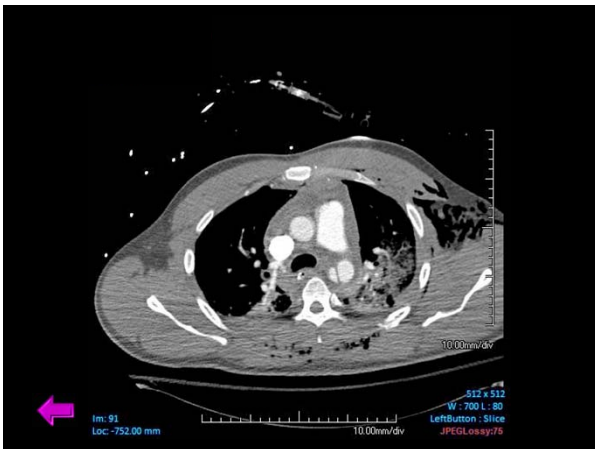


Right frontotemporal contusion with small subdural hematoma.

Where was the patient struck?

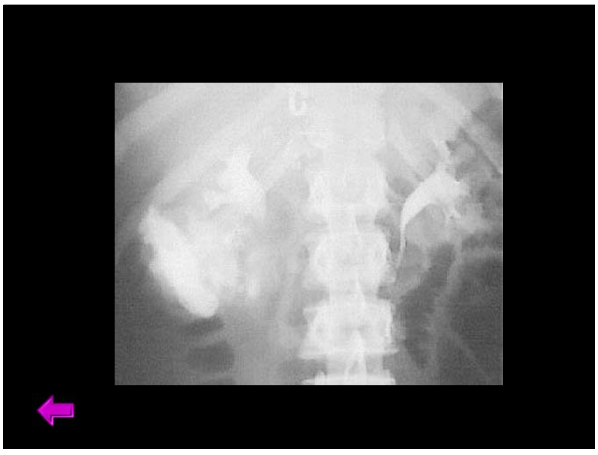
Widened mediastinum.

Concern for what injury?

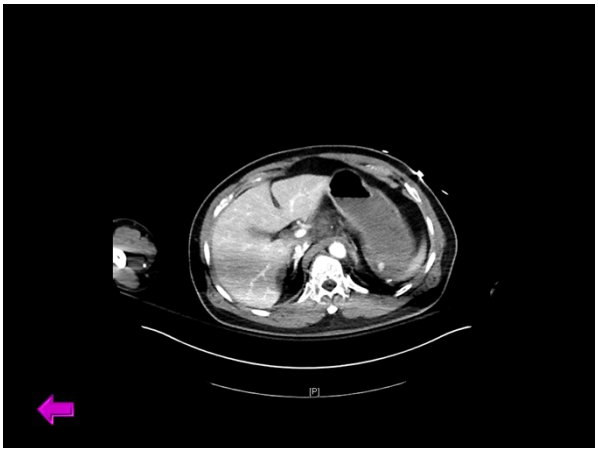


Traumatic aortic dissection.

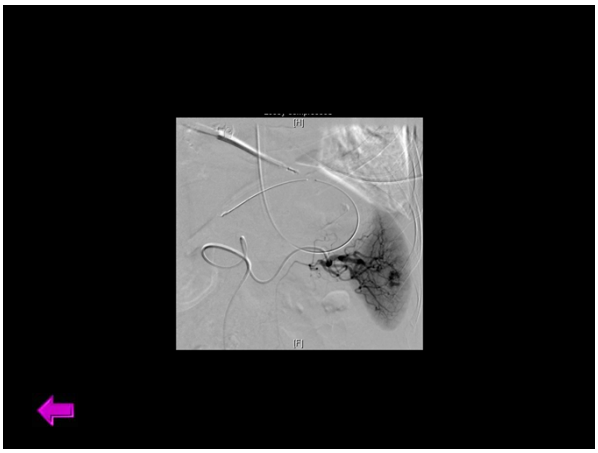
What's the common mechanism?

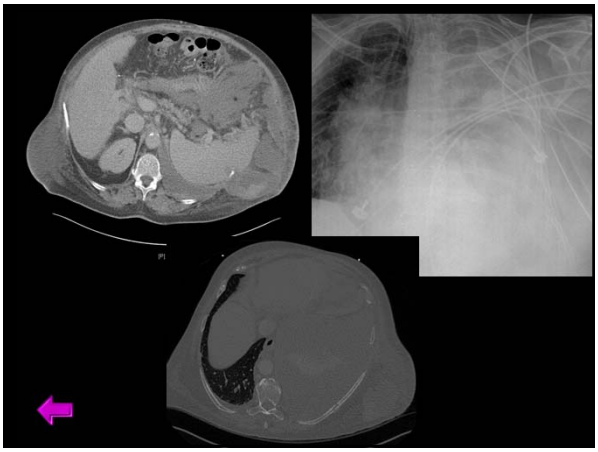


Right renal injury.



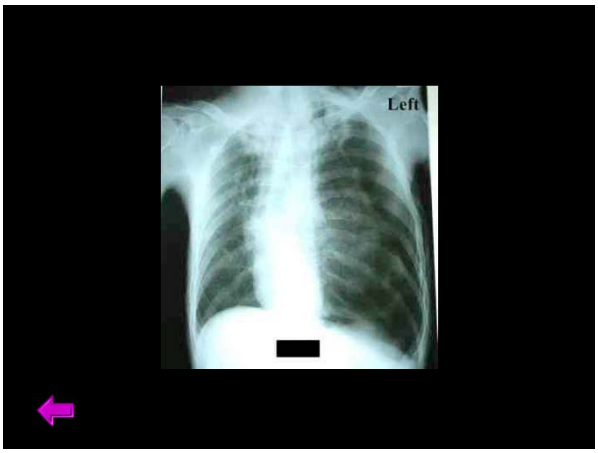
Gastric vs. Splenic Blush





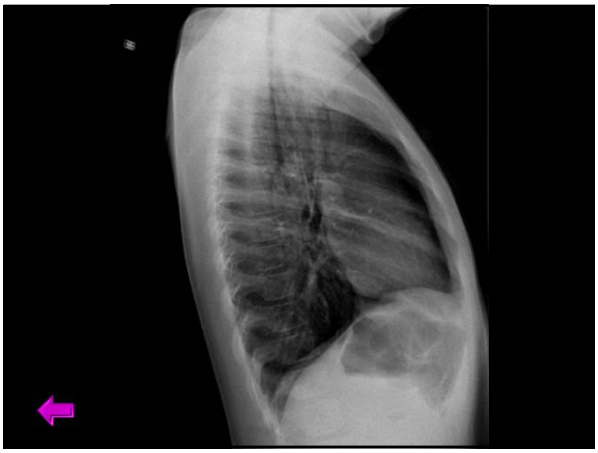
1. Splenic injury
2. Herniation of abdominal contents
3. Rib fracture

Take a look at the chest tube!



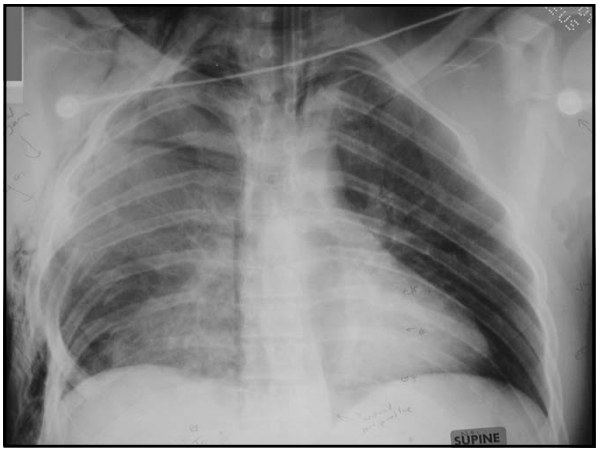
Left tension pneumothorax with multiple left sided rib fractures.

What is the immediate management?



Pneumomediastinum.

What's the most likely injury?

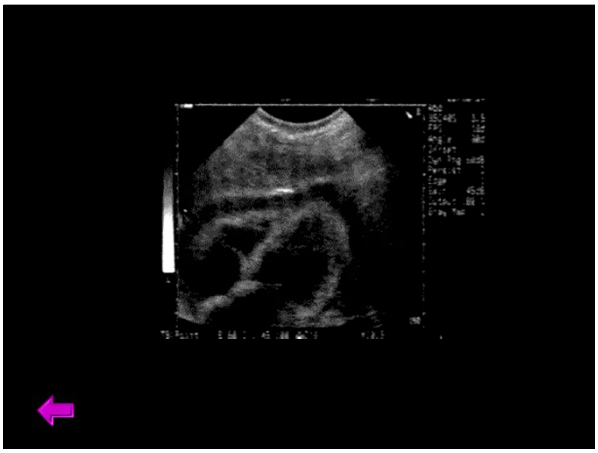


Right flail segment. Mutiple left sided rib fracture.

What is the parenchymal finding?

Left sided rib fractures and pulmonary contusion.

Will this get better or worse?



Pericardial effusion.

What is the immediate management?

Mid-shaft femur fracture.

What's the immediate intervention?

Open book pelvic fracture.

Is this life threatening?

What's the immediate intervention?

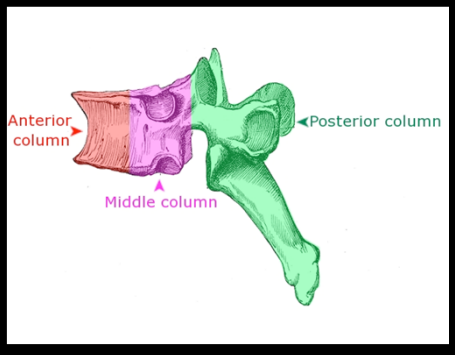
Stable

Or

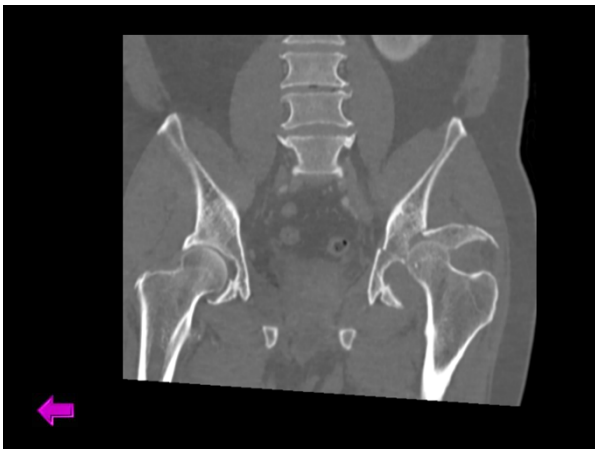
Unstable?

Unstable!

What are the radiographic determinates of spinal stability?



http://pgblazer.com/2009/11/three-column-concept-of-spine-stability.html



Left acetabular fracture.

How do you stop the bleeding?

Bilateral sphenoid sinus fractures.

What further imaging is required?