NORMAL, NORMAL VARIANTS AND CONGENITAL ANOMALIES OF THE CERVICAL SPINE

Cervical Spine AP

Open Mouth AP
Typical “adequate” open-mouth radiographic projection.

- Complete obscuration of the occipital condyles by the maxillary premolar and molar teeth (∗).
- Obscuration of the tip of the dens is of secondary importance because of the rarity of a type I dens fracture.
- The lateral atlantodental asymmetry (arrows) is positional.

Optimal open-mouth radiographic projection shows the intact occipital condyles (oc) and lateral masses (LM) of C1, the entire dens (D), and the axis body (AB).
Cervical Oblique

- Set your patients in the oblique position.
- Place the marker on the corresponding side of the patient i.e. right on right, or left on left.

- Since there are two pedicles, the pedicle closest to the left marker must be the left pedicle and this must be the right neuroforamen!

Normal Pediatric Variants

- Pseudosubluxation
- Pseudospread of C1 on C2
- ADI space
- Absence of cervical lordosis
- Normal appearance of ossification centers and epiphyses
- And lots more......

Other Common Variants

- ADI space
  - Maximum of 4mm (new literature) in children
- Absence of cervical lordosis
  - Can be seen in children up to 16 yrs
- Oval/wedge shaped vertebrae are normal
  - Not to be confused with compression fx
- Normal appearance of ossification centers and epiphyses can simulate fractures.
Pseudosubluxation

- Normal variant.
- Related to growth and ligament physiology.
- Occurs most commonly at C2/C3.
- Also occurs at C3/C4.

Why do they pseudosublux?

- Horizontal facets.
- Weak neck musculature.
- Cartilage artifact.
- Ligamentous laxity.
- Increased with neck flexion.

Swischuk's line distinguishes pseudosubluxation from pathological subluxation.

- A line drawn connecting the anterior cortices of the spinous processes of C1 and C3 should intersect or lie within 1 mm of the anterior cortex of the spinous process of C2.
- If C2 is >2 mm off of this line, it is a true injury.

Swischuk Line

Problem's with Swischuk Line

- We see normal Swischuk line with hangman's fractures - not sensitive or positive in disease.
- We see abnormal Swischuk line with normal necks in flexion - not specific or negative in health.
- A value >1.5 -2 mm suggests an occult hangman’s fracture.

Nasty MVC - child badly hurt

Normal Swischuk Line with a Hangman’s Fracture

Swischuk line is a diagnostic adjunct
- Consider pre-test probability
- Consider concordance with tests
- Low likelihood of injury and abnormal film
  - consider repositioning/disregard
- High likelihood of injury and normal film
  - continue investigating

Physiologic Hypermobility

- Laxity of ligaments in some infants and young children may resemble ligamentous injury
- Wide interspinous distance at C1-2 can be as wide as 10-12 mm

ADI

- Dens to C1 distance may be as wide as 4-5 mm
- May increase 1-2 mm with flexion

Pseudospread of C1 on C2

- Normal variant
- Lateral mass displacement relative to the dens
  - Up to 6 mm is common <4 yoa
  - Can be seen up to 7 yoa
- Probably a result of disproportionate growth of the atlas on the axis.
- Misdiagnosed as Jefferson fracture
  - Rarely occurs prior to teen years.

• Open-mouth radiograph demonstrates a pseudo-Jefferson fracture with pseudospread of the atlas on the axis (arrow).

CT scan through C1 in an infant show the ossification centers of C1 with open synchondroses (arrows). Note the segmented tip of the dens (arrowhead in b).

Open mouth view

Dens Tilting

- Posterior
- Often normal
- Beware of anterior or lateral tilt
Lateral radiograph of the cervical spine in a pediatric patient shows normal anterior wedging of multiple cervical vertebral bodies, most prominently at the C3 level (arrow).

C2 with synchondroses

Prevertebral soft tissues

- Buckling and pseudothickening
- Full inspiration-extension
- Pharyngeal-tracheal stepoff
- Don’t spend too much time

Lateral cervical spine radiograph in a 3-year-old child.

- While not as precisely defined as in adults, the cervicocranial prevertebral soft-tissue contour (arrowheads) is concave above and below the atlas tubercle and convex anterior to the tubercle.

- Prevertebral space: Widened. It is slightly thicker than the width of a vertebral body.

- Retropharyngeal abscess.
• Prevertebral space: Slightly full, but less than the width of a vertebral body.

• Epiglottis: Thumb-like in appearance (white arrow). It should normally appear thin or triangular. The pre-epiglottic space (black arrow) is narrow and nearly obliterated.

Bone Development

- Enchondral ossification
  - cartilage model of much of the skeleton is formed from the mesenchyme
  - extremities, spine, base of the skull

- Intramembranous ossification
  - bone tissue replaces membranous fibrous skull

Primary Ossification Centers

- Present before birth
  - one for centrum
  - two for each neural arch

Secondary Ossification Centers

- Present after birth
  - epiphysis
    - forms articular cartilage
    - gives length to bone
  - apophysis
    - attachment for ligament & tendons

Block Segmentation
Clinical Data

- failure of somite segmentation
- most common at C5/D8, C2/C3, L4/L5
- aka
  - "fusion"
  - nonsegmentation
- Significance
  - minimal clinical significance or risk
  - may create aberrant segmental motion above and below the fusion site
- DDx
  - surgical fusion
  - pathological fusion
    - juvenile chronic arthritis
    - infection

Imaging

- rudimentary disc sometimes with calcification
- maintenance of vertebral body height
- smooth, often concave anterior vertebral body margins
  - Wasp vertebra
- well formed foramen on the lateral projection
- Additional Studies
  - flexion/extension x-rays to evaluate adjacent segmental motion

Surgical vs. Congenital
Failure of Fusion of C1 Neural Arch
(p. 333)
- Spina bifida occulta, dysraphism, or rachischisis

Clinical Data
- defective ossification of the cartilage anlage
- composed of cartilage and fibrous tissue
- Significance
  - no clinical significance or risk
- DDx
  - none!
  - fracture
    - too smooth
    - no relevant trauma

Imaging
- cleft or complete absence
- absence of spinolaminar line on lateral
- hyperplastic anterior arch

Imaging
- failure of fusion anterior arch of C1

Agenesis Posterior Arch

Agenesis Posterior Arch
Occipitalization (assimilation) of the Atlas

Clinical Data
- Typically, the anterior arch of the atlas is fused to the skull base
- One half of patients with occipitalization of the atlas also have vertebral fusion at the C2-C3 spinal level
- Although the odontoid process is high, directly beneath the foramen magnum basilar impression is uncommon
- Significance
  - Is a normal variant that is asymptomatic in most cases
  - Hypermobility at the ADI
  - See craniovertebral anomalies discussion

Imaging
- Evidence of fusion
- Additional Studies
  - Flexion and extension sometimes needed to assure diagnosis
  - Also ADI
  - CT with reformatting on rare occasion

Occipitalization
- Can have partial or complete congenital fusion of the atlas to the occiput
- Occipitalization can lead to symptomatic chronic atlanto-axial instability and cord impingement
- Symptoms include weakness, atrophy, spasticity, headache, which are usually slow onset, but sudden death has been associated with the condition (traumatic in 1/2, major or minor)
- If the dens is in the foramen magnum, crowding of anterior elements can result. Usually asymptomatic if dens lies below the foramen magnum.
- 60% have odontoid > 3mm displaced behind anterior arch of atlas.
- Constricting dural bands are commonly associated.
- Physical exam findings include short neck, low hairline, torticollis, restricted neck motion.
- 20% have other associated congenital anomalies.

Craniovertebral Anomalies
- Basilar impression/occipitalization
- Chiari malformation
- Renal anomalies
- Potential neurological compromise
  - Posterior column signs
  - Long tract signs
  - Consider MRI

Chiari Malformation (p. 1395)
- Herniation of the cerebellar tonsils
- Ectopia
- Less than 3mm = normal variant
- Significance
  - Associated with
    - “Wrong way” scoliosis
    - Bony anomalies
    - Syrinx/syringomyelia
- Imaging
  - MRI
Pathophysiologic Mechanisms

- Underdevelopment of the occipital somites produces a diminutive, overcrowded posterior cranial fossa. Tonsillar herniation occurs secondarily as a result of mechanical factors.
- Altered CSF dynamics which is characterized by systolic and diastolic CSF displacements related to the phases of the cardiac cycle. Respiration also affects CSF flow pulsation.
- As the herniated tonsils fill the foramen magnum in the setting of CMI, CSF flow is reduced at the craniovertebral junction, and a compensatory pulsatile descent of the cerebellar tonsils is observed during systole. This combination can effectively plug the CSF pathway at the foramen magnum.

Syringomyelia

- Spinal cord cavity (syrinx)
- Etiology
  - Pressure
  - Tumor
  - Congenital
  - Arnold Chiari—secondary to pathologic CSF dynamics. The exaggerated pulsatile systolic wave in the spinal subarachnoid space drives the CSF through anatomically continuous perivascular and interstitial spaces into the central canal of the spinal cord.
- Imaging
  - MRI

“Wrong way” scoliosis

- Left convex scoliosis
  - Thoracic spine
- Significance
  - Syringomyelia
  - Arnold Chiari malformation
  - Neurology examination
- Imaging
  - Do MRI with neurological symptoms and adults
  - Do MRI in all children

Associated Osseous Anomalies

- Platybasia, basilar invagination (25-50%)
- Atlantooccipital assimilation (1-5%)
- Klippel-Feil syndrome (5-10%)
- Incomplete ossification of C1 ring (5%)
- Proatlantal remnant spine bifida at the C1 level
- Retroflexed odontoid process (26%)
- Scoliosis (42%)
- Kyphosis
- Increased cervical lordosis
- Cervical ribs
- Fused thoracic ribs

Side Note

- Always KNOW the diagnosis in all patients with neurological signs—BEFORE you adjust
- In other words know the anatomy
- Do NOT make subluxation a “garbage bucket” diagnosis
- These can all “look” the same
  - Subluxation
  - Disc hernation
  - Multiple sclerosis
  - Syringomyelia
  - Cord tumor
  - Spinal stenosis
  - IVF stenosis

Posterior Ponticle

- Ponticulus posticus
- Posticus posticus
- Kimmerly anomaly
- Forms the arcuate foramen
Clinical Data
- Ossification of the oblique portion of the atlanto-occipital ligament between the posterior aspect of the lateral mass and the posterior arch
- Contains the vertebral artery and the first cervical nerve
- 14% of anatomic specimens

- Significance
  - Minimal clinical significance or risk

Imaging
- Seen as bony bar
- Forms the arcuate foramen

- DDX
  - Do not confuse with the mastoid process!

Epitransverse Process
- Bony extension originating from the transverse process of C-1 to end at the skull base (vs paracondylar process goes the opposite way)

- Significance
  - May create lateral head tilt
  - May affect adjusting technique
  - Effective fusion of C1 to the occiput

Imaging
- Difficult on conventional radiography
- Accessory joint may be seen on occasion

- Additional Studies
  - May require tomography on rare occasion

Clinical Data
- Os Odontoideum
- May require tomography on rare occasion
Odontoid process anomalies

- B- os terminale
- C- os odontoideum
- D- odontoid agenesis

Clinical Data

- lack of fusion of the odontoid process with the body of C-2
- previous fracture of the odontoid synchondrosis
- associated with:
  - Down's syndrome
  - Klippel-Feil syndrome
- Significance
  - renders the transverse atlantal ligament incompetent
  - potential for significant neurological insult from trivial trauma.
  - high velocity adjusting contraindicated
  - consider neurosurgical consultation
- DDx
  - fracture
  - appropriate history?
  - smooth cortices

Clinical Data

- neurological symptoms variable
- often limited to one transitory episode of diffuse paresis following trauma or progressive myelopathy with weakness and ataxia
- vertebral artery compression with cervical and brainstem ischemia
  - gait ataxia, syncope, vertigo, and visual disturbances. Later, cerebellar and brainstem infarcts and seizures may occur.
  - Sudden death is rare but can occur.
- Physical examination of patients with os odontoideum includes a complete neck examination. Evaluate for pain, range of motion (ROM), and associated anomalies. A careful neurologic examination must include assessment of cerebellar and brainstem function. Gait evaluation and Romberg tests are helpful in diagnosing os odontoideum. Other upper motor neuron findings commonly are reported, including spasticity, hyperreflexia, clonus, and proprioceptive loss.

Clinical Data

- Indications for surgery include the following:
  - Significant motion on plain radiography
  - Neurologic or neurovascular involvement
  - Persistent and disabling pain despite appropriate nonoperative management
- Suggestions for management are based on reports of small series and tend to vary between authors. Some authors report resolution of symptoms following transient paresis and recommend continued nonoperative management. Others operatively stabilize any patient reporting neurologic symptoms.
- Imaging
  - well corticated separate ossicle
  - ossicle may be absent or difficult to see
  - C1 subluxation
  - short odontoid
  - hypertrophic C1 anterior arch
- Additional Studies
  - flexion/extension: evaluate instability
  - MRI: evaluate cord compression/contusion
Os odontoideum with attenuation of the spinal cord necessitating surgical fusion

Os Terminale (Bergman)
- Failure of union of the secondary center of ossification found at the tip of the dens. Usually seen after the age of 12 years old
- Not associated with instability.

Klippel-Feil Syndrome
- Clinical Data:
  - Complex of congenital anomalies that includes:
    - Multiple segmentation anomalies of the cervical spine
    - Short webbed neck (pterygium colli)
    - Low hairline
    - Decreased range of motion
  - Associated with:
    - Renal anomalies - 50%
    - Deafness (30%)
    - Spinal cord anomalies – syringomyelia and Arnold Chiari
    - Sprengel’s deformity 25-40%

Imaging:
- Initial studies include anteroposterior, AP open mouth and lateral views of the cervical spine.
  - Fusion of vertebral bodies and posterior elements
  - Anterior vertebral bodies
  - Scoliosis
  - Rib fusion
  - Sprengel deformity
- If anomalies are found, carefully assess the craniocervical junction to detect anomalies at that level.
- Flexion-extension radiographs are indicated if instability is suspected at the craniocervical junction.
- Obtain plain radiographs of the entire spine to detect other spinal anomalies.
- Examine the chest to rule out involvement of the heart. Examine the chest wall for the possibility of rib anomalies, which can include multiple rib fusions. Rib fusions can be revealed with plain radiography.
Imaging

- Additional Studies
  - flexion/extension
  - ultrasound to demonstrate the presence of 2 functioning kidneys
  - intravenous urogram
  - neurological evaluation
  - MRI

Sprengel's Deformity

- Congenital elevation of scapula.
- incomplete descent of the scapula
- Omovertebral bone on occasion
- Seen in 20-25% of cases of Klippel-Feil syndrome
- relatively rare in chiropractic practice

Sprengel's deformity

Klippel-Feil syndrome

- Bilateral omovertebrae

Klippel-Feil syndrome
**Down Syndrome Trisomy 21**

- **Head and neck**
  - Brachycephaly
  - Upslanting palpebral fissures
  - Epicantal folds
  - Brushfield spots
  - Flat nasal bridge
  - Folded or dysplastic ears
  - Open mouth
  - Protruding tongue
  - Short neck
  - Excessive skin at the nape of neck

- **Extremities**
  - Short broad hands
  - Short fifth finger
  - Incurved fifth finger
  - Transverse palmer crease
  - Space between first and second toe
  - Hyper flexibility of joints

**Down Syndrome Major Musculoskeletal Disorders**

- Atlantoaxial instability
- Metatarsus Primus Varus
  - Problem with shoe fit
- Hallux Valgus
- Patellar Instability
- Scoliosis
- Slipped Capital Femoral Epiphysis

Most due to defect in collagen synthesis, resulting in generalized ligamentous laxity.

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**Down Syndrome Cervical Spine Abnormalities**

- Atlantoaxial Instability
- Occiput-C1 Instability
- Odontoid Dysplasia (6% of Down patients)
- Hypoplasia of posterior arch of C1
- Spondylolysis and Spondylolisthesis of midcervical vertebrae
- Precocious Arthritis of C4-C6

**Atlantoaxial Instability: Diagnosis**

- Lateral x-ray of the cervical spine in flexion, neutral, and extension
- Look at Atlas-Dens Interval (ADI)
  - Distance between anterior ramus of C-1 and the dens of C-2
  - Should not exceed 4.0mm
- All Down syndrome athletes must receive a diagnostic x-ray of the c-spine before entering Special Olympics participation

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**Downs with accentuated ADI**

**Downs Pelvis**
Cervical Ribs

Clinical Data
- Extra rib that articulates with the transverse process principally at C7, rarely C5 and C6
- 2:1 females
- 5% of the population
- Significance
  - Thoracic outlet syndrome with neurovascular compression even with small ribs
  - Symptoms become more common in older population
  - Evaluate for peripheral vascular and neurological compromise
- DDX
  - Differentiate from an enlarged C7 transverse process-observed articulation can be palpated and confused with an enlarged lymph node

Imaging
- Evidence of bone articulating with the transverse process
- Downward deflecting transverse process
- Additional Studies
  - Thoracic outlet syndrome
  - Clinical examinations
  - Neurovascular studies
  - EMG and doppler ultrasound on rare occasion

Transverse Process Hyperplasia
- Transverse process at C7 longer than T1

Soft Tissue Calcification
- Dystrophic
  - Tissue trauma inclusive of infection
- Metabolic/metastatic
  - Widespread (metastatic) soft tissue calcification secondary to metabolic and endocrinological diseases
- Physiological
  - Normal
  - Usually within cartilaginous tissue

Stylohyoideus Ossification
- Physiological
- Anatomical variation
- Significance
  - Minimal clinical impact
  - Chiropractic precautions
  - Eagle syndrome
    - Neck pain (rare)
Imaging

- extends from the styloid process at the base of the skull to the hyoid bone
- may be segmented

Costal Cartilage Calcification

Costal Cartilage

Calcification of the dura
- physiological
- no significance

Falx Cerebri Calcification

- calcification of the dura
- physiological
- no significance

Petroclinoid “Ligament” Calcification

- calcification of the dura
- physiological
- no significance

Pineal Gland Calcification

- physiological calcifications
- fifty percent of population
- should not exceed 10 mm
  - pinealoma
Lymph Node Calcification

Carotid Calcification

Persistent Apophyses and Epiphyses

Clinical and Imaging Data
- extremely common
- do not confuse the fracture
- use the history
- learn where they “live”
  - transverse processes
  - spinous processes
  - ring apophyses
  - trochanters

Imaging
os acetabuli

Oppenheimer's Ossicles

Congenital absence of pedicles

PEDIATRIC CERVICAL SPINE INJURIES

Epidemiology: Mechanisms

Epidemiology: Mechanisms

Figure 1: Mechanism of injury vs. percentage (%) of spinal injuries caused.

Epidemiology: Age

- The younger the child the... 
  - higher the lesion 
  - higher mortality

Epidemiology: Mechanisms

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Age younger than 6 mean (%)</th>
<th>Age 6 yrs or older (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian versus car</td>
<td>1.0 (9)</td>
<td>4 (2.9)</td>
</tr>
<tr>
<td>Bicycle versus car</td>
<td>0.3 (0.5)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Car passenger</td>
<td>10.0 (6.1)</td>
<td>45.0 (26.2)</td>
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<tr>
<td>Car driver</td>
<td>0 (0)</td>
<td>14 (7.8)</td>
</tr>
<tr>
<td>Fall</td>
<td>1.0 (0.5)</td>
<td>2 (0.6)</td>
</tr>
<tr>
<td>Sudden deceleration</td>
<td>1.0 (0.5)</td>
<td>1.0 (0.5)</td>
</tr>
<tr>
<td>Diving</td>
<td>0 (0)</td>
<td>16 (7.8)</td>
</tr>
<tr>
<td>Child abuse</td>
<td>1.5 (2.0)</td>
<td>0 (0.7)</td>
</tr>
<tr>
<td>Other Injury</td>
<td>10.0 (1.2)</td>
<td>1 (0.3)</td>
</tr>
<tr>
<td>Unknown</td>
<td>1.0 (0.5)</td>
<td>1 (0.5)</td>
</tr>
<tr>
<td>Total number of cases</td>
<td>32</td>
<td>197</td>
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Anatomy: Pediatric vs Adult

- Proportionally larger, heavier head = higher center of gravity: 
  "...the human head reaches 50% of its adult circumference by age 18 months, whereas thoracic circumference does not reach this milestone until 8 years of age."
- Weaker and underdeveloped neck musculature
- Greater elasticity and laxity of ligaments
- More horizontal orientation of facet joints
- Fulcrum of Cervical Spine Motion

Anatomy: Pediatric vs Adult
- Biomechanical and anatomic difference
  Begins to disappear at 8 years old
  Completes at 15-17 years old
- Literature suggest 2 distinct groups <8 and >=8

Anatomy: Pediatric vs Adult
- Higher prevalence of lesions above C4
- More cervical distraction injuries
- Spinal Cord Injury Without Radiographic Abnormality (SCIWORA)

Types of Injury
- Atlanto-occipital injuries
  - High energy
  - Typically fatal
  - More prevalent in young children than adults

Types of Injury
- Atlas Fracture
  - Axial load (like Jefferson burst fracture in adults)
  - Open synchondrosis
Types of Injury

- Traumatic Atlantoaxial Instability
  - Tear in transverse ligament
  - Rare

- Odontoid fracture
  - Most common fractures of cervical spine in children
  - Usually through the subdental synchondrosis in young children

- Pars interarticularis Fracture of C2
  - Hangman’s (hyperextension)
  - Extremely rare
  - Distraction Injuries

Pseudosubluxation

- Children have normal physiologic displacement @ C2-3 and C3-4 spaces.
Types of Injury: SCIWORA

Spinal Cord Injury With Out Radiographic Abnormality
- First described in 1980’s before advancements in MRI
- Subsequent literature suggest up to 30% all pediatric cord injuries*

Types of Injury: SCIWORA

Evolving Definition:
Positive neurological findings
- weakness, paresthesias, lightening/burning sensation
down the spine/extremity or related to neck movement
AND
- Xray (-), CT (-), MRI (+) 6% of SCI
OR
- Xray (-), CT (-), MRI (-) 1% of SCI

Who can be cleared clinically?

- National Emergency Medicine XRay Utilization Study (NEXUS) 9
  - Prospective
  - Evaluation of c-spine injury in children
  - Identify patients at low risk

NEXUS : Study Definitions

Low Risk Patient
Those with none of the following criteria:
- Midline cervical tenderness
- Focal neurologic deficits
- Altered level of alertness
- Evidence of intoxication
- Distracting painful injury

NEXUS : Study Definitions

High Risk Patient
Those with any of the following criteria:
- Midline cervical tenderness
- Focal neurologic deficits
- Altered level of alertness
- Evidence of intoxication
- Distracting painful injury
- Instability or inability to assess

Imaging choices
Imaging choices

- **Plain Film Xrays**
  - **Pro:** Less radiation than CT. Can be done in trauma bay. Can pick up most injuries if good technique. Less costly.
  - **Con:** Poor technique may lead to repeat shots. Can be difficult to get odontoid view in a young patient

- **CT Scan Neck**
  - **Pro:** Highly sensitive for fracture.
  - **Con:** Higher radiation dose to neck. In current facility have to move patient to another area. More costly.

- **Issue of initial CT Head and CT Neck versus CT Head and Plain Film Neck:** (Jimenez et al 2008)
  - Plain film first, then CT if needed

- **Flexion and Extension Lateral Xrays**
  - **Pro:** Can help diagnose ligamentous injury not seen on Xray or CT
  - **Con:** Patient must Actively move their head. Muscle spasm often limits this test

- **MRI**
  - **Pro:** “Gold Standard” (Munchow RD et al 2008) Highly sensitive for spinal cord injury. Helps with unconscious pts in whom there is high clinical suspicion of C-Spine injury. Visualizes the extradural space and integrity of the ligaments
  - **Con:** Higher cost, time

AN approach to clearing the c-spine following injury

**C-Spine Radiograph**

Lateral Plain Film

1. Film adequacy
2. C-spine alignment and curves
3. Inter-vertebral spaces: discs and joints
4. Pre-vertebral space
5. Pre-dental space aka atlantodens interval (ADI)
C-Spine Radiograph

- Lateral film
- Anteroposterior film
- Open-mouth odontoid view

Adequacy
- Visualize entire cervical spine
- Count 7 cervical bodies and 1 thoracic body

Alignment
- C-Spine Curves
  1. Anterior Vertebral Bodies
  2. Anterior Spinal Canal

Alignment
C-Spine Curves
1. Anterior Vertebral Bodies
2. Anterior Spinal Canal
3. Posterior Spinal Canal
4. Spinous Process Tips

Inter-vertebral spaces
- Disc spaces
- Cartilage
- Apophysial joints

Pre-vertebral space
- Space between vertebral bodies and air column
- Must measure space above the glottis
Pre-vertebral space
- Space between vertebral bodies and air column
- Must measure space above the glottis
- Normal size
  - ~1/2 to 2/3 of adjacent vertebral body
- Can be abnormal if
  - non-inspiratory film
  - Intubated
- Often normal in C-spine injuries

Pre-Dental Space: aka: atlantodens interval (ADI)

Pre-Dental Space
- Space between Dens of C2 and anterior side of C1 ring
- Must be less than or equal to 5 mm

Unstable C-spine fractures
- Jefferson (C1 burst)
- Bilateral facets
- Odontoid
- Any fracture dislocation
- Hangman’s (C2 pedicle fracture)
- Flexion/Extension teardrop

Tear Drop Fracture
- Avulsion of antero-inferior corner of cervical vertebral body by anterior ligament
- Most severe and unstable injury of the C-spine
- Mechanism: may be secondary to hyperflexion, hyperextension sudden, forceful flexion
  - Often the result of diving into shallow water
- Typically at C2
- Unstable with ligamentous instability
- Remainder of body displaced backward into spinal canal
- Facet joint and interspinous distances usually widened
- Disk space may be narrowed
- Neuro deficit in up to 70%
Unilateral facet dislocation

- Mechanism: flexion, combined flexion/rotation
- Anterior dislocation of one vertebral body by 25-30% on lateral view
- Stable if anterior displacement on lateral less than ½ width of VB
- Only 30% associated with neurologic defect

Unilateral facet dislocation

- AP view-disruption of spinous process line
- Oblique- disruption of the tilting of the lamina
  - Superior articulating facet impinges in neural foramina

Unilateral Facet Dislocation

AP view- spinous processes of the vertebrae above the dislocation displaced towards the side of the dislocated facet

Unilateral Facet Dislocation

Bilateral Facet Dislocation

- Mechanism: flexion, combined flexion/rotation
- Anterior dislocation of one vertebral body by 50% on lateral view
- Unstable
- Neurologic deficits common
  - Seen in up to 85%
Bilateral Facet Dislocation

Clay Shoveler’s Fracture
- Avulsion fracture of posterior spinous process of C7 or T1
- Mechanism: sudden load on a flexed spine or secondary to rotational injury
  - Shoveling snow, clay
  - Very stable

Clay Shoveler’s Fracture

Deaths from Falls in Children: How Far is Fatal?

- 10’ - 45’ 118 1 death (CHI)
- 4’ - 10’ 65 0 deaths
- < 4’ 100 7 deaths (CHI)

5/7 had signs of abuse (e.g. RH, fracture)

HEAD INJURY: INFLICTED OR ACCIDENTAL?

Additional indications of nonaccidental head injury
- Other injuries
  - Bruises; rib, long bone & other fractures
- Retinal hemorrhages
  - present in 70-80% of SBS
  - extent of hemorrhage correlates w/ injury severity
    - intra-retinal hemorrhage
    - subretinal / vitreous hemorrhage
- Social/family risk factors
Injuries that result in intracranial trauma

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<th>falls &lt; 3’ 6’</th>
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<td>Unexpected</td>
<td>Reasonable</td>
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<td>unlikely</td>
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Types of Imaging Studies

- Many children presenting with a possible mild traumatic head injury (MTHI) may not require an imaging study. However, the most commonly ordered studies are:
  - Computed Tomography Imaging (CT): preferred diagnostic tool that comes with benefits and risks; main risk factor - concern for radiation overexposure
  - X-Ray: useful to detect skull fracture, but not recommended in most cases
  - Magnetic Resonance Imaging (MRI): useful to detect skull fracture, but not recommended in most cases

CT: Benefits & Risks

There is no consensus regarding the use of CT to diagnose brain injuries.

**Benefits:**
- Can help determine the difference between MTHI and the more serious condition of traumatic brain injury
- Offers definitive results in determining structural damage

**Risks:**
- Exposes child to ionizing radiation (1 head CT scan can potentially equal over 200 chest X-rays)
- Transporting child to CT suite may take child away from ED skilled supervision and resources
- Pharmacologic sedation is often required in younger children (may increase overall health risk; requires additional monitoring)
- Prolongs time child spends in ED
- Incurs greater cost

Increased Use of CT

- The use of CT to evaluate children with head injuries has increased substantially over the past decade, almost doubling during that time and thus increasing the risks associated with radiation.
- 500,000 ED visits each year for children with head injury has resulted in an estimated annual usage of 250,000 CT scans used to diagnose potential head injury.

Recommendations of Image Gently Campaign

The Alliance for Radiation Safety in Pediatric Imaging began a public health campaign in 2006 called Image Gently. Its goal is to change CT practice by raising awareness of the opportunities to lower radiation dose in the imaging of children.

Examples of recommended techniques:
- Scan only the area required. Scanning beyond the body regions where there is clinical concern results in needless exposure.
- Reduce tube output (kVp and mAs). Exposure parameters should be reduced for the smaller patient size.
- Perform single phase studies. Most pediatric conditions are readily diagnosable with single phase CT; more phases unnecessarily increases radiation dose without adding substantial data to diagnoses.
Use of CT: Need for Guidelines

There is considerable debate regarding the value of a head CT to determine MTHI. Internal discussion needs to take place in order to set hospital policy and ensure consistency when CT scans are ordered.

Common issues for institutional discussion:

- Are there any institutional guidelines suggesting general criteria for ordering pediatric head CT image in certain situations?
- Do the benefits of ordering a head CT outweigh the potential risks from radiation?
- Do you discuss risks and benefits with parents/caregivers?

X-Rays

- X-rays can detect a skull fracture that may be missed by a CT.
- X-rays will not reveal metabolic or soft tissue injuries that may be present in MTHI.
- If imaging is indicated, CT scanning is the imaging modality of choice to evaluate for brain trauma.
- The mechanism and history of the injury, and the PGCS score are better indicators of significant head injury in children than x-rays.

Reed 2005

Magnetic Resonance Imaging (MRI)

- MRI is currently not as commonly used to image MTHI as CT. However, it is an evolving technology that may become increasingly utilized in the future.
- MRI may help determine some types of neurological damage when performed several days post injury.
- Since performing an MRI may require the sedation of the child, extra caution needs to be observed.
- MRI is a more costly procedure, and may not be as readily available as CT.
- Risks and benefits of MRI mimic those of CT.

Basilar skull fracture

- In 6-14% of pts with head trauma- hx of a blow to the back of the head.
- Loss of consciousness, seizures, and neurologic deficits may or may not be present.
- Prolonged nausea, vomiting, and general malaise,
  - Fracture near the emesis and vestibular brainstem centers.
- Battle sign, raccoon eyes, and CSF otorrhea and rhinorrhea
- Ocular nerve entrapment - 1-10% of patients.

Brain Injuries

Intracranial hemorrhage

- Epidural
  - Between skull and dura
- Subdural
  - Between dura and arachnoid
- Intracerebral
  - Directly into brain tissue
Acute epidural hematoma

- Arterial bleed
  - Temporal fracture common
  - Onset: minutes to hours
- Level of consciousness
  - Initial loss of consciousness
  - “Lucid interval” follows
- Associated symptoms
  - Ipsilateral dilated fixed pupil, signs of increasing ICP; unconsciousness, contralateral paralysis, death

Diagnostic Imaging

- Noncontrast CT scanning of the head (imaging study of choice for intracranial EDH) not only visualizes skull fractures, but also directly images an epidural hematoma
- It appears as a hyperdense biconvex or lenticular-shaped mass situated between the brain and the skull, though regions of hypodensity may be seen with serum or fresh blood
- MRI also demonstrates the evolution of an epidural hematoma, though this imaging modality may not be appropriate for patients in unstable condition

Epidural Hematoma

- Extraaxial, smoothly marginated, lense-shaped homogenous density
- Rarely crosses the suture line (because dura attached more firmly to skull at sutures)

Acute subdural hematoma

- Venous bleed
  - Onset: hours to days
  - Level of consciousness
    - Fluctuations
  - Associated symptoms
    - Headache
    - Focal neurologic signs
  - High-risk
    - Alcoholics, elderly, taking anticoagulants
Diagnostic Imaging

- MRI is superior for demonstrating the size of an acute SDH and its effect on the brain, however noncontrast head CT is the primary means of making a diagnosis and suffice for immediate management purposes.
- *Noncontrast head CT scan* (imaging study of choice for acute SDH)
  - The SDH appears as a hyperdense (white) crescentic mass along the inner table of the skull, most commonly over the cerebral convexity in the parietal region. The second most common area is above the tentorium cerebelli.
- Contrast-enhanced CT or MRI is widely recommended for imaging 48-72 hours after head injury because the lesion becomes isodense in the subacute phase.
- In the chronic phase, the lesion becomes hypodense and is easy to appreciate on a noncontrast head CT scan.

Acute Subdural Hematoma

Another example of acute subdural hematoma with a midline shift (noncontrast CT).

Subacute Subdural Hematoma

Noncontrast CT—note the clot appears less dense in this subacute subdural hematoma.

Intracerebral hemorrhage

- Arterial or venous
  - Surgery is often not helpful
- Level of consciousness
  - Alterations common
- Associated symptoms
  - Varies with region and degree
  - Pattern similar to stroke
  - Headache and vomiting
Subarachnoid Hemorrhage

Most common form of hemorrhage associated with head trauma
Disruption of the small vessels on the cerebral cortex.
Location: falx cerebri or tentorium and the outer cortical surface.
Nausea, vomiting, headache, restlessness, fever, and nuchal rigidity - blood in the subarachnoid space.

Subarachnoid Hemorrhage on CT

High density in the sulcal, cisternal, or fissural subarachnoid space
Symmetry is intact
No midline shift (usually)

SAH—more examples

Subarachnoid hemorrhage in the right sylvian fissure

SAH—more examples

Blood in the sulci
Edema causing a midline shift

What about skull films?

Limited role if no physical findings
+ skull fracture and no intracranial injury
- skull fracture and intracranial injuries

Skull films

It is still a good test for evaluating CHI's
Skull radiographs are 94-99% sensitive for detecting linear or depressed skull fractures.
CT imaging has a lower sensitivity, ranging from 47-94%
Pediatric Head Injuries

- Types of skull fracture
  - Linear
  - Depressed
  - Basal
  - Comminuted

- Brain injuries occur in proportion to the degree the brain is accelerated.

Skull films

When would it be OK to order one?

- Scalp hematoma over course of the middle meningeal artery
- Children < 1yr of age with a scalp hematoma
- Suspected abuse

Four Types of Hemorrhages Possible in every Head Injury

- Epidural or Extradural Hematoma
- Subdural Hematoma
- Intracerebral Hematoma
- Subarachnoid Hemorrhage

THORACIC SPINE
Cartilaginous (Schmorl’s) nodes

- Schmorl’s nodes have been widely assumed to be the herniation of the nucleus pulposus through the cartilaginous endplate into the body of a vertebra, ever since Schmorl first described them in 1927.
- The hypotheses of their origin and pathogenesis include developmental factors, degenerative conditions, pathological processes such as infection, neoplasia and trauma.

Hahns Groove

- Embryonic vascular channel
- No significance

Schmorl’s Nodes
The pathogenesis of Schmorl's nodes

- Schmorl's node appear to be an ingrowth of fibrous tissue or fibrocartilage from the necrotic area into the cartilaginous endplate since there was no evidence of the herniation of the nucleus pulposus through the disrupted cartilaginous endplate into the vertebral body. The local defect of the endplate may have been the consequence of degeneration and necrosis of the cartilaginous endplate secondary to the underlying osteonecrosis or alternative.

Clinical Data

- nucleus pulposus herniates through vertebral end plates.
  - embryological blood vessels
  - osteoporosis
  - trauma
  - back pain?
  - very common
  - associated with degenerative disc disease?

Imaging

- well-defined defect involving the endplate
- giant Schmorl's nodes
  - disc space narrowing
  - morphological vertebral body changes
  - decreased disc signal on MRI
- associated with Scheurman's disease

- Scheurmann's disease
  - aka
  - juvenile discogenic disease

Scheurmann's Disease

- the etiology is in question, but probably does not represent a necrosis.
- abnormality of the discovertebral junction.
- usually in teens
- chronic back pain
**Radiology**

- thoracic and lumbar spine
- three contiguous vertebra*  
- 5° anterior body wedging
- irregular end plates
- decreased disc space
- increased kyphosis
- Schmorls nodes

**Indications for radiography of the spine for scoliosis:**

- Alterations in normal spinal alignment on physical examination.
- Alterations in normal spinal alignment detected on other imaging studies.
- Evaluation of spinal curvature progression.
- Follow-up of treatment (orthotic or surgical).
- Evaluation of individuals with a history of scoliosis in immediate family members.

**Radiographic Assessment**

- Determine or rule out the various etiologies of the scoliosis
- Evaluate curvature size, site, and flexibility
- Assess the skeletal maturity
- Monitor the curvature progression or regression
Radiography

- AP @ 72°
- 14" x 17" or 14" x 36".
- Acceptable to perform 2 exposures with the patient in unchanged position.
- From angles of the mandible to the greater trochanters.
- Gonadal shielding should be used in boys and may be used in girls when the area of curvature does not include the sacrum.

PA Fullspine

- Decreases radiation dose to the thyroid and breast.
- The lateral radiograph facilitates assessment of kyphosis, lordosis, and spondylolisthesis.
- Spondyloysis may be detected, although this is best evaluated with dedicated images when relevant.

Filtration and Patient Protection

- a must for chiropractic practice
- Nolan Filters
- gonad shields required
- lead shields and gowns

AGFA Scoliosis Package

- 4 specialized cassettes with holder.
- Associated stitching software.

Definition:

- Lateral deviation (>15 degrees) and rotation of the spine, often associated with thoracic hypokyphosis.
- Severe disease distorts the chest wall enough to restrict pulmonary and cardiovascular function.
- Cosmetic deformity may also be serious.
Structural (Progressive)

- Idiopathic
- Arthritic
- Congenital
- Neuromuscular
- Tumors
- Post-Irradiation

Age Classifications

- Infantile
  - Uncommon, therefore congenital cause must be ruled out especially with a left thoracic curve.
  - M>F
- Juvenile
  - 3 to 10 years
- Adolescent (>10 years old)
  - Most common
  - F>M

Etiology:

- Must be determined in each case of scoliosis since prognosis and management are highly dependent on etiology.
  - Functional
  - Structural

Functional

- Non-progressive
- Muscle spasm
- Antalgia

may become structural if not corrected

Idiopathic:

- By far the most common (85%+)
- Thought to be related to defects in proprioception and vibratory sense
- Girls are more often affected than boys (7:1) and their disease is more likely to progress and require treatment
- Patterns may be thoracic (usually convex to the right), thoraco-lumbar, lumbar, or double major

Congenital:

- Secondary to skeletal anomalies
  - hemivertebrae
  - congenital fusion
- Bracing is ineffective, and progressing curves must be surgically fused early.
Tumors:
- Osteoid osteoma is the most common tumor that causes painful scoliosis.
- Usually located in posterior elements
- Scoliosis is long, with concavity on the side of the lesion
- Bone scan & CT

Neuromuscular
- Etiology may be:
  - Cerebral palsy
  - Syringomyelia
  - Poliomyelitis
  - Muscular dystrophy
- The curves are often long, single curves.

“wrong way” scoliosis
- left convex scoliosis thoracic spine
- Significance
  - syringomyelia
  - Arnold Chiari malformation
  - neurology examination
- Imaging
  - do MRI with neurological symptoms and adults
  - do MRI in all children

Syringomyelia
- spinal cord cavity
  - (syrinx)
- Etiology
  - pressure
  - tumor
  - congenital
  - Arnold Chiari
    - secondary to pathologic CSF
    - exaggerated pulsatile cystic subarachnoid space distress or anatomically continuous peri-meningeal spaces into the central spinal cord.
- Imaging
  - MRI
Associated Osseous Anomalies

- Platybasia, basilar invagination (25-50%)
- Atlantooccipital assimilation (1-5%)
- Klippel-Feil syndrome (5-10%)
- Incomplete ossification of C1 ring (5%)
- Proatlan tal remnant spina bifida at the C1 level
- Retroflexed odontoid process (26%)
- Scoliosis (42%)
- Kyphosis
- Increased cervical lordosis
- Cervical ribs
- Fused thoracic ribs

neurofibromatosi s

Neurofibromatosis:

- Dysplastic vertebral bodies form a short, angular, usually high thoracic curve
- Associated ribbon-shaped ribs and posterior vertebral body scalloping
- These curves must be monitored carefully since they can collapse rapidly and produce paralysis.

fibrosum molluscum

fibrosum molluscum

Normal NF
Radiation therapy:
- If the entire vertebral body of a skeletally immature patient is not included in a radiation port, growth in the irradiated portion stops, with resultant scoliosis.

Roentgenometrics
- Measure on the AP radiographs.
- Identify the uppermost and lowermost involved vertebra of the curve that tilt significantly toward the concavity and draw a line through the endplates.
- Draw perpendicular lines through those two lines and measure the resulting intersecting angle.

Multiple curves
- In many patients, more than one curve is present—an S-type curvature.
- Measure each curve independently.

Flexibility of curvatures
- Lateral bending radiographs.
- Helps in determination of primary versus compensatory curvatures.
- Compensatory curves usually correct with lateral bending.
Skeletal maturity....

- using the iliac apophyses to grade skeletal maturation
- The formation of the apophyses is graded in quarters relative to the excursion of the apophysis over the extent of the crest.

Skeletal maturity predicts

- Potential for progression
- Potential for correction
- Immature x-ray every 6-9 months

Monitoring progression

- The initial film should be good quality AP/lateral erect films, in order to evaluate for intrinsic vertebral abnormalities
- Subsequent films used only to evaluate progression should be high kVp and should be taken PA rather than AP, using filters
- Gonad and breast shields must be utilized
- Collimation is essential.

LUMBAR SPINE

Limbus Vertebra
Imaging
- free fragment at the anterior, superior body margins
- well corticated
- can be associated with juvenile discogenic disease

Nuclear Impression
Notochordal Persistence

Hemivertebra (p. 328)

Clinical Data
- vertebral body normally develops from two lateral ossification centers with a failure of growth occurring to form the hemivertebra
- lateral hemivertebra most common
- structural scoliosis
  - Significance
    - scoliosis
    - aberrant segmental motion inclusive of fusion
    - associated with other congenital anomalies (see block vertebra)
- DDx
  - compression fracture

Butterfly Vertebra

Clinical Data
- failure of fusion of lateral halves secondary to persistence of notochordal tissue
- widened vertebral body with butterfly configuration (AP view)
- adaptation of vertebral endplates of adjacent vertebral bodies
- most common in the thoracic and lumbar spine
  - Significance
    - usually insignificant
    - aberrant segmental motion probable
**Imaging**
- pronounced indentation of the endplate’s
- widening of the distance between the pedicles
- disk hypoplasia adjacently or possible fusion

**Spina Bifida**
- refers to a local failure of primordia of the two laminae to unite leaves vertebral canal open dorsally (spinal rachischisis, or spina bifida)
  - spina bifida occulta
    - defect involves primarily bone, but skin may be attached to dura, spinal cord, or nerve roots by fibrous bands
  - Meningocele
    - meninges may protrude
  - Myelomeningocele
    - spinal cord may protrude

**Spina Bifida Occulta**

**Transitional Vertebra**
- lumbarization
- sacralization
variations

Intervertebral disc hypoplasia
- Common cause of narrowed disc space, especially common in young patients where degeneration is not likely

Other variants
- The spaces between the sacral segments are synchondroses composed of fibrocartilage, not discs
  - Bone starts to be deposited in the fibrocartilage starting at puberty
  - *They do not move like vertebrae…*

SPONDYLolisthesis

Classification
- Dysplastic
- Isthmic
- Degenerative
- Traumatic
- Pathological
- Iatrogenic


http://www.bio.psu.edu/people/faculty/strauss/anatomy/skel/sacrum2.htm
Spondylolysis

- Found in 7-8% of general population
  - Found in 5% by age 6
- Males>Females (2:1)
  - Females more likely to progress to spondylolisthesis
- White>African-American
- Most commonly at L5 (90%; 80% bilat)
- Often asymptomatic/incidental finding

Who is at risk?

- Genetic predisposition
  - Alaskans 40% adults
  - Eskimos 54% adults
  - Family history
- Athletes with repetitive hyperextension
  - Gymnasts
  - Divers
  - Football offensive linemen
  - Pole vaulters
  - Weight lifters
  - Wrestlers

Spondylolysis and Spondylolisthesis

- L5-S1 level most common—may have tenderness at this level, may have hyperlordosis or palpable defect, frequently have hamstring tightness (limited SLR)
- More common in sports requiring hyperextension (gymnastics, wt lifting, wrestling)
- Increased pain with extension of lumbar spine

Spondylolysis:

Presentation

- Low back pain, typically at belt line
- Insidious onset, may increase with activity
- Rarely radiating
- Commonly in preadolescent growth spurt
- Usually no hx trauma
- Usually no neuro deficits

Spondylolysis:

Physical Findings

- Hyperlordosis
- Vertical sacrum
- Iliac crests high, ribs look low
- "Short" torso
- +/- "Step-off" at L5
- +/- Facet joint tenderness
- Hamstring spasm – classic in adolescents!

Spondylolysis:

Diagnosis

- X-Ray: First-line!
- SPECT: If films negative but H&P suggestive
- CT: If SPECT positive but dx inconsistent
- Bone Scan: If suspected acute pars fx
- MRI: If neuro involvement
Plain Films
- Oblique X-ray:
  - “Collar” of Scottie dog
  - Greyhound sign
- PA/Lat X-ray:
  - Contralateral sclerosis

Spondylolisthesis
- Meyerding’s method
  - Grade I < 25%
  - Grade II < 50%
  - Grade III < 75%
  - Grade IV < 100%

Spondylolisthesis
- Ulmann’s Line
  - if the L5 vertebra crosses the perpendicular line, spondylolisthesis may be present.
  - is less sensitive to spondylolisthesis than George’s posterior body line.
Spondylolysis: Return to Sports

- Sport are started gradually and cut back if symptoms recur
- Pain-free fibrous non nonunion (no bony healing) is acceptable end outcome
- Maintenance training program, avoidance of spine hyperextension, early treatment of symptoms prevents longer rehab if spondy becomes symptomatic again

Thoracic Spine

- Rigid
- Spinal canal narrower than cervical or lumbar spine
  - Large spinal cord diameter relative to canal diameter increases the risk of cord injury
- Injury, usually significant (complete), less common than in other regions
- Association between fractures of the thoracic spine and severe pulmonary injuries, mediastinal hemorrhage

Thoracic Spine Injuries

- Compression fracture
- Injury to anterior column due to anterior or lateral flexion
  - Middle, posterior column remains intact
- X-ray - decreased height anterior vertebral body, post body ht normal

Thoracic Spine Injuries

Burst

- Disruption of the middle column
- Mechanism- axial loading
- Varying degrees of retropulsion into the neural canal
- X-ray- spreading of post elements
- If post elements involved- 50% have neuro injury
- Neurologic injury more common in:
  - Loss of vertebral ht > 50%
  - Angulation > 20 deg
  - Canal compromise more than 40%

Lumbar Spine Fractures

- Thoracolumbar spine and lumbar spine are the most common sites for fractures due to the high mobility of the lumbar spine compared to the more rigid thoracic spine
- Injury to the cord or cauda equina occurs in approximately 10-38% of adult thoracolumbar fractures and in as many as 60-80% of fracture dislocations.
- Most occur in people younger than 30 years
- Nearly 60% of patients have serious disabling deficits
- Etiology- 40% caused by motor vehicle accidents, 20% by falls, and 40% by gunshot wounds, sporting accidents, industrial accidents, and farming accidents
Lumbar Spine Injury

- Lower lumbar spine is the most mobile
- Isolated fractures of the lower lumbar spine rarely result in complete neurologic injuries
- Injuries usually complete cauda equina lesions or isolated nerve root injuries

Sports injury

MVA 17 yo male

Etiology Multifactorial?

- Environmental & Mechanical
  - Breech Presentation: DDH Cases (16%): All deliveries (3%)
  - Birth Order: >50% Cases 1st. Born
  - Oligohydramnios
  - Sex Ratio (Relaxin): F(4 - 6) : M(1)
  - Side: L(2) : R(1)
  - Bilateral: 35%
  - Nursing Habits

Etiology- Breech

- Only 3% of children are Breech presentation
- 16% of DDH cases are breech
- Extended breech has 20% risk of DDH
- Footling breech 2%
Etiology-Ligamentous Laxity

- Maternal Relaxin hormones crosses the placenta and induce hip capsule laxity in infant and this effect is much stronger in females.

Etiology - Genetic Factors

- Genetic
  - There is an unknown genetic factor
  - Runs in families
  - Risk to next child increases as follows:
    - If one child is affected risk is 6%
    - Parent 10%
    - Parent and child 36%
- Genetic Predisposition
  - Families with Generalised Ligament Laxity
  - Families with Acetabular Dysplasia

Etiology- Nursing

- Rare in China, Asia, Africa (carry children with hips flexed and abducted)
- High in native American (Used to nurse with legs extended)
- Klisic reduced DDH by 65% in Belgrade by routine use of abduction diapering

Etiology Unknown Multifactorial

- Genetic whites
- Physiologic girls
- Mechanical breech
- Environmental swaddling

Associated conditions

Quoted risk of DDH with following conditions:

- Child with Torticollis* 15-20%
- Metatarsus adductus 10%
- Calcaneovalgus 10%


Barlow Provocative Test

- Dislocates hip (exit)
**Ortolani Maneuver**
- Reduces dislocated hip (entry)

**PE > 3 Months**
- 57° 43°
- Limited abduction is key

**PE > 3 Months**
- Asymmetric thigh folds
  - Limb-length discrepancy

**Radiographs**

**Developmental Dysplasia of the Hip**
- Putti’s Triad
  - small femoral head
  - shallow acetabulum
  - superior/lateral dislocated femoral head

**The Lines**
- Horizontal line of Hilgenreiner: drawn between upper ends of tri-radiate cartilage of the acetabulum.
- Vertical line of Perkins: drawn from the lateral edge of the acetabulum vertical to horizontal line.
- 4 quadrants:
  - Normal hip: the ossification center of the femoral hip lower medial quadrant.
  - Dislocated hip: upper lateral quadrant.
Developmental Hip Dysplasia

**Von rosen view:**
- Hips abducted 45º & medially rotated.
- Anteroposterior.
- Line through the central axis of the femoral shaft.
  - in normal hip (ossific nucleus) line will be inside the acetabulum.
  - in dislocated hip line will be above acetabulum.

Imaging
- Putti’s triad.
  - Absent or small proximal femoral epiphysis
  - Lateral displacement of femur
  - Increased inclination of acetabular roof
- Additional Studies
  - ultrasound
  - arthrography
  - CT

SCFE: Slipped Capital Femoral Epiphysis
- An acquired growth plate injury
- The separation of the proximal femoral epiphyses from the metaphysis at the level of the growth plate
- Most commonly occurs in adolescents and preadolescents who are vulnerable to slippage due to widened and weakened growth plates during periods of rapid growth

Ultrasound
- Alpha > 60º
  - Slope of osseus acetabulum

- Occurs in 2-10 per 100,000 adolescents in the US
- Peak age is 10-13 in females and 12-16 in males
- More common in males, male to female ratio is 2.5 : 1.6
- More common in Pacific Islanders and African Americans


**SCFE - Risk Factors**

- Obesity resulting in mechanical overload of an immature growth plate, 81% of cases are in children over the 95th percentile for BMI
- Local trauma
- Hypothyroidism
- Panhypopituitarism
- Growth hormone administration
- Renal osteodystrophy
- Previous radiation therapy

**SCFE - Presentation**

- Limp
- Hip, groin, thigh, or knee pain
- Hip pain often referred to the knee due to the pathways of the obturator and femoral nerves

**SCFE - Diagnosis**

- Radiography: bilateral AP and frog leg x-rays of the hips
- “Ice cream falling off the cone” the femoral head is the ice cream that falls off the femur which is the cone

**SCFE**

- Widened physis!

**Klines Line**

- Drawn across the outer border of the femoral neck
- Subtends the outer aspect of the femoral head

**Klines Line**

- Evaluates Slipped Capital Epiphysis (SCFE)
Shenton Line

- Normal is smooth arc
- Abnormal in:
  - Hip dislocation

26 year old

“Old” SCFE

SCFE - Treatment

- Screw fixation to prevent further slippage
- For severe slips, corrective osteotomy may be required

SCFE - Prognosis

- Occurs bilaterally in 25-40% of cases
- Most contralateral slips occur within 6-12 months of the index case
- Most stable or chronic SCFE’s are treated effectively with minimal complications, makes up >90% of all slips
- The more severe the slippage, the more altered are the mechanics of hip movement, and the sooner the hip wears down, leading to premature arthritis
- The most severe cases may eventually require total hip replacements
Avascular Necrosis

- Death of osseous and marrow components of bone.
- Synonyms
  - osteonecrosis
  - ischemic necrosis
  - osteochondrosis

Pathogenesis

- obstruction of extra- and intraosseous vessels by arterial embolism, venous thrombosis, traumatic disruption, external compression
- increased marrow space pressure

Etiology

- external vessel compression
  - trauma, steroids, infection, gaucher’s disease, hyperlipidemia
- vessel wall disorders
  - SLE, radiation, polyarteritis nodosa
- thrombo-embolic disorders
  - alcoholism, steroid, trauma, sickle-cell

PLASTIC RAGS

- Pancreatitis, Pregnancy
- Legg-Perthes disease, Lupus
- Alcoholism, Atherosclerosis
- Steroids
- Trauma
- Idiopathic (Legg-Perthes disease) infection
- Caisson disease, Collagen disease
- Rheumatoid arthritis, Radiation treatment
- Amyloid
- Gaucher disease
- Sickle cell disease

Avascular necrosis

Four Stages of Disease

- avascular
- revascularization
- repair
- deformity
Radiographic examination
- AP and Frog leg!

subchondral collapse

Healed AVN
- articular deformity
  - early OA
- acetabular dysplasia
- hanging rope sign
- trochanteric overgrowth

avenue sign (subchondral bone collapse)

“snow cap”
- healing phase
  - Osteoblastic
  - Compression

AVN- MRI
- MRI scans demonstrate a loss of marrow signal, particularly on the T1-weighted scan
  - often bilateral
  - may demonstrate joint effusion
Legg-Calve-Perthes disease

- Described in 1910 by Legg, Calve and Perthes
- Affects patients usually from 4 to 8 yo
- Boys 5:1, bilateral in 10-20%
- Limping, pain, limitation of motion, particularly abduction and internal rotation
- Trauma in 25% of the cases

- DDx Slipped capital femoral epiphysis (SCFE)

Legg-Calve-Perthes disease

- Radiographic findings
  - soft tissue swelling
  - small epiphysis
  - lateral displacement of ossification ctr.
  - flattening, fissuring and fracture of the ossification center
  - intraepiphyseal gas

Legg-Calve-Perthes

6 months later

Soft tissue signs of hip joint disease:

- capsular swelling
- small obturator (hip flexion)
- increased TDD
Tear Drop Distance

- Measurement of the medial hip joint space
  - Tear drop to the femoral metaphysis
- 9 - 11 mm
- > than 2mm from side to side
- CRC!
- Significance
  - trauma
  - infection
  - inflammation
    - Legg-Calve-Perthes
    - joint disease

Prognosis

- Dependent on:
  - age (better in younger patients)
  - sex (poorer in females)
  - poorer in advanced disease

Femoral herniation pits

- Capsule/synovial indentations
- Normal?
- An HP of the femoral neck is considered to be the result of mechanical stress from the hip capsule and related musculature on the superolateral quadrant of the femoral. This region of the femoral neck is prone to developing a reaction area composed of fibrocartilaginous elements that may penetrate tiny defects in the degenerative cortex leading to the formation of an HP.

Pubic Synchondrosis

- variant of maturation
  - point of fusion between the ischium and pubis
- Significance
  - none
- DDX
  - tumor
  - fracture

paraglenoid sulcus

- normal variant
- vascular groove
- female pelvis

Osteochondritis dissecans

- represents a focal subchondral infarction of sub-articular bone
- the necrotic bone may become a free floating fragment separated from the parent bone
- differentiate from trauma
  - osteochondral fracture
Clinical

- Age: adolescence and young adults
- M > F
- asymptomatic / vague complaints
- clicking, locking, limitation of motion
- swelling, pain aggravated by movement

Location

- knee
  - medial femoral condyle close to fossa intercondylaris
  - Weight bearing lateral 10% bilateral in 20 - 30%
- Talus (v. common)
- humeral head
- capitellum of elbow

Radiology

- lesion at the lateral aspect of the medial femoral condyle
- may detach .... joint mouse
- mouse = osteochondrotic fragment
- purely cartilaginous fragment unrecognized on plain film
- fracture line parallels joint surface
- soft-tissue swelling, joint effusion
Osgood Schlatters Disease

- fragmentation of the apophysis of the proximal tibia
- is probably traumatic rather than a true necrosis
- diagnosis is clinical
- Sindig-Larsen-Johannsen disease - involvement of the inferior pole of the patellar

Kohler's disease

- described in 1908, most evidence suggests AVN of tarsal navicular
- boys 4 or 6:1; those 3 to 6 yoa
- radiographs reveal patchy increased density and fragmentation
- local pain, tenderness, and swelling
The facts

- In the US, 1/100 children are neglected or abused
- Results in 1,200 deaths/year
- May manifest as virtually any pattern
- Majority are readily detectable on imaging
- Difficult at times to discern acutely
  - Follow-up increases likelihood of detection

What radiographs to order?

- Violent shaking and squeezing of an infant may result in subdural hemorrhage...and sheer-type brain injury, rib fracture.... and metaphyseal fracture.”

Pathognomonic for abuse

...is the metaphyseal fracture

none is more specific
for child physical abuse

Metaphyseal Fractures

- Specific for abuse
- Not as sensitive: 39-50%
- Seen almost exclusively <2 yrs old
- Kleinman et al coined the term ‘classic metaphyseal lesion’ or CML to describe the injury
- Most often occur in the...
  - Distal femur
  - Proximal tibia
  - Distal tibia
  - Proximal humerus
CML

- A series of microfractures
  - across the metaphysis (or subepiphyseal region of bone),
  - parallel to the physis,
  - and perpendicular to the long axis

- NOTE: Falls and blunt trauma CANNOT cause such horizontal motion across the metaphysis

Pathologic correlation

- The subepiphyseal region of bone is the most immature area of the mineralized matrix in the growing metaphysis.
- The fracture fragment may be conceptualized as a wafer as shown in the diagram.
- The edge of the CML tends to be thicker than its center

And the lucency looks like this...

Pathologic correlation

- A corner fracture is a radiographic descriptive term referring to a triangular fragment that corresponds to the thick edge of the ‘wafer’ seen on a profile view of the long bone.

Radiologic Appearance

- Compare the radiographs to the diagram in the center. Note the increased lucency (white arrows) corresponds to the thicker edges of the ‘wafer’ in the diagram.

Pathologic correlation

- If the fragment is separated from the long bone by a notable lucency on the radiograph, OR if the fracture is viewed at a slightly oblique angle, the thick rim may be visible as a curvilinear structure, hence the descriptive term:
  
  *bucket handle fracture*
Bucket Handle Fracture

Can you spot it?

Trick question!
There are two...

Bucket Handle Fracture

Rib fractures

- Strongly correlated with abuse in infants because the mechanism that generates the fractures is relatively specific.
- First rib fracture is virtually diagnostic of child abuse because of the force required.
- A tight hold around an infant's chest will result in fractures of the
  - anterior,
  - lateral,
  - and posterior aspects of the rib

Rib fractures

- At the costochondral junction, the anterior ribs are bent inward resulting in a fracture.
- Laterally, the inner cortex is buckled & compressed, while the outer cortex is distracted.
- The posterior rib is levered over the transverse process resulting in a fracture.
Other fractures

Without a good accidental explanation...

- ...spiral long bone fractures in the non-walking infant, due to the forces needed to create such fractures, are quite suggestive of child abuse.
- ...spinal fractures in the infant is suggestive of child abuse.

Other Fractures

- Multiple Fractures (right)
  - High suspicion of abuse, especially if the fx are in various stages of healing

Things to consider... before labeling child abuse

- With posterior rib fractures, rule out birth trauma.
- Is there a history of CPR?—a rare cause of fracture.

- With unexplained fractures, look for:
  - Blue sclera, recurrent fractures, dentinogenesis imperfecta, short stature, and bowing of extremities
    - THINK osteogenesis imperfecta
  - Growth retardation, metaphyseal flaring, prominence of costochondral junctions, frontal bossing; attributable to vitamin D deficiency
    - THINK rickets

Question

- A 12 year old male presented to the ED with a 2 day history of fever and right hip pain. He was noted to be limping on arrival. He denied any history of trauma. Abdominal physical examination findings revealed no guarding, but there was minimal tenderness in the right lower quadrant. Laboratory evaluation revealed a WBC 15.2. Hip radiographs were normal. What is the next best step in his management?
  a) Admit for observation
  b) Joint aspiration
  c) CT scan abdomen and pelvis
  d) Pelvic ultrasound
  e) Administer a dose of IV antibiotics, then discharge home with 24-hour follow up

Answer - C

- Because of the varied location of the appendix, the presentation of pain in a patient with acute appendicitis can be diverse. A patient with a low lying appendix can present with hip pain without significant abdominal findings.
- It is important to include appendicitis in the differential diagnosis of hip pain. If the diagnosis is delayed, appendicitis is associated with significant morbidity and mortality. A computed tomography of the abdomen and pelvis is the imaging modality of choice.
**Terminology**

- **Cellulitis**: infection of skin, subcutaneous fat, or connective tissue (tendons/ligaments/muscle)
- **Osteomyelitis**: infection of bone (marrow spaces)
- **Septic arthritis**: infection of joint (synovial tissue, articular surfaces)

**At risk groups:**

- Immunosuppressed
- Diabetics
- Post-surgical
- Vascular insufficiency
- Sickle-cell anemia
- IV drug users
- But any patient is at risk if the conditions are right......

**Drug addicts**

- Infections by unusual organisms at unusual sites.
- The "S" Joints
  - spine
  - sacroiliacs
  - symphysis pubis
  - sternoclavicular

**Organisms**

- *Staphylococcus aureus* (MC)
- *Mycobacterium Tuberculosis*
- *Neisseria Gonorrhoea*
- *Pseudomonas*
- Fungus
- *Streptococcus pyogenes*

**Modes of infection**

- Trauma/Post-surgical
- Urinary tract infection
- Pneumonia
- Skin infections
- Open wound or cellulitis
- Heel sticks in infants
Routes of dissemination
- Hematogenous (MC)
- Direct extension
- Direct implantation

Growth plates inhibit hematogenous spread

Most common locations
- Knee
- Hip
- Ankle (Distal tibia)
  - venous stasis
- Shoulder
- Spine

Suppurative Osteomyelitis
- Bone marrow infection by (pyogenic) non-tubercular organism (anything but TB)
  - Staph. Aureus
  - Strep. Pneumoniae
  - E. Coli
  - Pseudomonas

Clinical Features of Acute Infection
- Edema
- Lymphadenopathy
- Warm skin
- Cellulitis
- Joint pain

Early Stage:
- Radiographic Stage >10 days
- Soft tissue edema
- Osteopenia
Middle Stage

- Lytic destruction (that may cross anatomical barriers)

Late Stage

- Chronic incomplete resolution
- Immune deficient

- sequestrum
- involucrum
- cloaca
- Brodie abscess

Sequestrum

- Chalky, white area representing isolated dead bone.

Involucrum:

- “Bony collar” - chronic periosteal response.

Cloaca

- Draining sinus. More common with chronic disease.

Differential Diagnosis for infection

- Tumor
  - Respects growth plates/fascial planes
- Infection
  - No respect (for growth plate or joint spaces)
Case Study

- 13 year male
- 3 week history of ankle swelling after soccer game
- x-rays normal
- MRI

Case Study

- bone marrow edema (pus)
- infiltrate into surrounding tissue

Septic Arthritis

- Joint effusion
- Juxtaarticular osteoporosis
- Erosions
- Joint space loss
- Lytic destruction that crosses joint space

Septic Arthritis

Crosses the joint space
Teardrop distance
- >11 mm
- >2 mm difference from the opposite joint
- Effusion
  - Infection
  - Trauma

Hip fat planes

Spondylitis

Early Radiographic Features
- Rapid disc space loss
- Endplate destruction

Spine infection
- Endplate destruction
- Disc destruction
- Pre-vertebral ST swelling
- Differentiate from metastasis
  - Preserved disc space
Paraspinal Line

Paraspinal Mass MRI

Pediatric with disc space loss

Limitations of plain films

- Is not really a sensitive exam
- Must have a significant loss in bone density before it is detected
- Other imaging studies are better for detection of early infection
- Use a radiologist

Sensitivity of Plain Films for Osteomyelitis

- < 5% are abnormal on presentation
  - This is when you want to make the diagnosis!
- < 33% are positive for findings at 1 week
- Reach 90% sensitivity at 3-4 weeks
  - But lots of bone/joint destruction!

Bone scintigraphy
- Technetium (non-specific)
- Gallium tagged RBC, Indium tagged WBC
- Very sensitive
  - Cheap!
- Often followed by MRI to evaluate the soft tissue.

Computed Tomography (hi resolution)
- Advantages:
  - See findings earlier than plain films
  - Good for hard to image areas (spine, pelvis, sternum)
- Findings are more specific and suggestive of osteomyelitis
  - Increased marrow density
  - Sclerosis, demineralization, periosteal reaction

Plain film

CT

MRI
- Better than plain films and CT
- More sensitive for bone marrow paths.
- Direct view of intramedullary disorders
- May precede bone scan findings
- Multiple slices visualized
- Better soft tissue contrast
- Better anatomic definition

Osteomyelitis findings on MRI
- Decreased signal intensity on T1
- Increased signal intensity on T2
  - Fatty bone marrow signal is replaced by water signal (edema, exudate)
  - Also fat sat STIR
- Sensitivity: 92-100%
- Specificity: 89-100%

Brodie's abscess

T1
T2

Infect Disease N Am 1990: 4: 441-463
INFLAMMATORY JOINT DISEASES

Rheumatoid Types (seropositive)
Rheumatoid Variants (seronegative)

RHEUMATOID TYPES (SEROPOSITIVE)

rheumatoid arthritis
systemic lupus erythematosus
scleroderma

RHEUMATOID VARIANTS

Ankylosing spondylitis
Reiter's disease
Psoriatic arthritis
Enteropathic arthritis

CONNECTIVE TISSUE AUTOIMMUNE DISEASE INVOLVING SYNOVIAL TISSUE RESULTING IN POLYARTICULAR JOINT INFLAMMATION

Juvenile Chronic Arthritis (Juvenile Rheumatoid Arthritis)

- seropositive
  - RA adult type (10% poorest prognosis)
- seronegative
  - Still's disease (20%)
  - Polyarticular (50%)
  - Pauciarticular (30%)*

Radiology

- soft tissue swelling
- osteoporosis
- loss of joint space
- articular erosions
- subluxations
  - and characteristic in children:
  - growth disturbances
  - periostitis
  - ankylosis
JCA-by location

- hands: characteristic rheumatoid changes with periostitis and shortening
- knee: "ballooning" of metaphysis
- hip: acetabular protrusion
- cervical spine: erosions and posterior joint ankylosis; vertebral body and disc hypoplasia

JCA

- periostitis

Bone shortening
- Fusion
- Ballooned epiphyses

Uniform narrowing

Facet fusion

Adult with “old” JRA
Systemic Lupus Erythematosus

- rheumatoid type (seropositive)
- female
- ESR elevated
- presence of LE cells
- ANA positive
- Marked subluxation although the joints integrity is relatively normal.

Systemic lupus erythematosus (SLE)

- Damage to the joints, skin, kidneys, and serosal membranes secondary to excessive immunoreactivity
- 9F:1M; MC among those 20-40 yoa
- 90% have articular complaint; severe radiographic changes are not seen
- MC area is hands, feet, wrists, & knees

SLE

- Characteristic “butterfly” rash

SLE-distribution

- hands-
  - MCP and PIP usually affected
  - ligament laxity results in reversible nonerosive ulnar deviation of digits (classic & <50% of patients)
  - swan-neck & boutonniere deformity
- spine- ↑ADI (8.5%)

SLE

- Ulnar deviation
- Minimal joint disease

SLE

- Swan-neck deformity
Seronegative Spondyloarthropathies
- Rheumatoid Factor negative
- HLA B27 positive
  - Ankylosing spondylitis
  - Psoriatic arthritis
  - Reiter's disease
  - Enteropathic arthritis

Ankylosing Spondylitis
- Synonyms
  - Marie Strumpell's Disease
  - Rhizomelic Spondylitis
    - (Pierre Marie 1898).
- 50% of AS patients will have peripheral disease especially of the hips and shoulders..... Spondylitis Rhizomelique

Ankylosing spondylitis (AS)
- MC seronegative spondyloarthropathy
- affect 0.1-0.2%
- 1:1 to 1:10 female to male ratio
- 90% positive HLA-B27 (6-8% in general population)

Skeletal distribution
- Axial: SI and spine
- Appendicular:
  - proximal large joints of extremities (rhizomelic)
- Enthesis
  - (attachment of ligaments and tendons to bone)
- erosions, bony proliferation, and

Clinical Features
- male
- 15 - 30 years
- 3 moths of physician observed pain and stiffness
- limited spinal motion
- sacroilitis
- limited chest expansion (1" or less)
- presents as spinal pain & stiffness
- iritis, conjunctivitis
- lab: +HLA-B27, +ESR, -RA, -ANA
- usually no disability, sometimes severe
- aortic insufficiency, pulmonary fibrosis
Management

- Management is aimed at a long-term plan to prevent, decrease, or delay joint and postural deformities
- NSAIDS to limit joint inflammation and pain

Sacroiliac involvement

- Classic initial site of skeletal involvement
  - Hazy loss of subchondral (cortical) definition
  - Erosions and joint space widening
  - Fusion
  - 50% will progress to fusion

Normal SI joints

- Parallel joint surfaces
- Well defined subchondral bone

Bilateral symmetric joint changes

- Erosions
- Osteitis

SI joint ankylosis

- Loss of subchondral bone
- Osteitis (sclerosis)
- Joint widening
Initial Visit
- well defined joints and subchondral bone

5 years later
- ill defined subchondral bone

10 years later
- complete loss of joint definition

Sacrolilitis
- subchondral erosions
- osteitis

Osteitis Condensans Ilii
- not to be confused with ankylosing spondylitis
- seen in post partum females
- sclerosis at the inferior aspect of the SI joint, especially at the iliac aspect.
AS-spine
- targeted to thoracolumbar & lumbosacral
- joints involved:
  - discovertebral
  - apophyseal
  - costovertebral
  - atlantoaxial

AS-discovertebral
- corner erosions (Romanus lesions) reactive sclerosis (shiny corner)
- loss of anterior concavity (vertebrae squaring)
- thin syndesmophytes (bamboo spine)
- disc calcification
- interspinous ligament ossification (dagger sign)
- trolley track sign (z joint capsular ossification)
- whiskering (ischial enthesopathy)
- endplate destruction ("Andersson lesion")
- spinal fracture (carrot stick fracture)

Shiny corner

Radiology Spine
- Inflammatory enthesopathic spurs are the major feature of AS of the spine - syndesmophytes.
- Syndesmophytes are vertically oriented spurs that represent the sequelae of inflammatory disease of the spinal ligaments.

Vertebral body squaring
Squaring with early syndesmophytes

Vertebral squaring
- squaring with convexity

Syndesmophytes

Whiskering

“spondylitis rhizomelique”
- Looks like rheumatoid on imaging and

TUMORS
Age and tumors

- Benign tumors:
  - typically between 10 and 30
- Malignant tumors:
  - <10 = Ewing's, Osteosarcoma
  - >40 = Mets, Myeloma, Chondrosarcoma

Longitudinal location

- Epiphyseal
  - Giant cell tumor
- Metaphyseal
  - ABC
  - NOF
  - Chondrosarcoma
  - Osteosarcoma
- Diaphyseal
  - Ewing's
  - Multiple myeloma

Axial location

- SBC
- GCT
- NOF
- ABC

Benign periostitis

- Infection
- Trauma

Aggressive periostitis

- Ewing's
- Osteosarcoma
- Fibrosarcoma

Patterns of bone destruction

- Geographic
  - (SBC, GCT, NOF...)
- Motheaten
  - (Myeloma...)
- Permeative
  - (Mets...)

Aggressive

Non-aggressive
Tumor Matrix

- Bone (solid radiodense)
  - B=bone island, osteoid osteoma
  - M=osteosarcoma

- Cartilage (stippled radiodensity)
  - B=enchondroma, osteochondroma
  - M=chondrosarcoma

- Fibrous (hazy radiodensity)
  - B=fibrous dysplasia
  - M=fibrosarcoma

Bone Islands

- discrete area of bone sclerosis
- ischium, ilium, sacrum, prox. femur, humerus, vertebrae, etc.
- 30% grow over time
- well-defined intramedullary densities
- DDx from blastic mets if multiple, especially in the pelvis of patients >40
**Simple Bone Cyst**

- 3-15 yrs, clinically silent unless fx
- 75% in humerus and proximal femur
- central, expansile, geographic metaphyseal location
- fluid-filled, elongated, fractured septation ("fallen fragment" sign)

**Giant Cell Tumor**

- quasimalignant, 80% benign
- 20-40 yrs, distal femur, proximal tibia, distal radius, proximal humerus, sacrum
- subarticular, eccentric, expansile, no surrounding sclerosis, geographic, internal septa
- malignant vs. benign not possible on films
Giant cell tumor

Enchondroma
- 10-30 yrs., usually asymptomatic
- 50% occur in hands and feet
- 50% demonstrate matrix ca++
- long bone more often symptomatic
- centrally placed in metaphysis
- Multiple lesions = Ollier’s
- Ollier’s + soft tissue hemangiomas = Maffucci’s

Enchondroma

Multiple enchondromas (Ollier’s disease)

Osteochondroma
- most common benign tumor of bone
- cartilage exostosis from displaced epiphyseal cartilage rests
  - sessile (humerus and scapula)
  - pedunculated (hip, knee, ankle)
- asymptomatic, unless pressure on nerve or vessel

Osteochondroma
Osteochondroma

Hereditary Multiple Exostosis
- multiple (few to 100's) osteochondromas
- symmetric and bilateral, broad metaphyses
- hands and pelvis most common
- 20% malignant degeneration
- painless, lumpy joints

Fibrous Xanthomas
- fibrous cortical defect (< 2 cm)
  - common, posterior surface of distal femur, solitary, eccentric, smaller than NOF
- non-ossifying fibroma (> 2cm)
  - less common, distal tibia, distal femur, proximal tibia, solitary, expansile, eccentric, larger than FCD
- no tx necessary
Non-ossifying fibroma

Osteoid Osteoma
- 10-25 yrs., severe pain worse at night, alleviated with aspirin
- 50% femur and tibia, 10% spine (painful scoliosis)
- central radiolucent nidus, surrounding sclerosis
- location
  - cortical, intramedullary, subperiosteal
- DDx brodie’s abscess (>2cm nidus)

Aneurysmal Bone Cyst
- proliferation of vascular component of marrow
- 5-20 yrs., femur, tibia, and spine
- pain at site of lesion
- eccentric, metaphyseal saccular protrusion, markedly expansile, periosteal buttressing
**Aneurysmal bone cyst**

**Fibrous Dysplasia**
- following normal resorption, fibrous tissue replaces bone
- presents from 8 and 14 yrs., asymptomatic
- monostotic, polyostotic forms (30% have skin spots)
- ribs, femur, tibia, and skull
- McCune-Albright syndrome (polyostotic FD, precocious puberty, skin spots)
- “ground glass,” “smoke” matrix

**Osteosarcoma**
- second mc prim. mal. tumor of bone
- 10-25 yrs, painful swelling in limb
- usually around knee
- 50% sclerotic, 25% osteolytic, 25% mixed
- permeative or dense medullary lesion with periosteal response, codman's triangles, cortical disruption with soft tissue mass

**Ewing's Sarcoma**
- fourth mc prim. mal. tumor of bone
- 10-25 yrs., mimic infections
- permeative lesion w/ cortical saucerization found in diaphysis of femur, tibia, fibula, innominate
- round cell lesions (lymphoma, leukemia, Ewing's, EG, MM, osteomyelitis, neuroblastoma)
Steps in interpretation:
1) Is it abnormal?
2) What is the "pattern" of abnormality?
3) What are the possibilities?
4) Can the list of possibilities be narrowed?
**Radiography-rickets**

- Findings most prominent in fastest growing bones in the body.
  - costochondral junctions of the middle ribs
  - distal femur, the proximal humerus
  - both ends of the tibia
  - distal ulna and radius
- Widened, bulky physeal plates and irregularity ("fraying")
  - lack of mineralization of the cartilage matrix
- Splaying ("cupping") of the weakened bone at the junction of the metaphysis and physis.
  - predispose to a "slipped" epiphysis (epiphysiodesis)
- Bowing deformities
- "Rachitic rosary" of the chest due to cartilage overgrowth and metaphyseal splaying at the costochondral junction of the ribs

**Rickets**

- **Osteopenia**
- Widened, frayed metaphysis-epiphyseal plate junction

**Osteomalacia**

- **Osteopenia**
- Coarsened trabeculation
- **Loosers zone**

**Pituitary Tumor**

- **HEADACHES!!**
- Visual disturbances
- Generalized discomfort in extremities
- However, symptoms will vary depending upon the type of tumor the patient has
Enlarged Sella Turcica

- 16 x 12 mm
  - across x depth
- 40" FFD
  - Film focal distance
- Significance
  - empty sella
  - tumor
  - normal
  - aneurysm

Acromegaly and gigantism

- Pituitary adenoma secreting growth hormone

Giantism

- Etiology:
  Same as acromegaly except onset of growth hormone oversecretion occurs prior to skeletal maturation (open physis).

acromegaly

heel pad thickness > 23mm
Sickle cell anemia

- MC hemolytic anemia; about 1:600 African-Americans
- pain and swelling in hands and feet ("hands and feet" syndrome)
- infarct of bowel following obstruction of the mesenteric arteries (abdominal crisis)

Sickle cell anemia - imaging

- marrow hyperplasia
  - coarse trabeculation
  - osteopenia
  - long bone undertubulation
  - hair-on-end skull
- osteonecrosis
  - "H" shaped vertebrae
  - avascular necrosis

"H" vertebrae of sickle cell anemia

"hair on end"
Achondroplasia

- Background:
  - most common dwarfing skeletal dysplasia
  - marked by hypochondroplasia
  - normal life expectancy & mental status
  - normal or near normal trunk length with marked rhizomelic micromelia

Achondroplasia

- Imaging:
  - Pelvis
    - narrow broad pelvic inlet “champagne glass”
    - broad ilia, ribs, and sternum
    - broad and short
  - Extremities
    - Short tubular bones
Achondroplasia

- Imaging:
  - Spine-
    - Stenosis
      - short pedicles with narrowed interpediculate distance leading to a narrow, trefoil spinal canal
      - posterior body scalloping

- Clinical:
  - waddling gait; broad and flat nasal bridge

Cleidocranial dysplasia

- Clinical:
  - Defect of intramembranous bone growth

- Imaging:
  - Pelvis
    - Pubic diastasis

- Imaging:
  - Skull
    - inverted “pear shape”
    - wormian (intrasutural) bones
    - Persistent bregmatic suture
  - Clavicles
    - Hypoplasia (or aplasia)
  - Spine
    - Spina bifida occulta

Osteogenesis imperfecta

- Background:
  - marked by abnormal type I collagen formation
  - at least four subtypes exist ranging from mild osteopenia to dwarfism with multiple fractures
  - Blue sdera
Osteogenesis imperfecta

- Imaging:
  - osteopenia, bowed long bones, thin cortices, pathological fractures, kyphoscoliosis
- Clinical:
  - May be lethal at birth
  - Treatment is directed at limiting deformity and injury

Osteopetrosis

- Background:
  - Group of entities, representing a type of sclerosing bone disease
  - abnormality of decreased osteoclastic activity

- Imaging:
  - loss of medullary space
  - pathological fractures
  - dense bones, thick cortices
  - hypoplasia of frontal sinuses
  - “bone within a bone” or “endobone”
  - “sandwich” vertebrae
  - undertubulation of extremities resulting in an “Erlenmeyer flask” deformity

- DDX:
  - Lead poisoning
  - HPT (weak)

Osteopetrosis

- DDX:
  - Normal

“Bone in a bone appearance”
LEAD INTOXICATION (plumbism, Saturnism)

- 1,000,000 children aged 6m-5y, have blood lead levels above 30mg/mL
- Higher prevalence: low income families, older housing/pipes
  - Seizures
  - Encephalopathy
  - Mental retardation
  - Neuro-developmental impairment
  - Anemia

Imaging

- Abdominal X-Ray
  - Radio-opaque lead ingestion paint chips
- Bones X-Ray
  - “Lead lines” increased density in the metaphysis of growing long bones

Exposure during pregnancy

- Exposure to substantial amounts of radiation during pregnancy may cause
  - Birth defects,
  - Miscarriage,
  - Mental retardation,
  - Decrease in IQ,
  - A higher risk of childhood cancer
  - Higher risk of cancer in adult life,
  - Hereditary effects that can be passed on to future generations.
Deteministic Effects.

- This category includes radiation-induced cataract, fibrosis, fibrovascular atrophy, thyroid dysfunction, and effects in an exposed embryo or fetus.

Stochastic Effects

- Radiation-induced damage that is incompletely or incorrectly repaired increases the probability of genetic mutation in affected cells.
  - Somatic type effects,
    - cancer, appearing in irradiated people years or even decades after exposure.
  - Reproductive type effects
    - small probability of radiation-induced heritable genetic effects in the progeny of those exposed.

Prenatal radiation exposure

- Human embryo or fetus is protected in the uterus, a radiation dose to a fetus tends to be lower than its mother for most radiation exposure events.
- However the human embryo and fetus are particularly sensitive.

Estimated fetal radiation doses during some common radiodiagnostic procedures

<table>
<thead>
<tr>
<th>Examination type</th>
<th>Fetal dose (mrad)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-RAY</td>
<td></td>
</tr>
<tr>
<td>Lumbar spine radiography</td>
<td>400</td>
</tr>
<tr>
<td>Pelvic radiography</td>
<td>200</td>
</tr>
<tr>
<td>Hip and femur radiography</td>
<td>300</td>
</tr>
<tr>
<td>Retrograde pyelography</td>
<td>600</td>
</tr>
<tr>
<td>Abdominal (kidneys, uterus, bladder) radiography</td>
<td>250</td>
</tr>
<tr>
<td>Lumbar spine</td>
<td></td>
</tr>
<tr>
<td>Anteroposterior</td>
<td>750</td>
</tr>
<tr>
<td>Lateral</td>
<td>91</td>
</tr>
<tr>
<td>Oblique</td>
<td>150</td>
</tr>
<tr>
<td>Barium enema</td>
<td>1000</td>
</tr>
<tr>
<td>Intravenous pyelogram</td>
<td>480</td>
</tr>
<tr>
<td>COMPUTED TOMOGRAPHY</td>
<td></td>
</tr>
<tr>
<td>Head</td>
<td>0</td>
</tr>
<tr>
<td>Chest</td>
<td>16</td>
</tr>
<tr>
<td>Abdomen</td>
<td>3000</td>
</tr>
</tbody>
</table>

Estimated Fetal Exposure for Various Diagnostic Imaging Methods

<table>
<thead>
<tr>
<th>Examination type</th>
<th>(rad)*</th>
<th>Required for cumulative 5 rad dose†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest (two views)</td>
<td>0.0005</td>
<td>71,429</td>
</tr>
<tr>
<td>Abdominal (multiple views)</td>
<td>0.245</td>
<td>20</td>
</tr>
<tr>
<td>Lumbar spine</td>
<td>0.300</td>
<td>23</td>
</tr>
<tr>
<td>Femur</td>
<td>0.440</td>
<td>123</td>
</tr>
<tr>
<td>Hip (single view)</td>
<td>0.823</td>
<td>23</td>
</tr>
<tr>
<td>CT scan (slice thickness: 10 mm)</td>
<td>0.010</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Head (10 slices)</td>
<td>0.030</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Chest (10 slices)</td>
<td>0.180</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Abdomen (10 slices)</td>
<td>2.400</td>
<td>1</td>
</tr>
<tr>
<td>Lumbar spine (5 slices)</td>
<td>3.300</td>
<td>1</td>
</tr>
<tr>
<td>Barium enema</td>
<td>3.900</td>
<td>1</td>
</tr>
<tr>
<td>Iodine (131I) at fetal thyroid dose</td>
<td>590.000</td>
<td>‡</td>
</tr>
<tr>
<td>Environmental background radiation (cumulative dose over nine months)</td>
<td>0.300</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Diagnostic Imaging Modalities During Pregnancy

- "No single diagnostic procedure results in a radiation dose that threatens the well-being of the developing embryo and fetus." -- American College of Radiology
- "[Fetal] risk is considered to be negligible at 5 rad or less when compared to the other risks of pregnancy, and the risk of malformations is significantly increased above control levels only at doses above 15 rad." -- National Council on Radiation Protection
- "Women should be counseled that x-ray exposure from a single diagnostic procedure does not result in harmful fetal effects. Specifically, exposure to less than 5 rad has not been associated with an increase in fetal anomalies or pregnancy loss." -- American College of Obstetricians and Gynecologists
In order to avoid unwanted irradiation of the fetus, it is recommended to post warnings, both at the X Ray room entrance and in the waiting room such as:

"IF YOU THINK THERE IS ANY POSSIBILITY THAT YOU ARE PREGNANT, PLEASE TELL IT TO THE RADIOGRAPHER (RADIOLOGICAL TECHNOLOGIST) OR THE RADIOLOGIST, BEFORE THE X-RAY EXAMINATION IS PERFORMED".

Pregnancy

- MRI: There are no documented adverse effects upon the fetus, but it is recommended that all non-essential studies be avoided in the first trimester.
- Ultrasound: Recommended that the average power setting for ultrasound studies in the area of the fetus be kept to a minimum consistent with achieving a diagnostic study.

CHIROPRACTIC AND PEDIATRIC RADIOGRAPHY

Indications for Pediatric Radiographic Examination

- History
  - Will the imaging give you any added clinical data?
  - Will the results change management?
  - Will the study confirm the clinical suspicion?
- Is the study appropriate?
- Benefits vs. risk
  - American College of Radiology (ACR) Appropriateness Criteria available at www.acr.org

Radiation Exposure - Children

- Considerably more sensitive to radiation than adults
- Also have a longer life expectancy
  - a larger window of opportunity for expressing radiation damage


Technical Issues

- Instructional compliance
- Motion
  - The child should be stabilized by a parent
- Recumbent radiographs often a necessity in young children
  - acute fractures

Compared with a 40-year old, the same radiation dose given to a neonate is several times more likely to produce a cancer over the patient's lifetime.
Image Quality

- Be critical
  - "good enough" probably isn’t

- Establish a QA program
  - State regulations

- A CT/limited radiographer is QUALITY CONTROL

A Rule

- Radiographic imaging is a two dimensional representation of a three dimensional structure.

  Examinations require at least two views at 90 degrees each other.

Great Destroyers of Image Quality:

- Patient Motion
- Scatter Radiation
  - kVp
  - Body size
  - Collimation
  - Grids
- Dark Room Errors
- Positioning/Technical Errors
- Old/Bad/Inappropriate Equipment

Collimation Rules

- Collimation to include the required structures only
- Evidence of collimation on four sides
- Collimation in general should be such that the radiosensitive organs such as the thyroid, eyes, gonads and breasts receive the least dose commensurate with the image required.

The pediatric patient always presents with unique problems for the radiographer

- Keeping still
- Use of restraining devices
- Response to verbal direction
- Use of shielding
- Role of the family
Upright vs. recumbent

- trauma cases
- large patients
- infirm patients

Less motion
- Higher resolution
- Thinner patients
- Improved diagnostic accuracy

This film is for analysis

- No clinical justification
- Chiropractic analysis of radiographs and pathological findings are inseparable

Recording Media

- Are your screens older than 7 years?
- Have you cleaned them recently?
- Are the cassettes in good order?
Artifacts I Have Met

Identities have been removed to protect the guilty!

The following represents a selection of relatively common artifacts

Please try not to copy these!

It makes us all look bad!

Remember

Your radiographic quality might be considered a direct reflection of the quality of the practice.