AMERICAN COLLEGE OF EMERGENCY PHYSICIANS
SCIENTIFIC ASSEMBLY
1999

Trauma Radiology Lab: Diagnoses That Are Easy to Miss

This course will offer participants the opportunity to test their skills in reviewing a large number of trauma radiographs with subtle abnormalities. A self-paced workshop format with an on-site instructor will be used. (This lab is limited to 25 participants.)

- Identify subtle radiologic findings in trauma patients that are indicative of injuries.
- Describe a method for evaluating trauma radiographs.
- List three commonly missed radiographic findings in trauma.

MO-10
Monday, October 11, 1999
8:00 AM - 9:55 AM
Pavilion 4
Las Vegas Hilton

FACULTY

David T Schwartz, MD, FACEP

Assistant Professor, Clinical Emergency Medicine, New York University School of Medicine, New York, New York

Emergency Radiology Workshop

Introduction

ACEP Scientific Assembly
San Diego, California
October, 1998
David T. Schwartz, M.D.

This is a self-paced workshop. Each case should be approached as an actual clinical problem. To maximize the workshop's teaching value, you should evaluate the case before looking at the answer.

There is no sequence among the cases, so you can proceed from table to table in any order. However, within each table the case(s) should be reviewed from left-to-right.

Follow-up radiographs are displayed under the black sheets on the viewboxes -- be sure to look under ***all*** of the sheets for each **case. Written answers** and discussions are given in the handout and posted under the black cover-sheets next to the viewboxes. The clinical outcome is given towards the end of the write-up, separated by a line. The final diagnosis is also given on a separate answer sheet.

Please replace all of the black cover sheets when you have finished with each case for the benefit of the next workshop participant.

Answer Sheet

1.
2.
3.
4. A B C D E F
5.
6.
7.

a. A B C D E

9. B
10.
11.
12.
13.
14. B
15. B
16.
17. B
18.
19. B
20.
21.
22.
23.
24.
25.
26. B
27.
28.
29. B
30.
31.
32.
33.
34.
35.
36.

Trauma Radiology -- Bibliography

Harris JH, Harris WH, Novelline RA: The Radiology of Emergency Medicine, 3rd ed. Baltimore, Williams and Wilkins, 1993.

Keats TE: Emergency Radiology, 2nd ed. Chicago, Year Book Medical Publishing, 1989.

Rosen P, Doris PE, Barsan RM, Barsan SZ, Markovchick VJ: Diagnostic Radiology in Emergency Medicine. St. Louis, Mosby - Year Book, 1992.

McCort JJ, Mindelzan RE: Trauma Radiology. New York, Churchill Livingstoni, 1990.

Mirvis SE, Young JWR: Imaging in Trauma and Critical Care. Baltimore, Williams and Wilkins, 1992.

Redman HC, Purdy PD, Miller GL, Rollins NK: Emergency Radiology. Philadelphia, W.B. Saunders, 1993.

Feliciano DV, Moore EE, Mattox KL: Trauma, 3rd ed. Stamford CT, 1996, Appleton and Lange.

Hood RM, Boyd AD, Culliford AT: Thoracic Trauma. Philadelphia, 1989, W. B. Saunders.

Marx JA, ed.: Advances in Trauma. Emerg Med Clin North Am Feb. 1993; 1 l(1).

Rogers LF: Radiology of Skeletal Trauma, 2nd ed. New York, Churchill Livingstone, 1992.

Riddervold HO: Easily Missed Fractures and Comer Signs in Radiology. Mt. Kisco, NY., Futura, 199 1.

Browner BD, Jupiter JB, Levine AM, Trafton PG: Skeletal Trauma. Philadelphia, W.B. Saunders, 1992.

Rockwood CA, Green DP, Bucholz RW: Rockwood and Green's Fractures in Adults, 3rd ed. Philadelphia, Lippincott, 1991.

Ruiz E, Cicero JJ: Emergency Management of Skeletal Injuries. St. Louis, Mosby, 1995.

Simon RR, Koenigsknecht JJ: Emergency Orthopedics: The Extremities, 3rd ed. Norwalk CT, Appleton and Lange, 1995.

Harris JH, Mirvis SE: The Radiology of Acute Cervical Spine Trauma, 3rd ed. Baltimore, Williams and Wilkins, 1996.

Errico TJ, Bauer RD, Waugh T: Spinal Trauma. Philadelphia, Lippincott,1991.

Cwinn AA, Grahovac SZ: Emergency CT Scans of the Head: A Practical Atlas. St. Louis, Mosby, 1998

Cooper PR, ed. Head Injury, 3rd ed. Baltimore, 1993, Williams and Wilkins.

Alisa D. Gean: Imaging of Head Trauma. New York, Raven Press, 1994.

Swischuk LE : Emergency Radiology of The Acutely Ill or Injured Child, 3rd ed. Baltimore, Williams and Wilkins, 1993.

Bauman DH, Rose CC, ed.: Focus on Radiology. Emerg Med Clin North Am 9(4) Nov 1991 and 10(1) Feb. 1992.

Dalinka M, ed.: Symposium on Emergency Department Radiology. Emerg Med Clin North Am 3(3), Aug. 1985.

Fisch AE, Redman HC: Advanced Exercise in Diagnostic Radiology, Vol. 16: Blunt and Penetrating Trauma. Philadelphia, W.B. Saunders, 1982.

Langston CS, Squire LF: Exercises in Diagnostic Radiology, Vol. 7: The Emergency Patient. Philadelphia, W.B. Saunders, 1975.

American College of Emergency Physicians: Cost Effective Diagnostic Testing in Emergency Medicine. Dallas, American College of Emergency Physicians, 1994.

Radiology Workshop - Answers

1. Elbow fat pad sign, olecranon fracture.
2. Galeazzi Fracture (distal radial shaft fx with distal ulnar dislocation.
3. Trans-triquetral peri-lunate fracture/dislocation – scapho-lunate dissociation and ulnar styloid fracture.
4. Wrist fx's: A. scaphoid; B. triquetrum; C. torus; D. distal radius; E. 5th metacarpal base; F. DRUJ disloc.
5. Posterior shoulder dislocation.
6. Anterior shoulder dislocation with fractures of the greater tuberosity and humeral neck.
7. Axillary Artery embolism. Coraco-acromial ligament calcification (enthesophyte = bone spur).
8. Femoral neck fractures. E. Hip fracture needing additional study for diagnosis (bone scan).
9. A. Acetabulum fracture. B. Lateral compression pelvis fracture (bilateral pubic fxs and right sacral wing fx.)
10. Tibial plateau fracture.
11. Maisonneuve fracture - wide ankle mortise, proximal fibula fracture.
12. Retained splinter in sole of foot.
13. Fracture of body of C2 (Type III odontoid fracture).
14. Type II odontoid fracture (base of dens). B. Mach Band -artifact due to overlying bone.
15. Jefferson Burst fracture (Cl); hyperextension avulsion fracture of C3. B. Congenital incomplete arch Cl.
16. Hangman's fracture (traumatic spondylolisthesis of C2).
17. Hyper-flexion sprain -subluxation of C-5 on C-6. B. Degenerative spondylolisthesis.
18. Depressed skull fracture.
19. A. Tripod fracture, B. Blow-out fracture (medial orbital wall fracture).
20. Subdural hematoma.
21. Linear skull fracture, small SDH.
22. SAH, SDH, Basilar skull fracture (pneumocephalus, sphenoid sinus air/fluid level).
23. Sub-arachnoid hemorrhage-blood in interpeduncular cistern (non-traumatic).
24. Epidural hematoma.
25. Acoustic neuroma.

26-A. Traumatic aortic tear (wide & distorted mediastinum). 26-B. Normal (supine AP portable CXR).

27. Pneumothorax.
28. Pneumomediastinum.

29-A. Unilateral facet dislocation. 29-B. Normal -rotated lateral film.

30. Diaphragmatic hernia.
31. Tracheal deviation to left, right common carotid artery puncture with pseudoaneurysm.
32. Perforated hollow viscus (free-air under the diaphragm)
33. Umbilical hernia.
34. Splenic laceration, left rib fractures 6 & 7.
35. Splenomegaly + unconjugated hyper-bilirubinemia = autoimmune hemolytic anemia.
36. Gallstone ileus (pneumobilia, small bowel obstruction, ectopic gallstone),

1. How to Diagnose a Fracture

Although radiographs are considered the mainstay of fracture diagnosis, two orthopedic axioms must be kept in mind when managing patients with extremity trauma:

- **a fracture is a clinical, not a radiographic, diagnosis;** and
- **a fracture is a soft tissue injury with bony involvement.**

Radiographic signs of a fracture are:

1. Visualization of the fracture line (disruption of bony continuity);
2. Soft tissue changes (deformity or swelling due to edema or hemorrhage);
3. Alteration of the normal bony contour or alignment. (This can be the most difficult sign to recognize since it requires knowledge of the normal radiographic anatomy.)

Visualizing the' fracture line is the most obvious sign of a fracture. A minimum of two views perpendicular to each other are required. Additional oblique views or tomography are occasionally needed if the fracture line is non-displaced.

Soft tissue changes are sometimes easier to visualize than the fracture itself. These include soft tissue swelling or a joint effusion. Fat planes between muscle layers can sometimes be seen radiographically. Abnormal position of the fat plane or obliteration of the fat plane by edema or hemorrhage is a clue to an adjacent fracture.

Post-traumatic joint effusions are indicative of an intra-articular fracture. A joint effusion may cause increased soft tissue density adjacent to the joint. The elbow is a special situation because there is fat tissue in close proximity to the joint capsule. Normally these fat pads lie within the olecranon and coronoid fossae. Only the anterior fat pad is normally visible radiographically as a thin lucent line just anterior to the humerus on the lateral view. If the joint capsule is distended, the fat pads are displaced outwards. The **posterior fat pad** is now visible just posterior to the olecranon fossa. The **anterior fat pad** is displaced anteriorly, forming a triangle, the **"sail sign."** The most frequent fracture associated with the fat pad sign is a radial **head fracture.** This fracture may be difficult to visualize if non-displaced. Oblique views might reveal the fracture. If the fracture cannot be visualized, the patient should be treated as though a non-displaced radial head fracture was present (shoulder sling with early mobilization exercises).

Another intra-articular elbow fracture that can be difficult to visualize is a non-displaced **olecranon fracture. In this patient's** AP view, a very small fracture line through the olecranon in a longitudinal direction can be identified. An olecranon view demonstrates the fracture (tangential view across the flexed elbow). The patient was treated with a shoulder immobilizer for the elbow fracture and a long arm cast for the night-stick fracture of the ulna on the opposite arm.

Zimmers TE: Fat plane radiological signs in wrist and elbow trauma. Am J Emerg Med 1985: 2:526-532.

2. The Fracture of Necessity

The nature of an extremity injury can usually be predicted from the mechanism of injury, the age of the patient, and the patient's symptoms and physical examination findings. A fall on an outstretched hand is a common mechanism of injury and can cause fractures from the fingertips to the clavicle. In adults, wrist injuries are most frequent. The patient's age determines the weakest part of the wrist, i.e.; the part most susceptible to fracture. In children, the growth plate is the weakest element and Salter-Harris fractures are most common. Also common in young children are buckle (torus) fractures at the distal radial metaphysis. In young adults, scaphoid fractures are most likely. In the elderly with bone weakening due to osteoporosis; the distal radius is again the most vulnerable part.

A number of eponyms have been applied to fractures of the distal radius: Colles, Smith, Barton, Hutchinson (or chauffeur's fracture). The Colles fracture is the most common; it is characterized by dorsal displacement of the distal fragment. On physical examination, there is a characteristic "dinner fork" deformity. Colles described this fracture in 1814. In the pre-radiographic era, fracture diagnosis depended on physical examination and one of the principal signs was crepitus during ma&&t&n of the fracture (very painful). If there was deformity without crepitus, then ahislocation, not a fracture, was diagnosed. Colles' Contribution was in noting that an impacted fracture, such as at the distal radius, will not have crepitus even though the injury is truly a fracture and not a dislocation. Colles did not report his methods in reaching this conclusion and so his paper would probably have been rejected by modem scientific journals. The Colles fracture occurs through the metaphysis of the distal radius, not the diaphysis (shaft). (The metaphysis is distal to the shaft, where the bone flares out towards the articular surface.) The treatment and prognosis of Colles fractures depends on the extent of comminution and articular surface involvement. Since Colles did not describe ulnar styloid or articular involvement in his paper, some authors restrict the use of "Colles fracture" to injuries without articular or ulnar styloid extension (another point of confusion in the use of eponyms).

A fracture through the distal radial shaft should not be mistaken for a Colles fracture. The shafts of the radius and ulna are closely united by the interosseus ligament and a displaced fracture of one bone is almost invariably associated with a fracture or dislocation of the other. In this patient, the dorsally displaced fracture of the distal radial shaft is associated with a dislocation of the distal radio-ulnar and ulnar-carpal joints. This dislocation is readily seen on the lateral and oblique views. It is also evident on the AP view in which the distal ulna does not have its normal relationship to the distal radius or carpals. This patient also has osteoporosis and marked deformity of the distal radius and ulna due lo prior injury. This fracture-dislocation was described by Galeazzi in 1934. The Galeazzi fracture has been termed "the fracture of necessity" -- although closed reduction can often be accomplished, the reduction is unstable due to the extent of bone and ligament disruption. Internal fixation with a compression plate and screws is *necessary* for a good result.

Although eponyms are widely used for many common orthopedic injuries, they can be a source of confusion and misdiagnosis. It is preferable to accurately describe the anatomy of the injury rather than resort to potentially misleading terminology.

Colles A: On the fracture of the carpal extremity of the radius. Edinburgh Med Surg J 1814;10:182-186.

3. Perilunate Injury

Carpal fractures and dislocations can be difficult to diagnose because of the complex radiographic anatomy of this region. Examine the radiographs for several landmarks.

On the **AP view, three arches** are seen: 1) the proximal surface of the navicular, lunate and triquetrum; 2) the distal surface of these three carpals at the mid-carpal articulation; and 3) the proximal articular surface of the capitate and hamate. The space between the carpals should be uniform, approximately 2 mm. wide.

On the **lateral view,** the axes of the radial shaft, the lunate and the capitate should all be in alignment. The "C" shaped articular surfaces of the distal radius, lunate (proximal and distal) and'the'capitate should be nested one next to the other. The axis of the scaphbid'makes an angle of 30°- 60" with this radio-carpal axis.

Each of the bones of the wrist, including the distal radius and ulna and the proximal metacarpals, should then be carefully examined for evidence of a **fracture..** ,

---

In this patient, the AP view shows **a fracture of the ulnar styloid.** The proximal and distal carpal rows do not align in a smooth arc. The lunate has a triangular rather than rectangular shape. 'The space between the lunate and the scaphoid is too wide, due to disruption of the scapho-lunate articulation. This is called the **Terry-Thomas sign,** named for the distinctive grimace of the British comedian. The scaphoid is rotated such that its distal portion appears as a "ring" in the AP view.

On the **lateral view,** the axes of the radius, lunate and capitate are not properly aligned. The capitate is dorsally displaced relative to the lunate (a dorsal perilunate dislocation). The lunate axis is somewhat volarly angulated, indicative of a degree of volar lunate dislocation. In a complete lunate dislocation, the lunate is more angulated and looks like a "spilled teacup". The dorsal perilunate and volar lunate dislocation are a spectrum of hyperextension injury; with lunate dislocation there is greater ligamentous disruption.

The **oblique view** reveals a transverse fracture across the body of the triquetrum (the most ulnar located carpal of the proximal carpal row).

This patient has a **trans-triquetral perilunate fracture-dislocation** with associated **scapho-lunate dissociation** and a **fracture of the ulnar styloid.** This array of injuries is classified as a perilunate pattern of injury which occurs in an arc surrounding the lunate. The arc of injury may be close to the lunate, involving adjacent ligaments, or there may be a wider arc of injury with associated fractures of the scaphoid, capitate or triquetrum.

This patient had been inadequately managed on his initial visit. The dislocation should have been reduced rather than referring the patient to a clinic. The delay in treatment caused formation of considerable scar tissue preventing reduction. The patient required complete excision of the proximal carpal row.

Meldon SW, Hargarten SW: Ligamentous injuries of the wrist. J Emerg Med 1995;13:217-225.

Chin HW, Visotsky J: Ligamentous wrist injuries. Emerg Med Clin North Am 1993;11:717-737.

Frankel VH: The Terry Thomas Sign. Clin Orthop 1977:129:321-322.

4. The Sprained Wrist

Because the radiographic anatomy of the wrist is very complex, the approach to interpreting wrist radiographs must be systematic. Simply looking for bony irregularities or cortical interruption will make the search for injuries difficult and frequently misleading. Certain radiographic landmarks should be identified and certain areas of common injury scrutinized (Table).

There are two distinct regions to examine -- the carpals and the distal radius. Distal radius fractures are ten times more frequent than carpal fractures. The **three standard views** of the wrist are the PA, the lateral and the pronation oblique. On the PA view, the bones of the radial aspect of the wrist overlap; the pronation oblique view shows this area to better advantage (see Case A).

On the **PA view,** the bones of the proximal and distal carpal rows should be identified. The articular Surfaces of the radio-carpal joint and the intercarpal joint should be aligned in smooth arcs (figure). The spaces between the carpal bones should be of uniform width, approximately 1-2 mm. Examine each carpal bone for evidence of fracture, paying special attention to the scaphoid, the most frequently fractured carpal.

There are two common irregularities of the scaphoih that should not be misinterpreted as a fracture. First, the'cbrtex of the radial side of the scaphoid often has a small bump or angulation at the edge of the radio-scaphoid articular cartilage (see Cases D and F). Second, because the scaphoid appears foreshortened on the PA view, the distal pole of the scaphoid often overlaps the body of the scaphoid. This should not be misinterpreted as an impaction fracture (see Cases A, B and D).

The distal radius and ulna should also be carefully examined for fractures even though they are better seen on the lateral view. Fractures appear as an area of trabecular disorientation or impaction. A dense transverse band frequently seen **across** the distal radius is a remnant of the growth plate and should not be misinterpreted as a fracture (see Cases A and E).

Next, examine **the lateral view.** Distal radius fractures are usually more easily seen on this view. Look at the volar and dorsal cortical surfaces for interruption or angulation. The carpals overlap on the lateral view and fracture diagnosis is difficult, Carpal alignment is assessed by examining the carpal articulations that appear as a sequence of "C's" – the distal radius. the proximal lunate. the distal lunate and the proximal capitate. The dumbbell-shaped scaphoid makes an angle of 30" to 60" with the long axis of the wrist.

Finally, examine the pronation oblique view, looking primarily at the radial aspect of the wrist -- the trapezium, trapezoid and tuberosity (distal pole) of the scaphoid and the bases of the first and second metacarpals. In addition, the triquetrum is seen on this view without overlap by the pisiform

---

The following cases illustrate these principles as well as several additional points not mentioned in the above discussion.

Case A: A small nondisplaced fracture of the **scaphoid** can be seen only on the oblique view. This demonstrates the importance of including the oblique view in the standard wrist series. In patients with questionable abnormalities of the scaphoid on the three standard views or who have normal radiographs but "snuff-box" tenderness over the scaphoid on physical examination. a PA view with the wrist in ulnar deviation elongates the scaphoid and makes a fracture more easily detectable. Even if they have negative radiographs, patients with “snuff-box” tenderness should be immobilized because they may have an occult fracture. However, it is beneficial to obtain an ulnar-deviated “scaphoid view” in such cases to document the actual fracture.

Only 8% to 20% of patients immobilized for an occult fracture actually have a fracture. The degree of immobilization recommended is different for a definite fracture rather than a possible occult fracture. Some authors recommend a splint with thumb spica for an occult fracture and a cast for a documented fracture. Other authors recommend a short arm cast with thumb spica for an occult fracture and a long arm cast for a definite fracture. Other authors use a long arm cast only for a displaced scaphoid fracture.

<u>Case **B.**</u> A dorsal chip fracture of **the triquetrum is** visible on the lateral view. The triquetrum is the most dorsally projecting bone on the lateral view - see figure). The patient presents with tenderness over the dorsum of the wrist (ulnar aspect). The triquetrum is the second most frequently fractured carpal (20%) after the navicular (60%).

<u>Case</u> <u>C</u>. A 9 year old with a **torus (buckle) fracture** of the right distal radius. Compared with the left, there is diffuse soft tissue swelling of the right, wrist. On the left lateral-view, there is a normal **pronator fat stripe.** It is a radiolucent Stripe just anterior to the distal radius: On the right; the-fat stripe is obliterated, indicative of an adjacent fracture. A subtle buckling of the dorsal cortex of the distal radius can be seen on the lateral view. Growth plate fractures (Salter-Harris fractures) are also common in children, whereas carpal fractures are distinctly uncommon.

<u>Case **D.**</u> A 43 year old male with an abnormal pronator fat stripe (outwardly displaced). Careful inspection of the **distal radius** on the lateral view reveals cortical disruption and deformity due to a fracture. Trabecular disruption is visible on the PA and oblique views.

<u>Case **E**</u>**.** A minimally displaced fracture is seen of **the base of the fifth metacarpal.** The proximal metacarpals must be included your examination of the wrist. In some cases, the fourth and fifth metacarpal bases are not well seen on the standard PA view. The opposite oblique view (supination oblique) can be useful if an injury is suspected on clinical examination, but is not seen on the standard views.

<u>Case F</u>. The ulnar shaft is dorsally displaced relative to the radius. This malalignment could be due to poor positioning, i.e., the view is rotated or oblique rather than a true lateral projection. There are two ways to verify that the malalignment of the radius and ulna is not due to incorrect positioning. First, the ulnar styloid should normally point to the dorsal surface of the triquetrum even if the projection is rotated (see case A, lateral and oblique view). In this patient, the ulnar styloid is directed dorsal to the triquetrum. Second. the apex of the radial styloid on a true lateral view should be located between the volar and dorsal surfaces of the radius (as in this patient). If the lateral view is rotated, the tip of the radial styloid will be either too volar or too dorsal with respect to the radial shaft.

This patient had a distal-radio-ulnar joint dislocation. The dislocation is posterior (named for displacement of the ulna relative to the radius). When treated soon after the injury, closed reduction is usually successful. When treatment is delayed, open reduction and pinning may be necessary.

4

An ABC'S Approach to Reading Wrist Radiographs

Adequacy, Alignment, Bones, Cartilage, Soft Tissues

Two anatomical regions must be examined for injury--the distal radius and the carpals

PA View	Adequacy (proper positioning)	- No radial or ulnar deviation of the carpals: Axis of the 3rd metacarpal should align with the shaft of the radius,
	Alignment	- 3 smooth curves -- the articular surfaces of the proximal and distal carpal rows.
	Bones	- Carpal bones -- especially the scaphoid. Examine cortex and trabeculae. Scaphoid "ring" sign indicates rotary subluxation (scapho-lunate dissociation). Lunate has trapezoidal appearance (not triangular). - Proximal metacarpals - Distal radius and ulna -- including radial styloid and articular surface:
	Cartilage (joint spaces)	- Intercarpal joint spaces should be uniform (2 mm); especially scapho-lunate joint. - Distal radio-ulnar joint -- radial and ulnar articular surfaces separated 1-2 mm.
	Soft Tissues	- Scaphoid fat stripe -- if intact, a scaphoid fracture is less likely.
Lateral View	Adequacy (proper positioning)	- True lateral without rotation -- dorsal surface of the ulnar shaft overlaps or is 1-2 mm. dorsal to the radial shaft; radial styloid is aligned with radial shaft - NO flexion or extension at the wrist --- dorsal surface of the radius is parallel to the dorsal surfaces of the metacarpals.
	Alignment	- Longitudinal axes of radius, lunate, and capitate are nearly parallel. - Axis of the scaphoid -- makes an angle of 30° to 60° relative to the long axis of the wrist. - Distal radio-ulnarjoint -- ulnar styloid should point to the dorsal surface of the triquetrum-- if not, suspect distal radio-ulnar joint subluxation,
	Bones	- Distal radius (cortex and trabeculae) -- disrupted or deformed . - Triquetrum (dorsal surface) -- examine for a dorsal chip fracture.
	Cartilage	- Sequence of adjacent "C's" - articular surfaces of distal radius, lunate, capitate.
	Soft tissues	- Pronator fat stripe -- if bulging or obliterated, look for a non-displaced distal radius fracture.
Pronation Oblique View	Adequacy	- Trapezium, trapezoid and joint space should have minimal overlap
	Bones	- Bases of I and II metacarpals and trapezium and trapezoid. - Scaphoid tuberosity (distal pole). - Triquetrum (the most ulnar bone of proximal carpal row).

Extra Views--depending on clinical findings (site of tenderness).

Scaphoid View (PA ulnar deviation) -- If there is "snuff-box" tenderness and no fracture is seen on the three standard views.

Carpal Tunnel View -- If there is volar tenderness. Look for fractures of the hook of the hamate the pisiform or trapezium.

Supination Oblique -- If there is tenderness at the base of the fifth metacarpal or pisiform.

5

5. Lightbulb on a Stick

The shoulder is the most commonly dislocated joint in adults. The vast majority of these are anterior dislocations (>95%). Posterior shoulder dislocations are uncommon because the strong muscular and skeletal support prevents posterior displacement of the humeral head. Posterior shoulder dislocations are frequently misdiagnosed; up to 50% are missed on initial presentation. They are missed, because of a lack of awareness of this infrequent injury and failure to appreciate the findings on the standard AP radiographic views of the shoulder which are subtle and easily overlooked. The findings on physical exam are, furhtermore, quite characteristic. Over-reliance on radiographs, rather than physical examination findings, contributes to the high incidence of misdiagnosis. When a posterior dislocation is suspected, additional radiographic views should be obtained to confirm the clinical diagnosis.

There is significant morbidity associated with delayed diagnosis of a dislocation. Over time, reduction of the dislocation becomes increasingly difficult. Contractures eventually develop necessitating open reduction and operative reconstruction.

Clinical Diagnosis

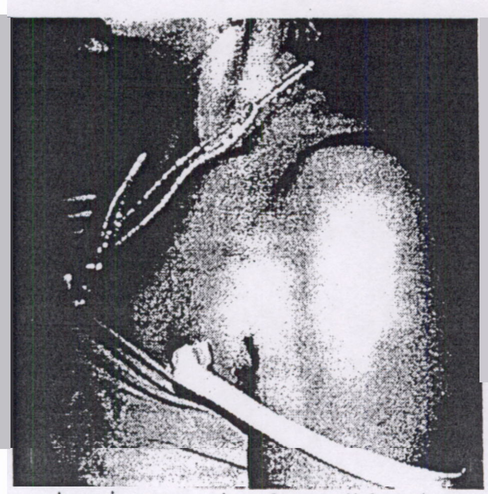
With a posterior dislocation, the patient holds his shoulder adducted and internally rotated and is unable to abduct or externally rotate. There may be a visible &palpable defect of the anterior surface of the shoulder (figure). The deformity was not evident in this heavy-set patient although he was unable to externally rotate and abduct his shoulder.

The usual **mechanism of injury** is a force applied to the anterior aspect of the shoulder either by a direct blow or by a fall on the outstretched arm. Tonic contraction of the shoulder muscles during an electrical shock or a seizure can also cause a posterior dislocation. This is because the strongest muscles that act on the shoulder cause internal rotation and posterior displacement. Nevertheless, anterior dislocation is still the most common dislocation following a seizure.

A posterior dislocation can occur in association with a fracture of the proximal humerus. Combined fracture/posterior dislocations must be specifically excluded in fractures of the humeral head or neck since it significantly alters patient management necessitating reduction of the dislocation. Additional radiographic views are often needed to detect concomitant posterior dislocations.

(con't.)

Normal rounded shoulder contour



Anterior concavity of post. dislocation

Inability to externally rotate the posterior dislocated left shoulder.. This patient was misdiagnosed as having a "frozen shoulder" for six months until the correct diagnosis was made

Radiographic Diaenosis

Standard AP shoulder views are oblique views of the gleno-humeral joint because the shoulder is not in the AP plane of the patient. This makes a posterior dislocation difficult to detect. **The key finding** on the standard x-rays is a **diminished overlap** of the humeral head and glenoid fossa. (Compare the above case with the normal sample.) The humerus is **fixed in internal rotation** and an external rotation view cannot be obtained. The humeral head in internal rotation has a spherical shape because the thin cortex of the greater tuberosity is seen en-face. This, when combined with the diminished overlap with the glenoid fossa, gives a posterior dislocation the characteristic appearance of a **"light bulb on a stick."** Lastly, there will be a compression fracture'of the anterior surface of the humeral head as it impacts upon the posterior rim of the glenoid fossa. This is seen as a vertical line parallel to the glenoid rim, the **"trough line."** (The axillary view shows this compression fracture clearly.) This is analogous to the Hill-Sachs deformity of anterior shoulder dislocations. These three findings are present in the first radiograph shown in this case.

Additional views assist in the diagnosis of posterior dislocation and should be obtainedwhenever it is suspected. A true en-face view of the gleno-humeral joint is seen on the scapular "Y" view. Normally the, humeral head is centered in the middle of the "Y" where the acromion, coracoid process and body of the scapula meet. With a posterior dislocation, the humeral head is displaced posterior to this point.

The **axillary view** most clearly shows the posterior dislocation. This view must be obtained with caution because by abducting the patient's arm to obtain the view, a fracture of the proximal humerus can become further displaced.

6. Whv obtain x-rays in shoulder dislocations?

Anterior shoulder dislocations are usually obvious on physical examination; radiographs are not necessary to make the diagnosis. The main role of radiography is to detect **an associated fracture** that occurs in 15% of cases:' In most instances, the associated fracture (usually an **avulsion of the greater tuberosity** of the humerus) does not alter the technique of reduction. The rotator cuff tendon holds the avulsed greater tuberosity in position. When the dislocated shoulder is reduced, the avulsed fragment is also brought back into proper position. If there is persistent displacement of 1 cm; or greater, internal fixation is indicated, particularly in younger patients. Proximal humerus fractures, including fracture-dislocations, occur more commonly in older patients. An associated fracture is seen in as many as 40% of shoulder dislocations in individuals over age 50. Therefore, the radiographs must be carefully inspected for evidence of a fracture.

Less common than an avulsion of the greater tuberosity is **a fracture through the bumeral neck.** These fracture-dislocations must be managed differently than simple dislocations. This is because of the inability to control reduction of the humeral head:. If the fracture through the humeral neck is not displaced initially, attempted closed reduction will cause separation of the fracture. This substantially increases the risk of avascular necrosis of the humeral head. A non-displaced humeral neck fracture can be difficult to visualize radiographically but should be specifically sought, particularly in older patients with shoulder dislocations.

In this patient, a two part fracture-dislocation was recognized (displaced fracture of the greater tuberosity). However, a non-displaced fracture of the surgical neck of the humerus was not appreciated. (80% of proximal humerus fractures are non-displaced, with the fracture parts held in alignment by the periosteum.) The fracture line can be identified by careful inspection of the region of the humeral neck. There is impaction and disruption of the trabecular bone at the humeral neck.

Standard closed reduction was attempted. Post-reduction films revealed complete displacement of the humeral head from the humeral shaft. The fracture-dislocation was converted from a two-part to a three-part fracture (Neer classification). Because of the risk of avascular necrosis as well as the difficulty of internal fixation, the patient was treated with a hemi-arthroplasty.

Management of a humeral neck fracture-dislocation consists of attempted closed reduction under *general anesthesia* with fluoroscopic control. If unsuccessful, open reduction is necessary. If an unsuspected humeral neck fracture is displaced during an attempted reduction. one author recommends immediate open reduction and internal fixation. thereby hoping to decrease the risk of later avascular necrosis of the humeral head.

Ferkel RD. Hedley AK. Eckardt JJ: Anterior fracture-dislocations of the shoulder: pitfalls in treatment. J Trauma 1984;24:363-367.

I lersche 0, Gerber C: Iatrogenic displacement of fracture-dislocations of the shoulder. J Bone Joint Surg (Br) 1994:76 30-33.

7. When Not to Get an X-Ray

With&t a clear idea of the information desired from a diagnostic test, its result could confuse rather than clarify the diagnosis. "Geographic" test ordering -- obtaining radiographs of the region that is symptomatic without regard 'for whether the potential disorder has radiographic findings -- should be avoided. Positive findings could be irrelevant and negative films falsely reassuring.

These radiographs were interpreted as showing a large osteophyte extending from the acromion. A more correct interpretation is calcification of the coraco-acromial ligament, a "traction spur." These degenerative changes could be responsible for shoulder pain and an impingement syndrome. However, these radiographic abnormalities are long-standing and are, in fact, ***irrelevant*** to thepatient's current Emergency Department visit. -We were almost mislead into thinking that we had found a benign cause for this patient's shoulder pain.

The differential diagnosis of **shoulder pain that radiates down the** arm'includes:

- localized **musculo-skeletal** disorders of the shoulder, such as tendonitis, bursitis or bone lesions (neoplasm and osteonecrosis), which can have distal radiation;,
- *reflex* sympathetic dystrophy following trauma, strokes or myocardial infraction (vaso-motor instability causing pain, paresthesia, swelling and, later, atrophy);
- various neurological disorders (a careful neuro exam is necessary):
    1. involvement of the brachial plexus by, for example, a tumor at the lung apex.
    2. a spinal cord tumor or compression of the cord from an epidural tumor or abscess
    3. impingement on a cervical spinal root (cervical disk hemiation or osteophyte)
- **thoracic outlet syndrome** compressing the neurovascular supply at the first rib and clavicle;
- **visceral disorders** (referred pain): cardiac or diaphragmatic irritation due to a sub-phrenic abscess. hepatic. splenic or biliary disorders.

The history of pallor of the extremity at the onset of pain suggests a vascular event. The patient was re-examined for signs of arterial insufficiency. These where not prominent. However, the event had occurred three days previously, so objective signs of diminished perfusion could have resolved. To add to the uncertainty, a shoulder impingement sign was positive (pain with shoulder abduction at the point where the greater tuberosity passes under the acromion).

The patient was referred for doppler studies of the arm, which revealed a diminished pulse waveform. suggestive of arterial obstruction. A thoracic aortogram revealed an aneurysm at the origin of the innominate artery with a large intra-luminal filling defect, the probable source of the cmbdism. The aneurysm was most likely due to atherosclerosis. A less likely etiology would be a chronic pseudo-aneurysm related to the blunt trauma one and a half years earlier.

Prior to aortic reconstruction surgery, the patient suffered an embolic event to the right carotid artery causing left arm paralysis. The patient eventually recovered from the stroke. but refused surgery

8. Hip Contusion

We can usually diagnose a hip fracture in an elderly patient from across the room; the patient lies on the stretcher with the involved leg externally rotated and foreshortened. However, a non-displaced hip fracture can present with subtle clinical and radiographic findings, and the diagnosis could be missed entirely on the initial evaluation. The consequences of delayed diagnosis of a subcapital hip fracture can be substantial.

The population at risk for this injury is clearly defined -- elderly women with osteoporosis. **Clinical findings** can be difficult to distinguish from a muscle strain, sprain, or contusion. The patient may complain only of mild pain about the hip, inguinal region or of referred pain to the knee without hip pain. Physical examination fmdings can be minimal as well. Inability to bear weight suggests a fracture however, the patient might be able to walk although with an antalgic limp (avoiding full weight bearing on the injured leg). There may only be mild pain on range of motion of the hip. Internal and external rotation should be specifically tested. Manipulation should not be done if it produces significant pain because movement could displace a fracture. Since the physical findings can be equivocal, one must carefully scrutinize **the radiographs,** looking for evidence of a subtle fracture..

Signs of a non-disnlaced subcanital fracture include:

1. Discontinuity of the normal smooth contour of cortical bone
2. Discontinuity or disruption of the normal trabecular architecture (drawing)
3. A transverse band of increased bone density (sclerosis) where the fracture fragments are impacted together. Elsewhere along the fracture there may be diminished bone density where the bone fragments are distracted
4. Foreshortening of the femoral neck
5. Abnormal angle between the femoral neck and the femoral head

Standard hip views include an AP and lateral view of the femoral neck. A true **AP** view requires that the patient's leg be rotated internally 15". When lying supine at rest, the hips tend to rotate slightly externally. This makes the femoral neck appear slightly foreshortened which is one of the signs of a femoral neck fracture. If this occurs, repeating the film with the patient's toes touching will elongate the femoral neck and might reveal a fracture that was not seen on the poorly positioned view. The lateral view that is most easily obtained is the "frog leg" **view.** This is in fact not a true lateral, i.e.. perpendicular to the AP plane. It is an AP view of the pelvis with the hip abducted and externally rotated. This view should be avoided in patients with significant hip pain because the movement needed to obtain this position could displace a fracture. A **true lateral** of the femoral neck is taken as a cross-table lateral with the opposite leg raised. The injured hip does not need to be moved for this view Interpretation of this view is difficult because of overlapping soft tissues and problems in understanding the orientation of the image.

8

Radiographic findings that could be mistaken for a fracture include degenerative changes of the femoral neck, a rim of osteophytes extending from the acetabulum or a skin fold overlying the femoral neck. In addition, the pelvis should be examined for fractures of the pubic rami or iliac crest.

Delay in diagnosis of a subcapital hip fracture causes additional morbidity because of increased potential for avascular necrosis of the femoral head. Most of the blood supply of the femoral head originates from the insertion of the joint capsule on the femoral neck and then flows up along the femoral neck to the femoral head. A fracture across the femoral neck, also called an intracapsular fracture, will interrupt the blood supply, especially if the fracture is displaced. A considerably more extensive surgical procedure is'needed to treat a displaced fracture. A nondisplaced femoral neck fracture can be treated by simple screw fixation whereas a displaced fracture usually requires a hemiarthroplasty (replacement of the femoral head with a prosthesis) because of this potential for avascular necrosis.

Hofinan A, Wyatt R: Missed subcapital fractures. Ann Emerg Med 1984;13:951-955.
Alba E, Youngburg R: Occult fractures of the femoral neck. Am J Emerg Med 1992;10:64-68.
Zuckerman JD: Hip fracture. New Engl J Med 1996;334:1519-1525.

SE. Occult Fractures

Occasionally, a patient will have a fracture of the proximal femur in which the **plain** films truly do not show the fracture. These fractures carry the same risk of complications as do radiographically visible fractures if they are not diagnosed and treated appropriately. Complications include displacement, avascular necrosis and non-union.

Various **management strategies** have been proposed for these patients. Some authors suggest sending the patient home at bedrest and non weight-bearing with a return visit for repeat radiography at some predetermined interval (one week, three days, one day). If the patient is still symptomatic and the plain films are again negative, then other imaging modalities are needed (bone scan or conventional tomography). Other authors disapprove of sending the patient home because any motion of the leg could cause'displacement of a non-displaced fracture. Instead, they recommend hospitalization to minimize movement of the hip. The decision whether or not to hospitalize a patient will depend on your estimate of the probability of an occult fracture based on the patient's risk (e.g.,. elderly women with osteoporosis) and the findings on physical examination -- recognizing that pain or limitation, of motion might not be great in the presence of a fracture.

Radionuclide **bone** scan is used frequently to detect fractures.' It is widely available and has a very high sensitivity (90-95%). One major limitation is that it does not become positive until three to five days after the injury. This is especially true in older patients with osteoporosis. In addition, a bone scan shows abnormal uptake in sprains, degenerative disease, arthritis, tumors and infection. Therefore, additional studies are often needed to confirm the diagnosis of fracture and delineate its anatomy. This usually entails computed tomography **(CT).** Although more sensitive that plain films, CT alone has less sensitivity than bone scan, especially if the fracture line is in the plane of the tomographic slice.

MRI is currently being applied to the early diagnosis of occult fractures and seems to offer advantages over other imaging techniques. Although it does not directly visualize bone, MRI readily detects and localizes edema and hemorrhage within the marrow that is associated with the fracture. Delay is not needed for the study to become positive. MRI accurately defines the location and extent of the fracture, eliminating the need for additional imaging. Although MRI is a more expensive test and less readily available. its expense is offset by the reduced length of hospital stay and need for additional imaging studies. Use of an abreviated scan sequence can further reduce cost.

This patient was admitted to the hospital and had a bone scan the next day (it was already several days since her injury). It showed markedly increased uptake in the region of the femoral neck. A CT confirmed a subtle incomplete cortical fracture of the femoral neck. The patient was treated with screw fixation, a considerably simpler procedure than hemi-arthroplasty.

Rizzo PF, Gould ES, Lyden JP. Asnis SE: Diagnosis of occult fractures about the hip: magnetic resonance imaging compared with bone scanning. J Bone Joint Surg (Am) 1993;75-A:395-401.

Deutsch AL. Mink JH. et al: Occult fractures of the proximal femur: MR imaging. Radiology 1989;170:113-116

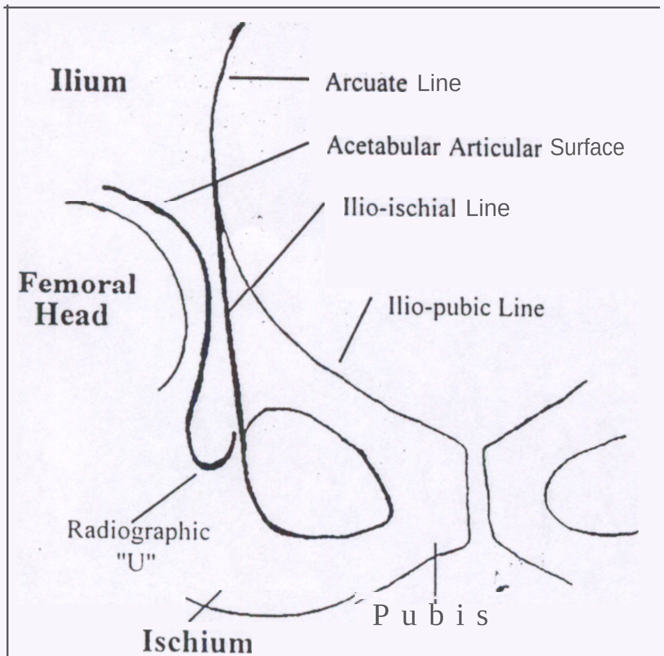
9

9. Life Saver

Because the pelvis is a nearly rigid ring-like structure, any single break in the pelvis, especially if it is displaced, requires another break elsewhere in the ring. If not immediately obvious, the second break must be searched for diligently. The same principle holds true for the obturator ring of the anterior pelvis.

In the first patient, there is an deformity of the left side of the pubic symphysis due to a fracture through the body of the left pubic bone. This constitutes a break through the obturator ring. When only one displaced fracture is identified in the obturator ring, a potential site for the second fracture is the acetabulum.

Detection of acetabular fractures requires knowledge of normal radiographic anatomy. The symmetry of the pelvis provides a normal side for comparison. There are several radiographic landmarks of the acetabulum that are distorted or disrupted by a fracture (see figure). The arcuate line-separates the superior and inferior portions of the pelvis. The anterior portion of the arcuate line is also known as the ilio-pubic line. It extends from the medial rim of the ilium to the superior edge of the superior pubic ramus. The vertically oriented ilio-ischial line extends from the medial surface of the ilium inferiorly along the quadrilateral plate (the medial wall of the acetabulum) to the ischial ramus. The curved articular surface of the acetabulum parallels the surface of the femoral head. The curve of the anterior acetabular surface at its inferior extent makes a sharp curve, appearing as a "U" shape. If the angle of projection is just right, these last three lines coincide to form an elongated “tear-drop” (see figure).



The Radiographic Tear-Drop

In this patient, a normal “tear drop” is seen on the right. On the left, the "tear-drop" is disrupted by displacement of the ilio-pubic line superiorly and medially. The actual fracture line is not well seen because it is in the coronal plane extending into the body of the ilium.

CT confirmed that this was a slightly displaced fracture of the anterior portion of the acetabuium. It did not involve the weight bearing superior portion of the acetabulum. The patient was treated non-operatively, initially with traction, then progressing to partial weight-bearing over a three week hospital stay.

(con't.)

In the **second patient,** there **are bilateral fractures of the pubic rami. This** pattern **is** sometimes called **a straddle fracture.** The purported mechanism of injury is anterior impact to the perineal area by an object that is straddled by the patient's legs. The anterior fracture fragment has a "butterfly" pattern. These bilateral pubic rami fractures constitute two breaks in the pelvic ring; an additional fracture need not be present. However, this mechanism of injury does not, in fact, account for most "butterfly" shaped fractures. In this patient, there is also a fracture through the right **sacral wing** at the level of the sacral neuro-foramina (the weakest part of the posterior pelvis).

Why are there three breaks in the pelvic ring in this patient ?

A different mechanism of injury is responsible for most bilateral pubic rami fractures. This patient was seated in a car that was struck on its side by another-vehicle; The laterally directed force displaces the right hemi-pelvis inwards causing an impaction fracture of the right sacral wing and shearing-type horizontally oriented fractures through the pubic rami (see figure).

A **lateral compression** injury to the pelvis is considered stable because the stroiig ligaments of the pelvic floor (sacro-spinous and sacro-tuberous) remain intact. This injury has been called a **"closed** book"pelvis. **Ii** is dstinguished from the "open **book"** pelvis that occurs when an anterior directed force causes pubic symphysis separation. In the x-ray films the amount of displacement of tbe fracture is often underestimated. Maximal displacement occurs at the time of impact. Because lateral compression reduces the pelvic volume, these injuries are less often associated with severe bleeding complications than are injuries that cause an increase in the pelvic volume, such as open book pelvis and vertical shearing injuries (Malgaigne fractures).

Injuries to the anterior pelvis are frequently associated with lower urinary tract injuries. The sharp ends of the fracture fragments can pierce the bladder at the moment of maximal compression. This is the usual mechanism of **extra-peritoneal bladder rupture.** Intra-peritoneal bladder rupture occurs when the patient's bladder is full at the time of impact. The hydraulic pressure within the bladder bursts the bladder at its weakest point -- the dome.

The magnitude of the second patient's injuries was not fully appreciated until the pelvic ring disruption was found on the initial radiographs. The patient was transiently hypotensive, but responded to rapid crystalloid infusion. Her serial hematocrits and blood pressure remained stable. When a foley catheter was inserted, gross hematuria was found. **A** cystogram revealed extra-peritoneal **bladder rupture** with contrast extravasation around the bladder neck. **An** abdominal CT was negative for other injuries. The patient had operative repair of her bladder laceration. From the orthopedic standpoint. this lateral compression injury is stable because the supporting pelvic ligaments remain intact. **These** fractures do not need operative fixation or prolonged bedrest. This patient was allowed out of bed on the fourth hospital day with weight bearing as tolerated on the left and partial weight bearing on the right.

McCort JJ. Mindelzan RE: Bladder injury and pelvic fractures. Emerg Radiolog 1994;1:47-51

10. Assessment of Knee Injuries

Fractures of the tibial plateau are aniong the most comnon knee injuries. Standard AP and lateral views are usually adequate to make the diagnosis. However, minimally displaced fractures often have subtle radiographic findings and the diagnosis can missed. Additional views could help demonstrate the fracture.

The **mechanism of injury** often associated with a tibial plateau fracture **is** a **"bumper" injury** -- the antero-lateral aspect of the knee suffers a direct impact from an automobile bumper. The force on the lateral femoral condyle drives it into the lateral tibia1 plateau. **Falls** from a height causing axial compression are responsible for most of the others.. **Osteoporosis** is an important risk factor. Elderly.women, can have tibia] plateau fractures with only a minor traumatic force. The lateral tibial plateau is fractured in 75-90% of cases. This is because the lateral plateau is weaker than the medial and it is subject to injury from a valgus (medially directed) force (common): Tibia1 plateau fractures are linear (split), impacted or a combination (see figure).

There **are, three important considerations** in the management of tibial plateau fractures: 1) recognition that a fracture is present;: 2) assessment of the degree of displacement; and 3) **detection** of associated ligamentous injury.

If the tibial plateau fracture is minimally displaced, it can be **difficult to detect radiographically. Often** the fracture is in an oblique plane and only an oblique film will show the fracture line. The tibial plateau should be examined for irregularity or disruption of the cortex or trabecular pattern. Impaction causes increased bone density ("sclerosis"). The medial tibia1 plateau bears most of the body weight and therefore has a denser trabecular structure. In lateral tibia1 plateau fractures, the trabecular density of the lateral tibia1 plateau is increased relative to the medial plateau.

The depth of depression of the tibial plateau fracture must be accurately assessed. Depression greater than 8 mm. or separation of the fracture fragments more than 5 mm. necessitates surgery to restore the articular surface. Because of the downwards slope of the Plateau surface, the depth of depression cannot be accurately assessed on an AP film. A 15° inferiorly directed AP view or CT or tomography is needed. Although this is not an emergency determination, if it seems possible that a significant depression is present, the patient must be kept non-weight bearing and have an expeditious work-up (possibly as an inpatient).

Assessment of **ligamentous and meniscal injuries** requires a complete and accurate physical examination. MRI is the test of choice to image these soft tissue injuries (although not. of course, in the Emergency Department).

Capps GW, Hayes CW: Easily missed injuries around the knee. Radiographics 1994;14:1191-210

Schatzker J: Tibial plateau fractures, in Browner BD, Jupiter JB, Levine AM, Trafton PG: Skeletal Trauma Philadelphia, W.B. Saunders. 1992. pp. 1745-1769.

Stiell IG, Greenberg GH, Wells GA, et al: Prospective validation of a decision rule for the use of radiography in acute knee injuries. JAMA 1996;275:61 l-5. Comment 641-2

Weber JE, Jackson RE, Peacock WF, Swor RA, Carley R, Larkin GL: Clinical decision rules discriminate between fractures and nonfractures in acute isolated knee trauma. Ann Emerg Med 1995; 26: 429.433

Bauer SJ, Hollander JE. Fuchs SH, Thode HC: A clinical decision rule in the evaluation of acute knee injuries. J Emerg Med 1995; 13: 61 l-615.

11

11. The Frenchman's Fibular Fracture

Occasionally misdiagnosed as a "sprained **ankle,"** the **Maisonneuve fracture can** present with subtle clinical and radiographic findings despite there being significant disruption of the ankle joint. The Maisonneuve fracture is a fracture of the proximal third of the fibula that occurs in association with ankle injuries. If unrecognized or inadequately treated, there can be progressive instability of the ankle and post-traumatic arthritis. The Maisonneuve fracture is, in fact, not an uncommon injury. It occurs in at least 5% of all ankle fractures (Pankovich, 1976). In most cases, the Maisonneuve fracture is associated with displaced ankle fractures and greater joint disruption and the severity of the injury is obvious.

Although the classification of ankle fractures and their mechanisms of injury is complex, the mechanism of this proximal fibular fracture was accurately deduced by Maisonneuve from cadaver experiments in the pre-radiographic era (1840). Forceful **external rotation of the foot** around the longitudinal axis of the tibia produces a sequence of injuries of increasing severity:

1. Tearing of the anterior inferior tibio-fibular ligament, which is often associated with a partial tear of the interosseous membrane (tibio-fibular syndesmosis);
2. Tearing of the posterior inferior tibio-fibular ligament or an avulsion fracture of the posterior tibia1 surface (seen in this case);
3. Further tearing of the interosseous membrane extending proximally to a fracture of the proximal fibula (the Maisonneuve fracture);
4. Tearing of the deltoid ligament (medial collateral ligament) or fracture of the medial malleolus.

Although patients usually cannot recall the precise forces involved in the injury, the mechanism of the Maisonneuve fracture is distinctly different from that of a typical ankle sprain. The vast majority of ankle sprains (-90%) are due to an inversion injury affecting the lateral collateral ligaments. The mechanism of the Maisonneuve fracture involves external rotation of the foot around the longitudinal axis of the tibia. This usually occurs by internal rotation of the patient's body with the foot planted on the ground.

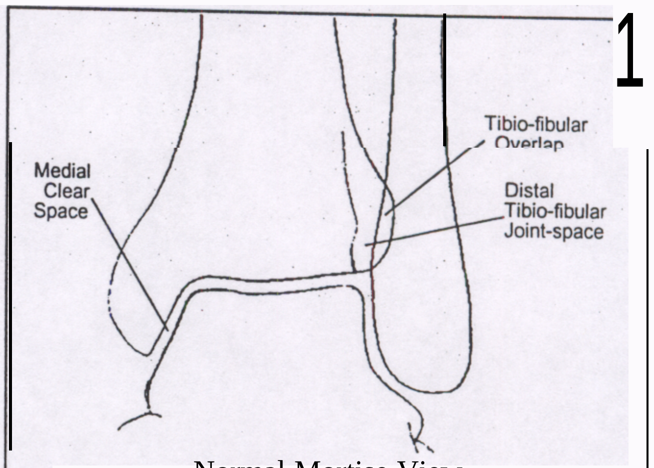
Most patients with ankle sprains are tender over the lateral aspect of the ankle. On **examination of the ankle,** there is swelling and tenderness over the medial malleolus or deltoid ligament. This patient's "sprain" is distinctly different from the usual ankle sprain because he has pain over the medial, rather than lateral, aspect of the ankle. His mechanism of injury was external rotation stretching the medial collateral rather than inversion stretching the lateral collateral ligament.

In all patients with ankle injuries, the knee should be examined for tenderness over the proximal fibula. The "squeeze test." i.e., compression of the tibia and fibula at the mid-calf level, will reveal tendefness due to interosseous ligament diastasis. Patients with a Maisonneuve fracture often do not complain of knee or calf pain because of the greater pain from the ankle injury. The diagnosis of a Maisonneuve fracture should be considered whenever there is a fracture or ligamentous injury to the medial, anterior or posterior aspects of the ankle without an injury to the lateral malleolus. Nevertheless, some authorities recommend radiography of the entire tibia-fibula in all patients with displaced ankle fractures.

Radiographically, the key view to assess the integrity of the ankle joint is the **mortise view,** an AP view with the foot in 15° to 20" of internal rotation. The joint space should have a uniform width around the superior, medial and lateral articular surface of the talus. The width of the joint space should be no more than 4 mm., however, joint space uniformity is a more reliable sign than its actual measurement. In this patient, there is slight widening of the lateral joint space between the talus and lateral malleolus. Separation and diminished overlap of the distal tibia and fibula on the AP or mortise view is another sign of disruption of the ankle mortise. The width of the join&pace between the distal fibula and tibia'should be no greater than 5.5 mm. The overlap of the distal tibia and tibula should be at least 10 mm. on the AP view and at least 1 mm. on the mortise view (figure). Nevertheless, the overall appearance of the ankle joint is often a more accurate assessment of mortise integrity than these measurements. In this patient, the space between the cortex of the distal tibia and tibula appears wide on the mortise view. A comparison view of the other side makes these abnormalities more evident. This view was obtained in order to assess operative reduction of the injured side.

On this patient's **lateral view,** there are several small bone fragments -- avulsion fractures of the posterior inferior tibio-fibular ligament, a component of the external rotation injury. In addition, there is a bone fragment just posterior to the talus. This is not a fracture, but is a common unfused secondary ossification center known as the os trigonum. The margins of this accessory ossicle are smooth and well corticated rather than jagged like a fracture.

After the initial set of radiographs, the patient was reexamined and tenderness was noted over the proximal fibula. Films of the tibia-fibula were obtained showing a Maisonneuve fracture. Intraoperative stress views of the ankle under anesthesia confirmed widening of the syndesmosis. but no abnormal talar tilt, i.e., intact deltoid and lateral collateral ligaments. A syndesmosis screw was inserted to stabilize the ankle joint.



Normal Mortise View

The entire mortise joint space should be of uniform width
The medial clear space should be < 4 mm.
The distal tibio-fibular joint space should bc < 5.5 mm.
The tibio-fibular overlap should be > 1 mm.
(> 10 mm. on the AP view).

del Castillo J, Geiderman JM The Frenchman's fibular fracture (Maisonneuve fracture) JACEP 1979.8 404-406.
Lock TR Maisonneuve fracture: case report of a missed diagnosis. Ann Emerg Med 1987; 16:805-807
Pankovich AM: Maisonneuve fracture of the tibula. J Bone Joint Surg 1976;58A:337-342.
Pankovich AM: Trauma to the ankle, in Jahss MH: Disorders of the Foot and Ankle, 2nd ed., WB Saunders 1992, pp. 2361-2432.

12

12. The Radiolucent Foreign Body

)

Three days later the patient returned to the ED with worsening pain and marked swelling of the foot, involving both plantar and dorsal surfaces. A **CT** was obtained revealing a radiodense foreign body with surrounding inflammation that extended into the flexor tendon sheath of the fourth toe. Surface markers placed during the CT scan assisted in localizing the foreign body. A 4.5 cm long wooden splinter was removed and the wound healed uneventfully.

Retained foreign bodies constitute a frequent pitfall in wound management. **Reasons for failure to detect a foreign body** include: (1) incomplete or inadequate'history of the injury; (2) misleading history (e.g., the patient does not recall stepping on a needle or toothpick); (3) inadequate wound exploration; (4) failure to obtain radiographs (e.g., in the belief that only leaded glass is radiopaque); or (5) radiolucency of the foreign body.

The diagnosis of radiolucent soft tissue foreign bodies is a vexing problem. Plain radiography has a very limited ability to distinguish soft tissues radiodensities, including organic matter foreign bodies that have a high incidence of infectious complications, e.g., wood, thorns, soil and fabrics.

Plain films will occasionally demonstrate a wooden foreign body. When the wood is dry, it has the radiodensity of air and might'therefore be detectable as a lucent density.

Xerography is a technique that produces edge enhancement making foreign bodies easier to visualize. However, controlled studies have shown that xerography does not increase the detection rate above that of plain radiographs.. It uses a high radiation dose and is no longer widely available;.

Ultrasound imaging depends on differences in acoustic impedance rather than x-ray attenuation and is therefore advantageous in detecting "radiolucent" foreign bodies. It also permits visualization in three dimensions and real-time which is potentially useful during wound exploration. Ultrasound works best when the foreign body is located close to the surface and embedded in relatively homogenous tissue. In regions of complex anatomy (such as the hand or foot) or where there is adjacent air, tendon, bone or fibrosis, identification of a foreign body can be difficult.

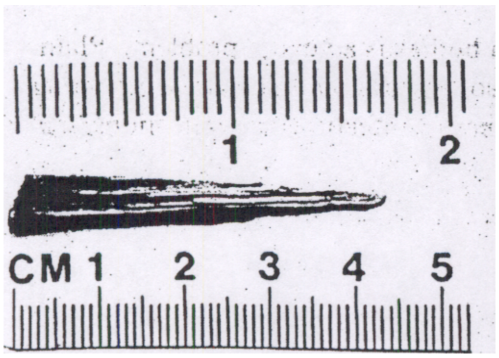
CT is able to distinguish differing tissue densities with tremendously greater sensitivity than conventional radiography. This makes it useful for detecting "radiolucent" foreign bodies. In addition, CT can localize objects in three dimensions and guide surgical removal of the embedded object.

There are several **potential sources** of error with **CT.** The foreign body might be mistaken for an anatomical structure such as a tendon. This could be avoided if both the normal and injured extremity were included in each CT image. If the foreign body has a radiodensity similar to soft tissue, then even CT may be unable to detect it. If the foreign body is very small then very thin CT slices (3 mm or 1.5 mm) would be necessary to detect it.

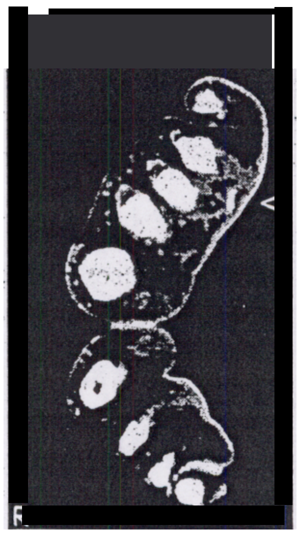
12

In reviewing **the management of this cask,** two issues arise. Some authors suggest that all plantar puncture wounds should be extended, “cored-out,” and probed to determine the depth of penetration and presence of a foreign body. Others feel that this is inadvisable for all wounds because its benefit is unproved and it is relatively invasive. A clinical clue to the presence of a foreign body is pain out of proportion to that expected from the wound alone.

An additional question is whether CT should have been obtained at the time of the patient’s initial visit to the ED. This would have permitted earlier diagnosis and reduced the potential for infection. Since the possibility of a retained foreign body was deemed small at the time the patient first presented, the clinical approach was to warn the patient of the potential for a retained foreign body. and to instruct the patient to return if signs of infection develop.



↑ - Splinter removed from patient’s foot.



← Radiodense splinter in the sole of the left foot. Note the adjacent inflammatory exudate (gray) and diffise swelling of the left foot in comparison to the right foot.

Lammers RL, Magill T: Detection and management of foreign bodies in soft tissue. Emerg Med Clin North Am 1992;10:767-78 I.

Flom LL. Ellis GL: Radiologic evaluation of foreign bodies. Emerg Med Clin North Am 1992; IO: 163-177

Verdile VP, Freed HA. Gerard J: Puncture wounds to the foot. J Emerg Med 1989; 7: 193-199.

Schwab RA. Powers RV: Conservative therapy of plantar puncture wounds. J Emerg Med 1995;13:291-295.

Chisholm CD. Schlesser JF: Plantar puncture wounds: controversies and treatment recommendations. Ann Emerg Mrd 1989; 18: 1352-1357.

13. The Ring of C-2

The areas of the cervical spine where fractures are most often missed are C- 1 ,C-2 and C-7. The region of C-1,C-2 is difficult because of the complex anatomy and multiple overlying shadows. A simple mnemonic that is useful to summarize an approach to reading the lateral c-spine film is “ABC’s” where: **A is** alignment (appears normal in this patient); **B** stands for bones; and C’s for cartilage and soft tissues.

Bones: Carefully inspect each vertebra for deformity or fracture lines. In this patient, there is anterior narrowing of the body of C-4. This probably does not represent an acute injury because there is evidence of healing with new bone formation. There **is** sclerosis about the cortex, osteophyte formation and ligamentous calcification. The articular facets of the lower vertebrae appear malaligned, but this is due to rotation of the patient; the alignment was normal on other films.

Cartilage and Soft Tissues: Pre-vertebral soft tissue swelling is an indirect indicator of a fracture or ligamentous injury. It may not always be present and, in fact, is not present in the above case. However, there is a slight bulge anteriorto the body of C-2.

The anatomy of the cervico-cranium iscomplex and fractures in this area can be difficult to visualize. One radiographic landmark on the lateral view is the **“ring of C-2.”** This oblong-shaped ring is formed by the cortex projecting laterally from the vertebral body of C-2. Disruption of the ring of C-2 signifies a fracture through the body of C-2. This type of fracture is termed a type III (or “low”) odontoid fracture, although it is actually a fracture through the body of C-2.

This patient has a **type III odontoid fracture** with disruption of the “ring of C-2” on the lateral cervical spine film. The AP view of C-l,C-2 (the open mouth view) does not demonstrate this fracture line. It was seen on a conventional tomogram of this area. CT readily shows the fracture through the body of C-2.

Lesions to the spinal cord at this level are usually fatal. However, because the spinal canal is widest at the level of C-1,C-2, fractures at this level often occur without injury to the spinal cord. The type III dens fracture is usually “stable” owing to the broad, irregular fracture line through the body of C-2. In this patient, stability was demonstrated by the lack of motion of the fracture fragments on flexion-extension views that were obtained later in the patient’s hospital stay. The prognosis for healing is much better with this fracture than a fracture through the base of the dens (type II odontoid fracture), which is frequently complicated by non-union.

This patient was observed in the hospital for one week and was discharged in a hard cervical collar.

Van Hare RS. Yaron M: The ring of C-2 and evaluation of the cross table lateral view of the cervical spine. Ann Emerg Med 1992;21:733-735.

Harris JH. Mirvis SE: The Radiology of Acute Cervical Spine Trauma, 3rd ed. Williams and Wilkins, 1996, pp. 42-44, 443.457.

14

14. Remember your A B C'S

After quickly reviewing the films for obvious injuries, a systematic review is essential to avoid overlooking subtle abnormalities. A simple mnemonic device is: “ABC’S,” “A” stands for adequacy and alignment. “B” stands for bones, which should be examined for fractures or deformity. “C” stands for cartilage (the spaces between the bones). “S” stands for soft tissue changes, which can provide an important clue to injuries that are not directly visible.

The ABC’s

Separately examine the cervicocranium and the lower cervical spine (C-3 to C-7).

A	Adequacy	All seven vertebrae must be seen.
	Alignment	Minimal rotation or tilt (facet joints), Four smooth curves: anterior and posterior surfaces of vertebral bodies, spino-laminar junctions, and tips of the spinous processes.
B	Bones	Fractures or deformity of thevertebral bodies, articular masses, lamina, arid spinous processes.
C	Cartilage	Equal space between the bones: intervertebral disks, facet joints, laminae and spinous processes. Predental space should be less than 3 mm. (between the dens and anterior tubercle of C-1).
S	Soft Tissues	Prevertebral soft tissues swelling.

<u>Lateral View:</u> All seven vertebrae are visualized, including the faint C-7 to T-l junction. It is best to actually count the vertebrae to be sure that they are all seen, rather than simply rely on visual inspection. Positioning of the patient should also be assessed. In this film, the patient’s neck is slightly tilted --the left and right facet joints do not overlap.

The alignment of the vertebrae is normal; four smooth lordotic curves are seen. There arc no evident fractures or deformity. The “cartilaginous” spaces are equal and parallel.

The crucial finding is an abnormal contour of the prevertebral soft tissues. In non-displaced fractures, especially of the cervicocranium, soft tissue swelling may be the only indication of a fracture. Normal limits of the width of the prevertebral soft tissues have been determined by studying large numbers of normal radiographs. Penning found the upper limits of normal lo be 10 mm. at C-l; 5 mm. at C-2; 7 mm. at C-3; and 20 mm. at C-5 to 7. The greater range at C-1 is due to retro-pharyngeal adenoidal tissue at and above C-l. especially in younger patients. The interposition of the esophagus within the prevertebral soft tissues of the lower cervical spine makes the detection of soft tissue swelling a much less sensitive (only 5%).

The usefulness of prevertebral soft tissue swelling has been the subject of controversy. In two recent studies. Soft tissue swelling was found in only 50% to 60% of injuries. More

14

reliable than the measured thickness of the prevertebral soft tissue at discrete levels is an assessment of its **contour** (Harris). The contour of the cervicocranial soft tissues should follow the anterior surface of the vertebrae. Normally, there is straightening or slight concavity anterior to the base of the dens and between C-l and skull base (except With enlargement of retropharyngeal adenoidal tissue). When there is swelling of the cervicocranial soft tissues, the plain films should be carefully scrutinized an injury. If an injury is not found, CT of the occiput to C-2 should be done to look for occult injuries.

In this patient, the maximal width of the soft tissues is normal: 10 mm. at C-l and 5 mm. at the base of C-2. However, there is a prominent bulge anterior to the dens. No definite fracture is seen.

__Open Mouth View:__ The AP view of C-l and C-2 is obtained through the patient's open mouth. The dens should be symmetrically located between the lateral masses of C-l. The lateral, masses of C-l and C-2 should be aligned. The radiograph should be scrutinized for fractures, especially through the base of the dens.

In this patient, the base of the dens is partly obscured by overlying bony structures. Optimal views were not obtained because of undue concern about opening thecervical collar and permitting movement of the neck. However, in, a cooperative and fully alert patient without excessive neck pain, this slight manipulation under adequate supervision should be allowed to ensure adequate views. Even with optimal views, a fracture through the base of the dens might not be seen if the fracture line is oblique rather than transverse.

__**Comnuted Tomography:**__ CT is exceedingly sensitive at detecting most fractures. However, fractures that lie in the plane of the CT slide, such as fractures through the base of the dens), may not be visible (Woodring, 1992). This is seen with). To visualize these fractures, CT reconstruction in the sagittal and coronal (frontal) planes may be necessary.

In this patient, the initial CT images were interpreted as negative. In one image, there is discontinuity of the trabeculae at the base of the dens. This was misinterpreted as an variation of trabecular architecture. The next morning, sagital and coronal reconstructions were done and the fracture was diagnosed. Fractures through the base of the dens are unstable because they can further displace when the patient moves. The patient was recalled to the ED. Police and an ambulance crew were dispatched to transport the patient. Fortunately, the patient remained neurologically intact. He was admitted to the neurosurgery service and was managed with immobilization in a Halo-vest. He was discharged from the hospital two days later.

Harris JH, Mirvis SE: The Radiology of Acute Cervical Spine Trauma, 3rd ed. Williams and Wilkins, 1996, pp. 475-500. 32.38.

Harris JH: Abnormal cervico-cranial retropharyngeal soft-tissue contour in the detection of subtle acute cervico-cranial injuries. Emerg Radiol 1994; I: 15-23.

DeBehnke DJ. Havel CJ: Utility of prevertebral soft tissue measurements in identifying patients with cervical spine fractures. Ann Emerg Med 1994;24:1119-1 124. Editorial: 1168-1 170.

Miles KA, Finlay D: Is prevertebral soft tissue swelling a useful sign in injuries of the cervical spine? Injury 1988;17:177-179.

Penning L: Prevertebral hematoma in cervical spine injury: incidence and etiologic significance. AJR 1981;136:553-561.

Woodring JH. Lee C: The role and limitations ofcomputed tomographic scanning in the evaluation of cervical trauma. J Trauma 1992;33:698-708.

15. Double Trouble

The overall **alignment** of the vertebral column appears normal. The C7 vertebra is not seen. Examination of the **bones reveals** a tiny **avulsion fragment** from the anterior-inferior comer of C3. There is marked **prevertebral soft tissue swelling (20 mm. at C2-C3),** and **an increased pre-dental space** (between the anterior margin of the dens and the posterior margin the anterior arch of Cl). This space should be 2.5 to 3 mm. and is here 5 mm. This implies disruption of the transverse ligament that holds the odontoid process against the anterior portion of the ring of Cl. Transverse ligament rupture is rarely an isolated injury. More frequently it is associated with a **burst fracture of the ring of Cl,** described by **Jefferson** in 1920. The actual fracture is usually not visible on the lateral view, although occasionally, a posterior arch fracture can be seen.

The fracture of the ring of Cl is better appreciated on **the open mouth view. It** shows asymmetry of the dens between the lateral masses of C1 and **lateral displacement of the lateral masses** of Cl relative to C2. Nevertheless, the diagnosis should be **made** from the initial lateral film and additional viewsdeferred until the patient is stabilized.

Management of a Jefferson burst fracture depends upon the stability of **the dens** with respect to the ring of C1; a function of the integrity of its ligamentous support. The transverse ligament is most important. The alar ligaments (from the apex of the dens to the base of the occipital condyles) and attachments extending from the Cl-C2 articular facet capsules also play a role. In most cases, the dens is at least partially stable and management can be non-operative (halo immobilization until healing). If the dens is completely unstable, Cl and C2 must be surgically fused. This will significantly limit mobility of the neck. Findings on plain film can estimate the extent of ligamentous disruption. A pre-dental space of 3 to 6 mm. implies partial disruption of the transverse ligament; 6 to 10 mm. implies complete disruption of the transverse ligament but intact accessory (alar) ligaments; and >10 mm. signifies complete ligamentous instability. On the open mouth view, if the lateral masses of Cl have a combined lateral displacement of 7 mm. or more with respect to the lateral masses of C2, there is disruption of the transverse ligament. The ultimate treatment decision is determined by dynamic studies (flexion-extension views). These are not done in the Emergency Department.

TWO hours after the patient arrived in the Emergency Department, bilateral hand grasp weakness was noted. High dose corticosteroids were started. At five hours the patient had 415 weakness of all muscle groups of both arms, consistent with a **central cord syndrome.** This was related to the hyperextension avulsion injury at C-3 and not the Jefferson burst fracture.

The open-mouth view showed >7 mm. widening of the lateral masses of C1 with respect to C2 consistent With rupture of the transverse ligament (predental space was 5 mm.) CT revealed fractures of the anterior and posterior arches of Cl, After one week in the hospital. the patient had recovery of his arm strength. After one month of immobilization. flexion/extension views showed no instability of the spinal column. enabling continued non-operative management.

16

16. The Ideal Lesion

Although a definite fracture is difficult to see, there is indirect evidence that a fracture is present, i.e., **malalignment** of the upper cervical spine. The anterior surface of the C-2 vertebral body shows slight anterior displacement relative to C-3. This is minimal in the first film, but a bit greater in the second film. The posterior neural arch of C-2 is displaced slightly posteriorly. This is determined by following the spino-laminar line at C-l to C-3, which is also called **the posterior cervical line.** Normally, the three points of the C-l, C-2, C-3 spino-laminar line should all lie within 2 mm. of a straight line. In this patient, the C-2 spinolaminar junction is displaced 2 mm. to 3 mm. behind the line linking C-I and C-3. Since the anterior part of C-2 is displaced anteriorly and the posterior part of C-2 is displaced posteriorly, there must be a fracture through the neural arch of C-2.

This injury is commonly **known as a Hangman's fracture.** The usual site of fracture **is the isthmus or pars interarticularis -- its** weakest part of the C-2 neural arch. This is located betweenthe superior and inferior articular facets. Alternatively; fractures can occur through the lamina, the articular facets or can extend into the body of C-2.

In the first film, there is a notch-like deformity along the superior edge of the C-2 lamina. This is suspicious for a fracture. In the second film, the superior border of the lamina is interrupted and is displaced superiorly, although a fracture line is not visible.

Soft tissue swelling could serve as a clue to an injury. However, in this patient the naso-gastric tube prohibits accurate assessment of the prevertebral soft tissues. In addition, the Hangman's fracture involves the posterior vertebral elements and so is less frequently associated with soft tissue swelling than anterior element fractures.

The typical **mechanism of injury** causing a hangman's fracture is a high speed motor vehicle crash in which the victim's face hits the dashboard or windshield, causing **hyperextension and compression** of the neck. This results in compression and fracture of the posterior neural arch. There is also often a distracting force on the anterior aspect of the vertebral body, stretching the anterior longitudinal ligament and intervertebral disk. This results in anterior slippage (anterolisthesis) of the C-2 vertebral body, which is often seen hangman's fractures and accounts for its other name: **traumatic spondylolisthesis of the axis.** Spondylolisthesis means slippage or displacement of one vertebral body relative to the subjacent one.

Hangman's fractures are classified into three types depending on the degree of ligamentous disruption and displacement. **Type 1** is non-displaced or minimally displaced (less than l mm to 3 mm). This type is the most frequent and the most subtle radiographically. Neurological deficits usually do not occur, which contributes to the likelihood of missing the injury. In Type **II** fractures. the body of C-2 is displaced or angulated with respect to C-3. The facet joints of C-2 articulate normally with C-3. In Type Ill fractures, the articular facet joints are disrupted. The facet dislocation in Type III injuries is due to an additional hyperflexion force. Type I and 11 fractures can be

16

managed without surgical intervention, whereas Type III injuries often need surgical stabilization.

The incidence of neurological injury is low with Hangman's fractures, especially Type I and Type II. This is because the spinal canal is widest at C-l and C-2, and the fracture through the neural arch actually enlarges the spinal canal. This fracture would therefore not be suitable for a hangman and, in fact, the true Hangman's fracture is quite different.

A **true Hangman's fracture** is caused by a different mechanism of injury and results in complete transection of the spinal cord. Interestingly, hangmen did not always produce a Hangman's fracture in carrying out their duty -- the Hangman's fracture was a relatively recent advance in the "art of hanging." Prior to the late nineteenth century, the hangman's knot was placed suboccipitally or subaurally. The spine was not usually fractured and the victim died by asphyxiation. Initially, there is jugular vein obstruction, which causes cerebral venous congestion. This is followed by carotid and/or airway occlusion. : Such strangulation can be inconvenient for judicial hangings because of the relatively long time required to cause death and the occasional non-fatal results. ,

In the nineteenth century, the "long drop" was instituted with the aim of achieving more rapid functional decapitation. The length of the drop is correlated to the weight of the victim (1,260 foot-pounds was recommended by Lord Aberdare of the British Commonwealth's Capital Sentences Committee in the late 1800's). In 1913, Fredric Wood-Jones studied the injury produced by a submentally placed knot and concluded that this produced the most certain and "humane" results. Hyperextension and forceful distraction produce a fracture of the neural arch of C-2 and cervico-cranial separation at C-2. The spinal cord is instantly severed. It is therefore the **"ideal lesion"** to be produced by a hanging.

The remainder of the patient's trauma evaluation was negative. Neurosurgical work-up included CT, conventional tomography and flexion/extension views. The patient was managed with a halo vest and eventually transferred for further care to a Naval hospital in Iowa.

Sternbach G, Sumchai AP: Frederic Wood-Jones: The ideal lesion produced by hanging. J Emerg Med 1989;7:517-520.

Wood-Jones F: The ideal lesion produced by judicial hanging. Lancet 1913;1:53.

Garfin SR, Rothman RH: Traumatic spondylolisthesis of the axis (Hangman's fractures), in Sherk HH: *The Cervical Spine*, 2nd ed. J. B. Lippincott. 1989. pp. 344.354.

James R, Nasmyth-Jones R: The occurrence ofcervical fractures in victims ofjudicial hanging. Forensic Sci Internat 1992;54:81-91.

17. Dumb Luck

The fact that a patient walks into the Emergency Department one day after an injury should not dissuade you from considering that he has suffered a serious or unstable cervical injury.

On **the lateral film,** examination of the **bones** reveals no acute fracture although there are **degenerative changes** (spondylosis) of the fourth, fifth and sixth vertebral bodies, i.e., loss of vertebral body height, osteophytes and anterior longitudinal ligament calcification.

The overall **alignment** of the vertebral column is normal. However, close examination reveals that C-5 is 3 mm. posteriorly displaced with respect to C-6. In patients with degenerative changes, the anterior vertebral body line is difficult to follow because of vertebral body deformities, and so alignment is more accurately assessed using the posterior. surfaces of the vertebral bodies. Although each vertebral body should be perfectly aligned with the adjacent ones, slight malalignment of up to 3.5 mm. of can exist without there being ligamentous disruption. However, this criterion was based on cadaver studies and was devised to assist surgeons in assessing spinal stab& and in planning definitive care.. This measurement should not be used to exclude an injury in an acutely traumatized patient in the Emergency Department. Ligament disruption can be present with lesser degrees of malaligmnent or even with normal alignment. Depending in the clinical circumstances, further studies such as flexion/extension views may be indicated to diagnose ligament injuries.

Examination of the **prevertebral soft tissues** reveal a prominent bulge at the level of C-5 to C-6, the same region as the malalignment. However, the width of the prevertebral soft tissues is less than 20 mm. at this level (within normal limits).

This patient had sustained sufficient trauma to injure his spine despite the fact that he was ambulatory following the injury. The purported abnormalities on his lateral film were therefore considered potentially significant. A CT scan through the area of question did not reveal any fractures. Because of the possibility of ligamentous injury, **flexion/extension** views were obtained. On flexion, there was anterior slippage of C-5 on C-6 with “fanning” of the spinous processes and facet joints due to disruption of the posterior ligaments. This is termed **hyperflexion sprain** -- a very unstable injury. The patient was hospitalized and had surgical fixation with plates and screws.

The next day. the patient’s initial radiographs were read by the attending radiologist. Before he examined the flexion view. he noted that the films showed only **chronic degenerative changes** with **“no acute injury.”** The radiographic findings that had been initially interpreted as abnormal (the prevertebral soft tissue bulge and vertebral body malalignment) were, in fact, not indicative of an acute injury. However, because of the misinterpretation of the initial lateral film, the correct radiographic study, i.e., flexion/extension views, was obtained and the patient was properly treated.

17

Although alteration in the prevertebral **soft tissues can serve as a clue to** an occult injury, abnormalities in the lower cervical spine soft tissues are seen in as few as 5% of spine injuries, including grossly displaced fractures. In this patient, the prominent bulge anterior to C-5 and C-6 was initially interpreted as abnormal. However, the contour of the prevertebral soft tissues in the lower cervical spine often shows “tucking-in” or narrowing at the cervico-thoracic junction and so the soft tissues in this patient should not be considered abnormal. On the repeat lateral film this bulge is less prominent. Furthermore, the patient’s injury involves posterior spinal structures and prevertebral soft tissue swelling occurs much less frequently with posterior injuries.

Degenerative changes are common in older individuals. They can mimic various pathological conditions. Degenerative spondylolisthesis causes vertebral body slippage and can be misinterpreted as traumatic spondylolisthesis. **In this patient,** there is degenerative retrolisthesis of C-S on C-6. This malalignment was not due to the traumatic injury -- hyperextension causes anterior, rather than posterior, displacement..

Flexion/extension radiographsare used to detect ligamentous injury!. Iii the Emergency Department, the indications for flexion/extension views are not well defined. They can play a role in patients with normal or equivocal radiographs. Equivocal radiographs include those with slight malalignment of questionable significance, such as those seen in patients with degenerative spondylosis. In patients with normal static radiographs who have greater than expected or persistent neck pain, ligamentous injury should be suspected and flexion/extension views should be obtained.

There are **two caveats** to the use of flexion/extension views in the acute setting. First, muscle spasm can prevent subluxation and mask a ligamentous injury. Second, there is potential for causing neurological damage by moving an injured spine. Dynamic studies should only be done only in alert and cooperative patients with a physician in attendance. The motion should be done by the patient and the study must be halted if there is increased pain or the appearance of a neurological deficit.

This patient’s injury is termed hyperflexion **sprain.** It is also referred to as “anterior subluxation” because anterior slippage of the articular facets is frequently associated with posterior ligament disruption. This injury is caused by combined flexion and distraction which tears the posterior ligaments. The radiographic finding can be very subtle or the films can even be normal. and a flexion view is needed to disclose the injury. In fact, one of the most important roles of flexion/extension views is the detection of hyperflexion sprain. Hyperflexion sprain is occasionally missed at the time of initial presentation. In such cases. there can then be progressive subluxation and deformity. In addition. there is risk of catastrophic neurological damage if the patent has another traumatic injury. This is referred to as “delayed instability“ or “hidden instability.“

In summary, flexion/extension views were obtained in this patient because the plain films were incorrectly interpreted. The vertebral body malalignment was due to degenerative changes rather than to the injury. The prevertebral soft tissues were really normal in contour and dimension. What should have prompted the ordering of

17

flexion/extension views was the fact that the patient had pain out of proportion to the radiographic findings. In this case, the patient (and his doctors) got lucky.

The patient's **thoracic spine** was normal. The innumerable subcutaneous metallic densities were from acupuncture treatment he had received two years earlier **in Korea.** (Some practitioners in Asia leave fragments of the acupuncture needles embedded under the skin to achieve a more lasting effect.)

Harris JH, Mirvis SE: *The Radiology of Acute Cervical Spine* Trauma, 3rd ed. Williams and Wilkins, 1996, pp. 45-48, 185-187, 245-270.

Lewis LM, Docherty M, Ruoff BE, et al: Flexion-extension views in the evaluation of cervical spine injuries. Ann Emerg Med 1991;20:117-121.

White AA, Johnson RM, Panjabi MM, Southwick WO:. Biomechanical analysis of clinical stability in the cervical spine. Clin Orthop 1975;109:85-96.

Scher AT: Anterior cervical subluxation: an unstable position. AIR 1979;133:275-280.

Webb JK, Broughton RBK, McSweeney T. Park WM: Hidden flexion injury of the cervical spine. J Bone Joint Surg (Br.) 1976;58-B:322-327.

Penning L: Obtaining and interpreting plain films in cervical spine injury, in Sherk HH, ed.: The *Cervical Spine*, 2nd ed., Lippincott, 1989, pg. 106-141.

Allen BL: Recognition of injuries to the lower cervical spine, in Sherk HH, ed.: *The Cervical Spine*, 2nd ed., Lippincott, 1989, pg. 286-298.

Lee C, Woodring JH, Rogers LF, Kim KS: The radiographic distinction of degenerative slippage (spondylolisthesis and retrolisthesis) from traumatic slippage of the cervical spine. Skeletal Radiol 1986; 15:439-443.

Kim KS, Rogers LF, Regenbogen V: Pitfalls in plain film diagnosis of cervical spine injuries: false positive interpretation. Surg Neurol 1986;25:381-392.

Chin ES. Austin JHM: Acupuncture needle fragments. New Engl J Med 1995;332:304; letter: 1792.

Gerard PS. Wilick E, Schiano T: Imaging implications in the evaluation of permanent needle acupuncture. Clin Imaging 1993;17:36-40.

18

Who needs radiographic examination following head trauma ?

The **indications for imaging studies** in patients who have had head trauma without obvious signs of neurological injuries is a subject of continuing study. One of the largest studies stratified patients into three groups depending on their risk of intracranial injury (Masters, 1987). **The high risk** group has definite signs of neurologic dysfunction (depressed level of consciousness, or focal neurological defects) and requires emergency CT scan and neurosurgical consultation. **The low risk** group has minimal symptoms (headache or dizziness) or local scalp trauma, and does not need radiographs and can have outpatient observation. Between these two groups is a diverse group of patients at **moderate** risk. These pose the greatest dilemma for the Emergency clinician Extended close observation and consideration of CT scanning is recommended.

For patients who have been struck **on the head with a hard object,** these guidelines recommend mandatory imaging for patients with definite evidence of skull penetration (i.e., a palpable depressed skull fragment). Patients with the possibility of a depressed fracture based on the mechanism of injury (i.e., assault, either definite of suspected, with any object), are classified as **moderate** risk.

The diagnosis of a depressed skull fracture is usually made **by physical examination** -- palpation of the skull at the base of the wound. Most depressed fractures (85%) have a laceration in the overlying skin because the force necessary to fracture the skull is usually sufficient to break the skin. In certain circumstances, palpation within a wound may fail to detect a depressed fracture. This can occur when: 1) the mobility of the scalp over the skull causes movement of the wound away from the fracture; 2) swelling of the soft tissues over the skull obscures the bony depression; and 3) the outer table of the skull tends to have lesser depression than the inner table, so the palpable defect may seem minimal. In the few patients with intact skin over a depressed fracture, palpation of the area of contusion will generally not reveal the underlying bony depression.

In this patient, the Water's view showed a depressed fronto-parietal skull fracture (the right test ordered for the wrong reason -- to rule-out an orbital fracture). The CT also demonstrated the fracture and confirmed the lack of underlying brain injury. A small radiolucent region just adjacent to the skull fracture fragments was suspicious for an air collection, implying that this was an open fracture with a dural tear.

This patient was treated by removal of the fracture fragments, closure of a small dural tear and replacement of the skull defect with a wire mesh prosthesis (a souvenir of his vacation in New York).

Cooper PR: Skull fracture and traumatic cerebrospinal fluid fistulas, in Cooper PR, ed. Head Injury, 3rd ed. Williams and Wilkins. 1993,.

Masters SJ, McClean PM, Arcarese JS, et al: Skull x-ray examinations after head trauma. N Engl J Med 1987: 316:84-91.

Carter WA. Davitt M. Gennis P, Lombardi G, Gallagher EJ: Does a perfect Glasgow Coma Scale of 15 obviate computed tomography of the head in traumatic loss of consciousness? (abstract). Ann Emerg Med 1993;22:889

19

19. Orbital Emphysema

In both of these patients, air is seen within the orbit (orbital emphysema). It appears as a radiolucent (dark) area in the superior portion of the right orbit, just below the superior orbital rim. This is caused by a fracture through one of the orbital walls into an adjacent air-filled'sinus. The fracture is either through the orbital floor into the maxillary sinus, through the medial orbital wall (lamina papyracea) into the ethmoid air cells or, least commonly, through the roof of the orbit into the frontal sinus. This is one of the findings of a "blow-out" fracture, but it is not unique to that fracture.

A **"blow-out" fracture** occurs when the anterior orbit is impacted by an object of larger diameter than the orbit itself, e.g., a baseball or a fist. The blow causes increased intra-orbital pressure fracturing its weakest part (the floor or medial orbital wall and not the globe itself). Given this mechanism of injury, there is a very high incidence of associated eye injuries (hyphema, vitreous hemorrhage, retinal detachment).

Radiographic signs of a blow-out fracture include:

1. orbital emphysema;
2. diffuse increased radiodensity over the peri-orbital region secondary to facial soft tissue swelling (non-specific, occurs with and without fractures);
3. opacification of the maxillary sinus;
4. an air/fluid level within the maxillary sinus (seen on upright Waters view)
5. a soft tissue density just below the roof of the maxillary sinus representing either focal hemorrhage or hemiation of orbital contents (the "tear drop" sign);
6. occasionally it is possible to **directly visualize the fracture of the orbital floor.** This, as opposed to the other findings mentioned above, is the only specific sign of an orbital floor fracture. On the Waters view, if the projection is just right, the orbital floor appears as a thin white line that will be disrupted or displaced if the actual fracture fragments are seen. The inferior orbital rim. on the other hand, appears as a grayish line superior to the orbital floor. The inferior orbital rim is intact in blow-out fractures.

In Case **A,** the patient does not have a blow-out fracture. The point of impact occurred more laterally, over the malar prominence. In addition to orbital emphysema, there is an air/fluid level in the maxillary sinus, and fractures through the inferior orbital rim. the zygomatic arch, and the fronto-zygomatic suture. This fracture of the zygomaticomaxillary complex is known as a "tripod fracture." The fourth component of a tripod fracture is a fracture through the lateral wall of the maxillary sinus (not seen here). The exact anatomy of a tripod fracture (and blow-out fracture) is best depicted by CT (axial and coronal cuts). although CT is not indicated emergently.

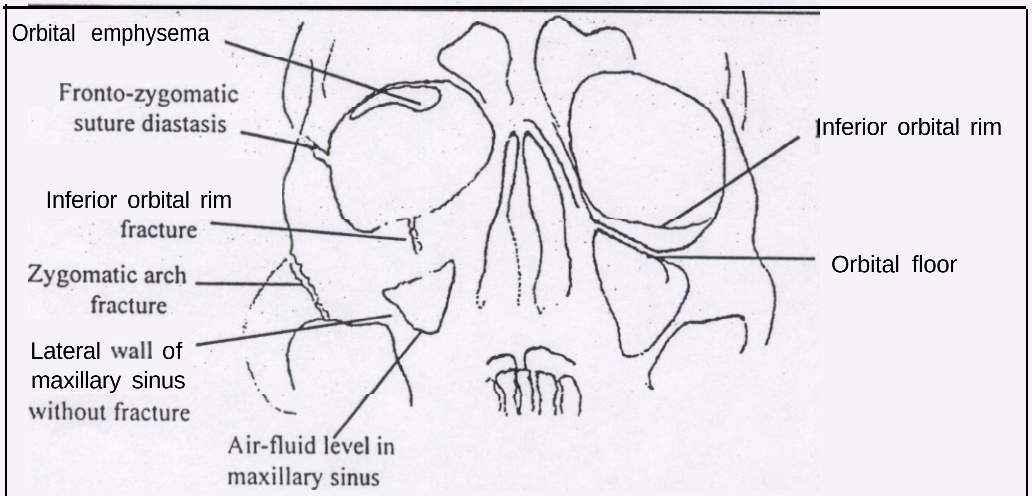
19

The second patient (Case **B)** has a **blow-out fracture**. The only radiographic finding on the Waters view is orbital emphysema. On the Caldwell view, there is opacification of the ethmoid air cells between the medial orbit and nasal cavity. This is due to a fracture through the medial orbital wall. It occurs in 25-50% of blow-out fractures.

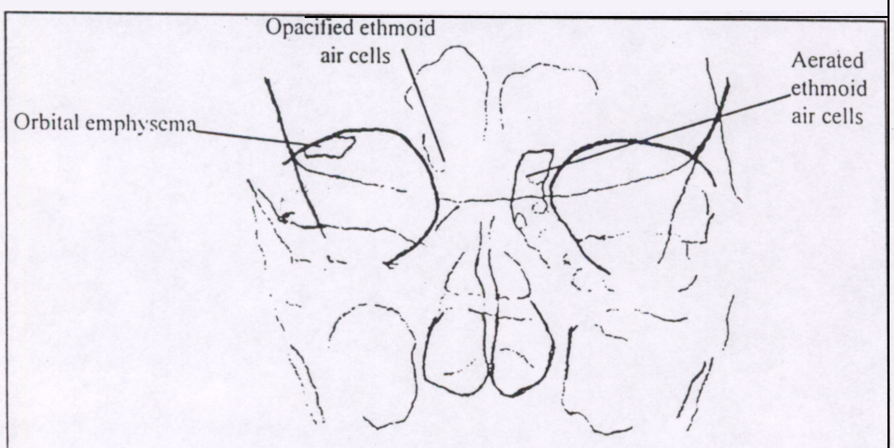
A blow-out fracture can be managed as an outpatient if there are no signs of entrapment impeding upward gaze, enophthalmos or eye injury. The patient should be instructed not to blow his nose, which would introduce air, and possibly bacteria, from the sinuses into the orbit. Orbital emphysema is usually of little clinical consequence. However, if a ball-valve mechanism exists, air becomes trapped within the orbit causing a progressive increase in intra-orbital pressure. Vision could become impaired due to compression and vascular compromise of the optic nerve, an ophthalmologic emergency treated by lateral canthotomy.

If the blow-out fracture has caused entrapment, the need for and timing of surgical correction is controversial. 'Some surgeons feel the patient should have elective correction only if entrapment does not resolve over ten to fourteen days.

O'Hare TH: Blow-out fractures: a review. J Emerg Med 1991;9:253-263.
Jordan DR, White CL, Anderson, RL, Thiese SM: Orbital emphysema:. a potentially blinding complication following orbital fractures. Ann Emerg Med 1988;17:853-855.
Sanerov B, Viccellio P: Fractures of the medial orbital wall. Ann Emerg Med 1988;17:973-976.



Case A: Tripod Fracture -- Waters View



Case B: Medial Orbital **Wall** Fracture -- Caldwell View

20. Subdural Windows

The CT scan is not a direct radiographic image. It is a mathematically constructed picture that is derived from measurements of a narrow x-ray beam as it passes through the patient in a multitude of different directions. CT scanning has two major advantages over conventional radiography. First, it provides cross-sectional slices of the body part being imaged: .This eliminates superimposition of overlapping structures and improves anatomical resolution. Second, CT is able to distinguish tissue densities with far greater sensitivity than conventional radiography (about 100 times greater). This ability to discriminate tissue densities exceeds that which can be shown on, a single x-ray film. Therefore, each CT slice is usually displayed in two or three images each showing a different range of tissue densities over the range of x-ray film den&ties (the gray scale). The choice of which tissue densities are shown depends on the part of the body being evaluated and the pathological conditions suspected.

The units of radiodensity in CT imaging are called **Hounsfield Units** (H.U.) in honor of one of the inventors of CT scanning. This is an arbitrary-scale in which the density of water is assigned a value of zero, air a **value** of -1000, and dense cortical bone a value of +1 000. Brain tissues have density values spread over a fairly narrow range from approximately +20 to +60. Acutely clotted blood has a value of approximately +50 to +100. (figure): ,

The image display is expressed by two parameters: 1) the **window level sets the** tissue radiodensity that is shown as a middle gray; and **2)** the **window width sets the** range of tissue densities that is distributed over the film's gray-scale from white to black. All tissue densities outside the window width will be either white if the tissue is more radiodense than the upper limit of the window or black if the tissue is more radiolucent.

Non-contrast CT imaging in head trauma should include of three display settings: brain windows, bone windows and "subdural" windows. In **brain windows,** a narrow window width is selected to best discriminate the soft tissue detail of the brain itself, which varies over a narrow range. The window level is set at about +40 H.U. and the window width is set at 80 H.U. For **bone windows,** the window level is set at about +500 to +1000 to best display bone detail such as fractures. For subdural windows, the middle gray is set at the level of brain tissue (40 to 50 H.U.), but the window width is wider than for brain window settings (200 to 250 H.U.). The effect is that brain tissue densities are not well distinguished, so the brain appears a more uniform gray. However. substances of greater radiodensity are better distinguished, e.g., bone and acutely clotted blood. With brain windows, a small subdural hematoma has the same white appearance as the adjacent skull. It appears as a region where the skull seems thickened (see first film -- brain windows). On subdural windows, the, blood collection is readily distinguished from the adjacent skull (second film -- subdural windows).

In this patient. there is a.small extra-axial blood collection in the right parietal area (images 5.6.7). It has a crescent shape, which suggests that it is a subdural hematoma. l-here is no mass effect or brain edema. A small asymptomatic hematoma does not require surgical evacuation. This patient needs hospitalization and close observation for signs of neurological deterioration and expansion of the hematoma.

Ramsey RG: Neuroradiology, 3rd ed. W.B. Saunders, 1993.
Gean AD: Imaging of Head Trauma. Raven Press, 1994.

21

21. Are Skull Films Useful?

Although skull films are rarely used to assess head trauma in most Emergency Departments, the lateral view of the skull that serves. as a positioning scout film for the CT scan can occasionally yield useful information. This patient has a **linear skull fracture** of the right temporal bone visible on the lateral skull image. The fracture can also be seen with close inspection of the **bone widow** images 5, 6, 7, 8. If the fracture was in a horizontal direction (axial plane) it could be missed entirely on the CT slices since the fracture would parallel the plane of the CT slices. In this case, the fracture would only be visible on the scout lateral skull image.

A linear skull fracture is an indicator of a relatively great force of impact., The fracture serves as an indirect marker. for brain injury. Prior to the advent of CT, skull films were used as a screening tool in patients with head trauma. However, there is not a good correlation between the presence of a skull fracture and brain injury. A large proportion of intracranial injuries are not associated with skull fractures, and there is an exceeding small number of patients who have a skull fracture and do not have clinical signs of brain injury, i.e., are in the low risk group of head injuries (scalp contusion, mild headache without vomiting, no loss of consciousness, normal neurological examination and normal mental status). Therefore, skull films have been supplanted by CT in assessing head trauma.

In the **brain windows,** there is no sign of midline shift or mass effect. However, the skull in the left parietal area appears slightly thickened (images 10, 11, 12). In the **subdural windows** of these images, there is a small extra-axial blood collection representing a **small subdural hematoma** (images 10 to 16). This is a contra-coup injury since it is opposite the site of principle impact. There is no scalp swelling over the fracture site which is often a clue to an underlying skull fracture or nearby brain injury. In image 6 there is a very small dense (white) spot in the posterior temporal lobe. This may represent a small hemorrhagic cerebral contusion although it might instead be a bone artifact from the petrous bone seen on the next lower slice (image 5) (The image display size of the bone and subdural windows is very small to accommodate twice the number of images in 5 mm. cuts.)

The patient was observed in the hospital for two days and was neurologically intact upon discharge.

Cooper PR: Skull fracture and traumatic cerebrospinal fluid fistulas, in Cooper PR, ed. Head Injury, 3rd ed. Williams and Wilkins. 1993. pp. 115-119.

Masters SJ. McClean PM. Arcarese JS. et al: Skull x-ray examinations after head trauma: recommendations of a multidisciplinary panel and validation study. N Engl J Med 1987; 316:84-91

22

22. Secondary Injury

The primary aim of emergency CT scanning in patients with head trauma is rapid identification of neurosurgically correctable lesions such as subdural, epidural and intracerebral hematomas. For these patients, prognosis can be substantially improved with surgical treatment. Many patients, however, do not have such lesions despite significant cerebral dysfunction, e.g., white matter contusions/edema and brainstem lesions. MRI is more sensitive at visualizing these injuries although it does not alter the initial management. In some cases, there will be clinical and radiographic abnormalities that put the patient at risk for certain secondary injuries.

There are **five significant abnormalities** on this patient's CT. Three relate to **extra-axial blood collections** (appear white on CT) -- a small left fronto-parietal subdural hematoma (image 6, subdural window) and traumatic subarachnoid blood in the left sylvian fissure (image 4) and nearby the sulci (image 6). There is slight midline shift to the right (images 4-7) due both to the small subdural hematoma and mild post-traumatic **cerebral edema** on the left. In addition, the lateral ventricles are slit-like and cortical sulci are effaced due to the cerebral edema. These injuries put the patient at risk for delayed intracranial hemorrhage and progressive parenchymal edema.

There are two indirect signs that the patient **has** a **basilar skull fracture. (The** fracture line itself is not visualized.) There is a large amount of intracranial air (pneumocephalus) seen as dark bubbles surrounding the brainstem (images 3, 4, 5, 6). In addition, there is an air/fluid level in the sphenoid sinus (image 1 - bone window). In the setting of head trauma. this fluid is blood.

A basilar skull fracture can involve the anterior, middle or posterior cranial fossa (see figure) and can best be described by naming the particular bone involved. Basilar fractures have clinical importance for two reasons. First, they can directly damage nearby **cranial nerves** including the vestibulocochlear nerve (VIII), facial nerve (VI), optic nerve (II) or olfactory nerve (I). Middle or inner ear structures can be disrupted by petrous bone fractures. It is important to carefully examine the facial nerve at the time of injury. lmmediate facial nerve palsy is an indication for emergency surgical decompression, whereas delayed onset paralysis is caused by edema and is managed non-operatively.

The second important consequence of a basilar skull fracture is that the tightly adherent dura mater is usually torn and the cranial contents are exposed to infectious contamination from adjacent crania-facial sinuses. These patients must be closely observed for signs of **meningitis.** The use of prophylactic antibiotics is currently felt to be ineffective in preventing post-traumatic meningitis and may even be harmful by promoting growth of antibiotic-resistant organisms.

The **diagnosis** of basilar skull fracture largely depends on clinical findings: hemotympanum. raccoon eyes and Battle's sign (the latter two take several hours to develop). and CSF rhinorrhea or otorrhca. Emergency head CT is used to detect associated intracranial blood collections. Standard thick (5-10 mm.) CT slices usually only visualize indirect signs of the fracture, as demonstrated in this patient. Occasionally. the fracture line is seen. Direct visualization of the fracture generally requires thin sections (1.5 mm.) in axial and coronal planes. Such studies are not indicated on an emergency basis. They are obtained electively when operative repair is being considered.

22

The patient was admitted to the Neurosurgical Intensive Care Unit. A follow-up CT scan was done the next day. There is enlargement of the left subdural hematoma, a new left temporal contusion (images 2 and 3) and marked midline shift (due both to the expanding blood collection and to increased cerebral edema). Despite the worsening CT, the patient remained clinically stable -- alert but oriented only to person. He was treated with intravenous mannitol. The patient gradually improved over the next several days. His month long hospital course was complicated by post-traumatic meningitis due to the open skull fracture. Thin section CT showed a transverse fracture through the petrous bone. At four months, his neurological status was normal aside from right sensory-neural hearing loss. This patient therefore had three secondary injuries:' delayed intracranial hemorrhage, meningitis and eighth cranial nerve dysfunction.

Delayed intracranial bleeding (either intracerebral or extra-axial) is a major concern fojlowing head trauma. Patients admitted to the ICU are monitored with serial head CT scans to screen for this complication. Delayed intracranial hemorrhage is a phenomenon in patients with severe injuries (i.e., abnormal neurological function and/or abnormal CT scans). It is generally believed that this does not occur in patients with minor head trauma who are neurologically normal and have normal CT scans. These patients can usually be safely discharged from the Emergency Department:... However, a recent report describes three cases of delayed, subdural hematoma occurring one to' three months after minor head trauma. 'All patients had negative initial CT scans. Each patient was evaluated several times subsequently for persistent headache. The headache was attributed to a post-concussive syndrome. CT scans were not repeated because of the lack of neurological deficits and because the prior CT scan was normal. Only when the patients developed neurological signs was a CT scan repeated. In all three cases, a large SDH was discovered that required surgical drainage.

Cooper PR: Head Injury, 3rd ed. Baltimore. Williams and Wilkins, 1993, pp. 124-136.

Gean AD: Imaging of Head Trauma. New York, Raven Press, 1994, pp. 51-73.

Doezema D, King JN, Tandberg D, et al: Magnetic resonance imaging in minor head trauma. Ann Emerg Med 1991;20:1281-1284.

Nageris B, Hansen MC, Lavelle WG, et al: Temporal bone fractures. Am J Emerg Med 1995;13:21 l-4,

Snoey ER, Levitt MA: Delayed diagnosis of subdural hematoma following normal computed tomography scan. Ann Emerg Med 1994;23: l 127-l l3 l.

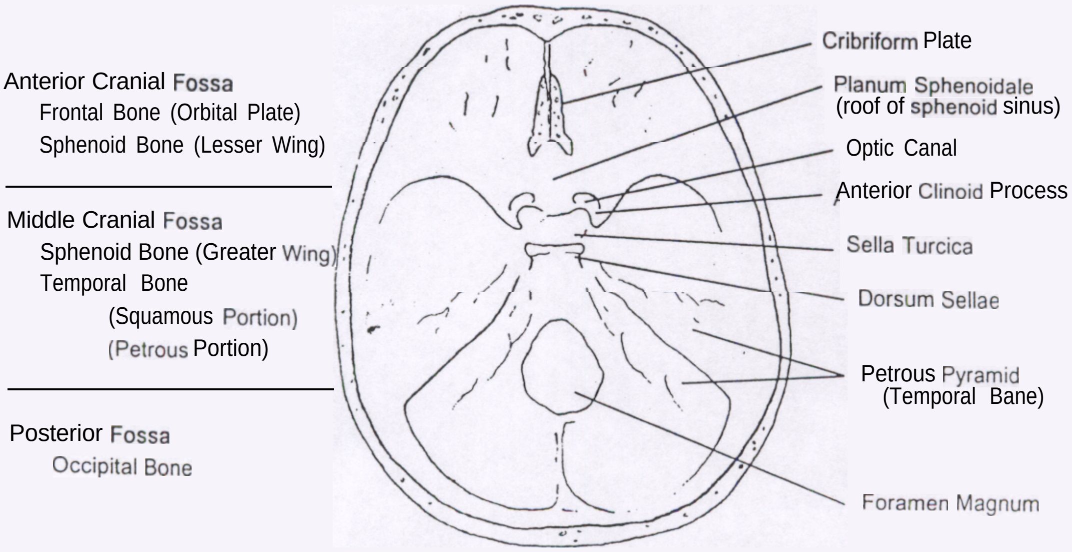


Diagram of the Skull Base

23. How Bad is a Headache

The non-contrast head CT was initially interpreted as negative. A lumbar puncture revealed bloody spinal fluid. The official CT reading diagnosed a subarachnoid hemorrhage., **What are the CT signs of a subarachnoid hemorrhage?**

Non-contrast CT is the study of choice for the diagnosis of SAH. Normal CSF has a lower attenuation than brain substance (appears darker on CT). Fresh blood in the CSF has a higher attenuation (appears white relative to. brain). In some cases, the CT diagnosis of SAH can be difficult. Many of the CT signs of SAH occur in midline structures so interpretation requires knowledge of normal CT neuroanatomy. There is no normal side with which to compare a possible abnormality especially if only a small amount of blood is present. Blood in the CSF is rapidly lysed and becomes less radiodense in 12-24 hours. Small bleeds can become undetectable by CT in this time period.

Subarachnoid hemorrhage originates from a berry aneurysm in the Circle of Willis in 70-90% of cases. Hemorrhage appears most often in the basal cisterns surrounding the brainstem. In this patient, blood is visible **only in the interpeduncular cistern -- a small** white spot between the cerebral peduncles where there should be dark CSF (visible in CT **image** 4). In a second patient, the entire perimesencephalic cisterns &filled&h blood outlining the mesencephalon at the level of the cerebral peduncles. Another common site of blood accumulation in SAH **is the sylvian fissure. In the** second case, there is a large amount of blood in the right sylvian fissure.

Using current CT scanners (and exnert interpretation), is a lumbar puncture still needed after a negative scan?

Many textbooks state that CT is diagnostic in only 7590% of patients with subarachnoid hemorrhage. However, most of the studies on which this statement is based date from the early 1980's and used early generation CT scanners. These studies included all patients with subarachnoid hemorrhage, the majority of whom had major bleeds in which the CT findings would be obvious. It is the patient with minimal symptoms due to a minor bleed (warning leak) that is are most likely to have a negative CT scan. In one study of such patients. only 45% had a positive CT. Although this remarkable number is often quoted. the study involved only nine patients who had very atypical presentations. Most had persistent headache and were not diagnosed when they first presented to medical attention. The bleed was therefore no longer acute and the CT signs were diminished by this delay.

A recent study from a center with expertise in the diagnosis of SAH looked at 175 patients who were oriented. had no focal deficits, and had CT scans within 12 hours of the onset of headache (Van der Wee,1 998). Current generation scanners were used and thin cuts (three mm.) were obtained through the brainstem. (Ten mm. cuts are the usual standard with five mm cuts through the brainstem and posterior fossa.) Two of 119 patients who had a subarachnoid hemorrhage had a negative CT (98% sensitivity). Therefore. lumbar puncture is still necessary in the presence of a negative CT scan, even under such optimal circumstances.

23

Although the patient did not appear to be in acute distress due to her headache, clues to its serious nature were the sudden onset awakening her from sleep at 3 a.m. and the mild nucal rigidity. A cerebral angiogram was performed which showed an irregular narrowing of the supraclinoid internal carotid artery and middle cerebral artery possibly due to spasm or thrombosis of an aneurysm. No definite aneurysm was found (none is identified in 15% of SAH). The patient remained stable. A repeat head CT one week later showed complete resolution of the hemorrhage. The patient refused a second angiogram, which can demonstrate an aneurysm in 15% of cases in which none is identified on the initial angiogram. A series of similar patients with limited perimesencephalic hemorrhage and negative angiograms has found that there is a low risk of rebleeding. The site of bleeding is possibly non-aneurysmal (venous or capillary) (Rinkel, 1990).

Fontanarosa PB: Recognition of subarachnoid hemorrhage. Ann Emerg Med 1989;18:1199-1205.

O'Hare TH: Subarachnoid hemorrhage: a review. J Emerg Med 1987;5:135-148.

Verweij RD. Wijdicks EFM, van Gijn J: Warning headache in aneurysmal subarachnoid hemorrhage: a case control study., Ann Neurol 1988;45:1019-1020.

Leblanc R: The minor leak preceding subarachnoid hemorrhage. J Neurosurg 1987;66:35-39.

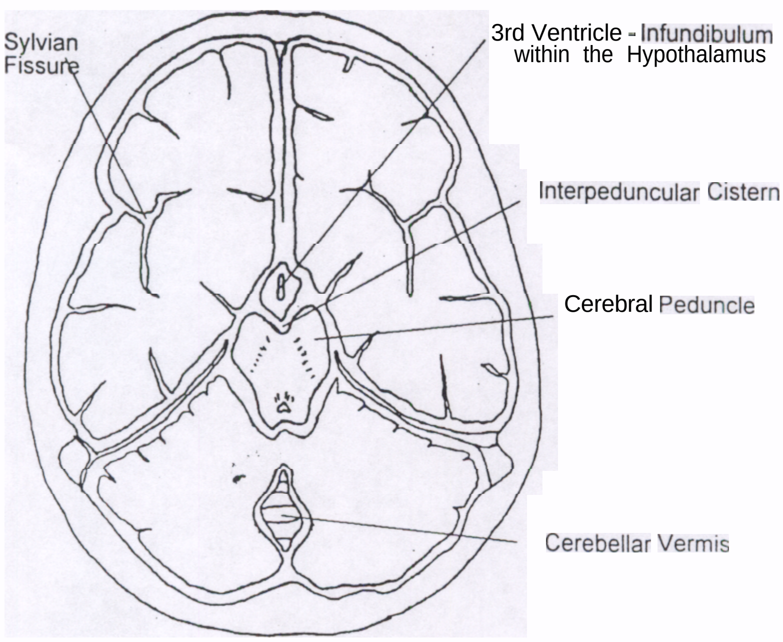
Van der Wee N, Rinkel GJE, Hasan D, van Gijn J: Detection ofsubarachnoid hemorrhage on early CT: is lumbar puncture still needed after a negative scan ? J Neurol Neurosurg Psychiatr 1995;58:357-359.

Sames, TA, Storrow AB, Finkelstein JA, Magoon MR: Sensitivity of new-generation computed tomography in subarachnoid hemorrhage. Acad Emerg Med 1996; 3:16.

Sidman R. Connolly E. Lemke T: Subarachnoid hemorrhage diagnosis: lumbar puncture is still needed when the computed tomography scan is normal. Acad Emerg Med 1996;3:827-31.

Singal BM: A tap in time? (Editorial) Acad Emerg Med 1996;3:823.

Rinkel GJE, Wijdicks EFM, Vermeulen M, et al: Outcome in perimesencephalic (nonaneurysmal) subarachnoid hemorrhage: a follow-up study in 37 patients. Neurology 1990;40:1130-I 132.



Brain Cross-Section at the Midbrain (Level of the Cerebral Peduncles)

25. Contrast Enhancement

The clinical presentation of this patient is classic for **an acoustic neuroma** (or other cerebella-pontine angle tumor). Unfortunately, this diagnosis is occasionally missed or delayed because of its gradual onset and the failure to appreciate the significance of unilateral hearing loss. In this patient, the tumor had grown to a very large size causing obstructive hydrocephalus and papilledema.

Tumors (and abscesses) can often be detected on **non-contrast CT** because the lesions are relatively hypodense compared to normal brain tissue and due to their surrounding edema'and mass effect distorting other normal brain structures. Lesions in the posterior fossa are often difficult to detect by CT because this region is surrounded by thick cortical bone that, causes a beam-hardening artifact. This diminishes the ability of CT to detect, subtle differences in tissue radiodensity.

With intravenous contrast, these lesions become readily apparent. **Contrast enhancement occurs in lesions that disrupt the blood-brain barrier and promote** neovascularization (parenchymal tumors and abscesses). Enhancement can be homogeneous or ring-like (if there is central necrosis due to insufficient vascularity). Certain intra-cranial structures that are not invested with a blood-brain barrier will normally take up contrast -- cerebral blood vessels and dura, including the falx and tentorium. Extra-axial tumors also show contrast enhancement, such as meningiomas and acoustic neuromas. They have a characteristic appearance -- dense homogeneous enhancement with sharp margins.

Because of its size, **the patient's tumor** was could not be entirely resected. The patient was left with a partial right faciatpalsy and a sixth nerve palsy, causing significant diplopia.

Contrast Enhancement:

- Normal Structures
  - Intracranial blood vessels (pial vessels on cerebral surface, major cerebral arteries, Circle of Willis)
  - Extracerebral connective tissue (dura, falx, tentorium) (has no blood-brain barrier)
- Abnormal Structures
  - Vascular malformations (AVM, large aneurysms)
  - Lesions that disrupt the blood-brain barrier and promote neovascularization (tumors, abscesses) -- ring or homogeneous pattern
  - Tumors of extracerebral structures (meningioma and cranial nerve neoplasm. such as acoustic neuroma) -- dense homogeneous pattern.

26

Case 26-A

A 49 year old male is hit by a van while crossing the street. Details of the accident were uncertain. EMS reported transient loss of consciousness at the scene and noted that the patient was mildly confused and oriented x 2 when they arrived. BP: 140/90, P: 100, R: 28. The patient was immobilized on a long board and transported.

In the "Trauma Slot" the patient was fully awake and alert. He was anxious and complained of pain in his right hip. He could not recall details of the accident.

Examination: BP: 120/88, P: 88.

HEENT: PERRL, EOMI, contusion above left eyebrow. No hemotympanum.
Neck: no tenderness or deformity.
Chest: tenderness and crepitus left lateral chest wall with questionable diminished breathsounds on the left.
Abdomen: non-tender. Pelvic brim stable.
Extremities: tenderness and swelling right proximal thigh; pain on motion of left hip; tenderness and ecchymosis of ulnar aspect of left hand. Good distal neuro-vascular function.
Neuro: no focal deficits (limited by pain in lower extremities).
Rectal: normal prostate and sphincter tone; stool guiac negative.
Back: no tenderness, ecchymosis or abrasion.

A chest **tube** was inserted on the left without return of blood or air.

Radiographs of the cervical spine, chest, pelvis and extremities revealed fractures of the right proximal femur, left acetabulum, left ribs 4-6, and left 5th metacarpal.

Urinalysis: negative for blood. **ABG:** 7.35/37/177 **(Fi 02: 100%).**

Serial hematocrit dropped from 44→42→38 with 1 liter LR. BP remained stable.

Diagnostic peritoneal lavage was negative. **Head CT** was negative.

The patient was admitted to the SICU.

The next morning he became **acutely short of breath** and hypoxic, requiring endotracheal intubation. An emergency pulmonary angiogram was negative for pulmonary embolism.

What would your management be at this point ?

The initial chest x-ray is shown.

After reviewing the case, go on to Case B before reading the answer

26

Why Order a Chest X-Ray in Patients with Blunt Trauma to the Chest?

For many types of traumatic injuries to the thorax, the diagnosis is evident by clinical findings; radiography serves simply to confirm the clinical impression (pneumothorax, hemothorax, rib fractures). However, traumatic tear of the aorta is a life-threatening injury that is notorious for its lack of clinical findings. Up to one-quarter of patients will have no external signs of thoracic trauma. The detection of aortic injury is perhaps the most crucial role of chest radiography in trauma patients. However, there is considerable uncertainty regarding the radiographic signs seen with this injury.

In 80% to 90% of cases, the aortic wall is completely tom, which is an immediately fatal exsanguinating injury. Patients who survive to reach medical care must therefore have an incomplete aortic tear and the hemorrhage is contained by the outer layers of the. aortic wall. This is an unstable condition. If untreated, most patients will suffer sudden fatal rupture and exsanguination. With prompt surgical treatment, survival is expected in 70% to 90% of patients. It is therefore essential to carefully consider this diagnosis in all patients who have sustained a sufficient mechanism of injury.

The definitive diagnostic test for aortic injury is an **aortogram.** Helical CT and transesophageal echocardiography (TEE) are being used experimentally to diagnose the aortic tear and may, in the future, replace aortography. Selection of patients for aortography involves consideration of the mechanism of injury and the findings on the initial chest radiograph. These are all patients who have experienced major traumatic forces. especially abrupt deceleration such as in a high speed motor vehicle collision or a fall from great height. Most patients have concomitant injuries to the abdomen, pelvis, head or extremities. External signs of chest trauma such as ecchymosis, fractures of ribs or sternum or palpable tenderness are suggestive. Direct physical signs of aortic injury, such as pulse deficits are infrequent. Selection criteria for aortography are not very specific. and only about 15% of aortograms will be positive. However, obtaining a large number of negative aortograms is necessary in order to avoid missing cases of this highly lethal but treatable injury.

It is important to carefully scrutinize the initial chest radiograph for findings suggestive of aortic injury. The plain film does not, in fact, visualize the aortic injury directly: rather it detects hemorrhage into the **mediastinum.** The source of this blood is not the injured aorta since this would be fatal; it comes from smaller branch vessels such as the intercostal arteries. internal mammary artery or corresponding veins. These vessels can be injured either with or without a concomitant aortic injury. This accounts for the unavoidably low specificity of mediastinal hemorrhage in diagnosing aortic injury.

The radiographic hallmark of mediastinal hemorrhage is **widening** of the **mcdiastinum.** However. the criteria used for increased mediastinal width are variable: greater than 8.0 cm. on a supine film. greater than 6 cm. on an upright PA film, greater than 25% of the thoracic width at the aortic knob or the subjective impression of an experienced radiologist. The second most frequent sign of mediastinal hemorrhage is an **indistinct** or distorted aortic contour (aortic knob and descending aorta). The major problem with these two radiographic signs is that they can be mimicked or obscured by suboptimal radiographic technique, which often occurs with supine portable films especially if the patient has not taken a full inspiration. For this reason, “subjective impression” can he more reliable than actual measurements in discerning mediastinal

26

abnormality since an experienced observer can account for changes due to radiographic technique. In any event, the detection of mediastinal blood requires that the film be obtained with sufficiently good technique since, on a suboptimal film, it may be impossible to reliably 'detect or exclude mediastinal abnormalities. If the patient is stable, a repeat upright film with full inspiration can clarify the radiographic appearance of the mediastinum. An additional problem with the use of mediastinal widening as a sign of aortic injury is that 5% to 10% of aortic injury cases with not have a widened mediastinum. These cases will have more subtle radiographic signs of mediastinal blood.

Several other signs of mediastinal hemorrhage can be more reliable than mediastinal widening or an indistinct aortic contour because they are less dependent on radiographic technique and "subjective impression." **These are** due **to'distortion of mediastinal anatomy.** Identification of these signs requires knowledge of normal mediastinal radiographic anatomy (figure). These findings are: opacified aortico-pulmonary window (normal clear-space between the aortic arch and the left main pulmonary artery), widened right para-tracheal stripe, widkning of the left or tight para-spinal line, and spread of the mediastinal blood-over the apex of the left lung forming a left apical pleural "cap." Additional signs of aortic injury 'are caused by mass **effect** of blood surrounding the aortic arch which displaces adjacent structures such as the trachea, left mainstem bronchus and esophagus (with naso-gastric tube).

Whether a **normal** chest film excludes an aortic injury is a subject of controversy. In the radiology literature, careful review of the radiographs of aortic injury patients has not found (or only very rarely found) normal radiographs in these patients. However, these studies excluded technically suboptimal films and were conducted by expert trauma radiologists. In two recent clinical series, 5% to 7% of aortic injury cases had films that were interpreted as negative. However, the radiographs themselves were not shown and the quality of the radiographic technique was not discussed. From a practical standpoint, in a patient with a very high clinical suspicion of aortic injury based on the mechanism of injury and the presence of concomitant injuries, the diagnosis of aortic injury should be pursued with aortography (or CT) even with a negative chest film (many of these films will be technically suboptimal). Nevertheless, most patients (94% or more) admitted to trauma centers do not undergo aortography based on their clinical evaluation and the lack of findings on the chest film. A clear understanding of the radiographic manifestations of aortic injury as described here can improve the accuracy of the clinician's interpretation of the chest radiograph.

Since many of these patients have sustained multiple injuries, it is important to be systematic in their evaluation and establish correct management priorities. It should be remembered that initial survivors of aortic injury have an incomplete tear of the aortic wall and are not bleeding from the aorta itself. If the patient is hemodynamically unstable. a site of blood loss other than the aorta must be present. Abdominal, pelvic or intracranial hemorrhage should be identified and treated before the diagnosis of aortic injury is pursued.

Because conventional (non-helical) chest **CT** is not completely effective at detecting the aortic tear, it has not replaced aortography as the definitive diagnostic test for aortic trauma. However, CT is a very reliable means of visualizing mediastinal hemorrhage. CT serves a role in patients in whom the plain radiographic findings of mediastinal hemorrhage (mediastinal widening) are equivocal and the probability of aortic injury is

26

moderate or low. This is especially convenient if the patient is having a CT scan of another body region, such as the abdomen. Absence of mediastinal blood or an aortic wall abnormality on CT eliminates the need for aortography. If mediastinal blood is found, the patient must undergo angiography to search for aortic injury.

Case **A:** During the pulmonary angiogram (done to diagnose a pulmonary embolism as the cause of the patient's dyspnea), an abnormal aortic contour suspicious for a traumatic aortic injury was noted. An aortogram was performed which revealed an injury of the proximal descending aorta. The patient underwent emergency thoracotomy to replace the damaged portion of the aorta with a synthetic graft. His recovery was uneventful.

Review of the patient's **initial chest radiograph** reveals marked widening of the mediastinum (11 cm.). Despite the suboptimal technical quality (poor inspiration and rotation), the mediastinal contour is distorted. Definite signs of hemo-mediastinum are: abnormal convex contour above the aortic knob, wide right para-tracheal stripe (20 mm.), and left para-spinal line displaced 25 cm. The trachea is displaced to the left -- this is due to rotated positioning of the patient. Inhomogeneous opacification of the left lung is probably a pulmonary contusion. A displaced anterior sixth rib fracture can be seen in the lower left comer of the film.

Aortography demonstrated a flap extending across the aortic lumen and a pseudo-aneurysm. The aorta itself is of normal size, demonstrating that what appears to be a grossly enlarged aortic knob on the plain chest film is actually caused by blood surrounding the aortic arch and not the aortic pseudo-aneurysm itself.

Although the radiographic findings are retrospectively quite evident, the physicians caring for the patient were distracted by the multiple other injuries present (extremity, pelvic, abdominal).

Dyspnea occasionally occurs with traumatic aortic injuries purportedly due to compression of the trachea or mainstem bronchi by the expanding mediastinal hematoma.

Reasons that the diagnosis of traumatic aortic injury is missed

1. Lack of signs of external thoracic trauma
2. Distraction from consideration of this injury by other more common or obvious injuries -- abdominal, extremity or cranio-facial
3. Failure to appreciate the plain radiographic signs of aortic injury
4. Attributing the radiographic findings to the AP supine technique
5. Not obtaining a portable chest film with the best possible technique (poor inspiration)
6. Normal chest radiograph (controversial, seen in none to 10% of cases depending on the series, radiographic quality and interpreter)

Case B: Despite the description of a severe mechanism of injury, the patient appeared quite well. (Probably. he had slowed his car down considerably by the time of impact.) Although the chest film appears to show mediastinal widening (over l 1 cm.) and an indistinct contour. it was an AP supine film with a very poor inspiration which could account for this appearance. The trachea is deviated to the right, which is suggestive of aortic injury; however the patient was positioned with rightward rotation. as indicated by the displacement of the medial clavicle heads relative to the spinous processes.

26

Interestingly, a normal right paratracheal stripe can be discerned despite the poor radiographic technique. There were no other clinical or radiographic signs of chest trauma such as rib fractures, pulmonary contusion or hemothorax.

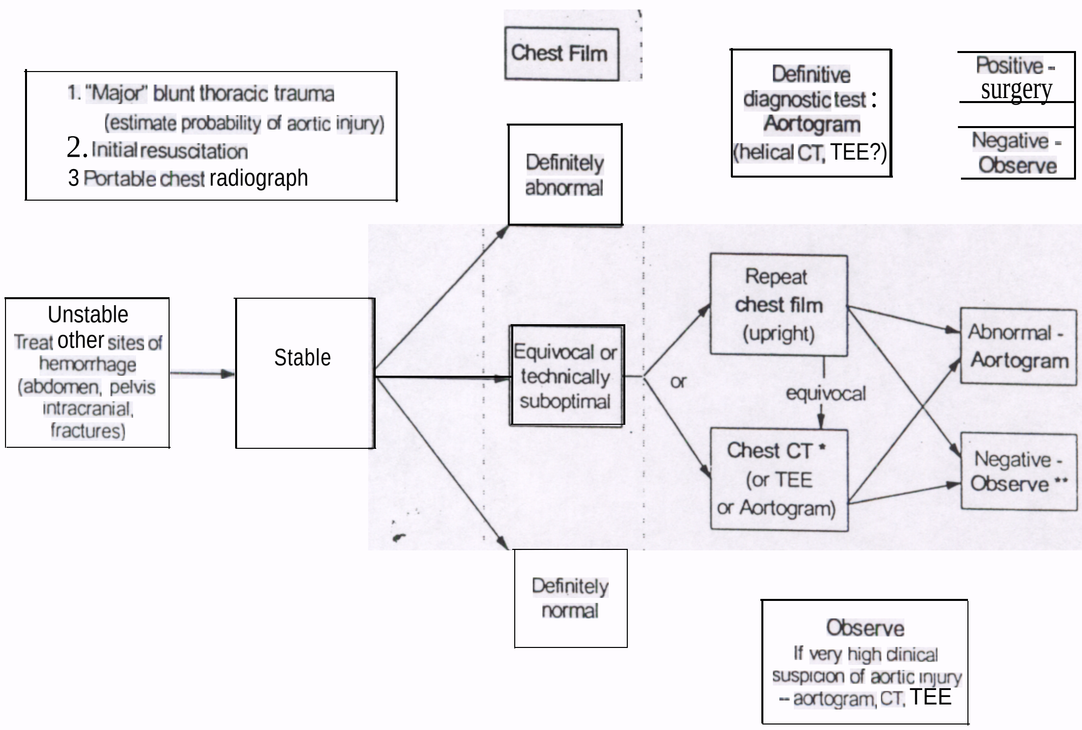
The patient was stable enough to have a **repeat AP upright chest film** with better inspiration. This was normal. Although, the mediastinum is not as well defined as on a PA film, several features can be identified. There is a normal concave aortico-pulmonary window. The right paratracheal stripe is normal (2 mm.). The right border of the superior mediastinum is the superior vena cava. This radiograph illustrates the difficulty in measuring mediastinal width -- it is 7.3 cm. including the superior vena cava, and 5.8 cm. without it.

Because of the mechanism of injury, he had a CT scan looking for intraabdominal injuries. Several CT images were'taken of the chest which confirmed the absence of mediastinal hemorrhage and excluded aortic injury.

Causes of mediastinal widening on portable radiographs

1. AP vs. PA technique enlarges anterior structures which are further from the film
2. Short distance between film and x-ray so&also magnifies anterior structures
3. Supine vs. upright position causes mediastinal soft tissues to flatten and become broader and the SVC becomes distended
4. Shallow inspiration is a major &correctable cause ofmediastinal widening
5. Rotated positioning of the patient
6. Lordotic projection further magnifies anterior structures

Diagnostic Imaging in Patients with Suspected Blunt Aortic Injury



-- CT will confirm or exclude an abnormal mediastinum (hemo-mediastinum or aortic wall abnormalites)
** If there is very high clinical suspicion of aortic injury consider ordering aortogram

26

Chest Radioeranhic Signs of Traumatic Aortic Injury

Identifies hemorrhage into the mediastinum, not the aorticinjury itself.

Mediastinal hematoma -- the source of bleeding is branch vessels, not the aorta itself.

Wide mediastinum:
- "Subjective impression"
- >8 cm. on supine film
- Mediastinal/chest width ratio > 25%
  - Dependent on technique of the film: AP, supine, level of inspiration
  - 5% to 10% of aortic injury cases will not have mediastinal widening on good quality chest films

Indistinct or distorted mediastinal contour: aortic knob, descending aorta
(This can also be caused by suboptimal radiographic technique)

Opacification of the aortico-pulmonary window

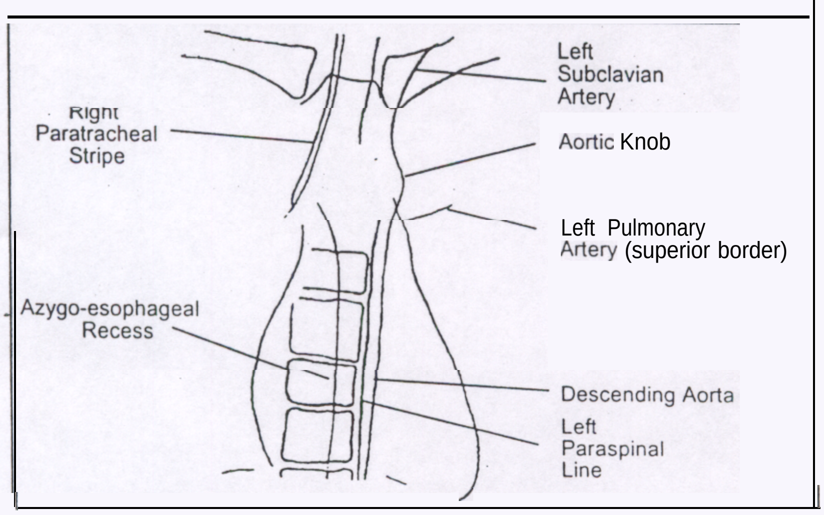
Wide right paratracheal stripe

Left paraspinal line widened or extending above aortic knob

Left apical pleural cap

Mass effect of blood surrounding the aortic arch:
- Tracheal displacement
- NG tube displacement
- Depressed left mainstem bronchus

Signs of severe chest trauma (clinical and radiographic)
- Rib fractures - I st or 2nd ribs
- Pulmonary contusion
- Hemothorax
- Pneumothorax
- Diaphragm rupture



Normal Mediastinal Pleural Lines

The left **subclavian** artery shadow disappears at the superior border of the clavicle.
The **right paratracheal stripe** is normally < 5 mm. wide. It terminates inferiorly at the arch of the azygos vein.
The **left paraspinal line** can be up to 15 mm. wide. It normally disappears above the aortic knob.
The **aortico-pulmonary window** is the clear space under the aortic arch and above the superior border of the left pulmonary artery.
The **azygo-esophageal recess** is the medial border of the right lung under the arch of the azygos vein. It is located just anterior to the vertebral column. The lung surface lies against the esophagus (not the medial border of the descending aorta).

Harris JH, Harris WH, Novelline RA: The Radiology of Emergency Medicine, 3rd ed. Baltimore, Williams and Wilkins, 1993, pp. 536-563.

White CS, Mirvis SE, Templeton PA: Subtle chest radiographic abnormalities in patients with traumatic aortic rupture. Emerg Radiol 1994;1:72-77.

Woodring JH: The normal mediastinum in blunt traumatic rupture of the thoracic aorta and brachiocephalic arteries. J Emerg Med 1990;8:467-476.

Lee FT, Katzberg RW, Gutierrez OH, et al: Reevaluation of plain radiographic findings in the diagnosis of aortic rupture: the role of inspiration and positioning on mediastinal width. J Emerg Med 1993;11:289-296.

Mirvis SE, Bidwell K, Buddemeyer EU, et al: Imaging diagnosis of traumatic aortic rupture. Invest Radiol 1987;22:187-196. (Critical literature review)

Mirvis SE, Bidwell JK, Buddemeyer EU, et al: Value of chest radiography in excluding traumatic aortic rupture. Radiology 1987;163:487-493.

White CS. Mirvis SE: Pictorial review: imaging oftraumatic aortic injury. Clin Radiol 1995;50:281-287.

Creasy JD, Chiles C, Routh WD, Dyer RB: Overview of traumatic injury of the thoracic aorta. Radiographics 1997;17:27-45. (Pictorial review)

Clinical

Fabian TC, Richardson JD, Croce MA, et al: Prospective study of blunt aortic injury: Multicenter trial of the American Association for the Surgery of Trauma. J Trauma 1997;42:374-80. 7% of patients had “normal” chest radiographs.

Hunt JP. Baker CC, Lentz CW. et al: Thoracic aorta injuries: management and outcome of 144 patients. J Trauma 1996;40:547-555. 5% of patients had “normal” chest radiographs.

Pate JW, Fabian TC, Walker W: Traumatic rupture of the aortic isthmus: an emergency? World J Surg 1995;19:119-25.

Pretre R. Chilcott M: Blunt trauma to the heart and great vessels. New Engl J Med 1997; 336: 626-632.

Imaging Modalities: CT, TEE

Mirvis SE, Shanmuganathan K. Miller B, et al: Traumatic aortic injury: diagnosis with contrast enhanced thoracic CT. Radiology 1996 200:413-422.

Gavant ML, Flick P. Menke P, Gold RE: CT aortography ofthoracic aortic rupture. AJR 1996: 166: 955-961. (Helical CT)

Raptopoulos V: Chest CT for aortic injury: maybe not for everyone. AJR 1994; 162: IO 53- IO j j

Hollerman JJ: A rational approach for imaging of blunt thoracic trauma to exclude aortic injury. Emerg Radiol 1994;1:206-208.

Harris JH, Horowitz DR. Zelitt DL: Unenhanced dynamic mediastinal computed tomography in the selection of patients requiring aortography for the detection of acute traumatic aortic injury. Emerg Radiol 1995;2:67-76.

Smith MD. Cassidy JM, Souther S, et al: Transesophageal echocardiography in the diagnosis of traumatic rupture of the aorta. New Engl J Med 1995;332:356-62. Editorial pp. 389.

Minard G. Schurr MJ. Croce MA, et al: A prospective analysis of transesophageal echocardiography in the diagnosis of traumatic disruption of the aorta. J Trauma 1996; 40: 225-230. (Not 100% reliable)

Vignon P. Lagrange P. Boncoeur MP, et al: Routine transesophageal echocardiography for the diagnosis of aortic disruption in trauma patients without enlarged mediastinum. J Trauma 1996;40:422-7

27

27. A Fine Line

An isolated pneumothorax is the most frequent complication following a small diameter puncture wound to the chest. The patient may complain of chest pain or shortness of breath, or be asymptomatic: On examination, there are absent or diminished breath sounds on the involved side, although, if the pneumothorax is small or moderate in size, breath sounds may be equal.

An upright PA or AP chest film is the test of choice for detecting a simple pneumothorax. **The radiographic findings** are usually clear cut, although occasionally they can be subtle. The key radiographic sign is identification of **the fine white line** representing the visceral pleura of the collapsed lung. The line parallels the inner aspect of the thoracic cage. There is relative radiolucency and **an absence of lung markings** outside of this pleural line. Contrary to what would be expected, the radiodensity of the collapsed lung is not greater than the normal lung. This is because pulmonary blood flow diminishes in proportion to the amount of collapse (except in the case of near total collapse) (normal lung markings are pulmonary blood vessels). If the radiographic findings are uncertain, **an expiratory film** will increase the relative size of the pneumothorax, and cause compression of adjacent lung tissue making it more radiodense. A lateral decubitus film may be useful if the patient is unable to sit upright. In a supine patient. the pneumothorax collects in the anterior costophrenic sulcus and is seen as the **“deep sulcus" sign.** However, a pneumothorax is usually difficult to detect on a supine chest film.

Although various measurements have been applied to calculate the percent pneumothorax based on the PA chest radiograph, these are inaccurate. It is usually sufficient to describe a pneumothorax as **small** (apical, <10%), **medium** (in above case, 1 0-60%) or **large** (near total collapse).

Treatment of a traumatic pneumothorax requires chest tube re-expansion. Although small spontaneous pneumothoraces can be treated by catheter aspiration or simple observation, this is not generally recommended for traumatic pneumothoraces because of the greater potential for sudden deterioration. Sometimes a pneumothorax is identified on the superior slices of an abdominal CT that was done to screen for abdominal injuries. These might be fairly large if the patient only had a supine chest radiograph. However, very small pneumothoraces can be identified by CT. Management of these is controversial. If endotracheal intubation and mechanical ventilation is anticipated, a chest tube should be inserted to prevent the likely development of a tension pneumothorax during positive pressure ventilation.

Boyd AD: Pneumothorax and hemothorax, in Hood RM. Boyd AD, Culliford AT: Hood RM. Boyd AD. Culliford AT: Thoracic Trauma. 1989. W. B. Saunders.

28

28. Pneumomediastinum

Occasionally, it is unclear if a patient has sustained a traumatic injury or has a non-traumatic disorder. The abnormality in this patient could potentially be due to either -- pneumomediastinum. The chest film shows **streaky linear air densities** between the parietal pleura (a fine gray line) and the mediastinal structures (heart, great vessels). The air extends up the mediastinal fascial planes into the neck. On the lateral film, there is air surrounding the mediastinal structures, particularly the aorta. Soft tissue neck films show prevertebral air.

Pneumomediastinum can occur with blunt or penetrating **trauma** or can occur **"spontaneously." The source of the mediastinal air** can be the esophagus, the tracheo-bronchial tree or the lung. Injury to any of these structures should be suspected in these patients. Usually, the clinical picture provides adequate evidence as to which organ is the source of the mediastinal air.

The most frequent source of mediastinal air is the lung. Pneumomediastinum occurs in settings associated with high intrapulmonary pressures such as asthma, positive pressure ventilation (especially with non-compliant lungs), blunt thoracic or abdominal trauma or inhalational use of illicit drugs, especially crack cocaine. Alveolar air ruptures into the interstitial spaces of the lung and'dissects along the broncho-vascular sheaths to the hilum and then to the mediastinum.

Esophageal perforation can occur with blunt or penetrating trauma, including iatrogenic trauma (instrumentation). It also can occur following forceful vomiting (Boerhaave's Syndrome). The overall clinical picture of esophageal rupture is usually sufficiently distinctive to prevent confusion with the more benign forms of pneumomediastinum. With the possible exception of a small esophageal puncture, esophageal rupture is accompanied **by** considerable mediastinal inflammation and edema, seen radiographically as mediastinal widening.

Trachea-bronchial laceration occurs with penetrating trauma or severe blunt deceleration. It is a catastrophic injury usually associated with a pneumothorax and other pulmonary abnormalities. It is not likely to be confused with an isolated pneumomediastinum. **Distal ainvays injury** is generally caused by penetrating thoracic trauma. A pneumothorax with persistent air leak is the usual presentation. not an isolated pneumomediastinum.

The clinical **course of patients with an isolated pneumomediastinum** has not been rigorously studied. Potential complications include expansion of the pneumomediastinum leading to respiratory compromise or rupture of the mediastinal air across the parietal pleura causing a pneumothorax. In addition, an occult injury to the esophagus or proximal airways is a possibility. However, as discussed above. esophageal or tracheo-bronchial injury would usually be evident on clinical grounds, A recent small retrospective series of patients with spontaneous pneumomediastinum (17 patients, 13 associated with inhalation of illicit drugs) found that all patients had a benign clinical course. There were no complications such as respiratory decompensation, pneumothorax or occult esophageal perforation. The authors suggest that these patients do not necessarily need to be hospitalized. However, the number of patients studied was small and collected retrospectively. In addition, in the patient presented here, the etiology was open to question because of the history of chest trauma.

This patient was admitted to the hospital and observed for two days. He remained asymptomatic. A contrast esophagram did not show perforation. Other studies were not done (esophagoscopy or bronchoscopy). The etiology was most likely due to valsalva during drug inhalation. Of course, in patients who have used cocaine and who present to the Emergency Department with chest pain, myocardial ischemia must also be considered.

The air seen surrounding the heart should not be misinterpreted as a **pneumopericardium** (air within the pericardial sac). In this patient, the air adjacent to the heart is an extension of the pneumomediastinum which has dissected into the virtual space' between the parietal pleura and parietal pericardium. The thin membrane seen surrounding the heart is therefore the parietal pleura not the pericardium. Pneumopericardium is rare. It occurs with blunt or penetrating trauma that tears the thick fibrous pericardium. Blunt trauma must be of significantly greater force than that causing a pneumomediastinum. Penetrating injury includes iatrogenic instrumentation, e.g., pericardiocentesis.

Radiographically, pneumopericardium can be distinguished from pneumomediastinum in two ways: 1) the pericardium is considerably thicker than the parietal pleura and is seen as a thicker gray line between the air surrounding the cardiac silhouette and the lung; and 2) air within the pericardial sac does not extent superior to the aortic root. Nevertheless, pneumopericardium is rare and the clinical settings in which it occurs is usually distinctive (severe blunt chest trauma, penetrating cardiac injury or instrumentation).

Panache EA., Singer AJ, et al: Spontaneous pneumomediastinum: clinical and natural history. Ann Emerg Med 1992;2 I :1222-1227.

Smith BA, Ferguson DB: Disposition ofspontaneous pneumomediastinum. Am J Emerg Med 1991:9:256-259.

Harris JH, Harris WH, Novelline RA: The Radiology of Emergency Medicine. 3rd cd Baltimore. Williams and Wilkins. 1993, pp. 520-535.

29. Bow Tie

The ABC's is a convenient mnemonic device for the interpretation of the lateral cervical spine film. In this patient, the **alignment** is normal. There is no evident fracture or distortion of the **bones.** The intervertebral disk spaces **(cartilage)** are all equal and there is no thickening of the prevertebral soft tissues.

The ABC's mnemonic does not encompass all of the features necessary to analyze the lateral view. This includes the alignment of the articular **facets and lateral masses of** C-3 to C-7. Each vertebra has two lateral masses (left and right). In a properly positioned lateral view, both are superimposed. In this patient's lateral film, there is slight rotation so the articular facets do not exactly'overlap. At C-3, there is an abrupt increase in rotation and the two lateral masses of C-3 are widely separated. This creates a double-diamond or **bow tie** appearance. This abrupt rotational malaligmnent is characteristic of unilateral facet dislocation.

With unilateral **facet dislocation, the articular facet** of one vertebra has slipped up and over the articular surface of the subjacent vertebra, and the lateral mass of the superior vertebra is dislocated into the neural foramina. This is sometimes called "locking" of the facet joint since the involved lateral mass is usually fixed in the dislocated position. Unilateral facet dislocation can be &table if there is a large fracture of the articular mass.

The **mechanism of injury** responsible for unilateral facet dislocation is distractive-flexion which separates the posterior elements of the spinal column. Rotational forces direct the injury to one side of the vertebral column. Unilateral facet dislocation does not usually cause spinal cord injury because the spinal canal is usually only slightly narrowed. However, displacement of the articular facet into the neuroforamina can cause nerve root injury (seen in approximately 50% of cases),

In many instances, unilateral facet dislocation is obvious radiographically. However, the radiographic findings can be subtle in up to 25% to 50% of cases, which can cause a delay in diagnosis.

The **radiographic signs of unilateral facet dislocation are: (Young, 1989 - 27 cases)**

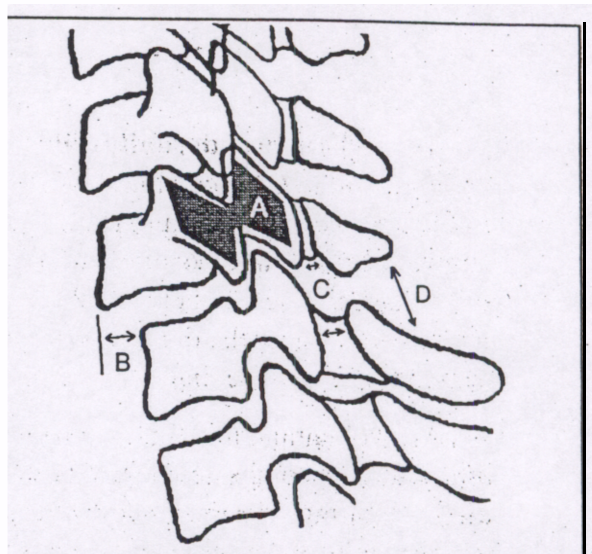
1. **Anterior displacement** of the vertebral body up to 50% of the vertebral body width. (22/27)
2. LOSS of superimposition of the lateral masses and articular facets that occur abruptly at one level which creates a **bow tie** or double-diamond appearance, The rotated lateral mass can be difficult to see if it overlies the vertebral body. (9 of 27 cases)
3. Abrupt reduction of the space between the posterior cortex of the lateral mass and the spino-laminar junction (the "laminar **space")** compared to the subjacent levels. (23/27)
4. **"Fanning"** of the spinous processes (increased interspinous distance). (I 0 of 27 cases)

29

In this patient, a double diamond is seen at C-3 with complete loss of the laminar space. There is no malalignment of the vertebral bodies which contributes to the difficulty in diagnosis in this case.

Additional radiographic views can help confirm this injury. On the **AP view, the** tips of the spinous processes should be aligned in a straight line and be evenly spaced. With the rotational deformity of unilateral facet dislocation, the spinous processes at the level of the injury abruptly shift to one side. This is not seen in this patient because the rotation is at and above C-3 which is obscured by the overlying mandible.

Oblique views are helpful in assessing the alignment of the posterior portion of the neural arch. On the normal oblique view, the laminae align like the "shingles on a roof." With unilateral facet dislocation, this alignment is disrupted, especially on the involved side.



Bow Tie: Abrupt rotation causes the reticular masses to lie adjacent to one another rather than overlap as at subjacent vertebrae.

- Anterior translation of vertebral body up to 50% of vertebral body width.
- Abrupt narrowing of the "laminar space" (distanc between the posterior cortex of the articular mass and the spino-laminar junction).
- Fanning of the spinous processes and angulation of the vertebral bodies due to hyperflexion injury

On **axial CT,** the articular surfaces of the facets normally face each other. With unilateral facet dislocation, the articular facets face outward and the articular surfaces are "naked." In addition, CT can identify fractures of the posterior vertebral arch which are often impossible to see on plain film.

The **treatment** of unilateral facet dislocation can be problematic, and various management strategies have been proposed. Closed reduction with axial traction is successful in a quarter of cases. If closed reduction fails, open reduction and posterior fixation is recommended. If the dislocation is not reduced and allowed to heal by spontaneous fusion, there is a high incidence of persistent pain and limitation of motion. Some authors note that closed reduction can be hazardous if there are fracture fragments or disk protrusion into the spinal canal, because these can cause neurological damage during traction. Pre-reduction MRI (or CT with myelography) is therefore recommended to identify bone or disk in the spinal canal. Open reduction is advised in these cases.

This patient's radiographic findings were surprising because his clinical signs were minimal. A CT was done to better define his injury. The unilateral facet dislocation was confirmed. but the articular facets were deformed and hypertrophied, suggesting that this was a long-standing abnormality. The patient did not recall having had previous trauma even though this was the likely explanation Due to the poor outcome associated with unreduced facet dislocation. the benefits of reduction were carefully considered. However. because the patient was asymptomatic, it was decided not to attempt reduction.

Young JW. Resnik CS, DeCandido P, Mirvis SE: The laminar space in the diagnosis of rotational flexion injuries of the cervical spine. AJR 1989;152:103-7.

30

Case 30

The right **lateral decubitus** film does not show a free-flowing effusion. Air pockets are seen within the area of increased density at the right lung base (these air pockets can, in fact, be seen on the.initial PA chest film). The film was initially interpreted as showing colonic interposition (an uncommon anomaly in which the hepatic flexure of the colon has migrated up between the liver and diaphragm -- this is occasionally confused with free air under the diaphragm). The correct interpretation is that bowel had herniated across a defect in the diaphragm and entered the thoracic cavity.

After obtaining this film, the patient was questioned regarding any prior traumatic injuries. ‘Six months ago he had been involved in a motor vehicle accident. He was the driver, wearing a seatbelt, and was evaluated in an Emergency Department, but was not hospitalized. Seven years ago he had been **stabbed in the right lateral chest.** He had a collapsed lung that was treated with a chest tube. The patient, indeed, had a small thoracostomy scar on his right chest wall.

The patient was admitted for repair of a **diaphragmatic hernia.** A pre-operative CT confirmed hemiation of both large and small bowel into the right chest. Interestingly, four years earlier he had had an evaluation for an abnormal chest x-ray film. An upper GI series showed hemiation of part of the stomach and small bowel. The patient refused surgery at that time.

At operation, a 5 x 6 cm. hole in the diaphragm was found. Herniated colon, stomach, omentum, liver, and gall bladder were reduced. The diaphragmatic defect was closed.

30

Is it a stab to the chest or the abdomen ?

Isolated diaphragmatic injury following traumatic events, either blunt or penetrating, can be difficult to detect. If there is massive hemiation of abdominal contents into the thorax, the diagnosis is obvious on plain radiographs. Large diaphragmatic tears are more typical of blunt trauma. The left side is almost exclusively involved because the right side is protected by the liver. With penetrating'wounds to the lower chest, the defect in the diaphragm can be small. A diaphragmatic injury can be inferred if the patient has signs of intraperitoneal injury (pain, tenderness or hemorrhage). However, isolated diaphragmatic injuries, or those with minimal intra-abdominal involvement, are notoriously difficult to diagnose. Management of lower chest stab wounds' is a subject of controversy.

It is important to detect these injuries early. Over time, abdominal contents will pass into the thorax because of the pressure differential between the chest and abdomen. Delayed complications of diaphragmatic hernias include visceral incarceration and strangulation. Respiratory insufficiency can occur if a large portion of the lung is displaced. The diaphragmatic defect should be repaired before these complications occur.

Techniques to diagnose diaphragmatic injuries include plain'chest radiography, CT, diagnostic peritoneal lavage (DPL) , laparotomy, and, recently, thoracoscopy.

Plain chest films will show gross hemiation of abdominal contents. With lesser injuries. only non-specific signs are seen, such as irregularity of the diaphragmatic contour or atelectasis at the lung base. CT is able to detect lesser degrees of hemiation of abdominal contents. However, without hemiation, CT is unable to visualize defects in the diaphragm. Some centers advocate mandatory laparotomy for all patients with penetrating trauma to the lower thorax. They argue that there is a lack ofreliable diagnostic techniques and have found a relatively high incidence of occult diaphragmatic injuries with this strategy (Stylianos). DPL has been used to evaluate anterior abdominal stab wounds and has also been advocated for lower thoracic wounds. However, because diaphragmatic injury may cause only minimal bleeding, the criterion for a positive DPL is lowered to 5.000 RBC/ml. False positive and negative results remain a problem. Recovery of peritoneal lavage fluid from a chest tube is good evidence for diaphragmatic penetration. The instillation of radio-contrast dye into the peritoneal cavity in the hope of identifying it on radiographs of the chest has not proven accurate.

Madden I-1. Paull D. Shires. et al: Occult diaphragmatic injury from stab wounds to the lower chest and abdomen. J Trauma 1989:29:292-298.

Root HD: Injury to the diaphragm, in Moore EE, Mattox KL, Feliciano DV: Trauma, 3rd ed. Norwalk CT, 1996. Appleton and Lange.

Stylianos S. King TC: Occult diaphragm injuries at celiotomy for left chest stab wounds. American Surgeon 1992:58:364-368.

Pagliarello G. Carter J: Traumatic injury to the diaphragm: timely diagnosis and treatment. J Trauma 1992:33:194-197

Mueller CF. Pendarvis RW: Traumatic injury oithe diaphragm: report of seven cases and extensive literature review. Emerg Radiol 1994;1:118-132.

Cameron EW. Mirvis SE: Ruptured hemidiaphragm: unusual late presentation. J Emerg Med 1996;14:53-58.

31

31. Occult Injuries from Penetrating Wounds

Penetrating trauma has the potential to injure deep structures with minimal overt clinical findings. Seemingly innocuous wounds may harbor injuries to vital structures. If substantial pathology is missed, there could be either sudden or delayed complications (e.g., ischemia; hemorrhage or sepsis). The opposite concern is how aggressively should one pursue the diagnosis of a concealed injury in a patient who may only have suffered only minor trauma. Invasive testing places the patient at risk for iatrogenic complications.

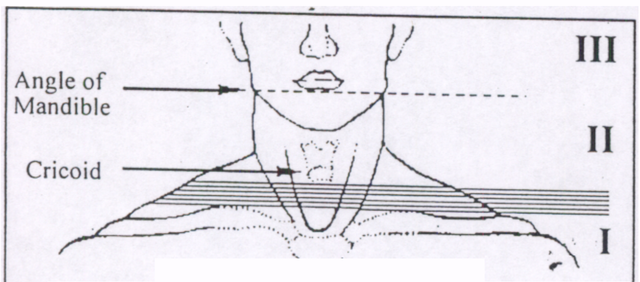
These concerns are especially heightened for **penetrating wounds to the neck.** The neck has a great number of vital structures in close proximity. Because of the difficulty in assessing patients without obvious signs of visceral injury, the management of penetrating neck injuries is the subject of considerable debate. Recommendations vary from: 1) mandatory exploration of all wounds that penetrate the platysma; 2) close observation for signs of deep structure injury; or 3) invasive diagnostic testing. The last approach entails angiography, esophagography, esophagoscopy, laryngoscopy and/or bronchoscopy. The specific approach depends on:

- the mechanism of injury: gunshot or stab wound;
- the location of injury: zone I (cervico-thoracic); zone II (mid-neck); zone III (cervico-cranial) (see figure);
- the experience and resources of the treating institution: availability and skill of angiographers and endoscopists and the frequency with which such injuries are seen.

Approach of the Bellevue Hosoital Trauma Service

Patients with clinical signs of **visceral injury** undergo immediate neck exploration. These signs include an expanding hematoma or considerable hemorrhage, airway compromise, hoarseness, subcutaneous or prevertebral air, hemoptysis, hematemesis, odynophagia or neurological deficits (cerebral, spinal or cranial nerves).

For stable asymptomatic patients, management depends on the location of injury, **Zone II injuries** between the level of the cricoid cartilage and angle of the mandible are routinely explored. This is because of greater confidence in detecting all visceral injuries by surgical exploration as opposed to invasive diagnostic testing. A negative neck exploration has minimal morbidity in comparison to the consequences of a missed visceral injury. This policy of mandatory exploration is the subject of greatest controversy. Other institutions practice a selective approach to surgical exploration. Some institutions will observe the patient for clinical signs of visceral injury in the belief that such injuries would be evident by careful serial



The Three Zones of the Neck.
Most authors consider the shaded area part of zone I, others include it in zone II.

31

examinations. Others recommend invasive diagnostic testing which includes angiography, esophagography and/or esophagoscopy. The aim is to reduce the relatively high rate of negative neck explorations from 40-60% to as low as 10%.

For **zone I and III injuries** the technique of surgical exploration is more difficult. There is both greater surgical morbidity and greater potential for missing injuries. Therefore, a selective approach using angiography, esophogography and endoscopy is advocated. Surgical exploration is reserved for those patients with injuries identified on diagnostic testing. This patient was managed as a zone III injury.

Plain radiography can reveal air within the soft tissues (subcutaneous, prevertebral or pneumomediastinum). **In this patient,** a subtle but significant finding is **deviation of the trachea** to the left, indicative of hematoma formation in the right paratracheal area.

A **carotid angiogram** revealed a puncture wound of the common carotid artery with pseudo-aneurysm formation. A contrast esophagram and ENT exam with laryngoscopy were negative. The patient was electively intubated and surgically explored. The carotid laceration was repaired with a saphenous vein patch arteriorrhaphy. (Suture closure of carotid lacerations is associated with later stenosis at the suture line.)

A crucial issue in these patients is **airway management.** Early intubation is advocated to reduce the risk of sudden airway compromise from an expanding hematoma - a potentially disastrous situation. Nevertheless, there is a dearth of studies addressing this issue. A recently published retrospective series of 114 patients found that only 23% needed urgent airway control due to respiratory distress, airway compromise from blood or secretions. extensive subcutaneous emphysema. tracheal shift or severely altered mental status. 38% of patients were electively intubated at the time of surgical exploration and 39% were managed without intubation. None of the patients suffered complications related to airway management difficulties. Nevertheless, the risk of sudden airway compromise must be fully appreciated.

Asensio JA, Valenziano CP. Falcone RE. Grosh JD: Management of penetrating neck injuries: the controversy surrounding zone II injuries. Surg Clin North Am 1992;71:267-294.

Sclafani SJA. Cavaliere G, Atweh N. Duncan AO, Scalea T: The role of angiography in penetrating neck trauma. J Trauma 1991:31:557-563.

Narrod JA. Moore EC. Initial management of penetrating neck wounds a selective approach. J Emerg Med 1984:2:17-22.

Golueke PJ. Goldstein AS. Sclnfani SJA. Mitchell WG, Shaftan GW: Routine versus selective exploration of penetrating neck injuries: a randomized prospective study. J Trauma 1984;24:1010-1014.

Eggen J F. Jorden RC: Airway management, penetrating neck trauma J Emerg Med 1993:11:381-385

32

Case 32

A 5 1 year old male presents with progressive **abdominal pain** of one day duration. There is no associated nausea, vomiting, diarrhea or melena. The pain radiated to his left shoulder.

He has a history of alcoholic hepatitis, COPD, and surgical repair of a colonic-bladder fistula ten years ago. He had had mild constipation and abdominal discomfort for the past few months.

On examination the patient was in moderate distress due to abdominal pain.

Vital Signs: BP - 130/70, P - 118, R - 24, T - 102.4' rectal.

His abdomen was distended but soft with mild diffuse tenderness and no rebound tenderness. There was possible shifting dullness. His stool was negative for occult blood. He was anicteric.

The initial chest and abdominal **radiographs** were interpreted as negative. In addition, 300 cc of air was insufflated via a nasogastric tube. The abdominal film was repeated. The air noted under the left hemidiaphragm was felt to be in his distended stomach.

The patient was admitted to the hospital with a diagnosis of **spontaneous bacterial peritonitis** and was treated with cefoxitin and metronidazol. The next day, because of persisting abdominal pain and fever, an abdominal CT was performed which revealed the correct diagnosis. Review of the original films show that the diagnosis was evident initially.

What are the significant findings on the films posted ?

What additional study could have been done to confirm these findings, other than a CT ?

32

32. The Low Yield of Abdominal Plain Films

The plain abdominal radiograph has a low yield in providing a specific diagnosis in most patients presenting with abdominal pain. Its main utility is in the diagnosis of bowel obstruction or perforation. Most cases of perforation or obstruction are evident clinically and the radiograph serves mainly to confirm the diagnosis. Occasionally, the clinical presentation of bowel obstruction or perforation is obscure, and radiography will provide the diagnosis. However, the radiographs must be correctly interpreted to yield accurate information.

The plain film is a very sensitive test to detect bowel **perforation,** being positive in 85 - 90% of cases. It can detect as little as 1 - 2 cc of air using optimal technique (Miller RE, Nelson SW. AJR 1971; 112: 574-585). Instances where plain radiography fails to reveal free air include a perforation that is quickly sealed by overlying omentum, perforation into the lesser sac, free air loculated by peritoneal adhesions, and perforation of the small bowel which normally contains little air.

The most sensitive radiograph to demonstrate free air is the upright **chest film** which shows free air under the diaphragm, In the above case, the patient had free intraperitoneal air that was not seen on the chest film -- Why?

Large amounts of subdiaphragmatic air can be seen on the **upright abdominal film,** although the findings are subtle. One region in which to look for this is **called** the **middle dome of the diaphragm -** a relatively flat region of the diaphragm that crosses the midline anteriorly. This portion of the diaphragm is usually not visible because both the heart and intra-abdominal soft tissue have similar radiodensity. If there is free air under the "middle dome" of the diaphragm. it will appear as a crescent shaped air density overlying the lower thoracic vertebrae in the midline. It can be seen in this case and in a second case displayed for comparison.

Free air under the left hemi-diaphragm is often impossible to differentiate from air within the stomach. In the above case, the large collection of air under the left hemidiaphragm was not seen before air was insufflated into the stomach. It therefore was possibly an air bubble within the distended stomach. This confusion does not occur with free air under the **right hemi-diaphragm** because that region is normally occupied by the solid soft tissue density of the liver. If the suspected free air is under only the left hemi-diaphragm, the patient can be placed in the left lateral decubitus position (left side down) for several minutes. The intraperitoneal air will migrate to the right flank. The upright chest film is then repeated to visualize the air under the right hemi-diaphragm.

Although the upright chest film is the most sensitive view for seeing free air, it must be done with proper technique to be effective. The x-ray beam must be horizontal to best demonstrate the nit- collection under the diaphragm. This patient was not in a full upright position. The film was taken AP with the patient sitting "erect" in the stretcher with the beam directed downwards.

32

In a patient who is too ill to obtain a true upright chest film, an alternative view is the **left lateral decubitus abdominal film. The** free air will collect under the highest portion of the peritoneal cavity in this position, usually between the right side of the liver and the lateral right ribs. The film is exposed with low penetration ("chest technique") and a horizontal beam. The air collection may be difficult to distinguish from the overlying ribs. Alternatively, the air may collect in the region of the right iliac crest, and this area must also be inspected for evidence of free air.

An **abdominal CT** performed early the next morning revealed a large amount of free air in the upper abdomen, predominantly loculated under the left hemi-diaphragm. The patient underwent an emergency **exploratory laparotomy.'** Copious purulent material was found in the abdominal cavity. A large **perforated gastric ulcer** was noted in the posterior wall of the stomach. A subtotal gastrectomy with Billroth II gastrojejunostomy was performed. The ulcer was benign.

Shaffer HA: Perforation and obstruction of the gastrointestinal tract: assessment by conventional radiology. Radio1 Clin North Am 1992;30:405-426.

Cho KC, Baker SR: Extraluminal air: diagnosis and significance. Radio1 Clin North Am 1994;32:829-845.

Woodring JH, Heiser MJ: Detection of pneumoperitoneum on chest radiographs: comparison of upright lateral and posteroanterior projections. AJR 1995;165:45-47. (In 20% of patients pneumoperitoneum was seen on the lateral CXR, but not on the PA film,)

Markowitz SK, Ziter FMH: The lateral chest film and pneumoperitoneum. Ann Emerg Med 1986;15:425-427. (In 14% of patients pneumoperitoneum was seen only on the lateral film.)

Lee CW, Yip AW, Lam KH: Pneumogastrogram in the diagnosis of perforated peptic ulcer. Aust N Z J Surg 1993;63:459-461. (Upright CXR detected only 66% of perforated peptic ulcers. Insufflating 200 cc. of air via a nasogastric tube increased the yield to 90%.)

Maull KI. Reath DB: Pneumogastrography in the diagnosis of perforated peptic ulcer. Am J Surg 1984;148:340-345.

Levine MS, Scheiner JD, Rubesin SE, Laufer I, Herlinger H: Diagnosis of pneumoperitoneum on supine abdominal radiographs. AJR 1991;156:731-735.

Menuck L. Siemers PT: Pneumoperitoneum: importance of right upper quadrant features. AJR 1976;127:753-756.

Miller RE. Nelson SW: The roentgenologic demonstration of tiny amounts of free intraperitoneal gas: experimental and clinical studies. AJR 1971;112:574-585. (Classic paper.)

Miller RE, Becker GJ. Slabaugh RD: Detection of pneumoperitoneum: optimum body position and respirator), phase. AJR 1980;135:487-490.

Stapakis JC, Thickman D: Diagnosis of pneumoperitoneum: abdominal CT vs. upright chest film. J Comput Assis Tomogr 1992;16:713-716.

Jeffrey RB, Federle MP. Wall S: Value of computed tomography in detecting occult gastrointestinal perforation J Comput Assist Tomogr 1983;7:857-827.

33

33. What makes something radiopaque ?

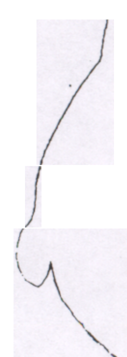
There **arc** several **factors** that contribute to the radiodensity of an object. Although we usually think of the intrinsic radiodensity of the substances making up an object as the major determinant of its radiographic appearance, the thickness of the object, i.e., its shape, plays a significant role in determining its x-ray image. This is illustrated in this case, in which the apparently radiodense object is actually composed of a relatively radiolucent substance.

The **intrinsic radiodensity** of a substance depends upon the **atomic numbers** of its constituent atoms and the concentration of atoms of high atomic number. A molecule will be more radiodense if it contains a greater proportion of atoms with high atomic numbers. The x-ray radiation is absorbed by matter when its energy is imparted to an electron in one of the inner orbital shells causing the electron to be ejected from the orbital. More x-ray energy is absorbed when the electron is tightly bound in its orbital. The force binding an electron in the orbital is a function of the positive electric charge of the nucleus, i.e., the number of protons in the nucleus (the atomic number). This is why bone that contains much calcium (atomic number 20) is more radiodense than soft tissue which is made up mostly of carbon (atomic number 6), hydrogen (atomic number 1), and oxygen (atomic number 8). Lead (atomic number 82) is a very effective barrier to x-rays, and iodine (atomic number 53) is the key constituent of radiocontrast dye.

In this case, however, the **shape of the object** (in this instance, the patient) determines its radiographic appearance. The radiodensity seen mid-abdomen on the AP film cannot represent **a** radiodense object within the abdominal cavity such as a solid ball (baseball?) that has been swallowed (or otherwise inserted) or a radiodense intra-abdominal tumor. Such an object would be readily visible within the abdomen on the lateral view. Thin flat objects can be difficult to see when viewed on end. However, a thin flat disc of sufficient radiodensity to give the above appearance on the AP film would be even more radiodense when viewed from the side on the lateral film.

When localizing objects in three dimensions, it is important to have at least two views in different. preferably perpendicular, planes. (Did the lateral help you in this case?) Nevertheless. **characteristics of the object's appearance on the AP film** indicate that it could not be a radiodense object contained within the abdomen. The object has very sharp, well demarcated margins inferiorly and laterally but its superior boarder is indistinct, gradually merging with the soft tissues of the abdomen. Hence. the object must be a broad based soft tissue mass protruding downwards from the anterior abdominal wall. Alternatively, it could be a soft tissue mass extending from the back of the patient, such as extremely large lipoma. If the lateral film is viewed with a very bright light. the soft tissue mass is faintly visible extending from the anterior abdominal wall.

This patient had end-stage renal disease and was being managed with peritoneal dialysis. He had developed a large umbilical hernia that was mildly tender and non-reducible (see figure of patient's torso in profile). The patient had no symptoms of bowel obstruction and the abdominal film did not show evidence of obstruction Because of the possibility that bowel was incarcerated within the hernia. the patient was taken to surgery. At operation. the hernia sac was found to contain loculated peritoneal fluid. The fluid collection was drained and the defect in the abdominal wall was repaired



34

Case 34

A 32 year old female presents five hours after being knocked down by an automobile. She was about to cross the street when the car, turning the corner at slow speed, side-swiped her. She was "winded" but got up soon after she was struck. After she rested for a while, her sister convinced her to go to a doctor at a nearby clinic. She was evaluated there and was found to have microscopic hematuria.

She was transferred to Bellevue for evaluation of her **hematuria.** She noted pain in the left lateral chest wall and left thigh. She had no head trauma or neck pain.

Her medical history was remarkable for hyperthyroidism diagnosed three months earlier. She was being followed by a doctor at that clinic.

On examination, she was a healthy appearing female in no acute distress.

Vital signs: BP - 120/70, P - 100, R - 18.
There were no orthostatic changes with standing.

There was tenderness and a small ecchymosis of her left lateral chest wall and her left anterior thigh. Breath sounds were equal bilaterally. Her abdomen was non-tender. Her pelvis and hip were stable.

The **urinalysis** had moderate blood on dipstick and 10-25 RBC/HPF. Her hematocrit was 34, unchanged from the value found three hours before at the clinic (MCV - 79).

A **chest x-ray and left rib films** were obtained

How would you manage this patient?

34

34. Bl[redacted]Tra[redacted]a an[redacted]Hematuria

The rib films revealed **fractures of the sixth and seventh left ribs.** During the two to three hours of evaluation, she remained stable but had continued pain of the left chest wall. She began to complain of nausea without vomiting. In addition, her resting tachycardia persisted, but still without orthostatic changes.

The evaluation of the patient with potential **blunt renal trauma and hematuria is** controversial. Generally, a patient with microscopic hematuria is presumed to have a minor urinary tract injury, such as a mild renal contusion, and does not require specific treatment. Patients with gross hematuria have a greater likelihood of significant renal injury and merit imaging studies. Patients hypotensive in the field or ED, however, can have significant renal injuries without hematuria. The traditional imaging study is an **IVP** looking for renal laceration, hematoma, extravasation of contrast or diminished function. In many centers, **CT** has become the preferred test because it provides better anatomic detail and has the ability to detect other abdominal injuries. Patients with blunt trauma and micro-hematuria without hypotension do not require urinary tract imaging with the possible exception of a forceful direct blow to the flank or severe deceleration injury. In some studies, hematuria has served as a marker for other abdominal visceral injuries. Above all, your management of a trauma patient should not limit its focus to one organ system.

Because of **this patient's** continuing left chest pain, general discomfort, nausea, and persistent tachycardia, a **CT of the abdomen** was obtained to search for visceral injury based on the mechanism of injury and her clinical appearance. This showed three **lacerations of the splenic parenchyma** and a minimal amount of peri-splenic blood. The patient remained hemodynamically stable and her splenic injury was managed non-operatively. A CT one week later showed resolution of the peri-splenic blood and no progression of the splenic lesions.

A **thyroid** evaluation revealed elevated thyroid hormone levels which might account for her continuing tachycardia. The patient was started on a beta-blocker and PTU.

The **spleen is the most frequently injured organ** in blunt abdominal trauma. The spectrum of injury ranges from exsanguinating hemorrhage to minimal symptoms that can escape diagnosis. Patients with undiagnosed splenic injuries are at risk for **delayed splenic rupture** one week or later after the traumatic event.

Signs of splenic injury should be carefully sought in all patients who have sustained trauma by a mechanism of injury that could potentially injure the spleen. The spleen can be injured by either a compressive force. such as a direct blow. or deceleration which creates shearing forces (the spleen is partly fixed to the retro-peritoneum and partly mobile).

(con't.)

34

Clinical **signs** suggesting splenic or other visceral injury in a hemodynamically stable patient are:

- **Hypotension,** which may be transient (e.g., observed only in the field).
- **Orthostatic hypotension** is a highly sensitive indicator of acute blood loss and must be specifically tested in all patients.
- **Tenderness** over the spleen. However, the abdominal exam in blunt trauma is notoriously unreliable. Fresh blood tends not to produce peritoneal irritation.
- **Rib fractures** on the lower left side, especially if multiple. Young children have very pliable ribs that do not fracture despite large forces and elderly patients have brittle bones that fracture with little impact.
- **Anemia,** or a falling hematocrit, is a poor indicator of acute blood loss; much less reliable than changes in vital signs.
- **Leukocytosis** is non-specific but correlates with occult visceral injury, esp. splenic.

Patients with underlying illness causing **splenomegaly** are especially prone to splenic injury with minimal trauma, such as mononucleosis, hematologic malignancy, and cirrhosis.

There are various **techniques to diagnose splenic injury.** Diagnostic peritoneal lavage **(DPL)** is very sensitive for intraperitoneal bleeding. However, it does not identify the source of hemorrhage or extent of splenic injury. **CT** is a highly reliable study for splenic injury. It can grade the degree of injury and is useful to follow patients being managed non-operatively. At centers with expertise in interpreting CT scans, CT has replaced DPL in the blunt trauma victim who is hemodynamically stable. It is most accurate for solid viscus injury, retroperitoneal and pelvic injury (a cause of false positive DPL).

Ultrasound has been used for blunt abdominal trauma and, in some European centers, has virtually replaced DPL. It is a rapid test, performed by the clinician at the bedside. The key finding is free intraperitoneal blood in the left or right pericolic gutters (Morrison's pouch between the liver and right kidney) and pelvis. In some instances, it is able to visualize the injury to the spleen or liver. Ultrasound's major use is in the rapid identification of intra-abdominal hemorrhage in severely traumatized patients. It has limited utility in guiding non-operative management of splenic or hepatic injuries. An interesting area for investigation would be ultrasound's reliability in screening patients with minimal clinical **signs** for solid viscus injury.

Mee SL. McAninch JW. Robinson AL. et al: Radiographic assessment of renal trauma: a 10 year prospective study of patient selection. J Urol 1989;141:1095-1098.

Knudson MM, McAninch JW, Gomez R, et al: Hematuria as a predictor of abdominal injury after blunt trauma. Am J Surg 1992:164;482-486.

Schneider RE: Genitourinary trauma. Emerg Med Clin North Am 1993;11:137-145.

Rozycki GS. Ochsner MG. Jaffin JH. Champion HR: Prospective evaluation of surgeon's use of ultrasound in the evaluation of trauma patients,. J Trauma 1993;34:516-527.

Jehle D. Guarino J. Karamanoukian H: Emergency department ultrasound in the evaluation of blunt abdominal trauma. Am J Emerg Med 1993;11:342-346.

Hoffmann R, Nerlich M, Mugga-Sullam M. et al: Blunt abdominal trauma evaluated by ultrasonography: a prospective analysis of 291 patients. J Trauma 1992;32:452-458.

Marx JA, ed.: Advances in Trauma. Emerg Med Clin North Am 1993:1 l(l).

35. The Differential Diagnosis of Jaundice

A plain abdominal radiograph is not usually helpful in the diagnosis of the jaundiced patient. In this case, it provided preliminary information that helped confirm the clinical impression before other laboratory evidence was available. Deducing the diagnosis from this limited information requires an understanding of the pathophysiology of bilirubin metabolism.

The most frequent causes ofjaundice are **decreased elimination of bilirubin** from the body either because of hepatocellular dysfunction or mechanical obstruction to the flow of bile in the extrahepatic biliary tracts. Less frequently, jaundice is due to **increased production of bilirubin** as occurs with the increased destruction of red blood cells in hemolytic anemia.

Liver function tests are useful to distinguish hepatocellular from obstructive jaundice. In obstructive jaundice, elevation of the canalicular enzyme, alkaline phosphatase, predominates. In hepatocellular dysfunction, transaminase elevation is greater. **The** serum **bilirubin** profile (direct (conjugated) and indirect (unconjugated)) is not useful in distinguishing obstructive from nonobstructive jaundice. In both cases there is a mixture of both direct and indirect bilirubin

When jaundice is due to increased bilirubin production, as occurs in **hemolytic anemia,** there is are increased levels of only unconjugated (indirect) bilirubin. All of the bilirubin conjugated by the liver will be readily excreted into the bile and the serum quantities of direct bilirubin will therefore not be elevated. Liver function tests will be normal. LDH of red blood cell origin will be elevated.

In this patient, absence of urinary bilirubin suggests that the jaundice is due to hemolysis; the elevated bilirubin is all unconjugated (indirect). The spleen is the site of RBC destruction and, in the above radiograph, the spleen is massively enlarged. The **splenomegaly** was suspected on examination but was difficult to confirm due to the patient's obesity. Radiographically, one sees a large soft tissue density in the LUQ displacing the stomach air bubble to the midline. The splenomegaly may be in reaction to the abnormal RBCs that are being removed from the circulation by the spleen. Alternatively, there may be a primary disease of the spleen causing splenomegaly such as infiltrative disease (neoplastic or metabolic). infectious or inflammatory disease or congestive splenomegaly due to portal hypertension. The splenomegaly in these cases causes pancytopenia due to sequestration and destruction of all blood elements by the spleen.

WBC 7.000 Hct. 20.9 reticulocytes 4.7% plt. 124.000

Bilirubin 4.82 (total). 0.50 (direct)

SGOT 30 SGPT 14 Alk. phos. 122 LDH 477

Coomb's Test: positive (direct) for anti-erythrocyte antibody on RBC surface

The patient's idiopathic immunohemolytic anemia was treated with prednisone (1 mg/kg/d) and her hematocrit steadily increased to 30 during her one week hospital stay

36

36. Rigler's Triad

This film shows the classic Rigler's Triad of gallstone ileus: 1) pneumobilia, 2) small bowel obstruction and 3) an ectopic gallstone (JAMA 1941; 117: 1753 - 1759). Rigler's Triad is, in fact, seen only in a minority of cases (25%).

Gallstone ileus is a disease of the elderly (average age 64). Most cases of gallstone ileus are not diagnosed preoperatively because of the lack of specific clinical or radiographic features. It is an uncommon cause of small bowel obstruction (1-2% of cases) but makes up a greater proportion of small bowel obstruction among elderly patients without prior abdominal surgery (up to 25% of this **much smaller group).** It is associated with a higher mortality (10-30%) than other causes of small bowel obstruction due to the age of the patient and more complex surgical treatment.

I) Pneumobilia -- In this case, an oval shaped air density is located over the liver shadow, too high to be within a loop of bowel. Furthermore, there is **a** tubular air density extending inferiorly from its medial aspect - air in the biliary ducts. Cholelithiasis is the most common cause of a biliary enteric fistula (90%). Because the gallbladder lies adjacent to the superior portion of the duodenum, 75% of fistulae form with this portion of the bowel. Twenty percent of fistulae connect to the transverse colon. The most common cause of air in the biiiary tree is a surgical procedure on the biliary system such as endoscopic sphincterotomy for common duct stones, or surgical anastomosis between the biliary tract and intestinal tract to drain an obstructed biliary system due to tumor, stricture, recurrent stones, etc.

2) Small bowel obstruction -- There are several loops of dilated small **bowel** in the mid-lower abdomen. On the upright film air fluid levels were seen.

3) Ectopic gallstone -- Only 10-l 5% of gallstones are sufficiently calcified to be visible on plain radiographs. The calcified portion of the gallstone may only be its central nidus and not reflect the true size of the stone. For a gallstone that enters the intestinal lumen to cause an obstruction, it must be sufficiently large (3 cm. or greater). The most common site where the gallstone lodges is at the iliocecal valve. One can also visualize the intralumenal gallstone by a **thin layer of surrounding intestinal air.** This is seen on the above radiograph **overlying the left sacral wing.** The ectopic gallstone is visualized in only 20% of cases of gallstone ileus.

The patient was brought to the operating room on the night of admission with a preoperative diagnosis of gallstone ileus. A mechanical small bowel obstruction was present with the point of transition in the mid-jejunum. A luminal mass was palpable and enterotomy revealed two large 3 cm. stones. The gallbladder was scarred with multiple adhesions to bowel and omentum. Two weeks later. a second operation was performed revealing two intestinal-gallbladder fistulae - cholecystoduodenal and cholecystocolic. The gall bladder was removed and the fistulae were closed.