Trauma Plain Film Diagnoses You Cannot Afford to Miss
S.V. Mahadevan, MD, FACEP, FAAEM (s.mahadevan@stanford.edu)

Objectives
- List the 5 most important, trauma-related life-threatening plain film diagnoses, that cannot be missed
- Interpret the radiographic findings indicate these diagnoses
- Review the confirmatory studies required to secure the diagnosis

Pneumothorax
- Air in the pleural space as a result of blunt or penetrating trauma causing a tear in the visceral pleura
- Also as a result of rupture of an alveolar bleb
- Positive pressure ventilation can rapidly lead to a tension pneumothorax

Pneumothorax: Plain film findings
- Visceral pleural line/edge without distal lung markings
- On the lateral, may be seen retrosternal or overlying the vertebra, parallel to the chest wall
- Forced expiratory views: Controversial
- During expiration, the lung decreases in volume and the visceral pleural line is easier to see

Quantifying / Classification
- Many approaches to quantifying the size of a pneumothorax, none are accurate
- Marginal, moderate, massive
- Small, medium, large
  - Small: Only the apex
  - Medium: Extends to the lateral thoracic wall
  - Large: Complete or near complete collapse of the lung
PTX ON SUPINE FILM

- Pleural air will rise to the most nondependent portion of the thorax, which is at the apex in the upright patient, and at the anterior, caudal aspect of the pleural space in the supine patient.
- Radiographic signs in the supine trauma patient include
  - Deep sulcus sign: a deep, lucent costophrenic sulcus
  - Double diaphragm sign: created by the interfaces between the ventral and dorsal portions of the pneumothorax with the anterior and posterior aspects of the hemidiaphragm
  - Hyperlucent hemithorax: A relative increase in lucency of the affected lung

Pneumothorax mimics
- Medial border of the scapula
- Skin folds
- Clothing/bed sheets
- Rib companion shadows (Need image!)
- When in doubt…

Occult pneumothorax:
- Bottom line: Supine CXR unreliable for the detection of pneumothoraces, especially occult or small ptx’s
- One study noted that 63% of all pneumothoraces are missed on trauma chest radiographs. Kirkpatrick et al. J Trauma 2004

Confirmation: CT
- Pneumothoraces that are not apparent on the supine chest radiograph (occult PTX)
- Revealed on CT in 10-50% of patients with head and blunt abdominal trauma
Computed Tomography
- Gold standard for detecting PTX
- More sensitive than radiography
  - Particularly in the supine patient
- Allows for further evaluation/delineation of underlying pulmonary disease or injury.
- Neither practical nor feasible for all trauma patients

Confirmation: Ultrasound
- A relatively new application
- US sensitive (95.5%) and specific (up to 100%)
- Looking for the absence of 2 signs
  - Pleural lung-sliding
  - Comet tail artifact
    - which suggests a pneumothorax
- The presence of either sign excludes a pneumothorax

Normal lung sliding
Lung sliding at the horizontal echogenic pleural interface and movement of comet-tail artifacts are apparent with respiratory motion.

Pneumothorax
The horizontal echogenic pleural interface is visualized. No comet-tail artifacts or lung sliding are evident at this interface, indicating separation of the visceral and parietal pleural surfaces by an anterior pneumothorax. Pneumothorax was confirmed at subsequent CT.

Why consider ultrasound?
- Supine CXR is insensitive for small pneumothoraces
- A small PTX is easily treated but potentially lethal
- Already doing a FAST exam
- Faster than radiography
- Easily repeated, no additional radiation exposure

Caveats
- False positives and negatives
  - Absence of lung sliding may be seen with other conditions such as bullous emphysema, pleural adhesions, large lung contusions and extensive subcutaneous emphysema
- Need more familiarity and training
**Traumatic Aortic Injury**

- **Causes:**
  - Motor vehicle collisions
  - Falls from height
  - Crush injuries
- 2nd most frequent cause of death in blunt trauma
  - 80-90% with TAI die at the scene
- **Without therapy:**
  - 30% die within 6 hrs
  - 50% within 24 hrs
  - 90% within 4 months
- **With prompt diagnosis and treatment:**
  - >70% who reach the hospital alive will survive

**Supine CXR: Classic teaching**

- 90% sensitive
- 95% negative predictive value
- Poor specificity (25%)
  - A wide mediastinum does not always correlate with mediastinal hemorrhage

**Value of the screening CXR: 16 Radiological signs**

<table>
<thead>
<tr>
<th>Features directly related to the aortic injury:</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irregularity or blurring of the aortic knob contour</td>
<td>72</td>
<td>47</td>
</tr>
<tr>
<td>Aortic knob enlargement</td>
<td>35</td>
<td>60</td>
</tr>
<tr>
<td>Features related to the presence of a mediastinal hematoma:</td>
<td></td>
<td></td>
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<tr>
<td>Mediastinal widening</td>
<td>90</td>
<td>19</td>
</tr>
<tr>
<td>Aorto-pulmonic window opacification</td>
<td>42</td>
<td>83</td>
</tr>
<tr>
<td>Displacement of the left lateral wall of the esophagus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>or of a naso-gastric tube</td>
<td>9</td>
<td>96</td>
</tr>
<tr>
<td>Displacement of the left lateral wall of the trachea</td>
<td></td>
<td></td>
</tr>
<tr>
<td>or of an endotracheal tube</td>
<td>20</td>
<td>92</td>
</tr>
<tr>
<td>Trachea anterior displacement on lateral views</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Left mainstem bronchus downward displacement</td>
<td>3</td>
<td>99</td>
</tr>
<tr>
<td>Cardiac silhouette enlargement and loss of definition</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Superior vena cava rightward displacement</td>
<td>7</td>
<td>96</td>
</tr>
<tr>
<td>Azygos vein obscuration</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Other features:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left apical cap</td>
<td>5</td>
<td>95</td>
</tr>
<tr>
<td>Opacification of the medial border of the left lung</td>
<td>12</td>
<td>95</td>
</tr>
<tr>
<td>Left hemithorax</td>
<td>5</td>
<td>97</td>
</tr>
<tr>
<td>Right paratracheal stripe thickening</td>
<td>30</td>
<td>99</td>
</tr>
<tr>
<td>Right or left paraspinal stripe thickening</td>
<td>2</td>
<td>97</td>
</tr>
</tbody>
</table>


**Value of CXR**

- CXR’s in 45 pts w/ blunt traumatic aortic injury
  - 7 % read as normal
  - 40% abnormal and TAI suspected (primarily widened mediastinum)
  - 53% abnormal but TAI not suspected
  - Suggests that CXR not a reliable screen – neither sensitive nor specific
CXR Findings:
- Mediastinum widened
- Tracheal deviation to the right
- L apical cap

What about Chest CT?
- Spiral CT Aortography (SCTA)
- Advantages:
  - Fast, relatively inexpensive, non-invasive, readily available
- Indications:
  - High clinical suspicion
  - Abnormal CXR
- Allows for 3D imaging and better anatomic detail
  - 100% sensitive, 99.7% specific for TAI

If the spiral CT shows
- Absence of mediastinal hematoma
  -and-
- No signs of direct aortic injury
  ➔ 100% negative predictive value for aortic injury

If the spiral CT shows
- Mediastinal hematoma
  -and-
- Direct signs of an aortic injury
  ➔ Call your cardiothoracic surgeon
- Direct signs of aortic injury
  - Curvilinear intimal flap
  - Intramural hematoma or dissection
  - Irregularity of the aortic wall or contour
  - Pseudoaneurysm
  - Pseudocoarctation
If the spiral CT shows

- Mediastinal hematoma *WITHOUT* direct signs of an aortic injury (5% of cases)

⇒ 2 choices:
- Proceed to AORTOGRAPHY
- OR-
- Just CLEAR THE PATIENT

<table>
<thead>
<tr>
<th>Aortography</th>
<th>Echocardiography</th>
</tr>
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<tbody>
<tr>
<td>Invasive</td>
<td>Transthoracic (TTE): Not reliable</td>
</tr>
<tr>
<td>Time-consuming</td>
<td>Transesophageal (TEE)</td>
</tr>
<tr>
<td>Expensive</td>
<td>Semi-invasive</td>
</tr>
<tr>
<td>May have false negative and false positive results</td>
<td>Sensitivity 91%, Specificity 98% but highly operator dependent</td>
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<tr>
<td>Replaced by contrast enhanced CT</td>
<td>Can be done in an intubated patient or during laparotomy</td>
</tr>
<tr>
<td></td>
<td>Reserve for</td>
</tr>
<tr>
<td></td>
<td>Operating room for another injury</td>
</tr>
<tr>
<td></td>
<td>Hemodynamically unstable</td>
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Cervical Spine Injury

Emergency physicians miss cervical spine injuries?
- Review of 32000 trauma patients
- Missed 34 out of 740 c-spine injuries
- 70% of these injuries UNSTABLE
- Consequences of these missed injuries
  - 2 deaths
  - 4 quadriplegic or paraplegic patients
  - 4 patients with permanent limb paralysis

*Davis JW et al. The etiology of missed cervical spine injuries. J Trauma 1993; 34:342-346*

Why do we miss c-spine injuries?
- Not suspecting an injury
- Failure to obtain radiographs
- Films do not reveal the injury
- Inadequate radiographs
- Incorrect interpretation of films

What do we miss?
- Reasons for missed c-spine injuries in 274 patients with spinal injuries
- Findings missed on x-rays
  - Failure to identify subluxation
  - Missed soft tissue swelling in front of the spine
  - Simply overlooking obvious fractures
- Failure to identify injuries accounted for an increased rate of secondary deficits

*Reid et al. Etiology and clinical course of missed spinal fractures. J Trauma. 1987; 27:980-986*
CERVICAL SPINE: LATERAL VIEW: The ABC'S © S.V. Mahadevan

Adequacy: Visualize Occiput & C1-T1; Articular masses are diamond shaped
Alignment: Look for misalignment: > 3.5 mm subluxation is always unstable
   Anterior Vertebral Body Line (AVBL)
   Posterior Vertebral Body Line (PVBL)
   Spinalaminar line (SLL) should be smooth curve except at C2 where
   there can be post displacement of up to 2mm
   Posterior Cervical Line (PCL) a straight line connecting the spinolaminar
   junctions of C1, C2 & C3; all junctions should lie within 1-2 mm of the PCL
Bones: Identify & inspect the following structures (see diagram)
   Anterior and posterior arch of C1
   Body of C2
   Post cortex of dens:
      Aligned with C2 vertebral body or slight posterior inclination
   Ring of C2 (Harris' ring) intact
   Vertebral bodies C3-C7
      Trace the boundaries: Start at the anterior-inferior corner
      Heights: Anterior and posterior should be equal
      > 2 mm disparity = compression fracture
      > 25% difference = unstable
   Posterior Bony Elements:
      Pedicles
      Articular Masses
      Laminae
      Spinous Processes
Cartilage:
   Disk spaces (C2/C3-C7/T1)
      End plates are parallel
      Intervertebral disk height is uniform; Joint spaces < 2 mm
      Angle between vertebral bodies is < 11 degrees (> 11 unstable)
   Facet joints: Articular surfaces are parallel; Joint spaces are uniform
Connective Tissue:
   Look for fanning between contiguous laminae or spinous processes
   Distance between C1 posterior arch & C2 spinous process < 18 mm
   Below C2, these spaces should not differ by more than 2 mm
Soft tissues and Spaces: (see diagram)
   Predental Space:
      Adult: < 3 mm; Children: < 5 mm
   Prevertebral Soft-tissue: Follow contour; look for bulging or abnormal width
      Adult: C1 (< 10 mm), C1-C4 (5-7 mm); Below C4 (< 22 mm)
      Children: Below C4 (< 14 mm)
   Spinal canal: Space between PVBL and SLL > 13 mm
   Basion Dental Interval (BDI) For age >13: BDI < 12 mm
   Basion Axial Interval (BAI) For all ages BAI < 12 mm
ABC’s OF THE LATERAL VIEW:

6 STEPS

• Step 1: Adequacy
• Step 2: Alignment
• Step 3: Bones
• Step 4: Cartilage
  – Disk spaces (C2/C3–C7/T1)
  – Facets
• Step 5: Connective Tissue
• Step 6: Soft tissues and Spaces
  – Spinal canal
  – Predental Space
  – Prevertebral Space
  – Basion Dental Interval
  – Basion Axial Interval

ADEQUACY

■ Adequacy:
  ■ Lateral radiograph:
    ■ Need to see
      ■ Occiput
      ■ Bodies of C1-T1
      ■ Lat masses diamond shaped

ADEQUACY

■ Options if can’t see down to C7-T1
  ■ Reshoot (gentle traction on the arms)
  ■ Swimmer’s View (37%)
  ■ Oblique (38%)
  ■ CT Scan

ALIGNMENT:

■ 5 LINES of the lateral c-spine xray
  ■ Anterior Vertebral Body Line (AVBL)
  ■ Posterior Vertebral Body Line (PVBL)
  ■ Spinolaminar Line (SLL)
  ■ Spinous Process Tips
  ■ Posterior cervical line

“Malalignment of the vertebrae, in patients suspected of blunt spinal trauma, is the quintessential sign of spinal injury.”

JH Harris, Jr

ALIGNMENT: **Subluxation**
- Any subluxation or abnormality of the lines of alignment should be carefully scrutinized
  - Physiologic - OR -
  - Pathologic: Fracture, Dislocation or Unstable Ligamentous injury
- Subluxation > 3.5mm = UNSTABLE

*Source: Musculoskeletal Trauma Vol. 8, Part 3, Frank H. Netter MD, 1993*

ALIGNMENT: **Posterior cervical line**
The C2 spinolaminar junction should lie within 1-2 mm of a line drawn between the spinolaminar junctions of C1 and C3

*Source: Rosen’s Emergency Medicine (2002)*

**BONES:**
**Anterior and Posterior Arch of C1**

*Fracture of posterior arch of C1*
**BONES: Fat C2 sign**
- The AP width of C2’s body should normally mirror that of C3

*Source: Radiology 2000; 217:359–360*

**BONES: Posterior cortex of C2**
- Posterior cortex should be aligned with the C2 vertebral body

*Source: Rosen’s Emergency Medicine (2002)*
- Posterior inclination or angulation of the dens in some patients (as much as 36 degrees)

**BONES: Ring of C2**
- The ring of C2 (Harris’ ring) should be intact
- Components of the ring of C2 identifiable in 94% of adults
- Ring components
  - anteriorly by the cortex of the C2 pedicles,
  - superiorly by summation of the density of an arc of the superior facet of C2 and the cortex at the base of the dens,
  - posteriorly by the posterior cortex of the C2 body.

**Disruption of the Ring of C2**
- Disruption of the axis (C2) ring is a specific radiographic sign of a Type III (low) dens fracture

**BONES: Vertebral bodies of C3-C7**
- Trace the boundaries
  - Start at the anterior-inferior corner and proceed clockwise
- Check heights
  - Anterior and Posterior heights should be equal
  - > 2 mm disparity suggests compression fracture
  - > 25% difference suggests instability
BONES: Posterior elements of C2-C7
- Pedicles
- Articular Masses
- Lamina
- Spinous processes

CARTILAGE:
- Disk Space C2-C3 -> C7-T1
  - End Plates are parallel
  - Intervertebral disk height is uniform
  - Joint spaces < 2 mm
  - Angle between the vertebral bodies is < 11 degrees
- Facets
  - Articular surfaces are parallel
  - Joint spaces are uniform

“A wide disc space is never a normal finding” RH Daffner

CONNECTIVE TISSUES
- Spinous process or laminar fanning
  - The space between the posterior arch of C1 and the spinous process of C2 should never exceed 18 mm
  - Below C2, the spaces should not differ by more than 2 mm

SOFT TISSUES AND SPACES
- Predental space: < 3 mm in adults, < 5 mm in children
- Prevertebral Soft Tissue: Adult: C1 (<10mm), C1-C4 (5-7mm); Below C4 (<22mm)
  Children: Below C4 (<14mm)
- Spinal Canal: Space between PVBL and SLL > 13 mm
SOFT TISSUES AND SPACES

- Basion Dental Interval
- Basion Axial Interval

Rule of 12’s

- Basion-Dental Interval (BDI)
  - Age > 13: <12 mm
- Basion Axial Interval (BAI)
  - All ages: <12 mm

Abnormal BDI and BAI > 12mm

Abnormal BDI or BAI suggests Occipito-Atlanto Dissociation (OAD)

Confirmation: Computed Tomography

- Helical CT with sagittal and coronal reformations
  - Sensitivity: 98% (Holmes et al. J Trauma 2005)
- Who needs a CT?
  - Abnormal plain films
  - Neurologic deficits
  - Hi energy mechanism
  - Other significant injuries/ going for other CT
  - Maha’s rule: Age > 65

Necrotizing Fasciitis

- Life threatening surgical emergency
- Commonly preceded by trauma
- Usually some degree of immunosuppression (e.g., diabetes)
- Widespread fascial necrosis with relative sparing of the skin and underlying muscles
- Predictor of mortality = delay in the diagnosis of necrosis

Necrotizing fasciitis

- Most common plain film findings
  - Increased soft tissue thickness and opacity (similar to cellulitis)
  - Soft tissue gas is seen in a minority of cases

Air in the soft tissues

- Differential diagnosis
  - Necrotizing fasciitis
  - Gas gangrene
  - Open wound
  - Industrial air gun accident

Confirmatory studies

- **CT**
  - May show soft-tissue air associated with fluid collections within the deep fascia
  - May show thickening and enhancement of one or both of the superficial and deep fascial layers. The subcutaneous fat may be similarly affected

- **MRI**
  - May show fascial fluid and increased signal intensity on T1-weighted images along thickened deep fascial planes.
  - Useful in differentiating NF from severe cellulitis with or without secondary abscess formation and pyomyositis

- **US**
  - May show distorted and thickened fascial planes with turbid fluid accumulation in the fascial layers and subcutaneous edema.

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**Non-Accidental Injury (NAI) / Child abuse**

- 1200 Child abuse related deaths per year
  - Children < 1 account for 44% of fatalities
- Estimated that > 80% of diagnosed child abuse-related injuries in the US are detected through medical imaging
- Skeletal injury: most common abuse related injury
  - Documented in up to 55% of physically abused children
- Patients with skeletal injuries may not have external evidence of injury
**Metaphyseal Fracture**

- Excessive pulling and twisting of the extremities results in shearing of the metaphyses
- Classic metaphyseal lesion (CML)
  - Very specific (pathognomonic) for NAI
  - Only rarely occurring with accidental injuries

*Source: Emergency Radiology by Schwartz and Reissdorff (1999)*

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**Classic metaphyseal lesion (CML)**

- Found in 39-50% of abused children < 18 mos of age
- Most often occur in
  - Distal femur
  - Proximal tibia
  - Distal tibia
  - Proximal humerus

**Fractures associated with NAI**

- Multiple
- Differing ages
- Metaphyseal
- Rib
- Scapula
- Vertebral
- Digital
- Outer end of the clavicle
- Skull

*Source: European Journal of Radiology 48 (2003) 103-124*
Rib fractures
- In infants without metabolic dz, rib fx’s are unusual outside the setting of abuse
- Fractures of the first rib – virtually diagnostic of child abuse

Confirmation: Skeletal survey

- **Skeletal survey**
  - Allows documentation and dating of multiple episodes of trauma
  - Multiple fractures of different ages
  - Excellent sensitivity and specificity
  - Greatest utility in children < 2 years of age
  - No BABYGRAMS!

- **Bone Scan** (skeletal scintigraphy)
  - May disclose unsuspected sites of earlier skeletal injuries
  - May detect bony lesions that are occult or subtle on plain films (esp. feet and hands)
  - Good for rib fractures
  - Excellent sensitivity, fair specificity

<table>
<thead>
<tr>
<th>Skeletal survey</th>
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<tbody>
<tr>
<td>Skull</td>
</tr>
<tr>
<td>Cervical spine</td>
</tr>
<tr>
<td>Lumbar spine</td>
</tr>
<tr>
<td>Pelvis</td>
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<tr>
<td>Humeri</td>
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<tr>
<td>Forearm</td>
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<tr>
<td>Hands</td>
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<tr>
<td>Femora</td>
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<tr>
<td>Tibiae</td>
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<td>Feet</td>
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