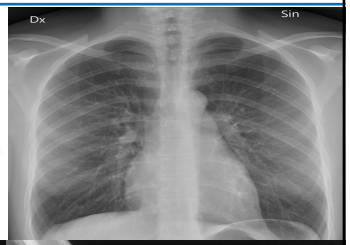
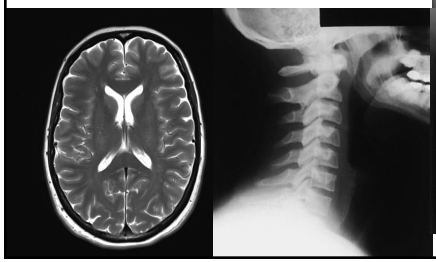
Medical Imaging Foundations

KEY CLINICAL SKILLS





1

The course

Recommendations:

- Download the course handouts
- Follow along and make notes on the handouts
- Take your time – you have 10 weeks
- View the units several times (you can go back multiple times)
- Let us know if we have made any mistakes (we are not quite perfect yet)
- Enjoy the course and tell others

2

Program goals

- What you will get:
  - Understand the basic science of X-ray, CT, MRI, Diagnostic Ultrasound
  - Identify the commonly used imaging views of the musculoskeletal system
  - Understand the fundamental process of image interpretation and practice these skills
  - Know and apply published **utilization** guidelines for medical imaging
  - Appreciate the **utility** of various medical imaging studies
  - Integrate imaging results into your existing practice

3

Program goals

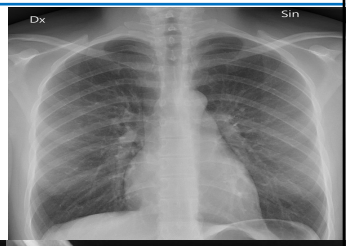
- **What you won't get:**
  - The skills needed to interpret medical diagnostic images independently
  - The right to order medical imaging (unless allowed by Provincial legislation & Regulatory College)

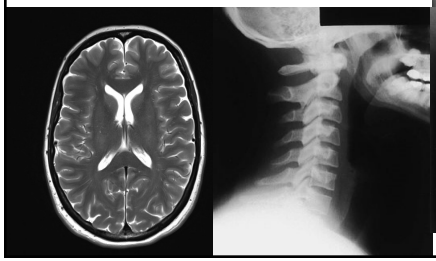
4

Medical Imaging foundations

Unit 1

- Generation of X-rays
- X-rays are . . .
- Radiation exposure
- Pre-course test





5

X-rays

- Discovered by Wilhelm Conrad Roentgen in 1895
- High energy – low wavelength ionizing radiation
- Measured in:
  - Roentgens
    - (the x-ray beam's ability to ionize air)
  - Rads
    - How much radiation the patient absorbs from the beam
  - Radms
    - The effect of that radiation on the person's body
  - 1 roentgen = 1 rad = 1 radm

6

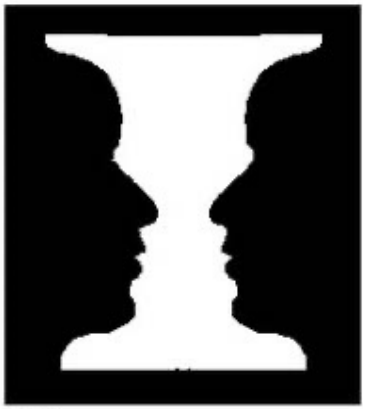
X-rays are . . .

7

Shadow pictures

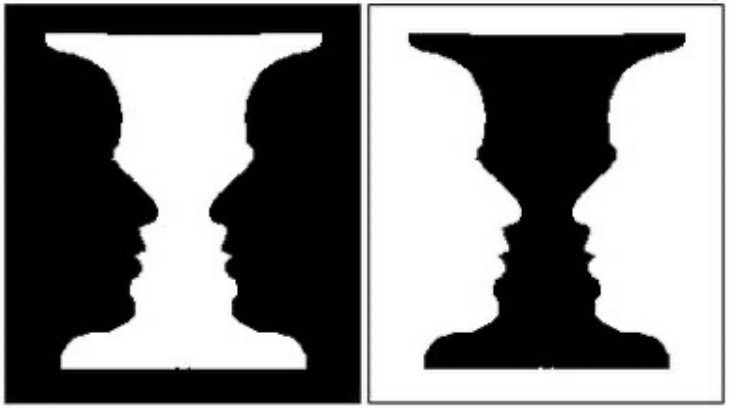
8

X-rays are . . .



9

Negative images



10

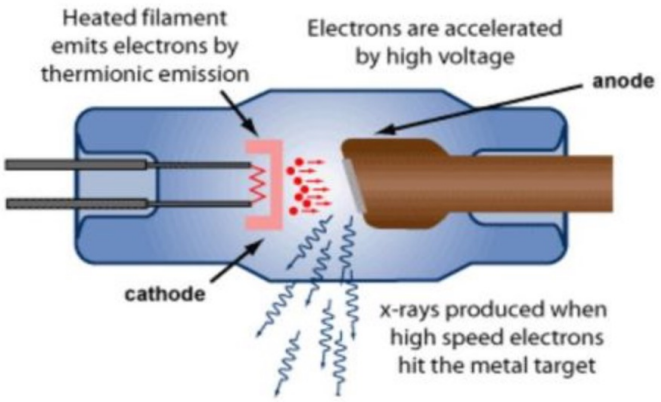
X-rays are . . .

11

2D images of 3 D objects

12

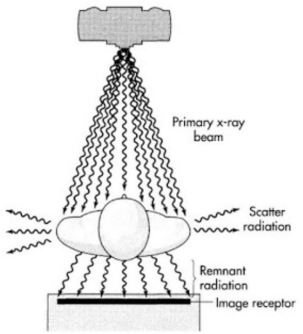
Production of X rays



13

Production of images

- X-rays exit the tube via a small aperture iris that is used to regulate the size of the beam
- The X ray beam is then directed at an X ray receptor (traditionally film – now digital)

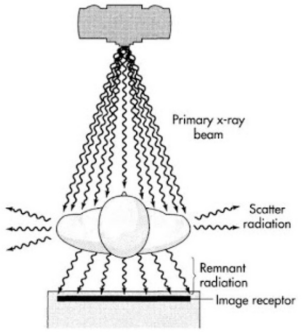


Scatter radiation forms when the primary xray beam interacts with matter

14

Production of images

- Object to be imaged placed between beam and receptor in standardized position
- The shadow of the radio opaque tissues is then seen as a negative image



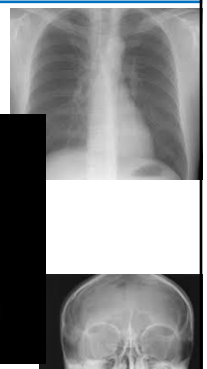
Scatter radiation forms when the primary xray beam interacts with matter

15

Production of X ray images

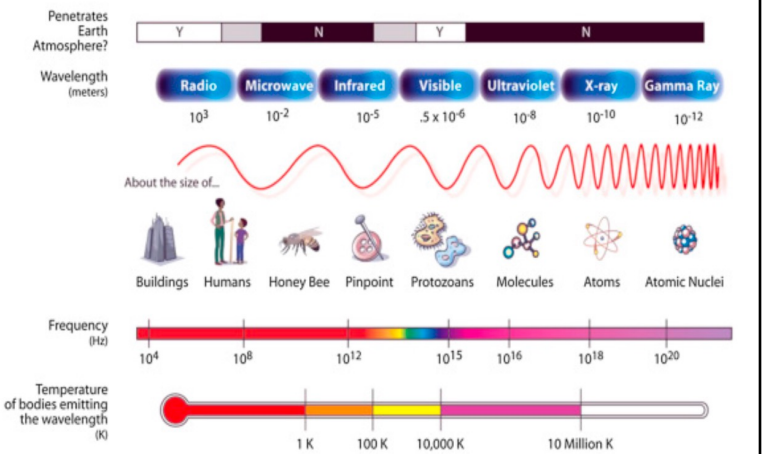
"Attenuation" is the degree to which X-rays are absorbed or deflected by the tissues

- Bones have a high atomic weight and effectively "block" X-rays from passing through.
- The less X-rays passing through the lighter the image (remember it is a "negative")



16

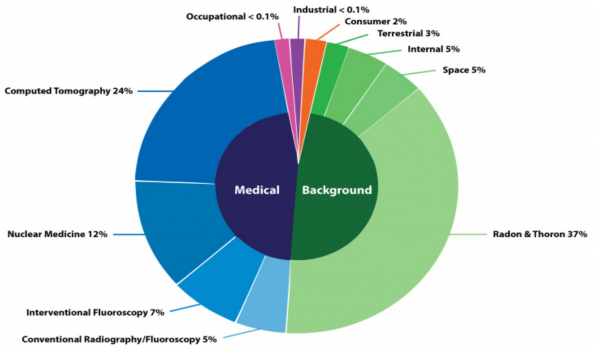
Electromagnetic spectrum



NCRPM 2018

17

Sources of radiation exposure



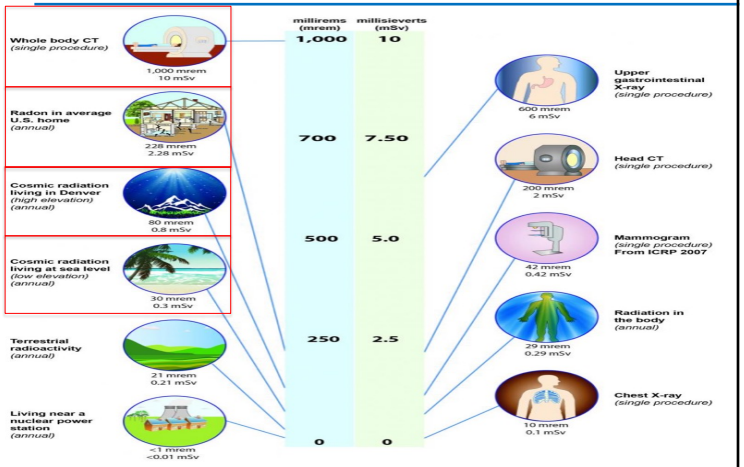
Average Annual Radiation Dose

Sources	Radon & Thoron	Computed Tomography	Nuclear Medicine	Interventional Fluoroscopy	Space	Conventional Radiography/ Fluoroscopy	Internal	Terrestrial	Consumer	Occupational	Industrial
Units											
mrem (United States)	228 mrem	147 mrem	77 mrem	43 mrem	33 mrem	33 mrem	29 mrem	21 mrem	13 mrem	0.5 mrem	0.3 mrem
mSv (International)	2.28 mSv	1.47 mSv	0.77 mSv	0.43 mSv	0.33 mSv	0.33mSv	0.29 mSv	0.21 mSv	0.13 mSv	0.005 mSv	0.003 mSv

NCRPM 2018

18

Relative doses from radiation sources



NCRPM 2018

19

Typical scan doses

Examination	Effective dose (mSv)	Milli rem
Chest x ray	0.1	10
Head CT	1.5	150
Screening mammography	3	300
Abdominal CT	5.3	530
Chest CT	5.8	580
Chest, abdomen pelvis CT	9.9	990
CT Colon	3.6-8.8	360-880
Barium enema	15	1500
Neonatal abdominal	20	2000

For comparison, survivors of the atomic blast at Hiroshima & Nagasaki were exposed to an average of 40mSv. Dependent on the patient and technique used, these levels are roughly equivalent to 2 -3 CT scans of the lumbar spine

20

Conventional Radiography

Decision making considerations	Advantages	Disadvantages	Primary uses	Variations
First-order diagnostic imaging modality Need at least 2 views at 90 deg.	Low cost Widespread availability Produces excellent skeletal images	Uses ionizing radiation Often over utilized Less sensitive to subtle pathology	Screening for & visualization of pathology of bone and joints (fractures, dislocations, neoplasms, arthridities) Monitoring fracture healing Visualization of orthopaedic hardware	Fluoroscopy Arthrography Myelography Discography

21

A little pre-course self-test

What is the view?

22

A little pre-course self-test

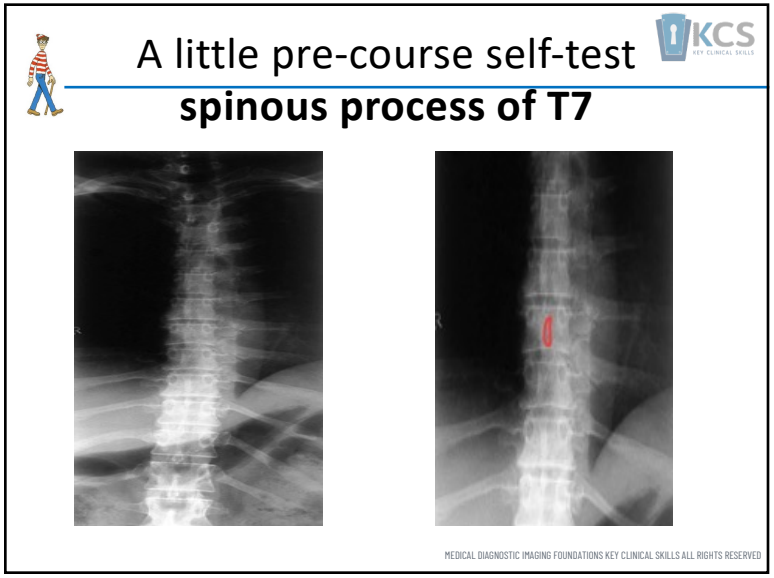
- Antero-postero thoracic spine

23

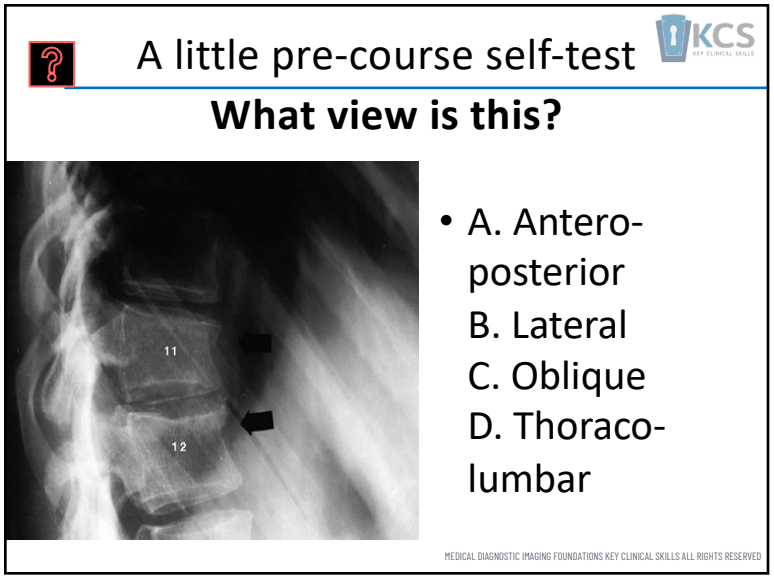
A little pre-course self-test

spinous process of T7

24


A little pre-course self-test
spinous process of T7
MEDICAL DIAGNOSTIC IMAGING FOUNDATIONS KEY CLINICAL SKILLS ALL RIGHTS RESERVED

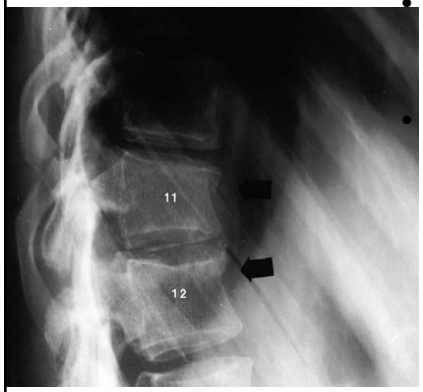
25


A little pre-course self-test
What view is this?
11
12
• A. Antero-posterior
B. Lateral
C. Oblique
D. Thoraco-lumbar
MEDICAL DIAGNOSTIC IMAGING FOUNDATIONS KEY CLINICAL SKILLS ALL RIGHTS RESERVED

26

A little pre-course self-test

What view is this?

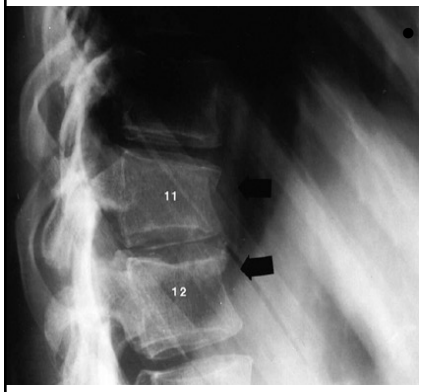


- D. Thoracolumbar
- A thoracolumbr view is a "*coned*" or close-up view of the thoracolumbar vertebrae, which are often the site of traumatic injury.

27

A little pre-course self-test

What is the pathology

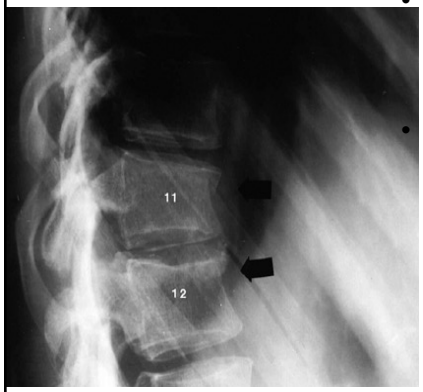


- A. Osteoporosis
  B. Vertebral body compression fractures
  C. Tuberculous osteomyelitis

28

A little pre-course self-test

What is the pathology



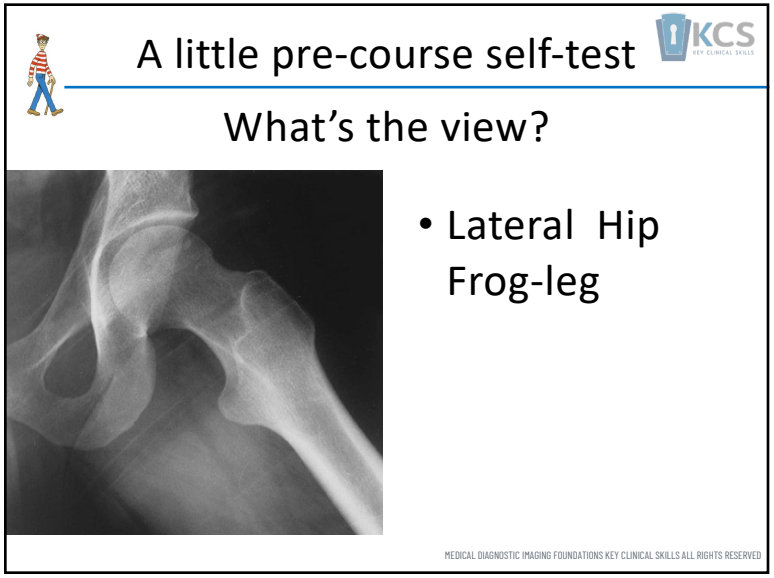
- B. Vertebral body compression fractures
- Imposed compressive forces on the spine convert to flexion forces and can result in anterior shearing of the vertebral disk, which may avulse the bony rim of an endplate and displace it anteriorly.

29

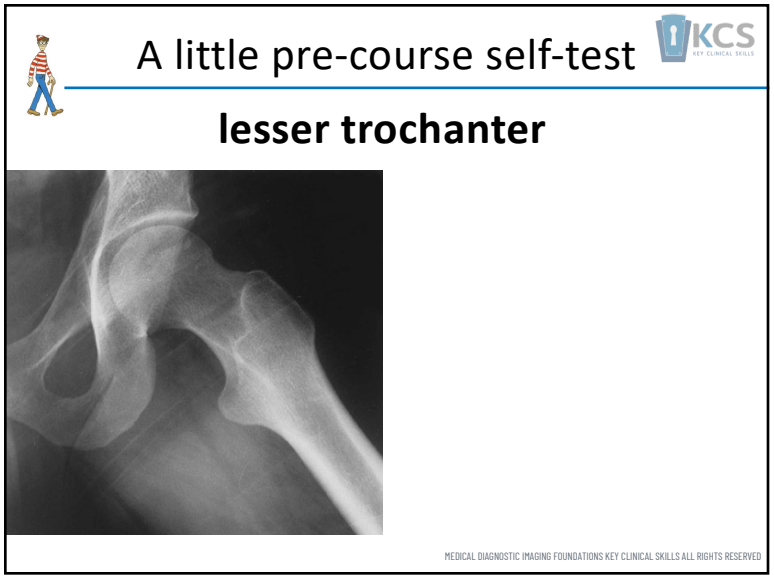
A little pre-course self-test

What's the view?

30


A little pre-course self-test
What's the view?
• Lateral Hip
Frog-leg
MEDICAL DIAGNOSTIC IMAGING FOUNDATIONS KEY CLINICAL SKILLS ALL RIGHTS RESERVED

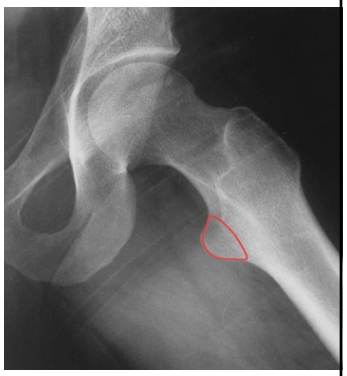
31


A little pre-course self-test
lesser trochanter
MEDICAL DIAGNOSTIC IMAGING FOUNDATIONS KEY CLINICAL SKILLS ALL RIGHTS RESERVED

32

A little pre-course self-test

lesser trochanter

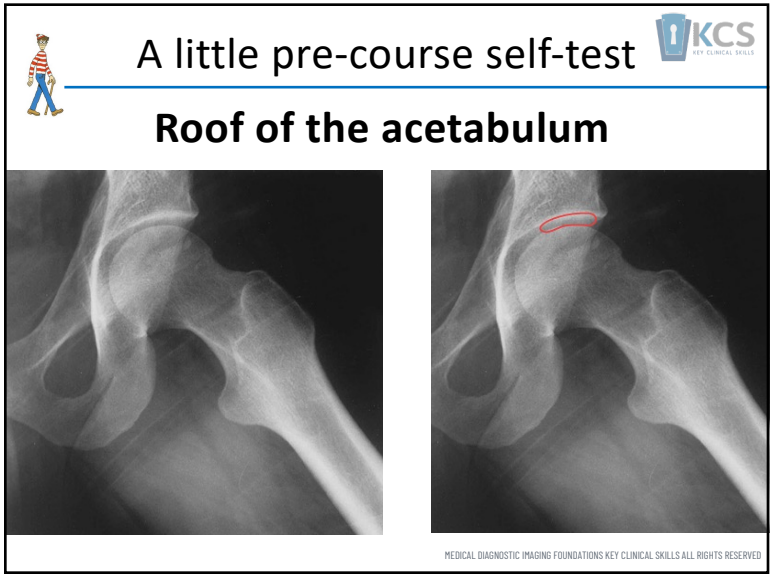


33

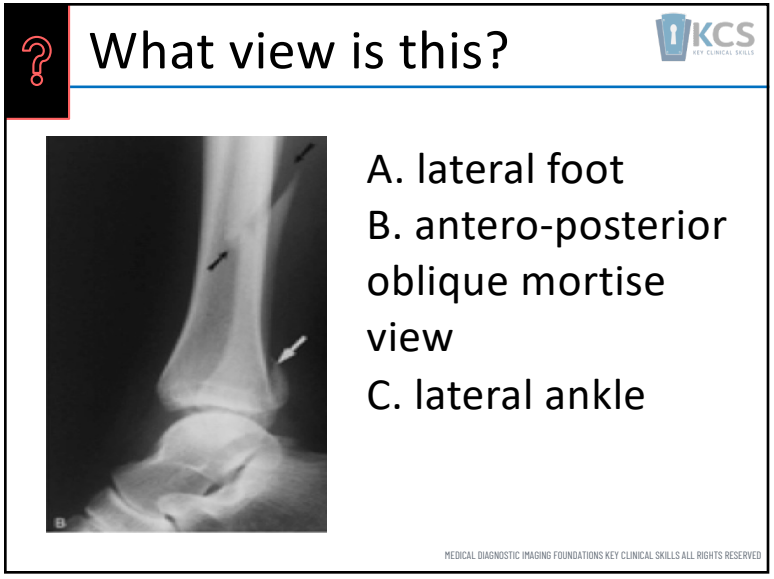
A little pre-course self-test

Roof of the acetabulum

34


A little pre-course self-test
Roof of the acetabulum
MEDICAL DIAGNOSTIC IMAGING FOUNDATIONS KEY CLINICAL SKILLS ALL RIGHTS RESERVED

35


What view is is this?
A. lateral foot
B. antero-posterior oblique mortise view
C. lateral ankle
MEDICAL DIAGNOSTIC IMAGING FOUNDATIONS KEY CLINICAL SKILLS ALL RIGHTS RESERVED

36

What view is this?

C. lateral ankle

- This sagital view of anatomy makes it a lateral projection; the inclusion of the lower half of the leg, and exclusion of the distal half of the foot, designates this as an ankle, not foot, examination.

37

What do the black arrows point to?

A. displaced fibular fragment

B. fracture of the anterior rim of the tibia

C. fracture of the posterior rim of the tibia

38

What do the black arrows point to?

A. displaced fibular fragment

- This is an oblique fracture of the fibular shaft at the junction of the middle and distal thirds of the shaft. It is oblique, not transverse, because the fracture line is diagonal to the long axis of the shaft. The fracture is complete, not incomplete, because the distal fragment is posteriorly displaced and therefore all the cortices must be fractured.

39

What do the white arrows point to?

A. displaced fibular fragment
B. fracture of the anterior rim of the tibia
C. fracture of the posterior rim of the tibia

40

What do the white arrows point to?

C. fracture of the posterior rim of the tibia

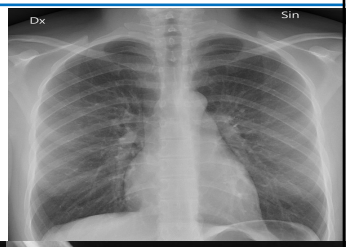
- The posterior rim of the tibia is often referred to as the "third malleolus" and is often fractured in conjunction with the medial malleolus, lateral malleolus, or fibular shaft.

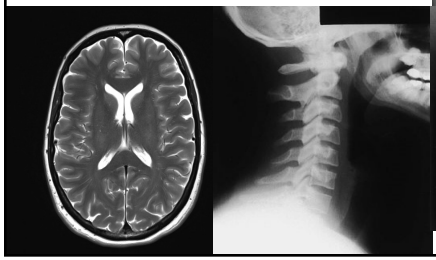
41

Medical Imaging Foundations

Unit 2

- Radiodensity
- Projection angles
- Image quality factors
- Imaging terminology



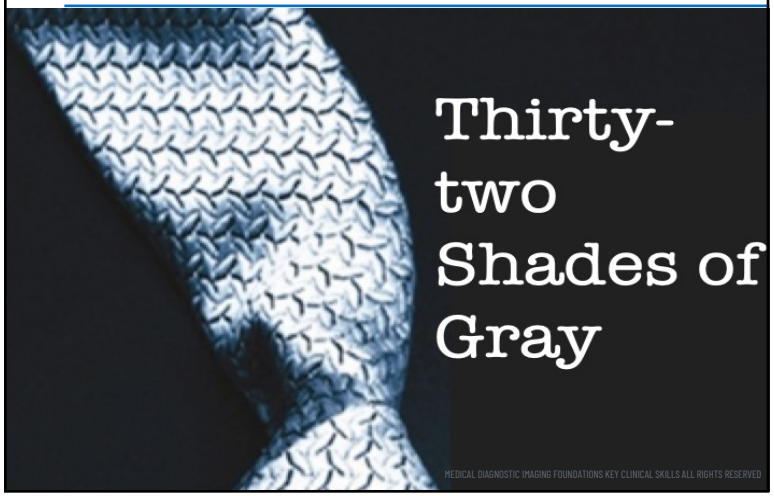


42

The human eye can detect . . .

43

(I get one joke)



44

32 shades of grey and radiodensity

↓↓↓ Density
Air
Black
Lungs
Trachea
Bowel
Thin fat
Thin connecting tissue
Adipose tissue

45

32 shades of grey and radiodensity

↓↓↓ Density	↓↓Density
Air	Fat
Black	Dark Gray
Lungs	Thicker adipose
Trachea	Multiple layers of thin tissue
Bowel	Osteoporotic bone
Thin fat	
Thin connecting tissue	
Adipose tissue	

46

32 shades of grey and radiodensity

↓↓↓ Density	↓↓Density	"Neutral" Density
Air	Fat	Water
Black	Dark Gray	Mid-Gray
Lungs	Thicker adipose	Muscle, tendon
Trachea	Multiple layers of thin tissue	Thin bones
Bowel	Osteoporotic bone	Overlapping
Thin fat		Soft tissues
Thin connecting tissue		Blood
Adipose tissue		Vasculature

47

32 shades of grey and radiodensity

↓↓↓ Density	↓↓Density	"Neutral" Density	↑ Density
Air	Fat	Water	Mineral
Black	Dark Gray	Mid-Gray	Light Gray
Lungs	Thicker adipose	Muscle, tendon	Cancellous bone, thin cortical thick muscle, tendon, organ tissues, super-imposition of thin soft tissues, large blood vessels
Trachea	Multiple layers of thin tissue	Thin bones	
Bowel	Osteoporotic bone	Overlapping	
Thin fat		Soft tissues	
Thin connecting tissue		Blood	
Adipose tissue		Vasculature	

48

32 shades of grey and radiodensity

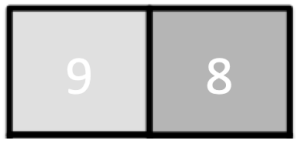
↓↓↓ Density	↓↓Density	"Neutral" Density	↑ Density	↑↑ Density
Air	Fat	Water	Mineral	Heavy Metals
Black	Dark Gray	Mid-Gray	Light Gray	White
Lungs Trachea Bowel Thin fat Thin connecting tissue Adipose tissue	Thicker adipose Multiple layers of thin tissue Osteoporotic bone	Muscle, tendon Thin bones Overlapping Soft tissues Blood Vasculature	Cancellous bone, thin cortical thick muscle, tendon, organ tissues, super-imposition of thin soft tissues, large blood vessels	Thick cortical bone Dental fillings Jewelry Orthopedic hardware Zippers Buttons

49

Radiodensity as a function of projection angle (seen as a negative)

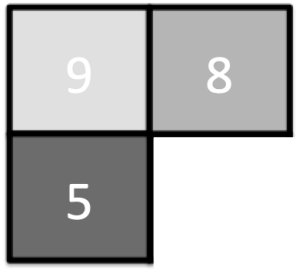
50

Radiodensity as a function of projection angle (seen as a negative)



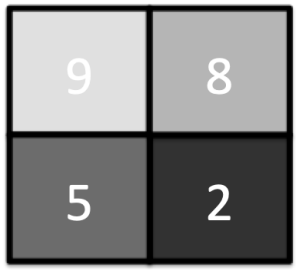
51

Radiodensity as a function of projection angle (seen as a negative)



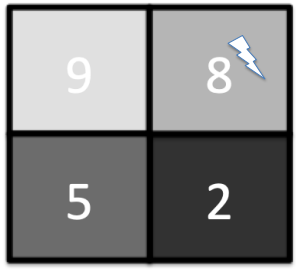
52

Radiodensity as a function of projection angle (seen as a negative)

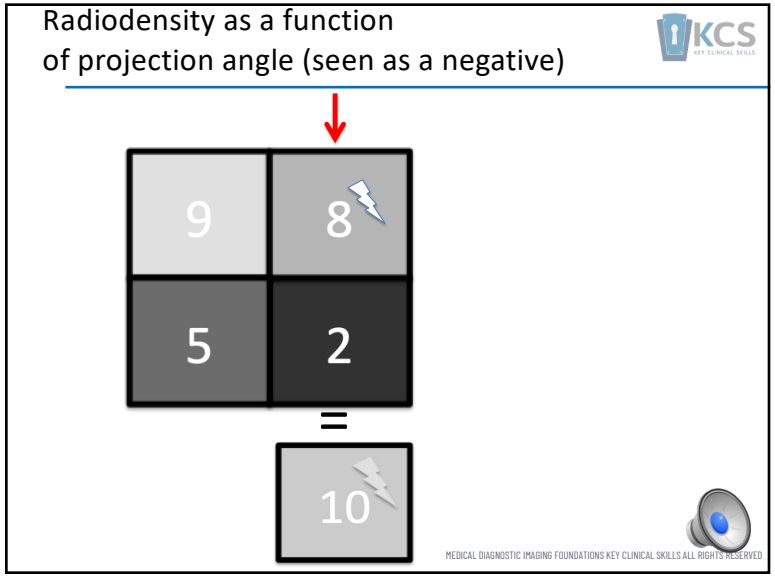


53

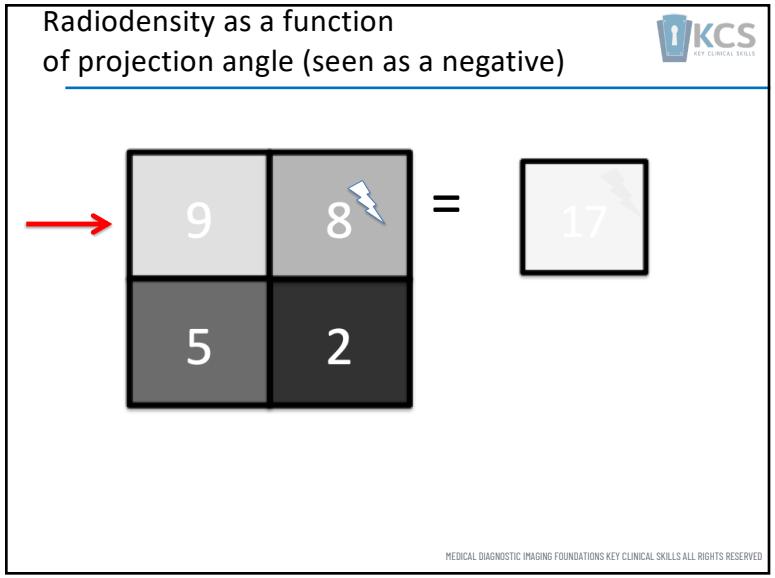
Radiodensity as a function of projection angle (seen as a negative)



54


Radiodensity as a function
of projection angle (seen as a negative)
9
8
5
2
=
10
MEDICAL DIAGNOSTIC IMAGING FOUNDATIONS KEY CLINICAL SKILLS ALL RIGHTS RESERVED

55

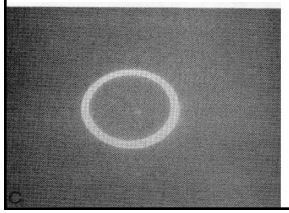

Radiodensity as a function
of projection angle (seen as a negative)
9
8
5
2
=
17
MEDICAL DIAGNOSTIC IMAGING FOUNDATIONS KEY CLINICAL SKILLS ALL RIGHTS RESERVED

56

Radio density helps us visualize 3D image from 2D picture

What do you notice about the density?

- Is it uniform?
- Does it change from top to bottom
- Does it change from left to right

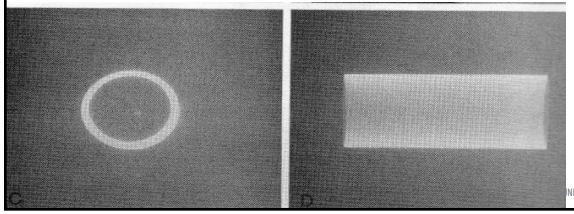


57

Radio density helps us visualize 3D image from 2D picture

What do you notice about the density?

- Is it uniform?
- Does it change from top to bottom
- Does it change from left to right



58

Radio density helps us visualize 3D image from 2D picture

Pipe on end looks like a ring but

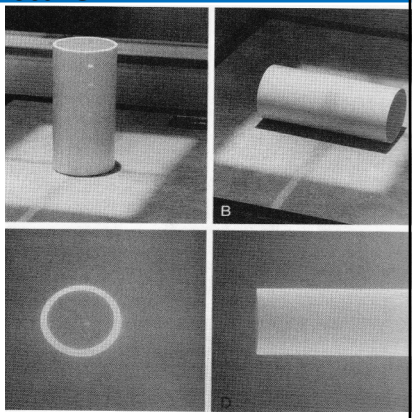
Even density of material

- Could be long –low radiodensity tube or could be short-high radiodensity ring

Pipe on side looks like rectangular block –

- lower density in centre higher density at top & bottom, equal density left to right

You always must have at least 2 views preferably at right angles to visualize

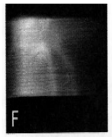


59

Radio density helps us visualize 3D image from 2D picture

What do you notice about the density?

- Is it uniform?
- Does it change from top to bottom
- Does it change from left to right

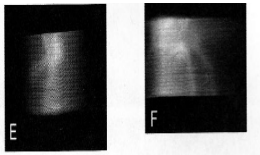


60

Radio density helps us visualize 3D image from 2D picture

What do you notice about the density?

- Is it uniform?
- Does it change from top to bottom
- Does it change from left to rig

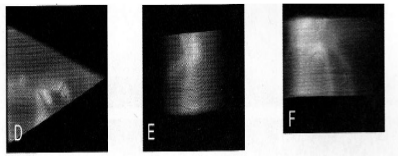


61

Radio density helps us visualize 3D image from 2D picture

What do you notice about the density?

- Is it uniform?
- Does it change from top to bottom
- Does it change from left to right



62

Radio density helps us visualize 3D image from 2D picture

Wedge on broad side looks like a wedge

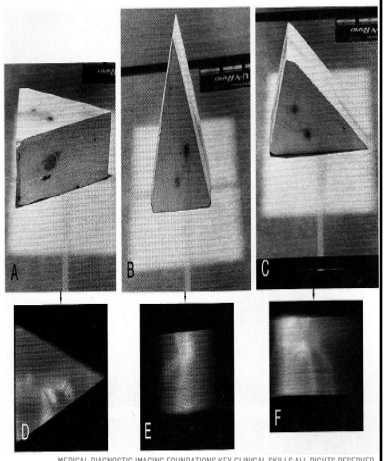
- Density of material not even
- (Notice the knot in the wood)

Wedge on base looks like block but -

- Denser in centre less dense left and right, evenly dense top to bottom

Wedge on side looks like a block but-

- Denser to left side, even density top to bottom



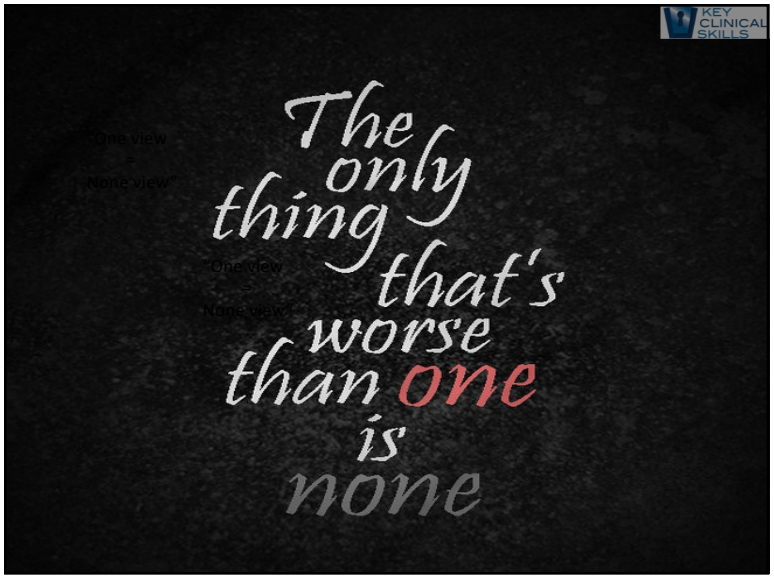
63

Interpretation with one view

64

Interpretation with one view

65



66

Quality of image if dependent on:

- Thickness of body part
- Motion during image capture
- Scatter of beam
- Magnification of image
- Distortion of image

67

Thickness of body part

68

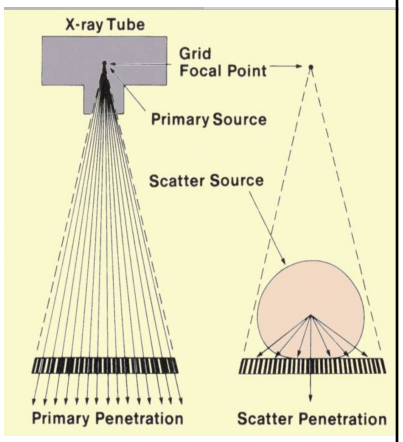
Motion

- Movement will cause blurring and distortion
- These factors are mitigated by:
  - Shorter exposure time
  - Intensifying screens

69

Scatter

- Scatter is produced by deflection of the beam.
- A scatter reduction grid will significantly reduce this effect.



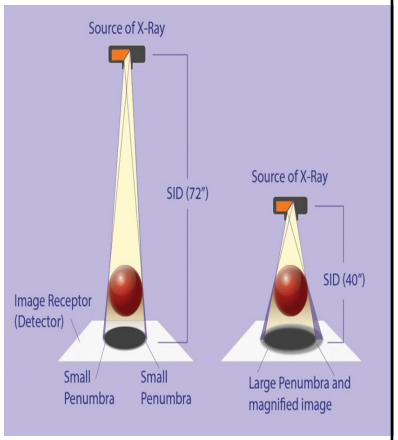
70

Magnification

Size

Primary factors are:

- Distance between beam source and patient
- Common practice is to use 100 cm
- The closer the image is to the receptor the less the magnification distortion and the better the detail

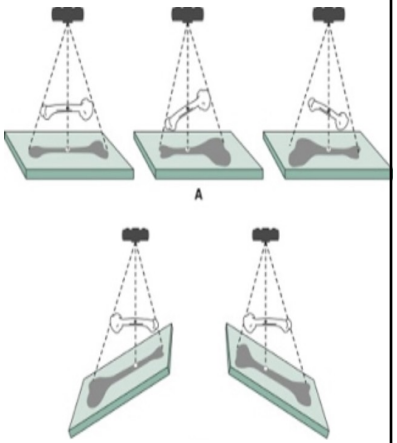


71

Distortion

Shape

- Unequal magnification of the structure
- Receptor angled relative to object
  - Elongated
  - Foreshortened
  - Only at the central ray is the beam perpendicular and should be closest to accurate



72

Projections, Positions, Viewing

Projection of beam

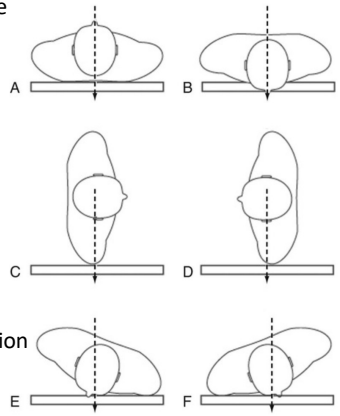
- Named after body part closest to image receptor
- Generally A-P
  (except at hands & chest P-A)
- Reduces effect of parallax

Position of patient

- Patient's body position
  - "Upright, seated, supine"
- Which body part is closest to receptor
  - "Right anterior oblique" (RAO)

Viewed

- Always viewed as if in anatomical position (facing patient)
- **Imagine you are speaking with them**



73

Skeletal radiology terminology

Osteoblastic

- Radiopaque
- Opacity
- Sclerosis
- Hypertrophic bone
- Increased radiodensity
- Blastic lesion
  - Reparative
  - Reactive bone

Osteoclastic

- Radiolucent
- Lucency
- Rarefaction
- Osteopenia
- Decreased radiodensity
- Demineralization
- Lytic lesion
  - Bone destroying

74

Interpretation pitfalls

- 20-40% of statements made on reports by radiologists and radiology residents were found to be erroneous when reviewed independently.
- Many of these errors were related to life-threatening consequences

Brady 2017

75

Interpretation pitfalls

- 20-40% of statements made on reports by radiologists and radiology residents were found to be erroneous when reviewed independently.
- Many of these errors were related to life-threatening consequences

Caused by:

- Errors of observation: Incomplete or faulty search patterns **(the Radiologist)**
- Errors of interpretation: Failure to link abnormal radiologic signs to relevant clinical findings **(the Clinician)**

Brady 2017

76

Examination of radiographs

5 possible outcomes

1. Positive for suspected diagnosis
2. Negative for suspected diagnosis
3. Negative for 1 diagnosis but raises suspicion of alternate
4. Wrong
5. Inconclusive requiring additional investigation

77

Examining medical images

When you see this . . .

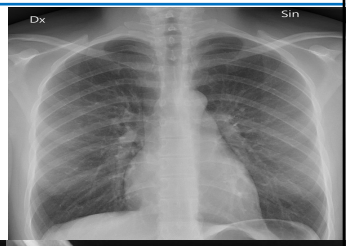
Think this . . .

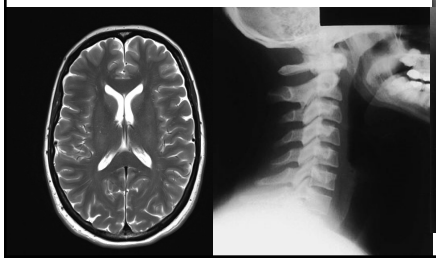
78

Medical Imaging Foundations

Unit 3

- Search patterns 1





79

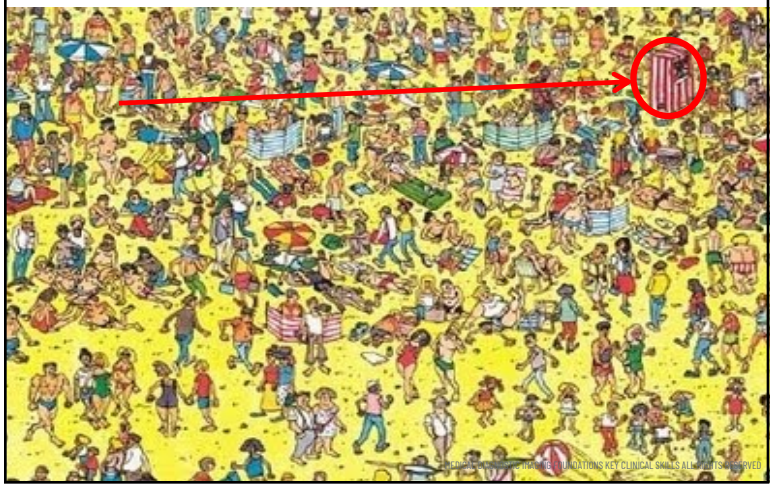
Search patterns

80

Waldo evaluation and search pattern – random glances

81

Waldo evaluation and search pattern – random glances

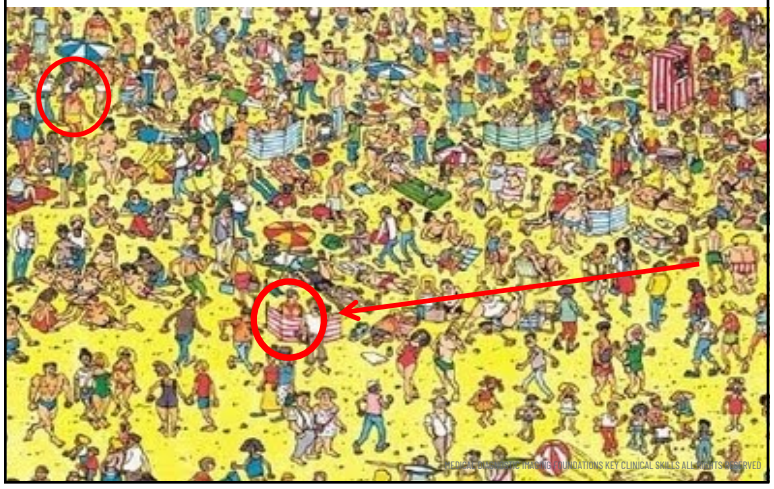


82

Waldo evaluation and search pattern – random glances

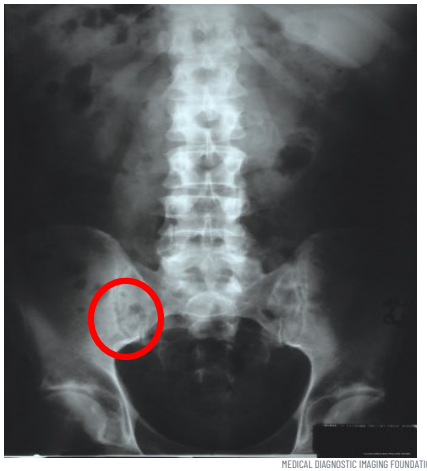
83

Waldo evaluation and search pattern – random glances



84

Waldo evaluation and search pattern – random glances

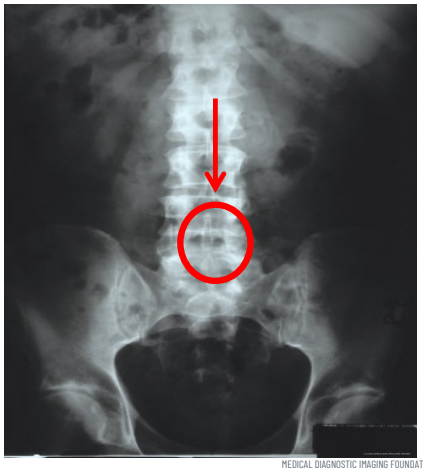


85

Waldo evaluation and search pattern – random glances

86

Waldo evaluation and search pattern – random glances

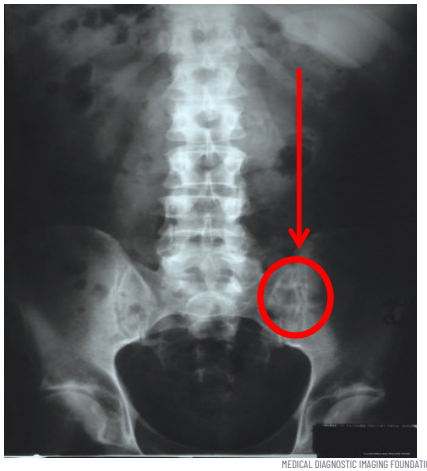


87

Waldo evaluation and search pattern – random glances

88

Waldo evaluation and search pattern – random glances



89

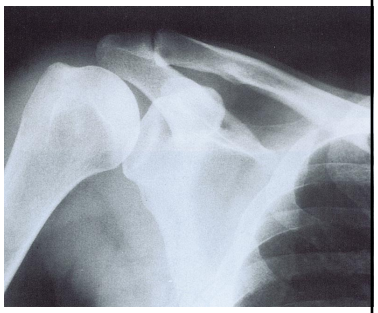
Know you're A – B – C - S

- **A**lignment
- **B**one Density
- **C**artilage Spaces
- **S**oft Tissues

90

A = Alignment

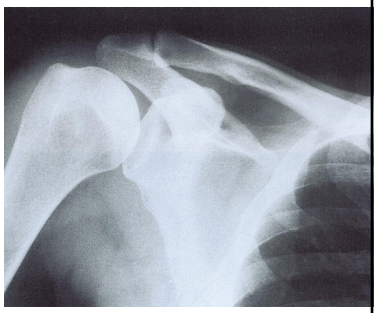
- **Size of bones**
  - Acromegaly
  - Giantism
  - Paget's disease
- **Bone and relative joint position**



91

A = Alignment

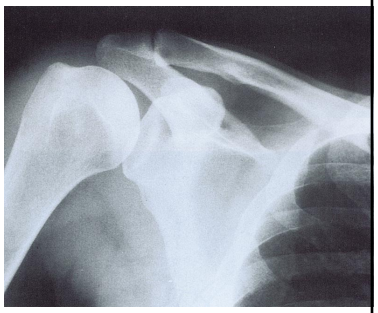
- **Size of bones**
  - Acromegaly
  - Giantism
  - Paget's disease
- **Bone and relative joint position**



92

A = Alignment

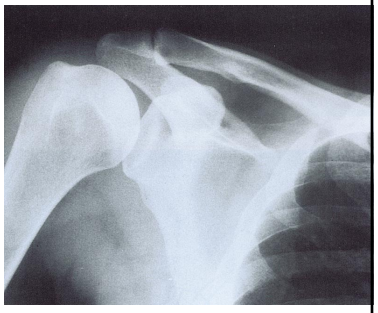
- **Size of bones**
  - Acromegaly
  - Giantism
  - Paget's disease
- **Bone and relative joint position**
- **Number of bones**
  - Count the bones to assess for extra or missing parts



93

A = Alignment

- **Size of bones**
  - Acromegaly
  - Giantism
  - Paget's disease
- **Bone and relative joint position**
- **Number of bones**
  - Count the bones to assess for extra or missing parts

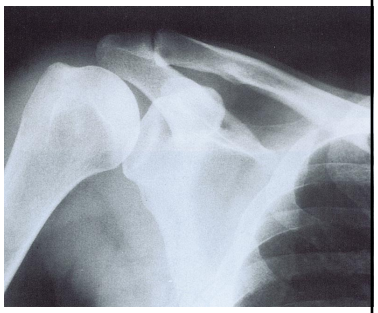


MEDICAL DIAGNOSTIC IMAGING FOUNDATIONS KEY CLINICAL SKILLS ALL RIGHTS RESERVED

94

A = Alignment

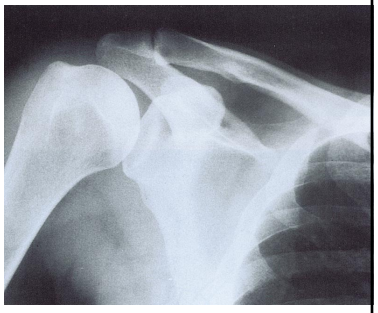
- **Size of bones**
  - Acromegaly
  - Giantism
  - Paget's disease
- **Bone and relative joint position**
- **Number of bones**
  - Count the bones to assess for extra or missing parts
- **Congenital abnormalities**
  - Cervical ribs
  - Transitional vertebrae



95

A = Alignment

- **Size of bones**
  - Acromegaly
  - Giantism
  - Paget's disease
- **Bone and relative joint position**
- **Number of bones**
  - Count the bones to assess for extra or missing parts
- **Congenital abnormalities**
  - Cervical ribs
  - Transitional vertebrae
- **Developmental deformities**
  - Scoliosis
  - Genu valgum.



96

A = Alignment

- Internal or external irregularities
- The cortical outline of each bone
- Bony outgrowths or spurs
- Breaks in continuity of the cortex
  - Cortical fracture
  - Sharp angle implies impact force
  - Site of ligament or muscle insertion
    - Avulsion fractures
- Markings of previous surgical site
  - Screw holes

97

A = Alignment

Alignment of bones relative to adjacent bones

- **Fracture**
  - That may disrupt joint articulations
- **Dislocation**
  - Fully reduced
  - Partially reduced
  - Unreduced
- **Subluxation**
  - Partial dislocation of joint surfaces
    - Trauma
    - Inflammatory joint disease
    - Degenerative joint disease

98

A = Alignment

Evaluation	Normal findings	Variations/anomalies
General Architecture	Gross normal size of bones Normal number of bones	Supernumary bones Absent bones Congenital deformities Developmental deformities Cortical fractures
General contour of bones	Smooth and continuous cortical outlines	Avulsion fractures Impact fractures Spurs
Alignment to adjacent bones	Normal joint articulations Normal spatial relationships	Markings of past surgical sites Fracture Joint subluxations Joint dislocations

99

What is the pathology?

- What image are we looking at?
- Size of the bones look good?
- Do we have the correct number of bones?
- Is the contour and shape normal?
- Can you identify the acromion process, the coracoid process and the distal end of the clavicle?
- Is the AC joint in the correct position?
- Is the humeral head in its correct location?

100

What is the pathology?

Axillary view demonstrates posterior dislocation with reverse Hill-Sachs lesion (bony impaction-type fracture in humeral head)

101

What is the pathology?

102

B = Bone

1. General bone density
2. Focal bone density
3. Trabecular alteration

103

B = Bone

General bone density

- View from a regional standpoint (step back and admire the scene)

104

B = Bone

General bone density

- View from a regional standpoint (step back and admire the scene)
- Healthy mineralized bone distinctive differences in shades of gray between the more dense cortical bone and the less dense cancellous bone.

105

B = Bone

General bone density

- View from a regional standpoint (step back and admire the scene)
- Healthy mineralized bone distinctive differences in shades of gray between the more dense cortical bone and the less dense cancellous bone.
- Bone may de-mineralize as much as 30 to 50% before it will be noticeable on a radiograph.

106

B = Bone

Focal bone density

- Look for focal changes in bone density

107

B = Bone

Focal bone density

- Look for focal changes in bone density
- Wolff's law (the phenomenon of remodeling, bone deposited in sites subjected to stress

108

B = Bone

Focal bone density

- Look for focal changes in bone density
- Wolff's law (the phenomenon of remodeling, bone deposited in sites subjected to stress
- Bone cells will align in such a way as to most efficiently withstand stress.

109

B = Bone

Trabeculae

- Changes in trabecular appearance often early indication of mineralization changes of bone
  - Fluffy – often seen in Paget's disease and hyperparathyroidism
  - Smudged- indistinct trabeculae characteristic of osteomalacia

110

B = Bone

Trabeculae

- Changes in trabecular appearance often early indication of mineralization changes of bone
  - Fluffy – often seen in Paget's disease and hyperparathyroidism
  - Smudged- indistinct trabeculae characteristic of osteomalacia
  - Coarsening – often seen in chronic renal failure and osteoporosis
  - Lacy (delicate) – secondary to Cooley's anemia

111

B = Bone

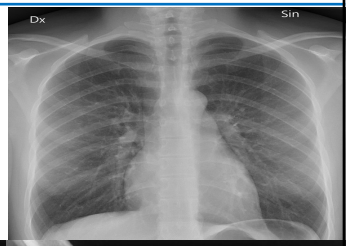
Evaluation	Normal findings	Variations/Abnormalities
General bone density	Sufficient contract between soft-tissue shade of gray and bone shade of gray Sufficient contrast within each bone, between cortical shell and cancellous centre	General loss of bone density resulting in poor contrast between soft tissues and bone Thinning of or absence of cortical margins
Texture Abnormalities	Normal trabecular architecture	Appearance of trabeculae altered; may look thin, delicate. lacy, smudged, coarsened, fluffy
Local bone density changes	Sclerosis at areas of increased stress such as; weight bearing surfaces or sites of ligamentous, muscular or tendinous attachments	Excessive sclerosis Reactive sclerosis that "walls off " a lesion Osteophytes

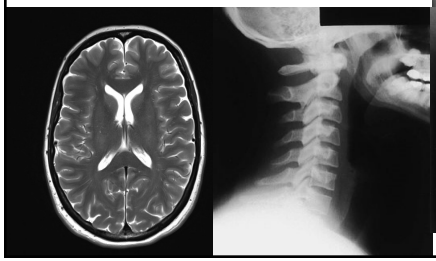
112

Medical Imaging Foundations

Unit 4

- Search patterns 2
- Predictors





113

C - Cartilage

Joint Space

- Width
- Symmetry

Subchondral Bone

- Contour
- Density

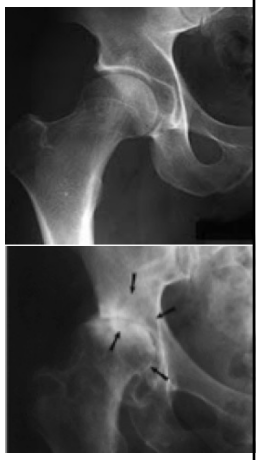
114

C - Cartilage

Joint Space

Width

- A well preserved joint space implies normal cartilage or disc thickness
- Decreased joint space implies loss of cartilage or disc thickness as a result of degenerative process



115

C - Cartilage

Joint Space Symmetry

- Normal symmetry implies and even weight distribution pattern of loading
- Asymmetrical loss of space indicates increase loading in one joint compartment

116

C - Cartilage

Subchondral bone

- **Increased sclerosis**
  - Seen in degenerative arthridities as new bone is formed to help offset loss of joint cartilage
- **Erosions**
  - In inflammatory arthridities (RA, Gout) there is no reparative sclerosis but radiolucent cysts

117

C - Cartilage

Epiphyseal plates

- Size of the epiphyses should be related to the skeletal and chronological age
- Borders of the epiphyses should have a band of sclerosis indicating increased bone activity from growth
- Position of plates as designated by the relationship of the ossified portion of the secondary epiphysis to the metaphysis

118

C - Cartilage

Evaluation	Normal findings	Variations / Abnormalities
Joint space width	Well preserved joint spaces Even space across joint surfaces	Decreased joint spaces Uneven space across the joint surface
Sub-chondral bone	Smooth surface	Excessive sclerosis (implies DJD) Erosions (implies RA etc.)
Epiphyseal plates	Normal size relative to epiphysis and chronological /skeletal age	Compare contra-laterally for changes in thickness that may be related to abnormal conditions or trauma

119

S = Soft Tissue

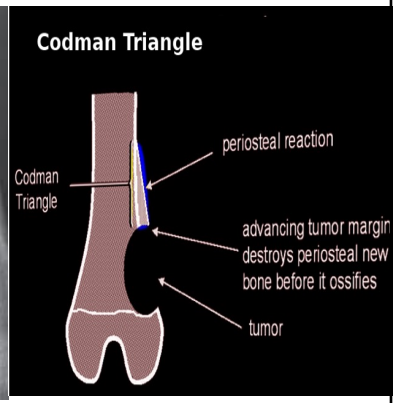
Gross musculature

- Bulk
- Density
- Symmetry
- Foreign bodies
- Gas

120

S = Soft Tissue

Periosteum



121

S = Soft Tissue

Fat Pad Sign

"Sail sign"

–Fat normally outside the synovium

–Typically "hidden"

–Usually not visible

–Intra-articular hemorrhage forces fat out of the fossa

–Triangular radiolucent shadows

122

S = Soft Tissue

Foreign bodies

- Internal fixators
- Surgical instruments
- Gun shots
- Aspirated objects
- Ingested objects

123

S = Soft Tissue

Gas

- May be produced by advanced infection “Gas gangrene”
- May have been induced externally (Poor injection technique, high pressure air)

124

S = Soft Tissue

Evaluation	Normal findings	Variations / Abnormalities
Muscles	Normal size relative to epiphysis and skeletal/chronological age	Gross wasting Gross swelling
Fat pads and fat lines	Radiolucent crescent parallel to bone Radiolucent lines parallel to muscle	Displacement of fat pads from bony fossae Elevation or blurring of fat planes
Periosteum	Normally indistinct Solid periosteal reaction normal at fracture sites	Solid Laminated Onion skin Spiculated Sunburst Codman's triangle
Miscellaneous soft-tissue findings	Soft tissues normally water density shade of grey	Foreign bodies Gas bubbles appear radiolucent Calcifications appear radiopaque

125

Predictor variables for bone and joint lesions ("Daffner's 11")

1. Behaviour of the lesion

- Osteobalstic
  - Sclerosis
  - Increased mass
  - Oteophytes
- Osteolytic
  - Geographic (destroying large areas of bone in one location)
  - Permeative (destroying multiple smaller areas of bone in no confined area)

126

Predictor variables for bone and joint lesions ("Daffner's 11")

2. Bone or joint involved

- Various types of arthritis and tumors tend to have predilection for certain bones/joints
  - RA in the hands
  - OA in the hips
  - Osteosarcoma in distal femur

127

Predictor variables for bone and joint lesions ("Daffner's 11")

3. Locus with the bone

- Epiphysis
- Metaphysis
- Diaphysis
- Articular surfaces

128

Predictor variables for bone and joint lesions ("Daffner's 11")

4. Age, Gender

- Certain arthridities are more common in different age groups
  - Ankylosing spondylitis onset under 45 yrs)
- Genders
  - OA more common in women
  - AS more common in men

129

Predictor variables for bone and joint lesions ("Daffner's 11")

5. Margins of lesion

- Sharp or well-defined lesions tend to be benign / slow growing
  - The bone has had time to wall off the lesion)
- Poorly defined lesions tend to be aggressive and possibly malignant

130

Predictor variables for bone and joint lesions ("Daffner's 11")

6. Shape of lesion

- Longer shaped lesions are generally benign
- Wider shaped lesions are generally more aggressive and possibly malignant

131

Predictor variables for bone and joint lesions ("Daffner's 11")

7. Crossing of joint space

- Tumors rarely cross joint (or disc) spaces
- Infections and inflammatory processes can cross the joint (or disc) space

132

Predictor variables for bone and joint lesions ("Daffner's 11")

8. Bone reaction

Bone can react to a disease process by:

- Reactive sclerosis which walls off the lesion
- New growth (sclerosis) to fortifying the area to meet the increased stress
- Buttressing (osteophyte growth) to increase the weight bearing area of a joint

133

Predictor variables for bone and joint lesions ("Daffner's 11")

9. Matrix production

The substance of a tumor's matrix can help identify the type of tumor

- Chondroid matrix - (popcorn-like) calcifications are seen in tumors invading soft tissue
- Osteoid matrix is typical of osteoid osteoma
- Mixed matrix

134

Predictor variables for bone and joint lesions ("Daffner's 11")

10. Soft tissue changes

- Edema or hemorrhage can indicate underlying fractures. Displaced fat pads are associated with trauma
- Tumors often disrupt tissue planes

135

Predictor variables for bone and joint lesions ("Daffner's 11")

11. History

- Trauma
- Overuse
- Surgery
  - Where
  - When
  - What
- Idiopathic
  - Gradual onset
  - Rapid onset

136

Predictor variables for bone and joint lesions ("Daffner's 11")

1. Behaviour of the lesion
   - Osteolytic
   - Osteoblastic
2. Bone or joint involved
3. Locus within a bone
   - Epiphysis
   - Metaphysis
   - Diaphysis
   - Articular surface
4. Age, gender, race of patient
5. Margin of lesion
   - Sharply defined (slow-growing)
   - Poorly defined (aggressive)
6. Shape of lesion
   - Longer > wider = slow growing)
   - Wider > longer = aggressive
7. Joint space crossed
8. Bony reaction
   - Periosteal
   - Sclerosis
   - Buttressing
9. Matrix production
   - Osteoid
   - Chondroid
   - Mixed
10. Soft tissue changes
11. History of trauma or surgery

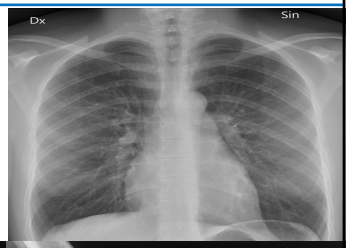
137

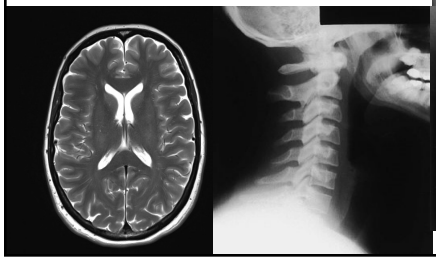
Medical Imaging Foundations

Unit 5

Advanced imaging 1

- Diagnostic ultrasound
- Bone scan
- Fluoroscopy

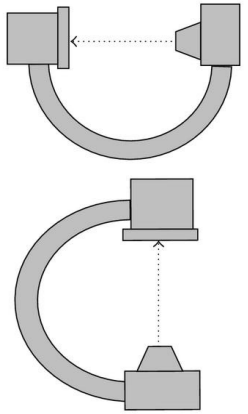




138

Fluroscopy

- X-ray examination in real time
- Receptor screen connected to X-ray source so that both move simultaneously (C-arm)
- Patient is positioned within C arm
- Used in fracture fixation, arthrography, discography, facet injections, biopsy, surgery etc.



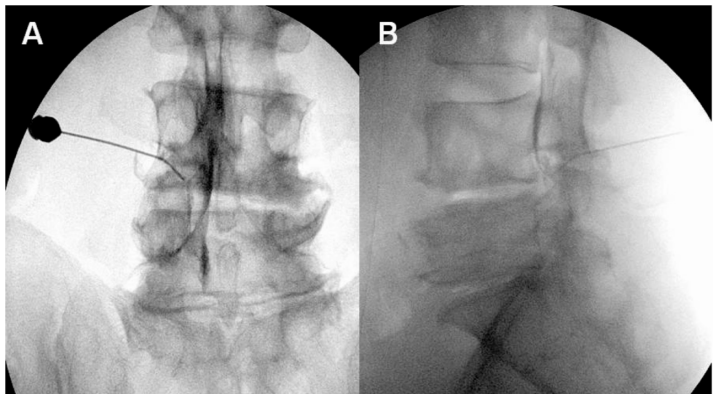
139

Fluoroscopy

140

Fluoroscopy

Trans foraminal epidural “Selective root block”

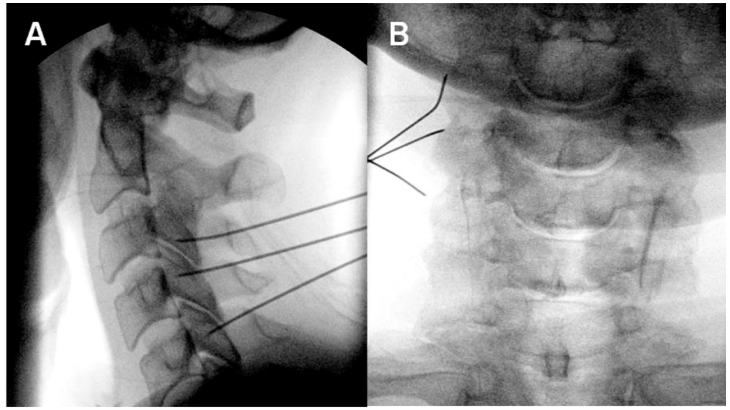


Candido 2018

141

Fluoroscopy

Medial branch block

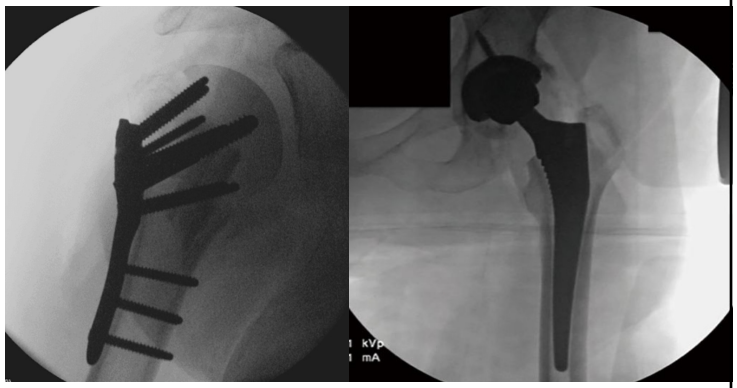


Candido 2018

142

Fluoroscopy

Intraoperative



143

Fluoroscopy

144

Fluoroscopy

145

Bone Scan

- Patient injected with a marker (Technetium - 99n Phosphate) to reflect increase blood flow.
- Marker is absorbed by hydroxyapitate crystals in bone in areas of increase metabolic activity (infection, recent trauma neoplasm).

146

Bone Scan

Very useful in diagnosis of:

- Subtle fractures
- Avascular necrosis
- Decrease blood flow
- Osteomyelitis
- THA/TKA loosening

3 phase most reliable for diagnosis of non displaced scaphoid fractures

147

Bone Scan

X-ray read as normal

148

Bone Scan

Advantages

- Highly sensitive modality

Disadvantages

- Low specificity
- Somewhat invasive (injection required)

Primary use:

- Localizing bone tumors
- Detecting skeletal metastases
- Early diagnosis of stress fractures

149

Diagnostic Ultrasound

- Frequency range of 1 – 15 Mhz
- Pulser delivers bursts of US in 1000 to 5000/ min. range
- Greatest intensity at centre of beam “focal zone”
- Higher frequencies
  - Less spread
  - More likely to be reflected off tissue interfaces
  - Do not travel as far as lower frequencies

150

Diagnostic Ultrasound

White areas

- Represent "echoic" structures
- Transmit & reflect waves
  - Soft tissue
  - Muscles, fat
  - Vessels, nodes
  - Masses

Black areas

- Represent anechoic structures
- Transmit but do not reflect waves
  - Fluid

Lines

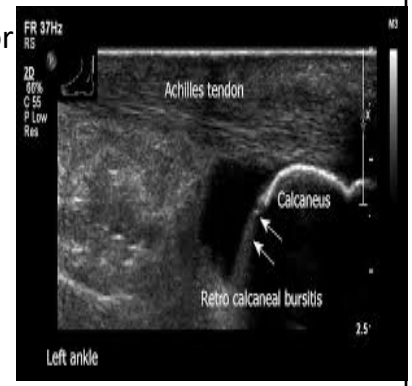
- Represent boundaries between structures with different echoic properties

151

Diagnostic Ultrasound

Tissue characteristics

- Air –-near total reflector (scatter reflector)
- Fluid - near total propagation (no reflection)
- Bone - near total reflection
- Soft tissue - partial propagator / partial reflector



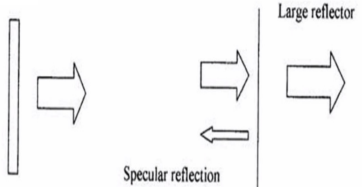
152

Diagnostic Ultrasound

Reflections

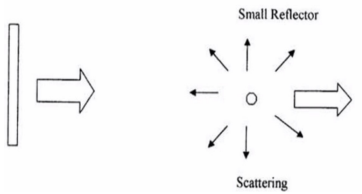
Specular

- Echoes from large smooth structures
- Relatively intense (bone)



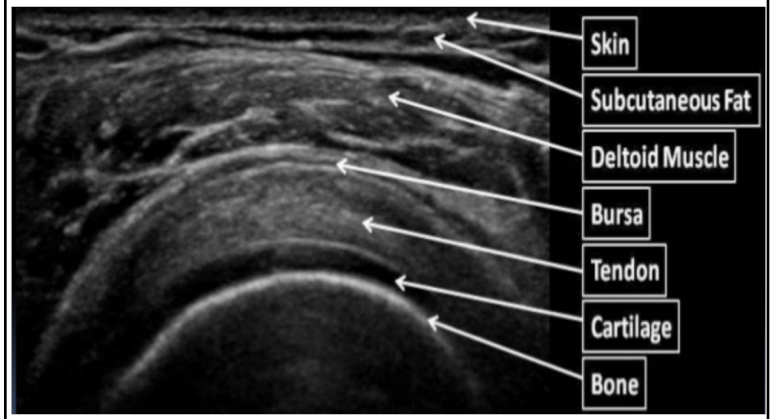
Scattered

- Echoes from relatively small irregular shaped objects (red blood cells)



153

Diagnostic Ultrasound



154

Diagnostic Ultrasound

Tissue	Characteristics
Cortical bone	Hyperechoic, smooth, continuous
Tendons, ligaments	Hyperechoic, distinct parallel fiber pattern
Muscle	Hypoechoic, parallel fibrous hyperechoic bands
Bursa	Thin hyperechoic line
Hyaline cartilage	Hypoechoic layer next to hyperechoic cortex
Nerve	Hyperechoic relative to muscle
Cysts	Anechoic

155

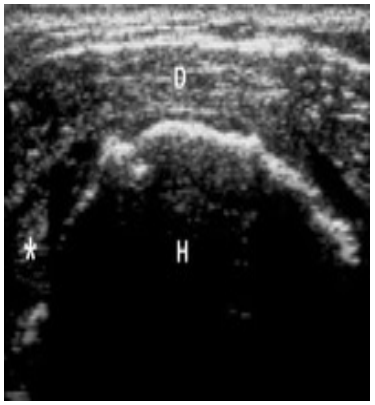
Diagnostic Ultrasound

- Extensive chronic bursitis.
- Thickened synovial bursal layers *(B)*,
- Mimics a thickened rotator cuff tendon (SSP) (ie, tendinosis)

156

Diagnostic Ultrasound

- Full-thickness tear of the supraspinatus tendon.
- The deltoid muscle *(D)* lies directly on the humeral head *(H)*, thus mimicking the rotator cuff. *



157

Diagnostic Ultrasound

Massive full-thickness tear of the supraspinatus tendon.

- The moderately hypoechic layer *(ST)* is subcutaneous soft tissue.
- The hypoechoic layer between the deltoid muscle *(D)* and humeral head *(H)* is intra-articular fluid *(F)*.
- The deltoid muscle should not be mistaken for the rotator cuff *.

158

Pathological US image characteristics

Pathology	Characteristics
Fracture	Break in continuity, uneven surfaces
Tendon /ligament strains	Thickening of mixed echogenicity (hypoechoic if inflammation or hematoma) Disrupted fiber pattern
Tendon/ligament rupture	Disruption of structures, (hypoechoic if acute hematoma) Separation of structure ends
Muscles strain	Disruption of fibrous bands (hypoechoic in acute hematoma)
Muscle rupture	Retraction of muscle stumps
Bursitis	Increased width of bursa (should be thin line)
Cartilage damage	Inhomogeneous thickness, (early stage), Irregularity and disruption (later stages)
Nerve compression	Flattening, swelling proximal to compression (axonal flow blockage)
Distended /abnormal cyst	Increased volume, thickened walls, internal debris

159

Clinical utility of ultrasound

Advantages

- Affected area may be placed in variety of positions
- Can activate musculotendinous structure during examination
- Can apply traction/compression during examination
- Can stress ligaments during examination
- Just as accurate as MRI for imaging muscles
- Can demonstrate internal structure of tendons
- Comparable to MRI for imaging ligaments
- Can demonstrate inflammation in nerves
- Can predict risk of fracture from osteoporosis

160

Clinical utility of ultrasound

Limitations

- Limited field of view
- More operator dependent than other modalities
- Doesn't penetrate bone
- Does not cross air interface
- Obese patients do not image well

161

Diagnostic Ultrasound

Utility

Shoulder:
- Dx of RC tears

Hip:
- Congenital hip dysplasia, illiopspoas bursitis

Knee:
- Articular cartilage thickness & intra-articular effusions

Fractures:
- Healing progression

Other:
- Soft tissue masses
- Hematoma
- Tendon rupture
- Abscesses
- Foreign bodies

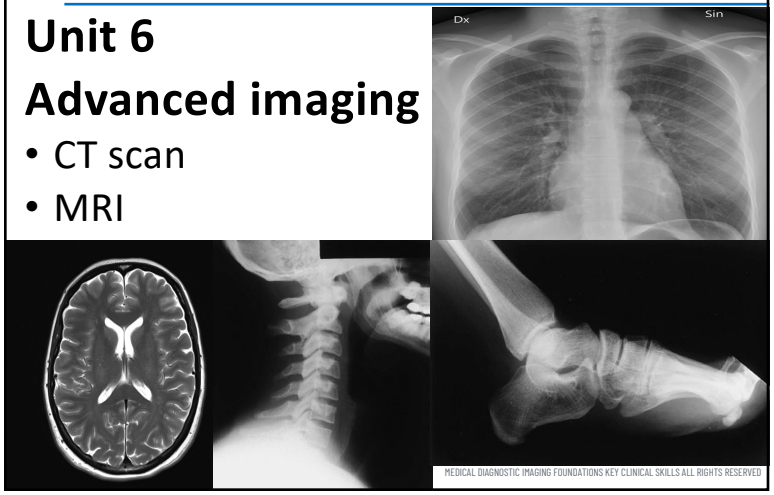
162

Medical Imaging Foundations

Unit 6

Advanced imaging

- CT scan
- MRI



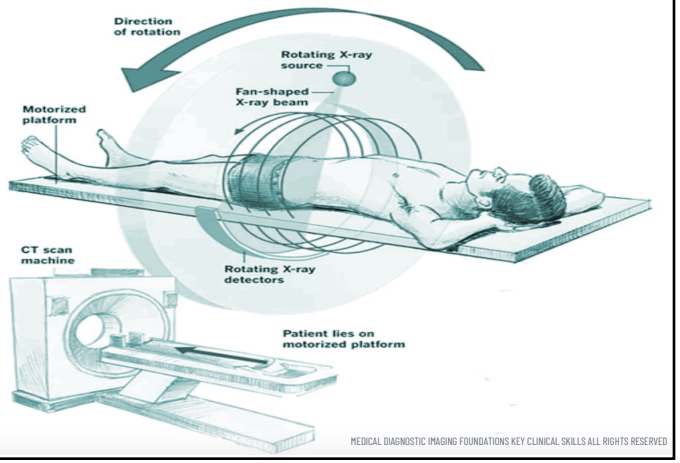
163

Computed tomography (CT)

- Use high intensity X-ray
- Scanner moves around patient
- Creates series of “slices”
- Spiral scanners in common use
- Faster scan times
- Controlled overlap between slices
- Can be set for “bone window “ or “soft tissue window”

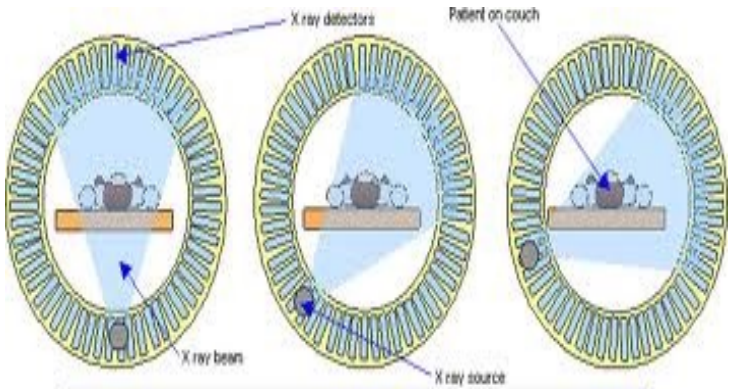
164

Computed tomography



165

Computed tomography



166

Viewing CT images

Radiodensities

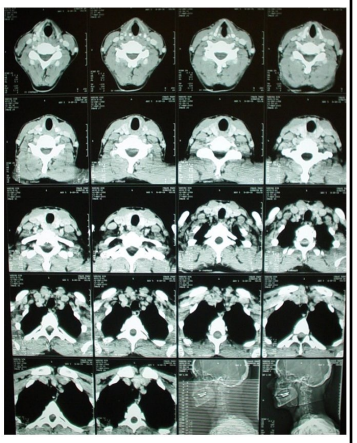
- CT accurately reflects the radiodensity in shades of grey
  - Is still and X-ray
  - Is still a negative image
- Volume averaging smooth's images but loses detail

167

Viewing CT images

Axial image

- Displayed as if patient lying in supine and viewed from caudo to cephalic
- **You are looking up from below**
- Left side of image is pt's right side



168

Clinical utility of CT

- Loose bodies in joints
- Subtle fractures
- Degenerative changes
- Serious trauma
- Spinal stenosis
- Accurate measurement of osseous alignment in any plane
- Claustrophobic patients (less “tight” than MRI)

169

Advantages of CT

- Less expensive
- Greater availability
- Faster image times
- Less operator time
- Thinner slices
- Less loss of image quality (motion)
- Greater resolution power for cortical bone
- Easier imaging for patients with ferous metal implants

170

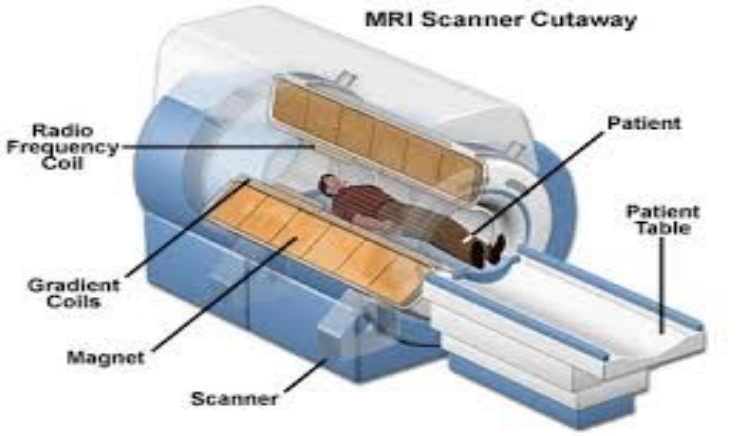
Radiation dose of CT exams

Examination	Effective dose	Chest X-ray equivalent
CT brain	2.8	140
CT chest	6.2	310
CT abdomen & pelvis	17.2	860
CY whole aorta	13.4	670
CT pulmonary vessels	3.6	180
CT cervical spine	2.1	105
CT lumbar spine	2.7	135

Brix 2003

171

Magnetic Resonance Imaging (MRI)



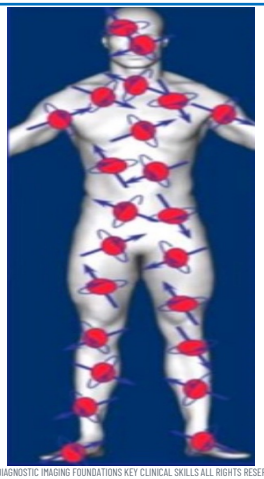
172

Magnetic Resonance Imaging (MRI)

Polar molecules

- "North pole"
- "South pole"

Human polar molecules are randomly assorted



Maher 2018

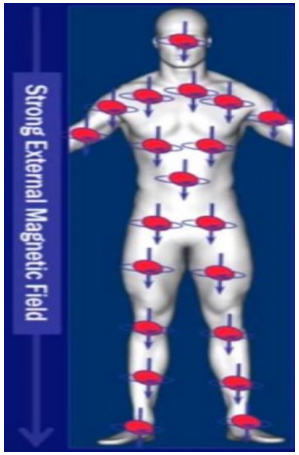
173

Magnetic Resonance Imaging (MRI)

Polar molecules

When placed in strong magnetic field

- Polar molecules align



Maher 2018

174

Magnetic Resonance Imaging (MRI)

Radiofrequency pulse on:

- 63 MHz
- Cause protons to jump to higher level of excitation

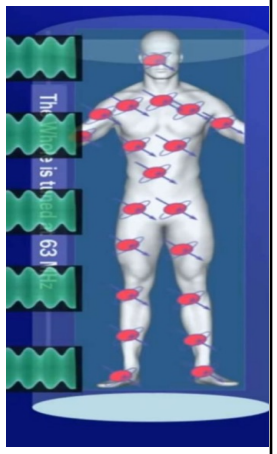
Maher 2018

175

Magnetic Resonance Imaging (MRI)

Radiofrequency pulse off:

- Cause protons to return to lower level of excitation
- Emit energy



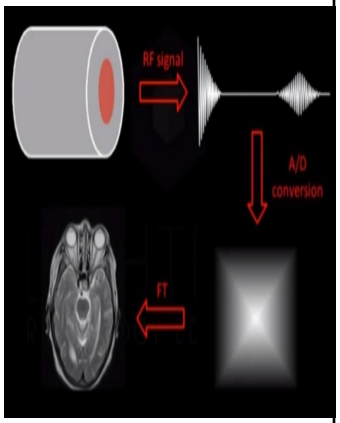
Maher 2018

176

Magnetic Resonance Imaging (MRI)

Computer system

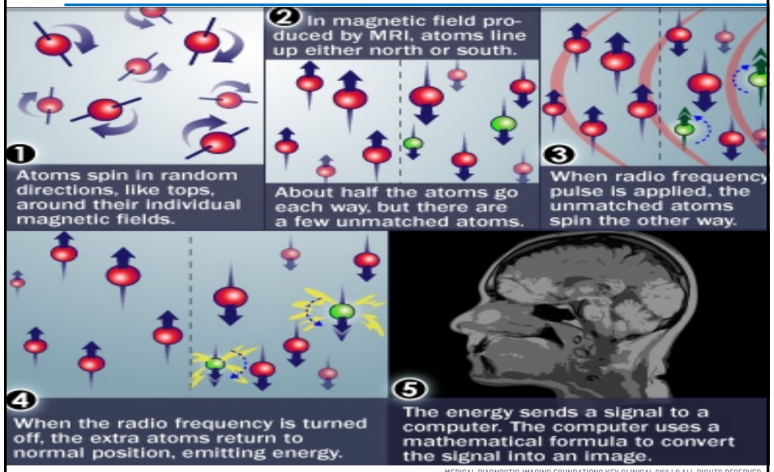
- Receives RF signal
- Digital signal sent to processor
- Transformation into image



Maher 2018

177

Magnetic Resonance Imaging (MRI)



Gould 2008

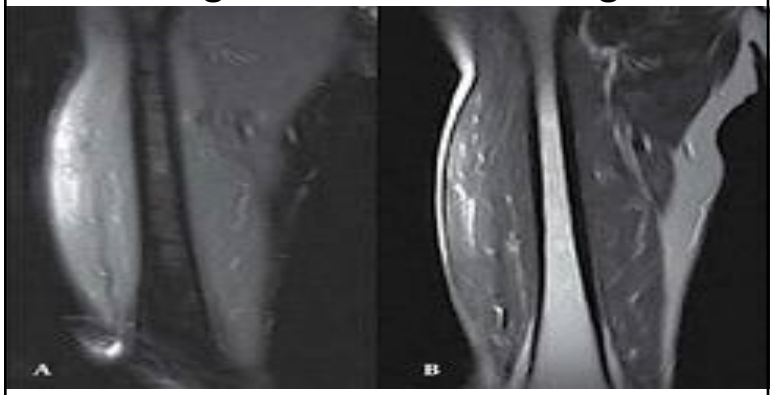
178

Time for "T"

179

Time for "T"

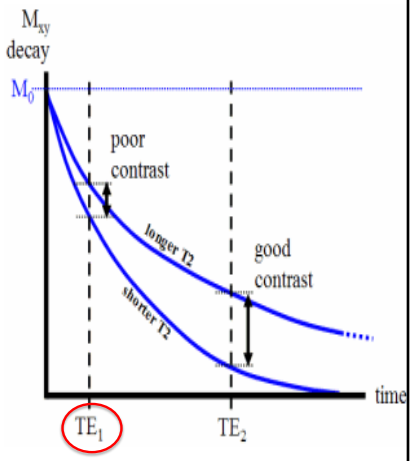
T1 image T2 image



180

Time for "T1"

- Measures structures that rapidly give up energy (ie. fat)
- Good anatomical detail
- Fairly balanced picture of tissues



181

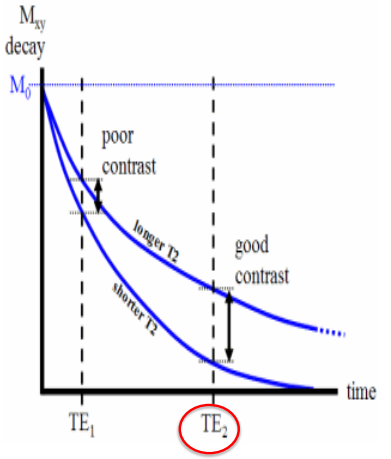
Time for "T1"

- Measures structures that rapidly give up energy (ie. fat)
- Good anatomical detail
- Fairly balanced picture of tissues

182

Time for "T2"

- Measures structures that give up energy slowly (ie. water)
- Valuable for detecting inflammation
- Selectively shows specific structures



183

Time for "T2"

- Measures structures that give up energy slowly (ie. water)
- Valuable for detecting inflammation
- Selectively shows specific structures

184

T1 vs T2

185

MSK MR signal intensity T1 vs T2

Tissue type	T1 weighted image	T2 weighted image
Cortical bone/calcium	Very low	Very low
Red marrow	Intermediate/Low	Intermediate
Fat/yellow marrow	High	Intermediate
Ligaments and tendons	Low	Low
Muscle	Intermediate	Intermediate
Fluid	Low	High

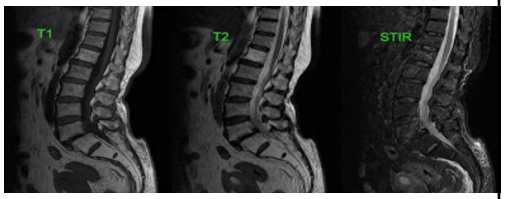
186

MR STIR, FLAIR

STIR

Short T1 Inversion Recovery

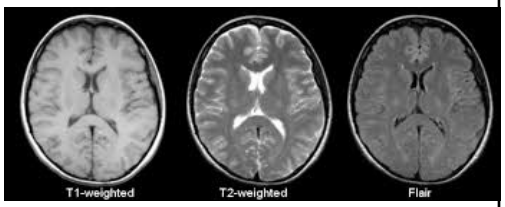
- Nulls signal from fat



FLAIR

Fluid attenuation inversion recovery

- Nulls signal from fluid



187

CNS MR signal intensity CT/MR FLAIR

Image intensity						
CT	CSF	Edema	White matter	Gray matter	Blood	Bone
MR T1	CSF	Edema	Gray matter	White matter	Carti-lage	Fat
MR T2	Carti-lage	Fat	White matter	Gray matter	Edema	CSF
MR T2 FLAIR	CSF	Cartilage	Fat	White matter	Gray matter	Edema

188

MR - PD & GRE

PD

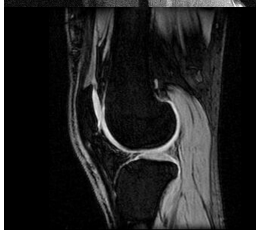
Proton Density

- Signal picked up ½ way between T1 and T2
- Nulls signal from fat

GRE

Gradient echo

- Thin slices allow cartilage to be viewed
- Fat suppression narrows grey range providing greater contrast

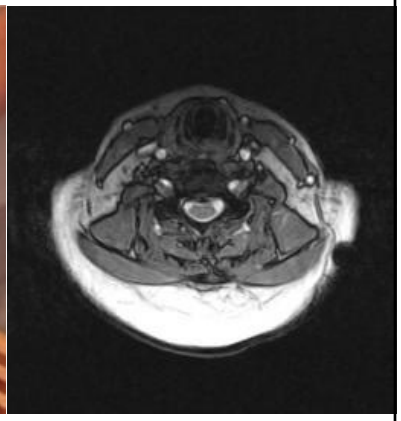


189

How do you slice your bread?

190

A transverse problem will be best visualized in:



191

A longitudinal problem will be best visualized in:

192

Clinical Utility of MRI

- Sensitive to changes in bone marrow – bone tumors and avascular necrosis
- Soft tissue detail – tears in tendon and ligaments
- Replaces invasive investigations – meniscal, labral tears ("open it up and have a look")
- 3 dimensional capability means can stage neoplasms
- More sensitive than bone scan for bone metastases (bone scan still a good screening tool)
- Differential diagnosis of disc herniations and other nerve root impingements

193

Advantages of MR

- Greater contrast resolution for soft tissue imaging
- Greater ability to image organs surrounded by bone
- No ionizing radiation
- No artifacts from interfering bone
- Less risk of missing disease as pathology missed on T1 is found on T2 and vice versa
- Greater image quality in non-axial planes

194

Abnormal findings on MRI

Pathology	T1 weighted signal	T2 weighted signal
Inflammation	Decreased	Increased
Acute Hemorrhage	High	Moderate
Sub-acute Hemorrhage	Moderate high	Moderate low
Soft-tissue calcifications	Low	Low
Soft-tissue tumors	Low	High
Bone tumors	Variable	Variable
Acute fractures	Low	Low
Stress fractures	Low	High

195

MRI "pathology" in asymptomatics

Image findings	20 yrs	30 yrs	40 yrs	50 yrs	60 yrs	70 yrs	80 yrs
Disc degeneration	37%	52%	68%	80%	88%	93%	96%
Disc signal loss	17%	33%	54%	73%	86%	94%	97%
Disc height loss	24%	34%	45%	56%	67%	76%	84%
Disc bulge	30%	40%	50%	60%	69%	77%	84%
Disc protrusion	29%	31%	33%	36%	38%	40%	43%
Annular fissure	19%	20%	22%	23%	25%	27%	29%
Facet degeneration	4%	9%	18%	32%	50%	69%	83%
Spondylolisthesis	3%	5%	8%	14%	23%	35%	59%

Brinjikji 2015

196

Utility of MRI/CT/US

Spine

	CT	MRI	U/S
Osseous	Complex fractures Intra-articular fragments at shoulder & elbow	AVN humeral/femoral head AVN scaphoid	
Tendon injury		Rotator cuff tendinitis vs partial tear vs full tear	Rotator cuff tendinitis vs partial tear vs full tear AC joint injury
Ligament injury		Instability of shoulder Labral tears Ligamentous lesions wrist	Ligament strain elbow on stress tests Tenosynovitis and ganglia
Nerve entrapment	Dimensions of carpal tunnel		Flattening of median nerve in carpal tunnel

197

Utility of MRI/CT/US

Upper extremity

	CT	MRI	U/S
Osseous	Fractures, loose fragments Bony tumors	Tumors Infections	
Radiculopathy	Osseous narrowing of spinal canal and IVF	Nuclear herniation vs annular prolapse Other causes ie. facet, cysts, tumors infection	
Degenerative changes	Facet joint degeneration & osteophytosis	Intra-discal degeneration, RA	
Functional application		Dimensions of canal in various positions Fatty infiltrates of muscle	Pre-manipulative testing of VA Measurement of muscle size Trunk muscle recruitment

198

Utility of MRI/CT/US

Upper extremity

	CT	MRI	U/S
Osseous	Complex fractures hip, knee, ankle	Occult fractures & tumors Osteochondral fractures Osteochondritis dissecans Early AVN hip Stress fractures Epiphyseal fractures	
Pediatrics		Congenital dislocation hip	Congenital dislocation hip
Ligament injury		Meniscal tears Best modality for tears of ACL, PCL	Capsular & ligament tears knee, ankle
Tendon injury		Tendinitis, thickening, increased fluid	Tendinitis, partial & full tears

199

Clinical indications for advanced imaging

Clinical or radiographic indication	MR	CT	Scintigraphy (bone scan)	Ultrasonography
Extremities				
Evaluation of neoplasms	++	+		
Determining skeletal distribution of neoplasms or other multifocal skeletal diseases			++	
Internal joint derangements	++			
Osteomyelitis	++	+		
Osteonecrosis	++			
Complex fractures		++	+	
Suspected occult fracture (stress or acute)	+	+	+	
Complicated disease processes or findings unexplained by more conservative tests	+	+		
Soft tissue injury: muscle, tendon, ligament	+			
Intra-articular bodies and joint effusion	++			
Nerve entrapment, injury, neuropathy	++			
Foreign bodies in soft tissue				+

200

Clinical indications for advanced imaging

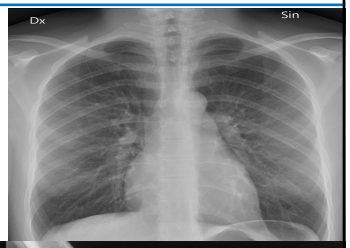
Clinical or radiographic indication	MR	CT	Scintigraphy (bone scan)	Ultrasonography
Spine				
Evaluation of neoplasms detected on radiograph	++	+/- contrast		
Determining skeletal distribution of neoplasms or other multifocal skeletal diseases			++	
Clinical or laboratory tests suggesting plasma cell myeloma	++			
Myelopathy	++			
Cauda equine syndrome	++			
Lumbar radiculopathy with positive straight leg raise, abnormal reflex, dermatome or myotome deficits not responding to 4 weeks of conservative care	++			
Infectious spondylo-discitis	++			
Neural tumors and multiple sclerosis	++			
Post-operative evaluation of arthrodesis		+		
Post-operative evaluation of recurrent disc herniation vs fibrosis	++ +/- GAD			
Burst fractures or other unstable fractures	++	+		
Suspected occult fracture		+		
Complicated disease process or findings unexplained by more conservative tests		+		

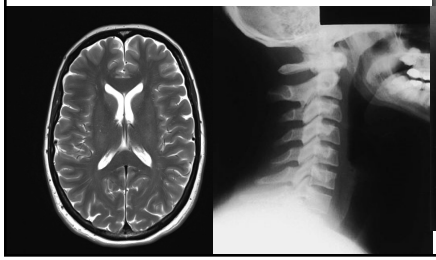
201

Medical Imaging Foundations

Unit 7

Fractures 1





202

Fractures
Radiological features

- Focal discontinuity in the structure of the bone (cortical lines)
- Displacement of bone
- Focal alteration in the smooth contour of the bone
- Change in shape of bone
- Linear region of sclerosis

203

Fractures
Radiological features

- Lucent line
- Avulsion fragment
- Double density
- Lipo-hemarthrosis or fat/blood interface “FBI” sign
- Abnormal fat pad
- Displaced fat pad

204

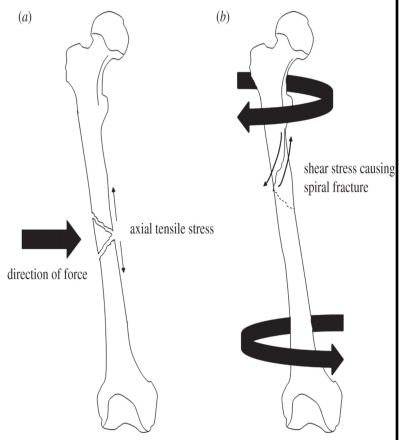
Injury

Direct force

- Bone breaks at point of impact,
- Soft tissues are also damaged at this site

Indirect force

- Bone breaks at a distance from where fore is applied
- Repetitive stress
- Pathological fractures

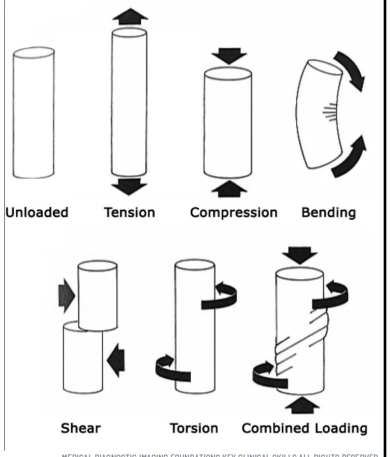


205

Fracture patterns

Some fracture patterns reveal the dominant mechanism:

- Spiral-twisting
- Oblique-compression
- Triangular-bending
- Transverse-tension



206

Fractures

Fatigue fractures

- AKA “stress fractures”
- Occur in normal bone subjected to repeated heavy loads
- Typical in; athletes, dancers new military recruits

Pathological fractures

- Inflammatory (Paget’s disease)
- Infective (Osteomyelitis)
- Neoplastic (Ewing’s sarcoma)
- Nutritional (Rickets)
- Genetic (Osteogenica Imperfecta)
- Drugs (steroids and methotrexate)

207

Fractures

- X ray is the fundamental tool in diagnosis of fractures
- High specificity “Rule in” (If you see a fracture then there is probably a fracture)

BUT

- Just because you don’t’ see it does not mean it’s not there
- Essential to get 2 views “one view is none view”

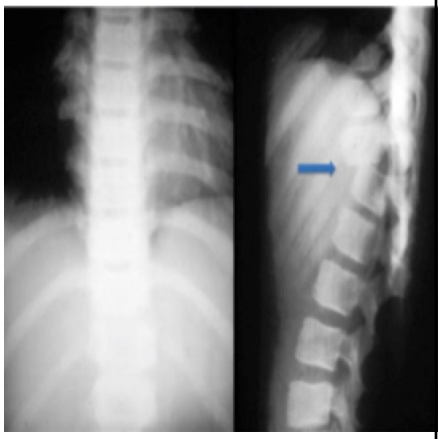
208

Fractures

- X ray is the fundamental tool in diagnosis of fractures
- High specificity “Rule in” (If you see a fracture then there is probably a fracture)

BUT

- Just because you don’t’ see it does not mean it’s not there
- Essential to get 2 views “one view is none view”



209

Fractures

Fracture classification

Consistent terminology

- Provides treatment guidelines
- Predicts prognosis
- Improves communication

1. Anatomic description
2. AO classification
3. Salter-Harris classification
4. Gustillo open classification
5. Fracture specific classifications

210

Fracture terminology

Anatomic Description

- Things that may be used to describe fractures:
  - Open vs closed
  - Anatomic location of fracture
  - Fracture line
  - Relationship of fracture fragments
  - Special classifications

211

Anatomic description

Describes the precise anatomic location of the fracture

- States:
  - If left or right
  - Name of bone
- Location:
  - Long bones divided into thirds
    - Proximal
    - Middle
    - Distal

212

Anatomic description

- Besides location it is helpful to describe if the location involves the adjoining joint space “intra-articular”
- “Intra-articular fracture of the base of the first metacarpal”

213

Anatomic description ?

214

Anatomic description ?

"Simple, transverse, non-comminuted distal radial and ulnar fracture with 100% radial translation, 45 degrees apex ulnar angulation and 2 cm of shortening"

215

Open vs Closed

Closed fracture

- Simple fracture
- No open wounds of skin near fracture

Open fracture

- AKA "Compound fracture"
- Cutaneous (open wounds) of skin near fracture site
- Open fractures are open displaced and/or comminuted
- Medical emergency

216

Open vs Closed

Radiographic signs of open fracture

- Soft tissue defects
- Bone fragment protruding beyond soft tissues
- Gas in soft tissues
- Intra-articular gas
- Presence of foreign body
- Missing bone fragments

217

Open Fractures

Gustillo Classification

Used to classify open fracture based on quantity of soft tissue damage

Grade 1

- <1 cm wide
- Min. tissue injury
- Wound clean & min. comminution
- Av. union in 21-28 wks.

Grade 2

- >1 cm wide
- Mod. tissue injury & contaminated
- Mod. comminution
- Av. union in 26- 28 wks.

Grade 3A

- Wound > 10 cm wide
- Wound crushed & contaminated
- Soft tissue coverage possible
- Av. union 30-35 wks

Grade 3B

- Wound > 10 cm wide
- Wound crushed /contaminated
- Soft tissue cannot cover
- Requires free flap
- Av. union 30-35 wks

Grade 3C

- Major vascular injury

218

Fracture lines

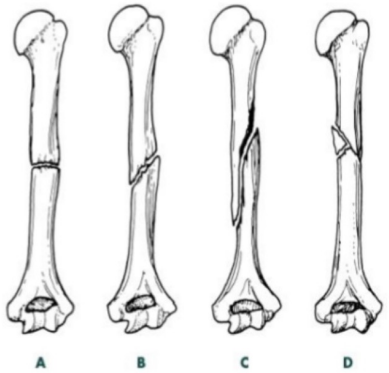
Types of fracture lines

A. Transverse

B. Oblique

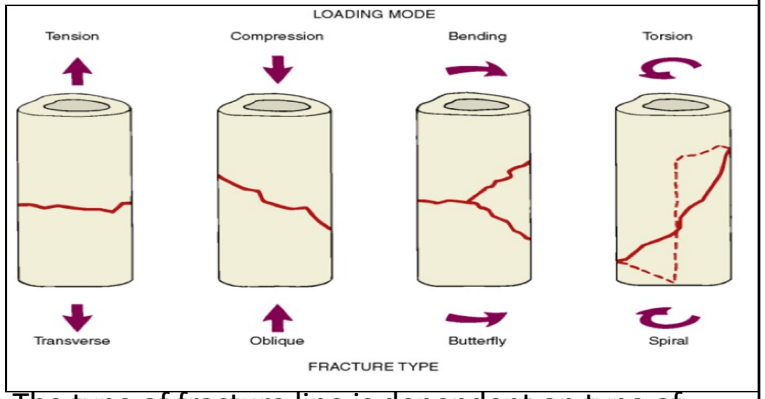
C. Spiral

D. Comminuted



219

Fracture lines



The type of fracture line is dependent on type of load applied to bone

220

Fracture lines

Spiral fractures

- AKA “Torsion fracture”
- Only possible from twisting force
- Typical of specific mechanisms of injury
  - –Skiing
  - –Child abuse

221

Fracture lines

There is also impacted fractures where the fracture ends are:

1. Compressed together (i.e. vertebral compression fractures)
2. Distracted apart (i.e avulsion fractures)

222

Fracture lines

Comminution

- Measure of the number of pieces of broken bone
- Mild
- Moderate
- Severe

223

Fracture lines

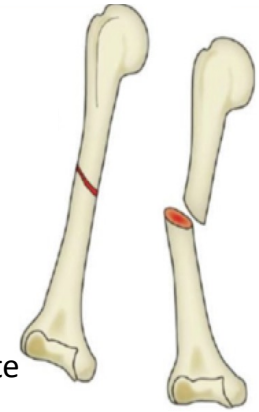
Displacement

Amount the pieces have moved from their normal location

Fracture displacement

Dependent on:

- Force of the injury
- Effects of gravity
- Pull of muscles attached to site

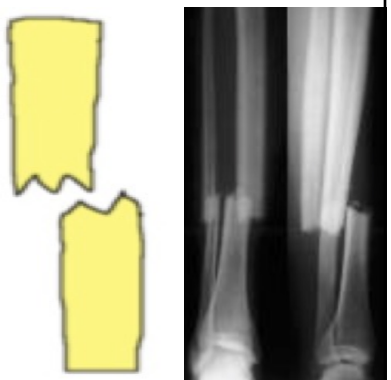


224

Relationship of bone fragments

Translation

- Sideways movement of fracture
- Usually described as % of diameter of the bone



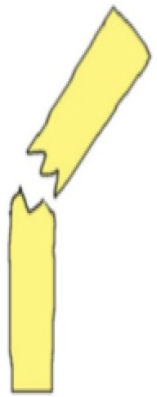
225

Relationship of bone fragments

Displacement

Angulation

- Amount of bend at a fracture
- Described in degrees
- With respect to the apex of the angle or with respect to direction of distal fragment



226

Relationship of bone fragments

Displacement

Shortening

- AKA “bayonette apposition”
- The amount a fracture is collapsed
- Expressed in cm.

227

Fracture description?

228

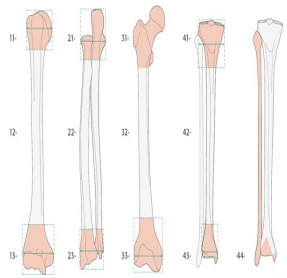
Fracture description?

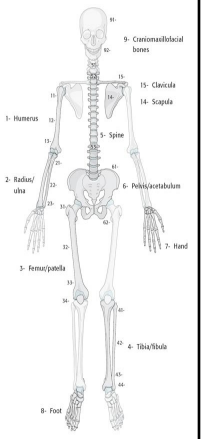
"Simple, transverse, non-comminuted mid-shaft radial and ulnar fracture with 30 degrees apex radial angulation"

229

AO Classification

- 1st number = long bone
- 2nd number = segment



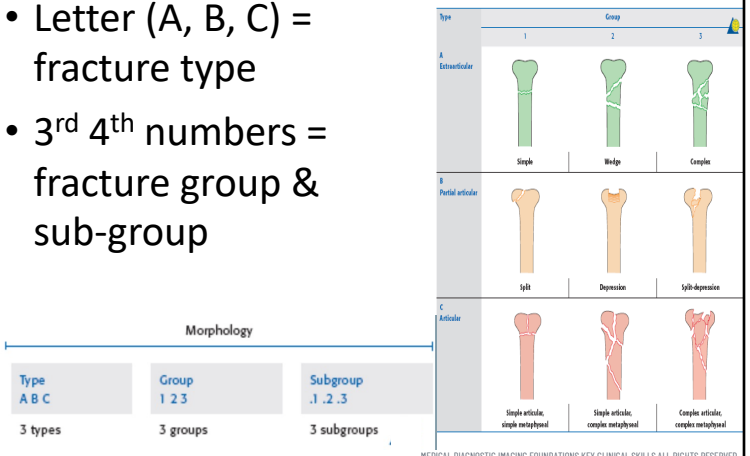


Localization	
Bone 1 2 3 4	Segment 1 2 3 (4)
4 long bones	3 or 4 segments

230

AO Classification

- Letter (A, B, C) = fracture type
- 3rd 4th numbers = fracture group & sub-group

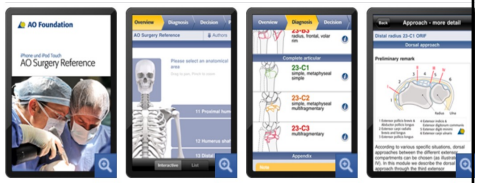


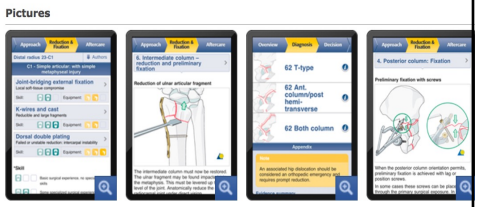
231

AO Classification

AO app

- https://aotrauma.aofoundation.org/Structure/education/self-directed-learning/mobile-apps/Pages/mobile-apps.aspx#null



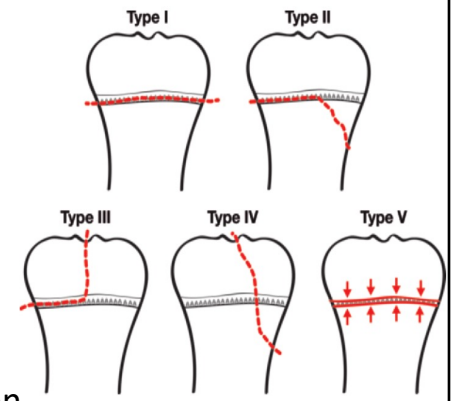


232

Salter-Harris Classification

Only used for pediatric fractures that involve the physis (growth plate)

- Five types
- Prognostic value for future bone growth disruption

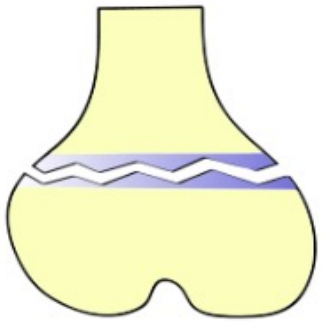


233

Salter-Harris Classification

Type 1

- Fracture is across the physis with no metaphysial or epiphyseal injury
- Low risk of growth disturbance



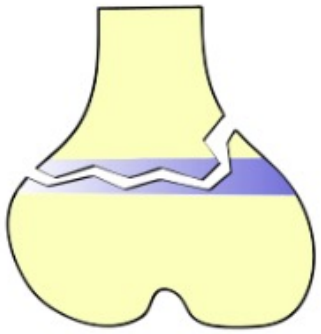
Type 1 - 5%

234

Salter-Harris Classification

Type 2

- Fracture is across the physis which extends into the metaphysis
- Most common
- Variable growth disturbance
  - Depends on location (rare in wrist but high in distal femur)

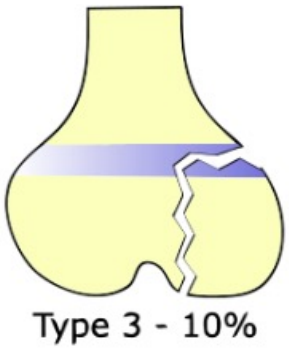


235

Salter-Harris Classification

Type 3

- Fracture is across the physis
- Which extends into the epiphysis
- Variable growth disturbance
- Anatomic reduction important as fracture involves joint

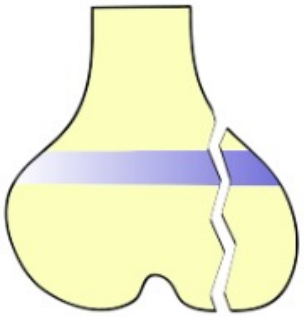


236

Salter-Harris Classification

Type 4

- Fracture is across the physis with metaphysial and epiphyseal injury
- Low risk of growth disturbance



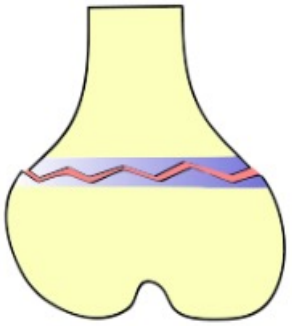
Type 4 - 10%

237

Salter-Harris Classification

Type 5

- Fracture is across the physis with no metaphysial or epiphyseal injury
- Physis has been compressed
- High risk of growth disturbance



Type 5 - uncommon

238

Salter-Harris Classification

Use the Salter-Harris system to classify these fractures

239

Salter-Harris Classification

II III IV

240

Greenstick Fractures

- Incomplete fractures of long bones
- Usually seen in children under 10 yrs
- Commonly mid-diaphyseal
- Affect forearm & lower leg
- Distinct from Torus fractures

241

Torus Fracture

AKA "buckle fractures"

- Incomplete fractures of shaft of long bone
- Characterized by bulging of cortex
- Result from trabecular compression from axial load (long axis of bone)

242

Compression Fractures

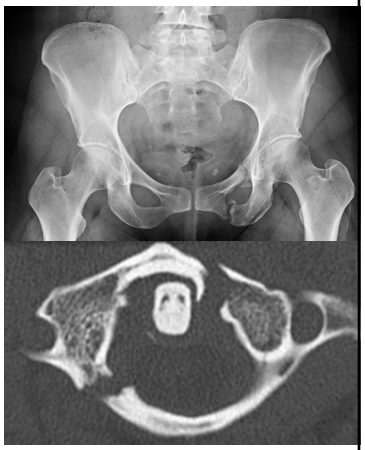
- Vertebral collapse of at least 15-20% in height
- Loss of bone density (osteoporosis) often the underlying cause
- Spinal malignancy also possible

243

Fractures of rings

Complete rings of skeletal bone seldom fracture in only one location

- Jefferson
- Hangman's
- Obturator foramen
- Pelvic ring
- Spinal canal



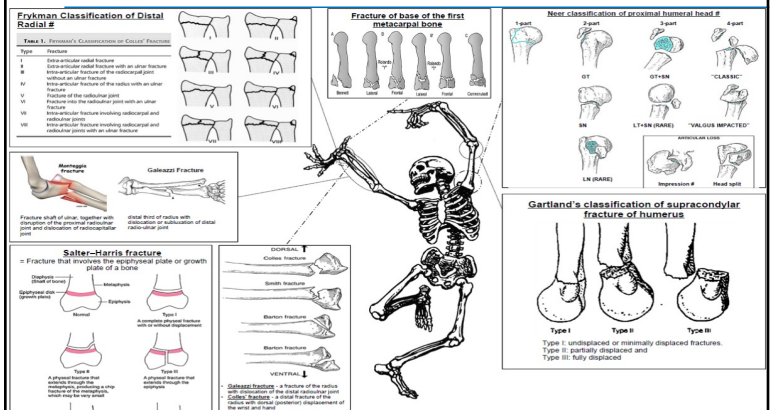
244

Fracture "Nicknames"

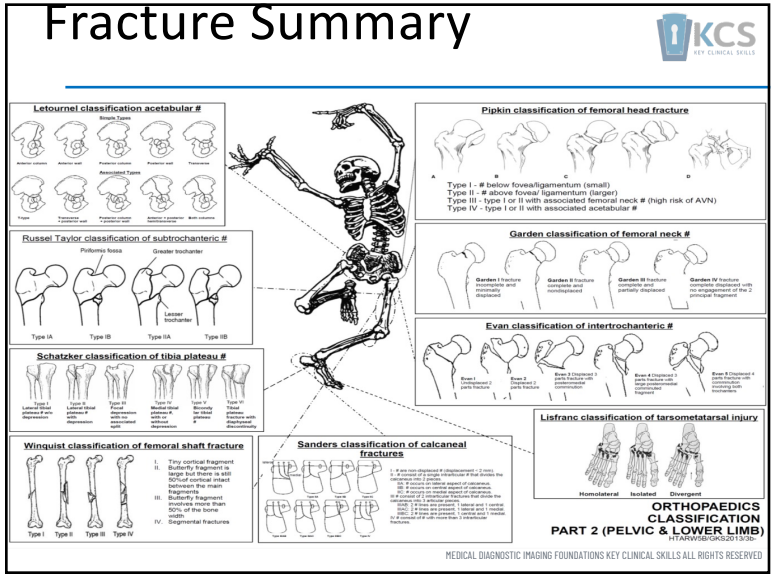
- Aviator's #
- Astragalus #
- Barton's #
- Bennett's #
- Bosworth's #
- Boxer's #
- Burst #
- Chance #
- Chauffeur's #
- Chopart's #
- Clay shoveler's #
- Colles #
- Cotton's #
- Die-Punch #
- Dupuytren's #
- Duverney's #
- Essex-Lopresti's #
- Galezzi's #
- Greenstick #
- Jefferson's #
- Hangman's #
- Hill-Sach's #
- Holstein -Lewis #
- Jones #
- Lisfranc #
- Maisonneuve's #
- Malgaigne's#
- Mallet finger
- Monteggia's #
- Nightstick #
- Posada's #
- Pott's #
- Rolando #
- Segong #
- Shepherd's #
- Smith #
- Stieda's #
- Straddle #
- Teardrop #
- Tillaux's #
- Torus #
- Walther's #

245

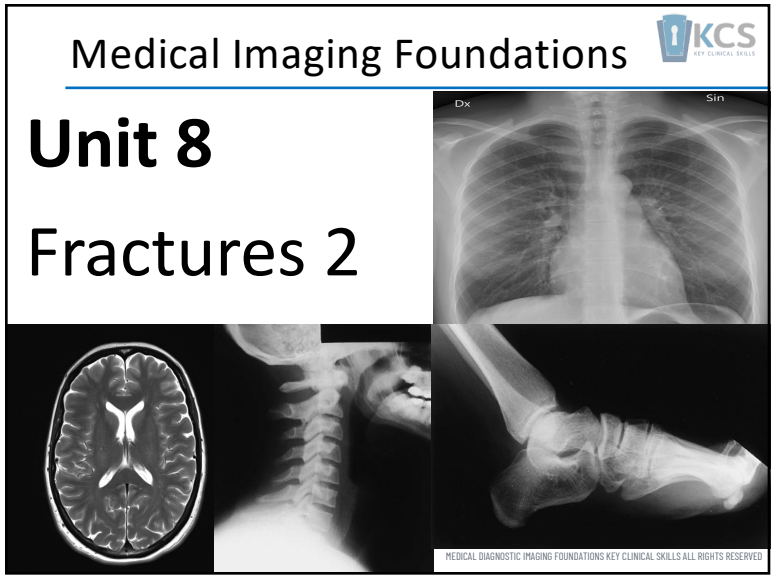
Fracture Summary



246


Fracture Summary
KCS
KEY CLINICAL SKILLS
Letournel classification acetabular #
Pipkin classification of femoral head fracture
Type I - # below fovea/ligamentum (small)
Type II - # above fovea/ ligamentum (larger)
Type III - type I or II with associated femoral neck # (high risk of AVN)
Type IV - type I or II with associated acetabular #
Russel Taylor classification of subtrochanteric #
Piriformis fossa
Greater trochanter
Lesser trochanter
Type IA
Type IB
Type IIA
Type IIB
Garden classification of femoral neck #
Garden I fracture incomplete and minimally displaced
Garden II fracture complete and nondisplaced
Garden III fracture complete and partially displaced
Garden IV fracture complete displaced with no engagement of the 2 principal fragment
Evan classification of intertrochanteric #
Schatzker classification of tibia plateau #
Lisfranc classification of tarsometatarsal injury
Homolateral
Isolated
Divergent
Winquist classification of femoral shaft fracture
I. Tiny cortical fragment
II. Butterfly fragment is large but there is still 50%of cortical intact between the main fragments
III. Butterfly fragment involves more than 50% of the bone width
IV. Segmental fractures
Type I
Type II
Type III
Type IV
Sanders classification of calcaneal fractures
ORTHOPAEDICS
CLASSIFICATION
PART 2 (PELVIC & LOWER LIMB)
MEDICAL DIAGNOSTIC IMAGING FOUNDATIONS KEY CLINICAL SKILLS ALL RIGHTS RESERVED

247


Medical Imaging Foundations
KCS
KEY CLINICAL SKILLS
Unit 8
Fractures 2
Dx
Sin
MEDICAL DIAGNOSTIC IMAGING FOUNDATIONS KEY CLINICAL SKILLS ALL RIGHTS RESERVED

248

Factors affecting bone healing

- **Age** – Fractures unite faster in children
- **Type of bone** – Faster union in flat & cancellous bone
- **Fracture pattern** – Spiral > oblique > transverse > comminuted
- **Disturbed patho-anatomy** – Soft tissue inter-postision and ischaemia prevent faster healing
- **Immobilization** – Depends on bone (scapula & ribs not needed)
- **Open fracture** – Often go into delayed union &/or non-union
- **Compression fractures** – Enhances union (cancellous) & primary bone healing (cortical)

249

Fracture Healing

Reparative process of self-healing (*union*) occurs in stages:

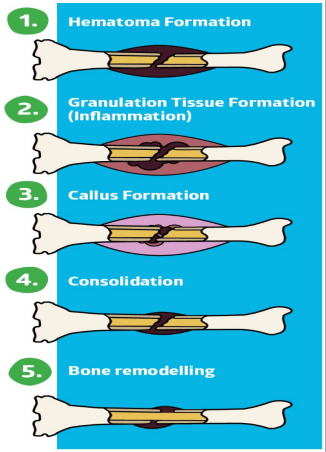
A. Fracture hematoma (d/t bleeding, edema)

B. Granulation tissue → osteoid (3 – 14 days post injury)

C. Ossification (3 wks – 6 mos)

D. Consolidation (distance between fragments decreases → closes).

E. Remodeling (union completed; remodels to original shape, strength)



250

Fracture Healing

251

Fracture Complications

Delayed / non-union

Biological Causes:

- Inadequate blood supply
- Severe soft tissue damage affects fracture healing by:
  - Reducing muscle splintage
  - Damaging local blood vessels
  - Diminishing osteogenic input from mesenchymal stem cells within muscle

252

Fracture Complications

Biomechanical

- Imperfect splintage
- Over-rigid fixation
- Infection
- Periosteum stripping

Patient-related

- Poor / non-compliance to weight bearing restrictions
- Obesity
- Nutritional (Rickets)

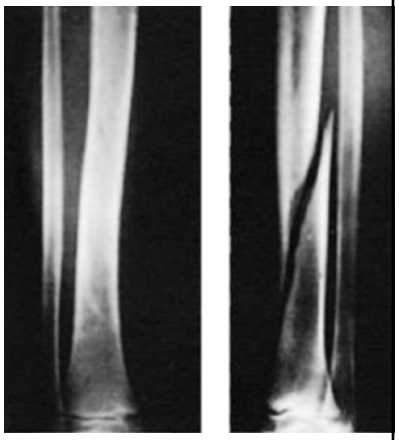
253

X-ray investigation

Rule of two's

2 views

- A fracture or dislocation may not be seen on a single x-ray.
- 2 views at right angles must be taken.



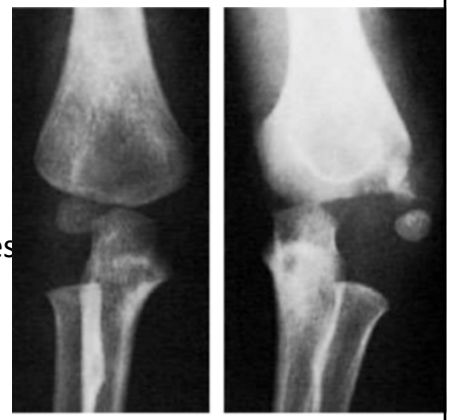
254

X-ray investigation

Rule of two's

2 limbs

- In children, the appearance of immature epiphyses may confuse the diagnosis.
- Contralateral uninjured limb comparison needed



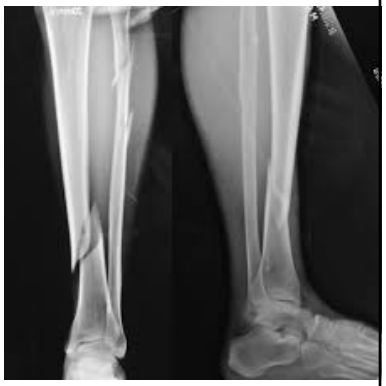
255

X-ray investigation

Rule of two's

2 injuries

- Severe force often causes injuries at more than 1 site
- Fractures of rings



256

X-ray investigation

Rule of two's

2 joints

- In the forearm or leg one bone may be fractured & slightly angulated
- However significant angulation is not possible unless other bone is broken too

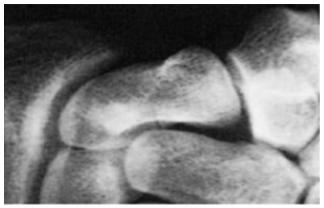
257

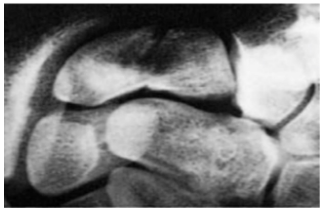
X-ray investigation

Rule of two's

2 occasions

- Some fractures notoriously difficult to detect early.
- Second x-ray (delayed by 1-2 weeks) may reveal it (distal clavicle, scaphoid femoral neck, lat. maleolus





258

Advanced imaging

CT

- May be helpful in lesions of the spine or for complex joint fractures (ie. calcaneus, acetabulum

MR

- May be the only way to demonstrate if spine fractures are threatening spinal cord

Bone scans

- Helpful in diagnosing suspected stress fractures

259

Fracture Complications

Visceral Injuries

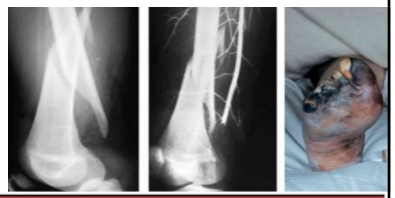
- Fractures around trunk
  - Penetration of lung by rib fractures can cause pneumothorax
- Rupture of bladder or urethra in pelvic fractures
  - Can cause peritonitis
  - Require emergency treatment

260

Fracture Complications

Vascular Injuries

- Ischemia distal to fracture site



Injury	Vessel
First rib fracture	Subcalvian
Shoulder dislocation	Axillary
Humeral supracondylar fracture	Brachial
Elbow dislocation	Brachial
Pelvic fracture	Presacral and internal iliac
Femoral supracondylar fracture	Femoral
Knee dislocation	Popliteal
Proximal tibial	Popliteal or its branches

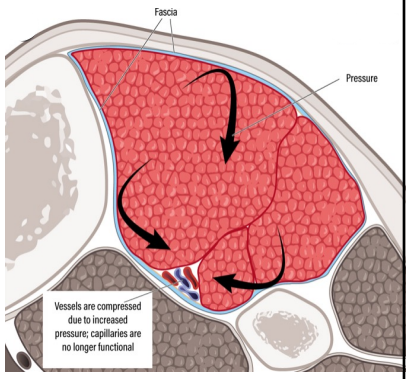
261

Fracture Complications

Compartment Syndrome

"Six Ps"

1. Paresthesia
2. Pain
3. Pressure
4. Pallor
5. Paralysis
6. Pulselessness



262

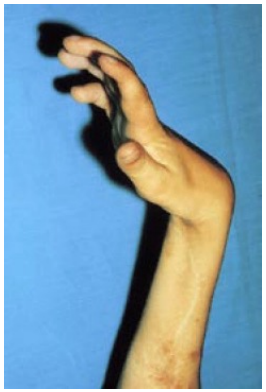
Fracture Complications

Volkman's Ischemic contracture

- Severe manifestation of compartment syndrome
- Permanent flexion contracture of hand, wrist & fingers

Most affected

- Flexor digitorum profundus
- Flexor pollicus longus



263

Fracture Complications

Venous Thrombosis

- Veins of lower extremities & pelvis highly susceptible to thrombus formation after fracture, especially hip fracture
  - Venous stasis caused by incorrectly applied casts or traction
  - Local pressure on a vein
  - Immobility
- Lack of anti-coagulant prophylaxis

264

Fracture Complications

Fat Embolism Syndrome (FES)

Clinical Manifestations

- Usually occur 24-48 hours after injury
- Interstitial pneumonitis
- Rapid and acute course
- Feeling of impending disaster
- Patient may become comatose in a short time
- Produce symptoms of Acute Respiratory Distress Syndrome (ARDS)

Symptoms of ARDS:

- Chest pain
- Tachypnea
- Cyanosis
- Dyspnea
- Apprehension
- Tachycardia

265

Fracture Complications

Fractures that most often cause FES:

- Long bones
- Ribs
- Tibia
- Pelvis

Tissues most often affected:

- Lungs
- Brain
- Heart
- Kidneys
- Skin

266

Fracture Complications

Closed nerve injuries

Seldom severe

90% recovery in 4 months

Open nerve injuries

- Poor prognosis
- Should be surgically repaired if possible

Injury location	Nerve
Shoulder dislocation	Axillary
Humeral shaft	Radial
Humeral supracondylar	Radial/Median
Elbow medial condyle	Ulnar
Monteggia fracture-dislocation	Posterior inter-osseous
Hip dislocation	Sciatic
Knee dislocation	Peroneal

267

Fracture Complications

Hemarthrosis

- Intra-articular fractures
- Joint swells rapidly
- Patient resists all movements
- Fat pad sign
- Aspiration and lavage recommended

268

Fracture Complications

Infection

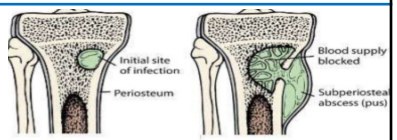
- Gustillo classification of open fractures

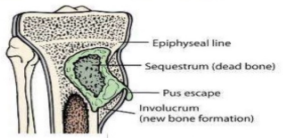
Early osteomyelitis

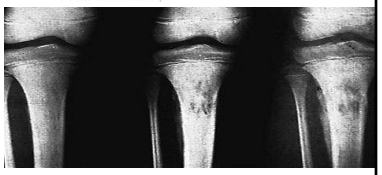
- May present as wound inflammation & discharge

Late osteomyelitis

- May present with a sinus
- X-ray evidence of sequestra







269

Fracture Complications

Gas Gangrene

- Produced by clostridia infection
- Toxins cause necrosis of tissue & promote spread of disease

Clinical features

- Intense pain
- Swelling round wound
- Brown discharge
- Little to no pyrexia
- Increase pulse
- Characteristic smell
- Rapid decline to coma & death

270

Fracture Complications

Myositis ossificans

- Heterotropic ossification post-injury

Common sites:

- Post-dislocation of elbow (brachialis)
- Post femur # (quadriceps)
- 8 weeks palpable and x-ray visible

271

Fracture Complications

Avascular necrosis

Common sites

- Head of femur
- Proximal part of scaphoid
- Lunate
- Body of talus

Consequences

- Deformation of bone
- OA in few years
- Pain
- Limitation ROM

272

Fracture Complications

Growth disturbance

- In children due to damage to physis
- Salter-Harris type 3 & 5 most at risk

273

Fracture Complications

Fracture blisters

- Clear fluid filled vesicles
- Occur during limb swelling

Plaster & pressure sores

- Friction from splints/casts
- Bed sores from immobilization (pelvic, hip fractures)

274

Fracture Complications

Joint instability

- Ligamentous injury at time of fracture
- Recurrent dislocation

Stiffness

- Knee, elbow, shoulder

Arthritis

- Post intra-articular fracture

275

Dislocations

Complete & persistent displacement of a joint at which at least part of supporting joint capsule some of its ligaments are disrupted

Congenital

- Hip

Acquired

- TB hip, septic arthritis
- Neurological (Polio, CP)
- Inflammatory disorders RA

276

Dislocations

Dislocations are named by the relative position of the distal segment in relationship to the proximal one

Q: Describe the dislocation.

277

Dislocations

Dislocations are named by the relative position of the distal segment in relationship to the proximal one

Q: Describe the dislocation.

A: "This is an anterior dislocation of the knee"

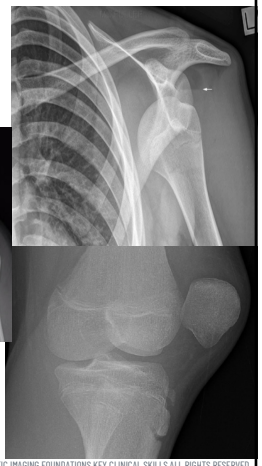
278

Dislocations

Possible at all joints

Most common at:

- Shoulder
- AC joints
- Hip
- Patella
- Elbow
- MCP joints
- Facet joints



279

Dislocations

Acute Complications

- Injury to peripheral nerve blood vessels

Chronic sequelae

- Recurrent dislocation
- Traumatic OA
- Joint stiffness
- Avascular necrosis
- Myositis ossificans

280

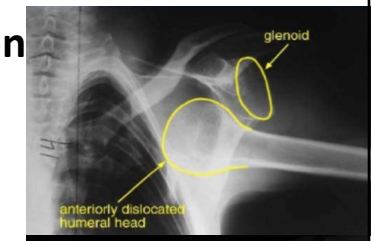
Dislocations

Shoulder dislocation

Anterior

- Sub-coracoid
- Sub-glenoid
- Sub-infraclavicular
- Inferior

Posterior



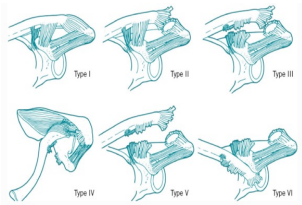
281

Dislocations

Acromio-clavicular dislocation

AKA "shoulder separation"

- MOI fall on point of shoulder



282

Dislocations

Posterior Hip dislocation

- Generally dashboard injury

Thomas & Epstein classification

Type	Characteristics
1	Posterior dislocation without significant posterior wall fragment
2	Dislocation with large posterior wall fragment
3	Dislocation with comminuted posterior wall fragments
4	Dislocation with acetabular floor fracture
5	Dislocation with femoral head fracture

283

Dislocations

Elbow dislocations

- MOI FOOSH

MCP, MTP, IP Dislocations

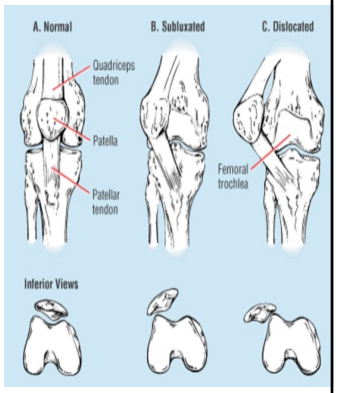
284

Dislocations

Patellar dislocations

Type	Dislocation	Pain	Swelling
Acute	Trauma	+	+
Recurrent	Occasional in response to trauma	+	+
Habitual	Each time knee is flexed	-	-
Congenital	Since birth	-	-

Subluxed vs dislocated



285

Dislocations

Facet Joint Dislocation

AKA "Jumped facets"

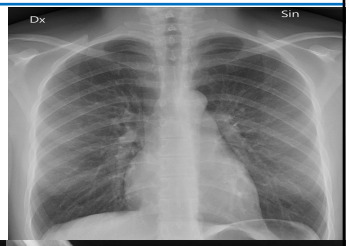
- Commonest cervical spine orthopaedic injury
- Medical emergency
- May lead to quadriplegia
- May require open reduction

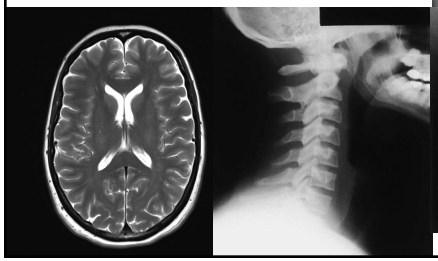
286

Medical Imaging Foundations

Unit 9

Practice integration 1





287

Practice integration

What's the view?

288

Practice integration

What's the view?

- Antero-postero open mouth

289

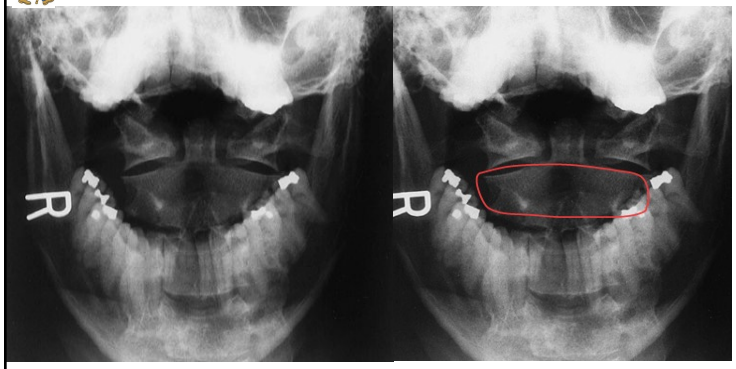
Practice integration

Body of C2

290

Practice integration

Body of C2



291

Practice integration

What do the arrows indicate?

292

Practice integration

What do the arrows indicate?

- A. Osteophytes at the vertebral endplates
  B. Schmorl's nodes
  C. Facet joint dislocation

293

Practice integration

What do the arrows indicate?

A. Osteophytes at the vertebral endplates

- Osteophytes at the vertebral endplates result from degenerative changes at the intervertebral segment.

294

Practice integration

What's the view?

295

Practice integration

What's the view?

- Antero-postero cervical spine

296

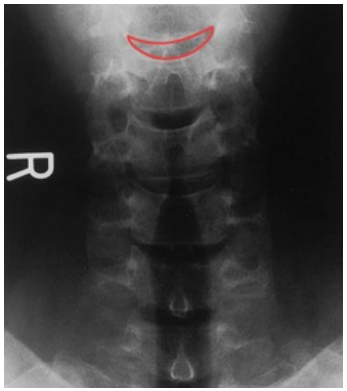
Practice integration

C2-C3 intervertebral disc space

297

Practice integration

C2-C3 intervertebral disc space



298

Practice integration

left pedicle of C6

299

Practice integration

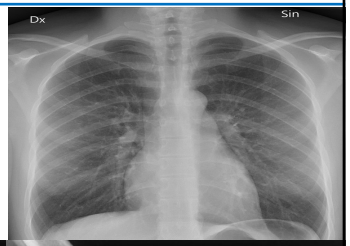
left pedicle of C6

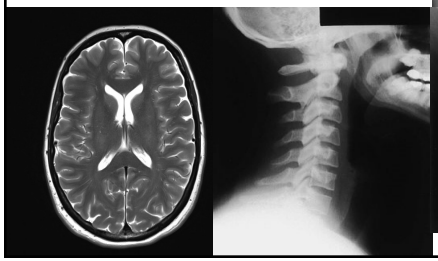
300

Medical Imaging Foundations

Unit 10

Practice integration 2

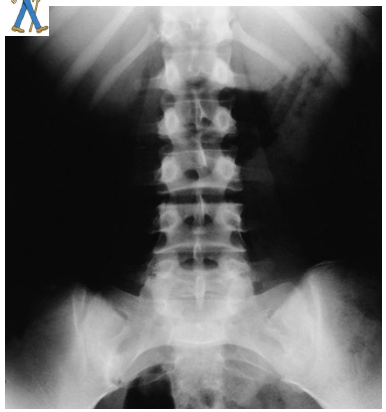




301

Practice integration

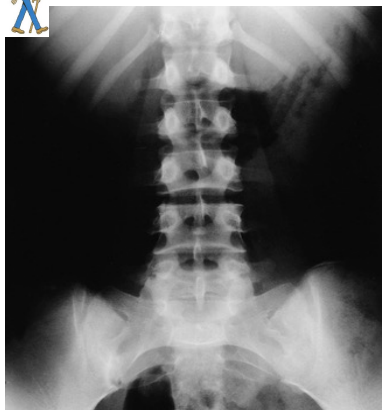
What's the view?



302

Practice integration

What's the view?

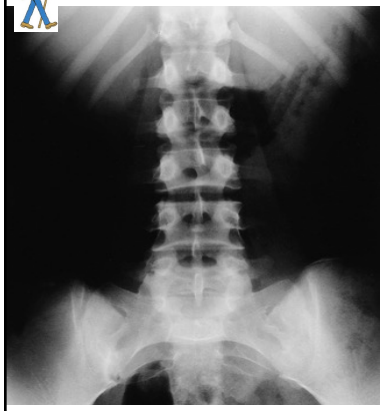


- Antero-postero lumbar spine

303

Practice integration

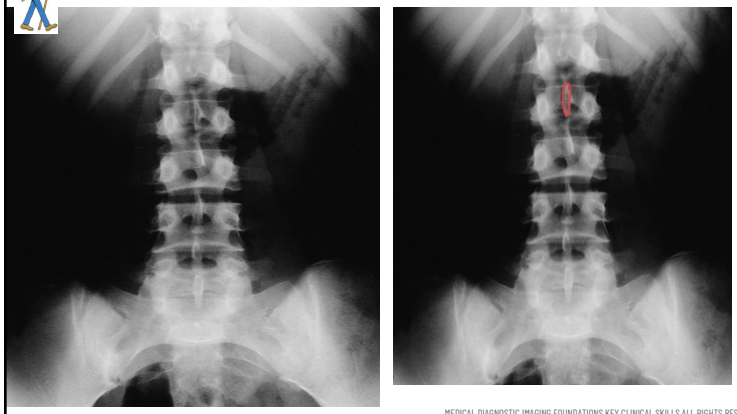
spinous process of L2



304

Practice integration

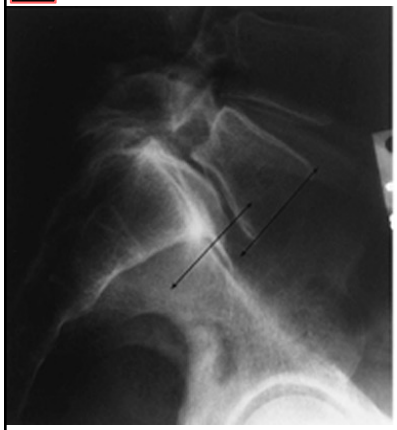
spinous process of L2



305

Practice integration

What view is this?

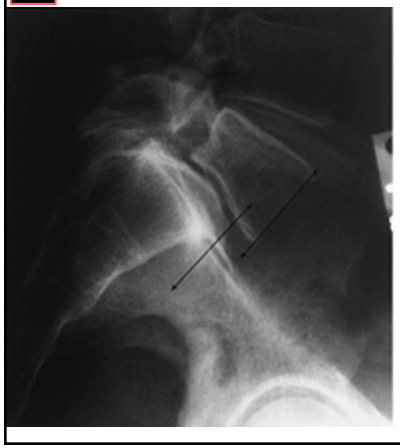


- A. Antero-posterior lumbar spine
  B. Lateral lumbar spine
  C. Lateral lumbo-sacral spine

306

Practice integration

What view is this?

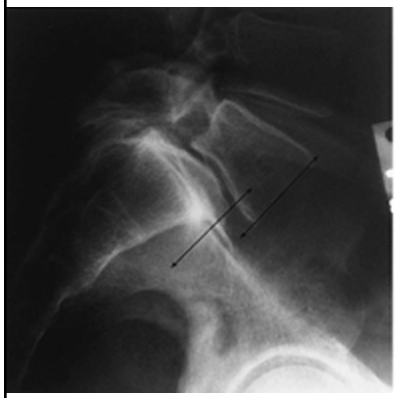


- C. Lateral lumbosacral spine
- This is a *"coned"*, or close-up, lateral view of the lumbo-sacral articulation.

307

Practice integration

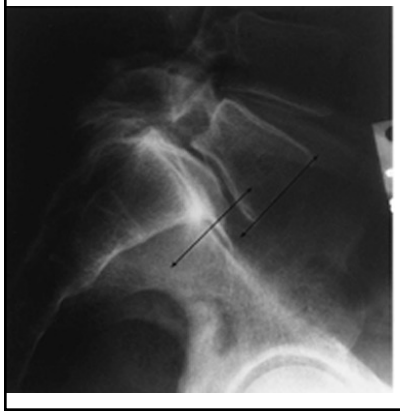
The *lined arrows* represent a disruption in the _____.



308

Practice integration

The *lined arrows* represent a disruption in the _____.

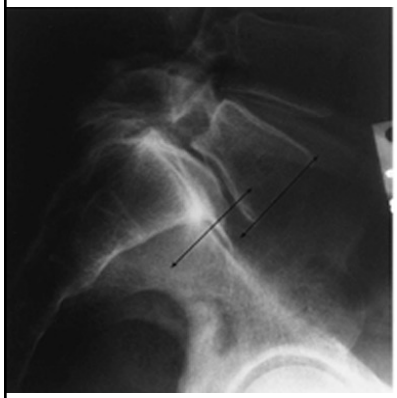


- A. anterior vertebral body line
- B. posterior vertebral body line
- C. lateral vertebral body line

309

Practice integration

The *lined arrows* represent a disruption in the _____.



- A. anterior vertebral body line
- The *anterior vertebral body* line represents the connected anterior borders of the vertebral bodies and normally forms a continuous lordotic curve.

310

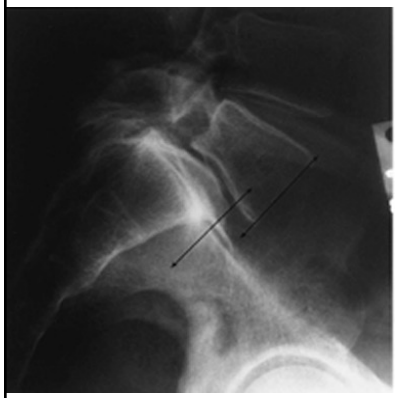
Practice integration

This pathology is described a_____

311

Practice integration

This pathology is described a_____



- Degenerative spondylolisthesis, grade 1+
- This degenerative spondylolisthesis is differentiated from fracture spondylolisthesis by the intact vertebra. The grade is determined by the amount of forward displacement. L5 has translated forward by more than 25 percent of its depth, so the grade is 1+.

312

Practice integration

What's the view?

313

Practice integration

What's the view?

- Antero-postero hip

314

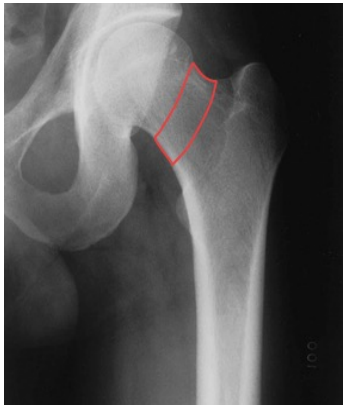
Practice integration

femoral neck

315

Practice integration

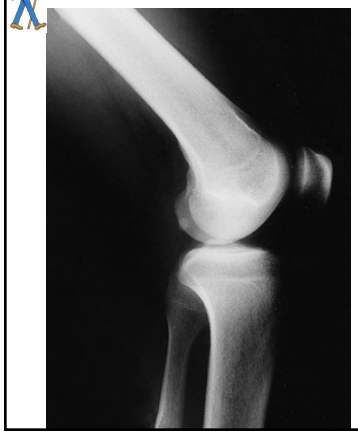
femoral neck



316

Practice integration

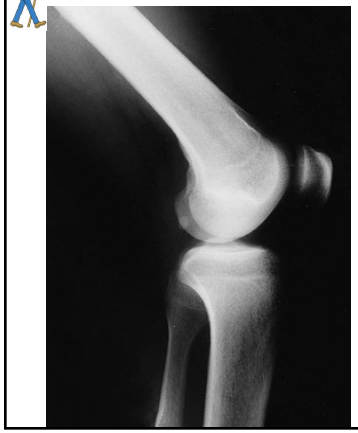
What's the view?



317

Practice integration

What's the view?



- Lateral knee

318

Practice integration

anterior supracondylar shaft of the femur

319

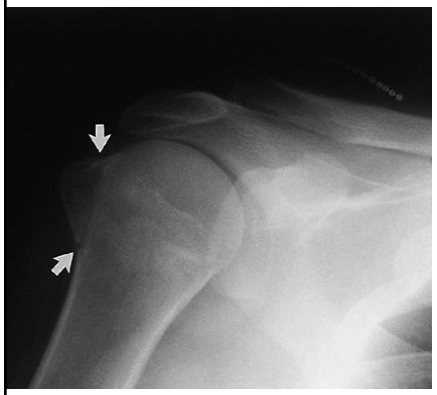
Practice integration

anterior supracondylar shaft of the femur

320

Practice integration

What view is this?

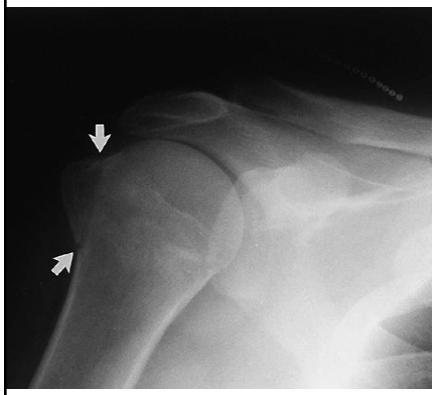


- A. antero-posterior external rotation
- B. antero-posterior internal rotation

321

Practice integration

What view is this?

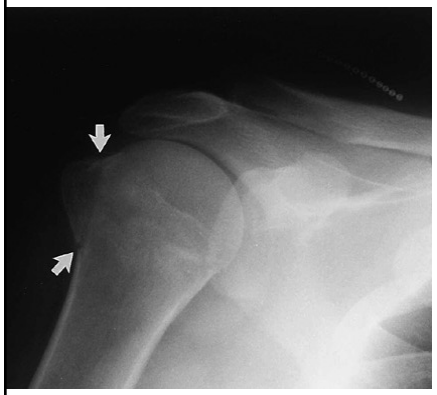


- A. antero-posterior external rotation
- The image of the greater tuberosity, and not the lesser tuberosity, determines that this is an external-rotation view.

322

Practice integration

What do the arrows point to?

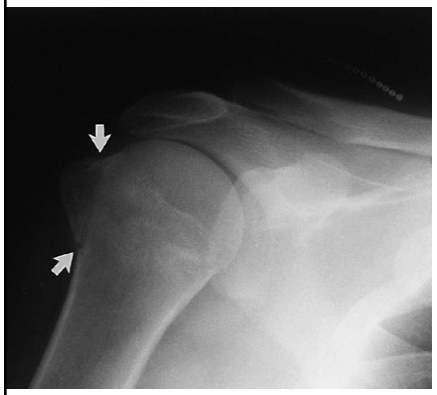


- A. surgical neck fracture
  B. greater tuberosity fracture
  C. lesser tuberosity fracture

323

Practice integration

What do the arrows point to?

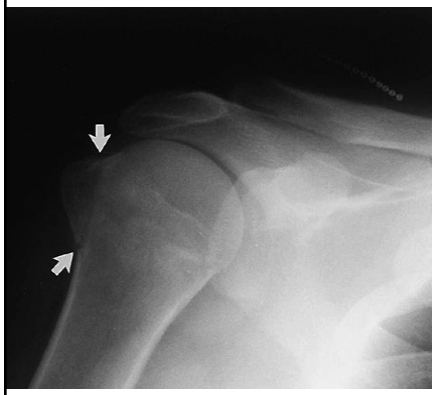


- B. greater tuberosity fracture
- A complete, vertically oriented fracture line is evident through the greater tuberosity.

324

Practice integration

What can be said about the subacromial joint?

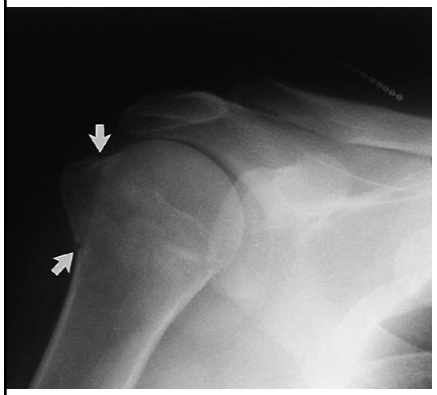


- A. The joint space appears normal.
- B. The joint space appears decreased.
- C. The joint surface has also been fractured.

325

Practice integration

What can be said about the subacromial joint?

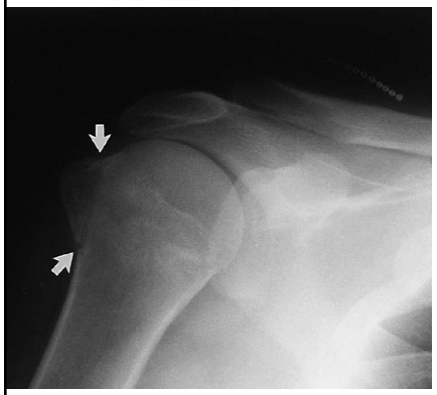


- A. The joint space appears normal.
- B. The joint space appears decreased.
- C. The jointsurface has also been fractured.

326

Practice integration

What do the arrows point to?



- B. The joint space appears decreased.
- The joint space appears abnormally decreased. There are no signs of osteoarthritis at present, such as Subchondral sclerosis or spurring. It is not clear why the joint space is decreased. Possibilities include a spasm of the deltoid that would pull the head of the humerus superiorly, or simply error in patient positioning due to the fact that this is a trauma exam and positioning is not always perfect.

327

Practice integration

What's the view?

328

Practice integration

What's the view?

- Lateral elbow

329

Practice integration

olecranon process of the proximal ulna

330

Practice integration

What's the view?

331

Practice integration

What's the view?

- Postero-antero wrist

332

Practice integration

scaphoid.

333

Practice integration

scaphoid.

334

Practice integration

lunate

335

Practice integration

lunate

336