

# Pediatric Cervical Spine Trauma

## When Is Cross-sectional Imaging Needed?



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HEALTH SCIENCE CENTER  
AT HOUSTON

# Spine Fractures in Children

- **Uncommon – 1-3% of pediatric trauma patients**
- **60-80% spine fxs in children involve C-spine, especially those <8 yrs of age**
- **Combined injuries common**
  - **>60% with C spine injury have head injury, neurologic deficit**
  - **0.2% with head injury have C spine injury**
- **Causes**
  - **MVC, auto-ped, falls, sports**
  - **Birth trauma (breech delivery)**
  - **Non-accidental trauma**

# Pediatric Spine Differences

- **Fractures are rare**
- **Clinical assessment challenging**
- **Immobilization can be difficult**
- **Ossification incomplete**
  - **Normal variants common**
- **Mild normal laxity can be present**
  - **Injuries can occur without fracture**

# Objectives

- **Plan safe and effective imaging protocols for C-spine injuries in infants and children**
- **Understand mechanisms and patterns of pediatric cervical spine injuries**
- **Recognize anatomical variations and subtle injuries that benefit from cross-sectional imaging.**

**1** **What percentage of patients in your practice are < 15 years of age?**

**1) 80 - 100%**

**2) 50 - 79%**

**3) 25 - 49%**

**4) 5 - 25%**

**5) < 5%**

# When Is C-spine Imaging Needed?

- **NEXUS (National Emergency X-ray Utilization) study**
  - Children evaluated as part of large, multi-age study (9% of all patients)
  - **Criteria**
    - Midline cervical tenderness
    - Altered mental alertness
    - Evidence of intoxication
    - Neurologic abnormality
    - Painful distracting injury
  - Only 30 injuries in 3065 patients <18 yrs (0.98%)
    - 4 younger than 9 yrs
  - Decision rule predicted 100%, but not directly applicable to children

# Radiographic Evaluation

- **Lateral view most valuable**
  - Should include C7-T1 disc space
  - 65 – 87% accuracy
- **AP view usually obtained, but of questionable value**
- **Odontoid view difficult to obtain in children <5 years**
  - Not needed under age of 9
- **Flexion/extension views**
  - Not used in acute injuries
  - May be helpful for FU of ligamentous injury



# **Radiographs for C-spine Injury in Children**

- **Useful for those familiar with the differences of the immature spine**
  - **Incomplete development**
  - **Normal degree of laxity**
  - **Challenges of obtaining good quality images**
  - **Congenital anomalies**



**2 Which of the following C-spine radiograph findings can be normal in children?**

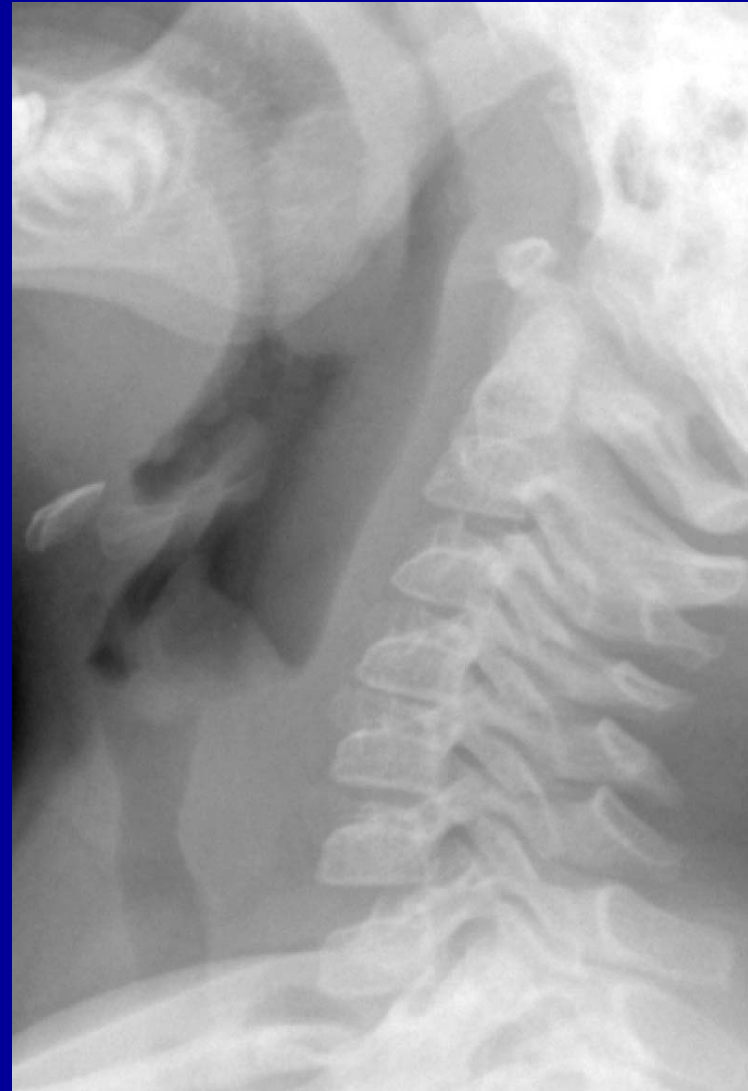
- 1) Atlantodental distance of 6 mm**
- 2) Anterior tilting of the dens**
- 3) 4 mm anterior displacement of C2 on C3**
- 4) Basion to dens distance of 15 mm**
- 5) Anterior wedging of the C3 vertebral body**

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# Precervical Soft Tissue Thickness

Can be misleading on radiographs



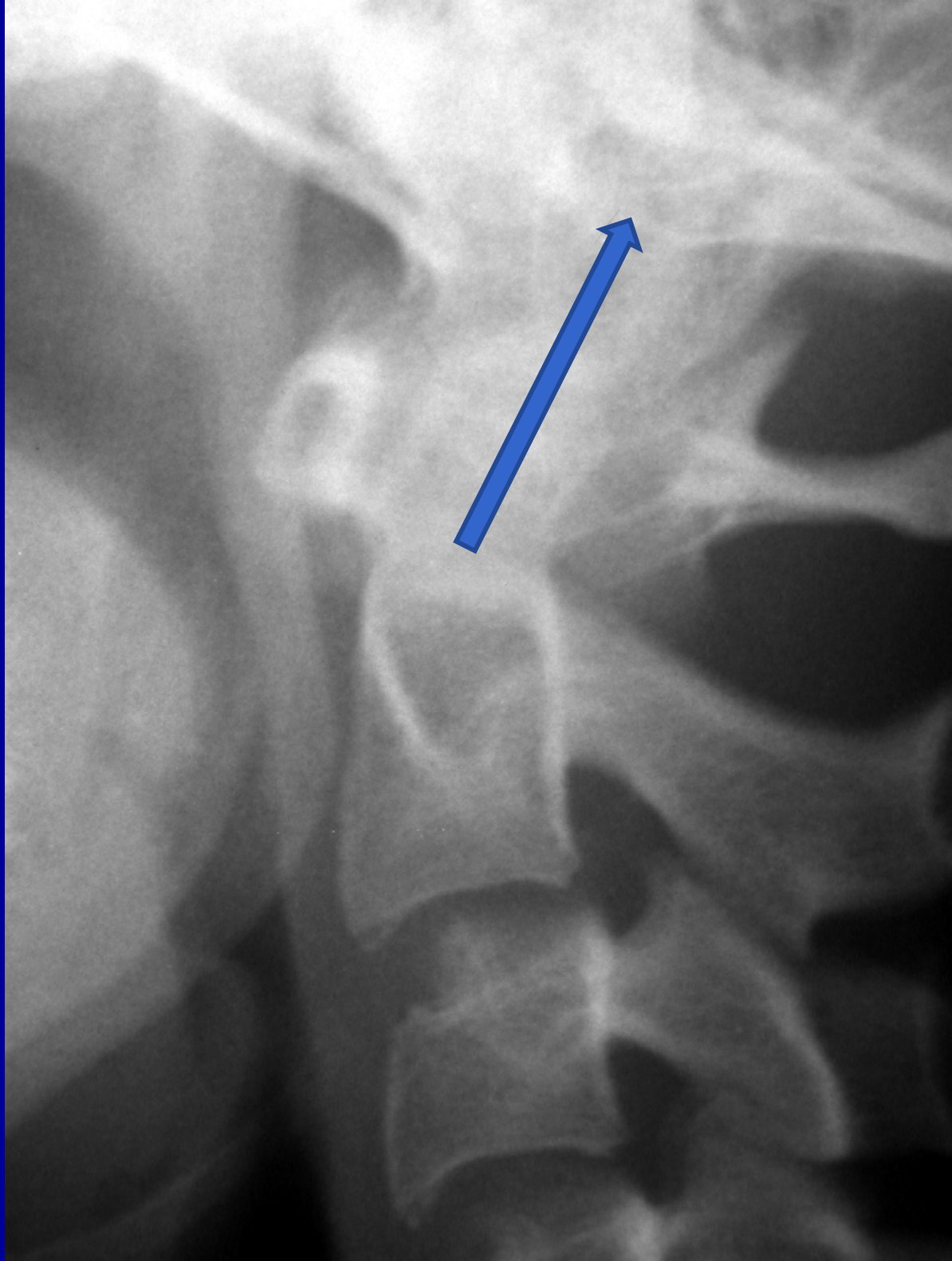




**Normal Neurocentral  
Synchondrosis  
(gone by age 8)**

# Dens Tilting

- Posterior often normal
- Beware of anterior or lateral tilt

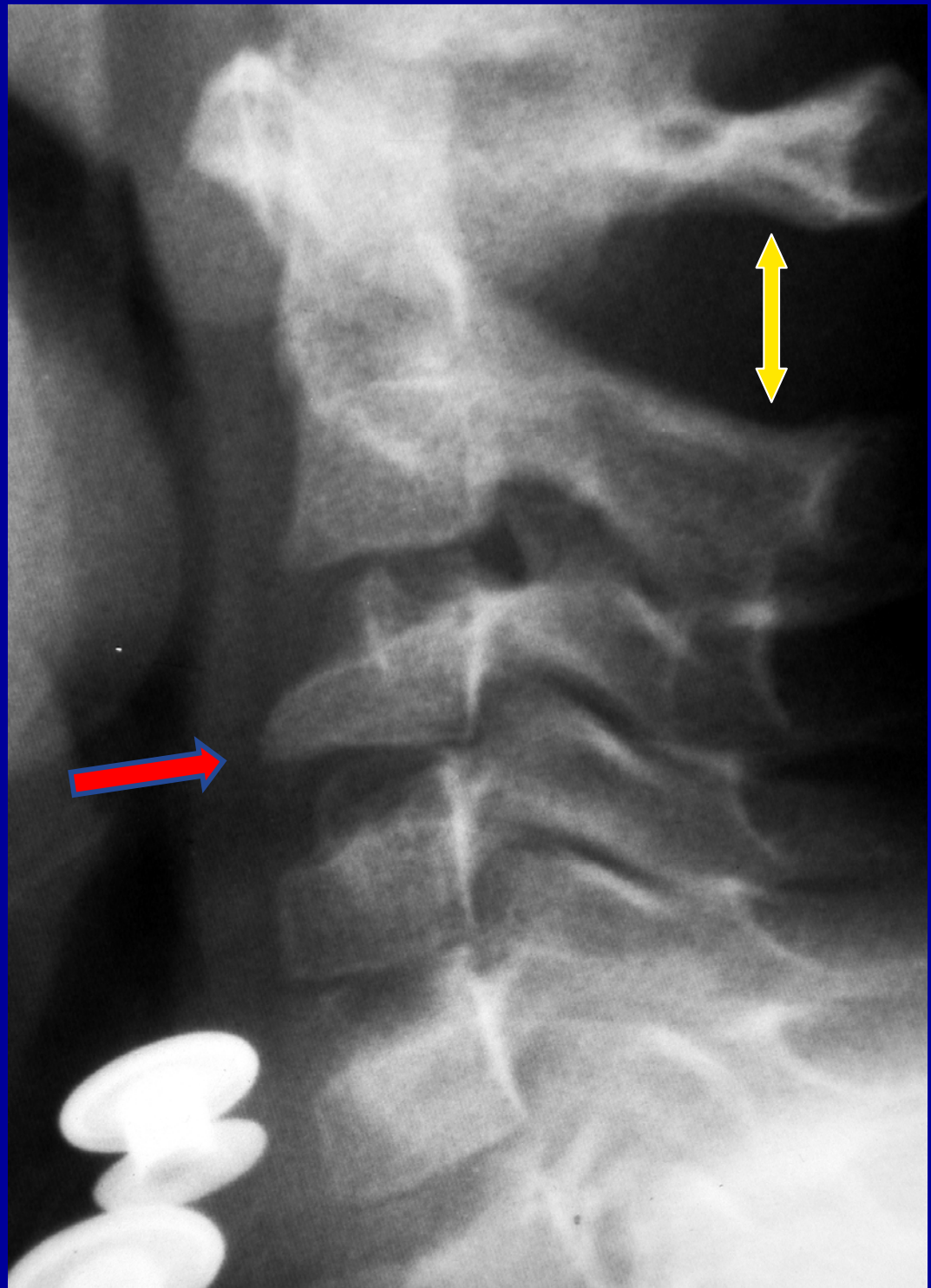


# Physiologic Hypermobility in Young Children

- Ligamentous laxity leads to misleading appearances on XR
  - Pseudosubluxation
  - Increased interspinous distance
  - Increased dens-to-C1 distance

# Wide Interspinous Distance

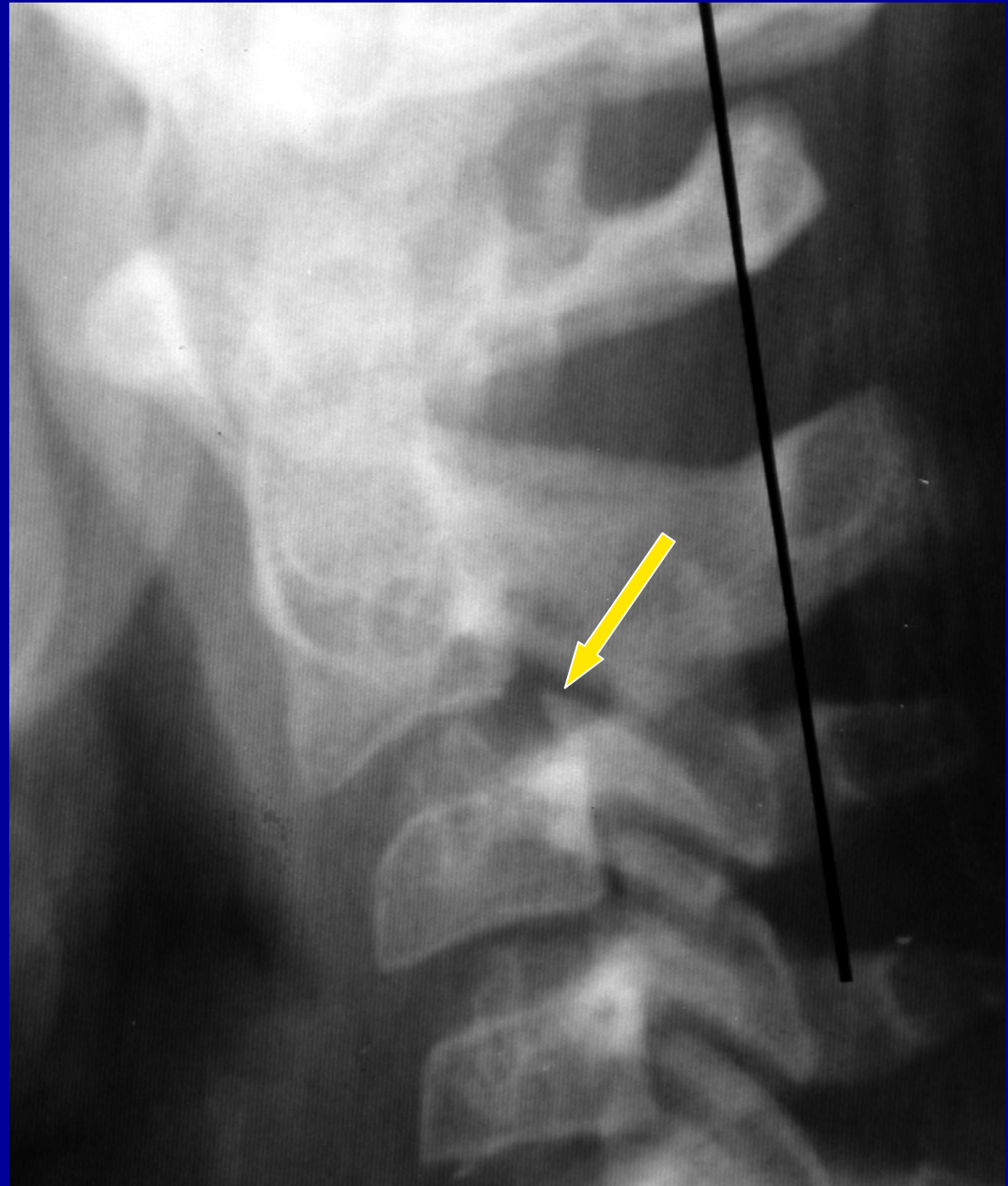
- Can be as wide as 10-12 mm



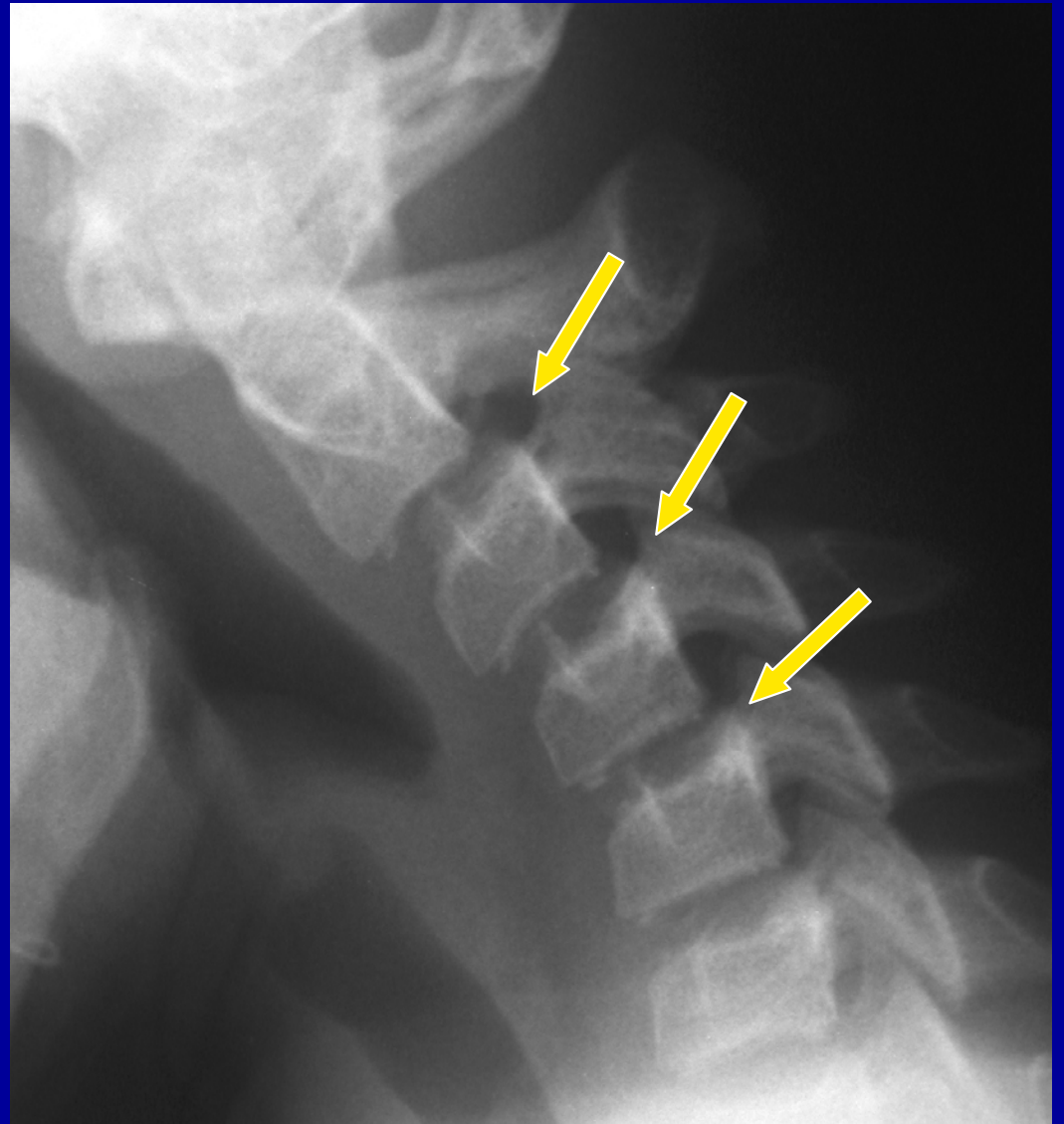
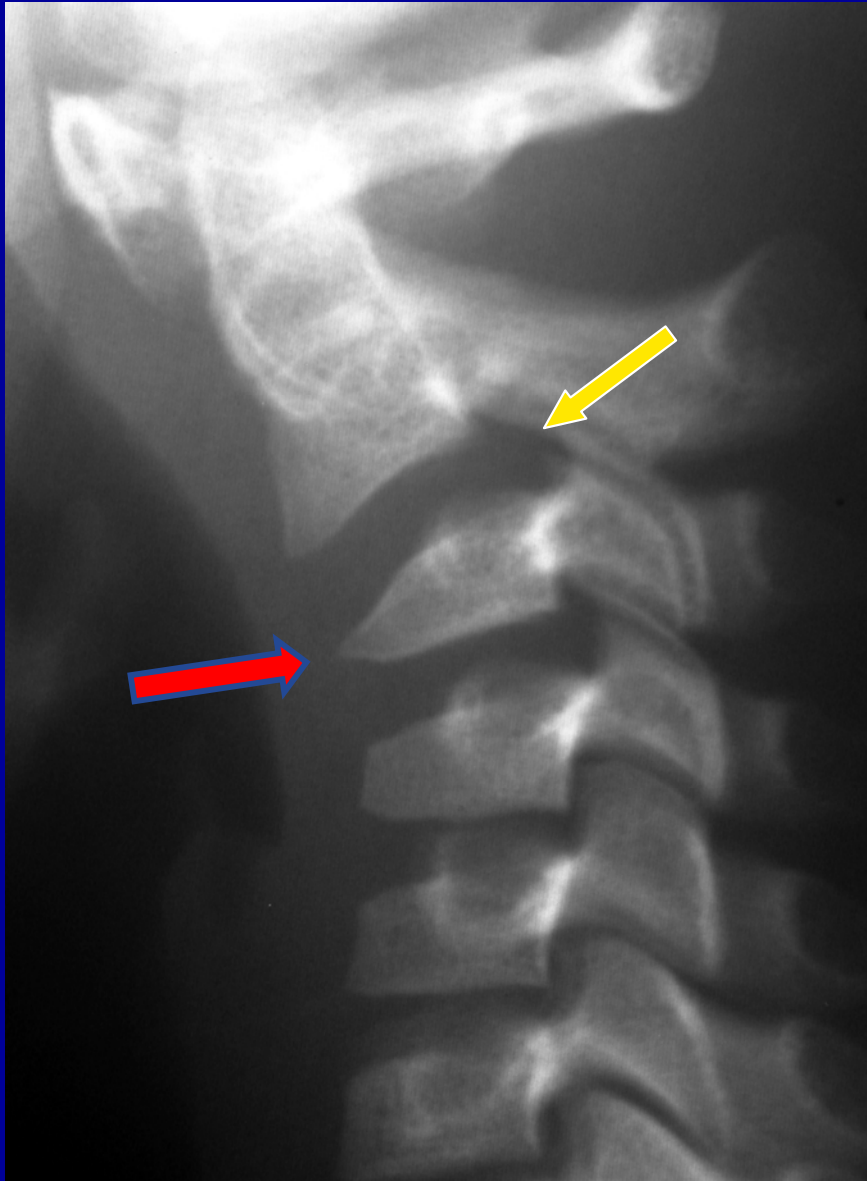


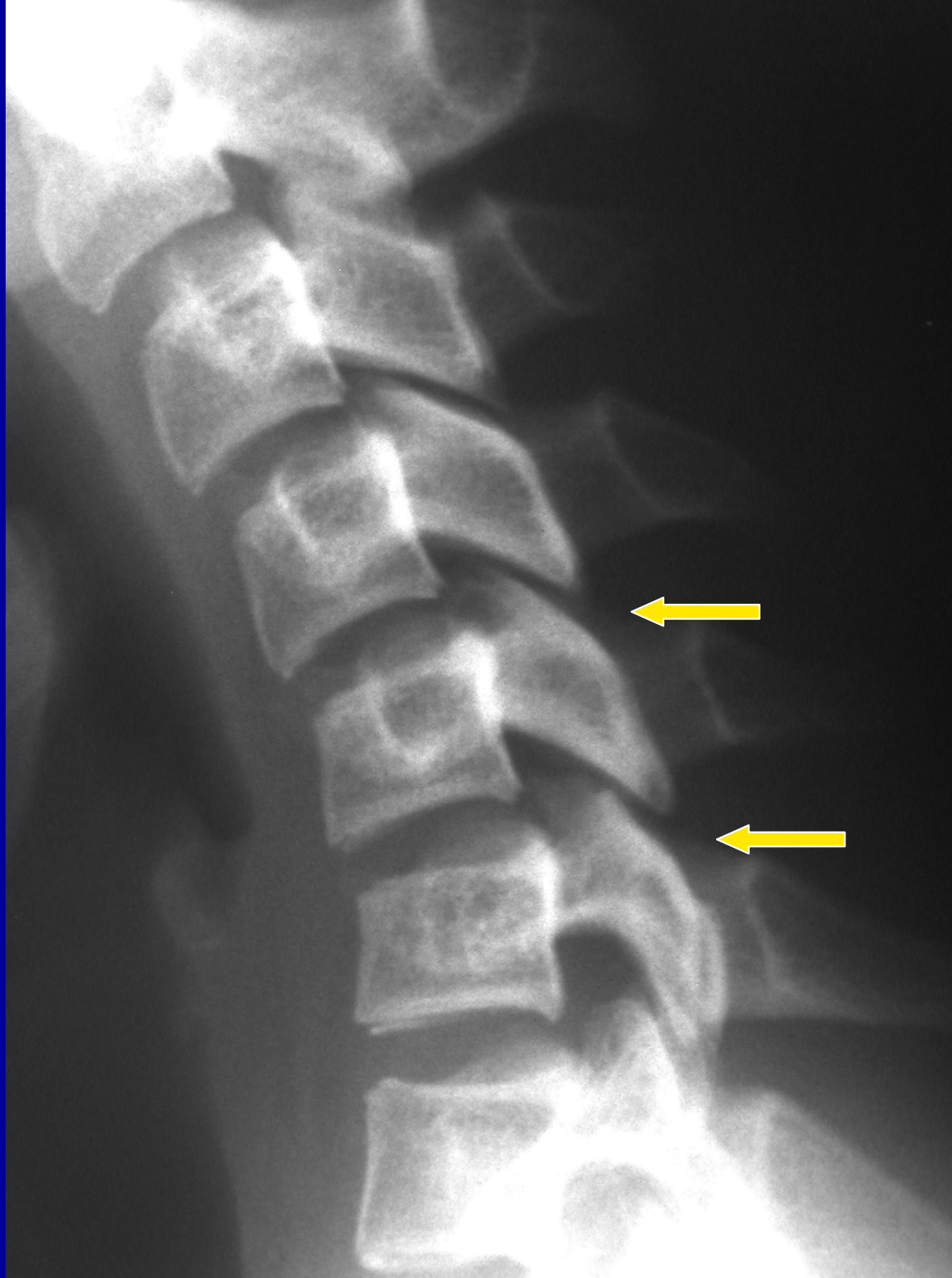
# Physiologic Subluxation

- 1-2 mm
- Normal spinolaminar line
- Caveat
  - Apophyseal joints intact



# Pseudosubluxation occurs in 19% of normal children between 1 – 7 yrs age

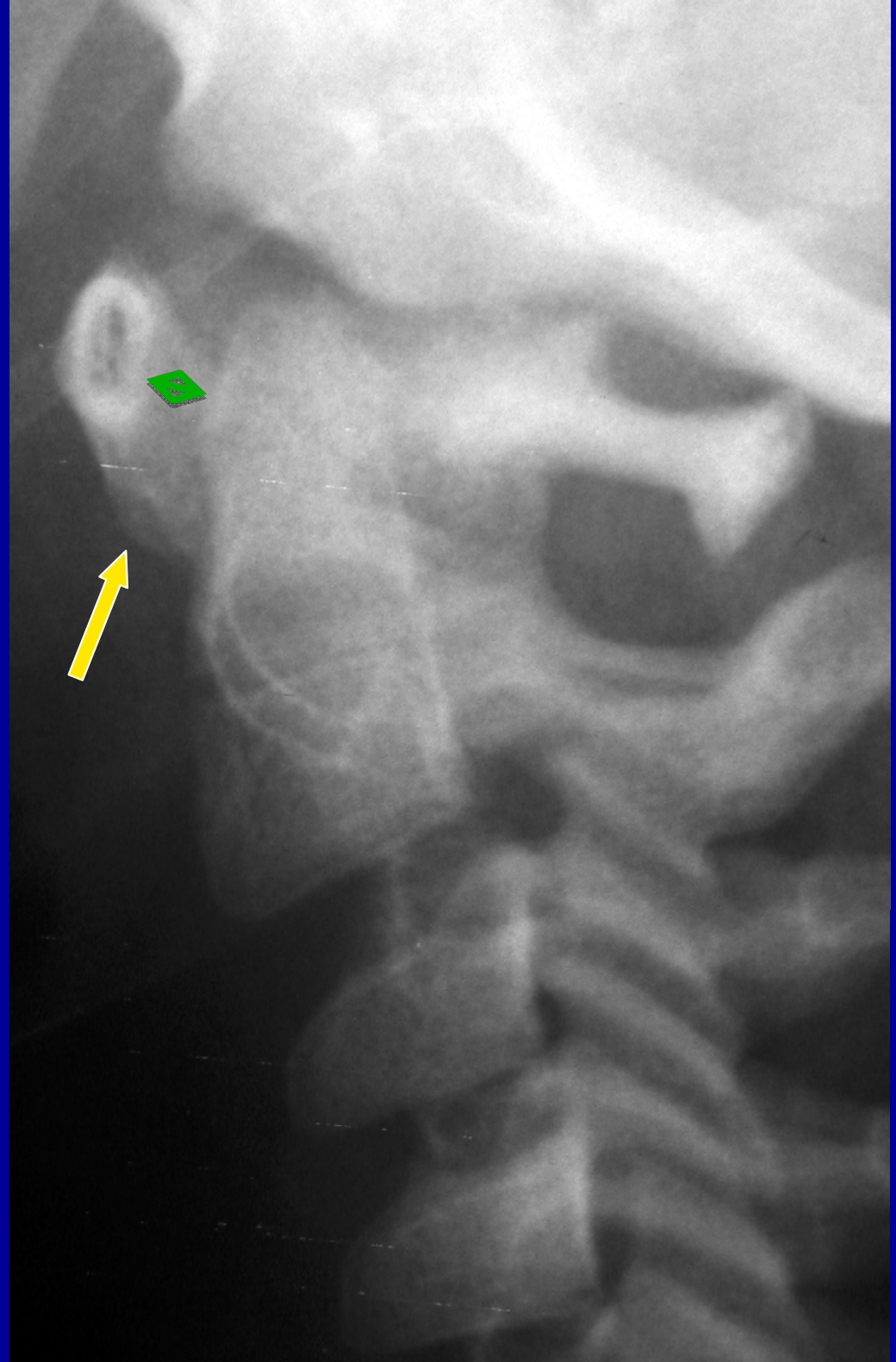


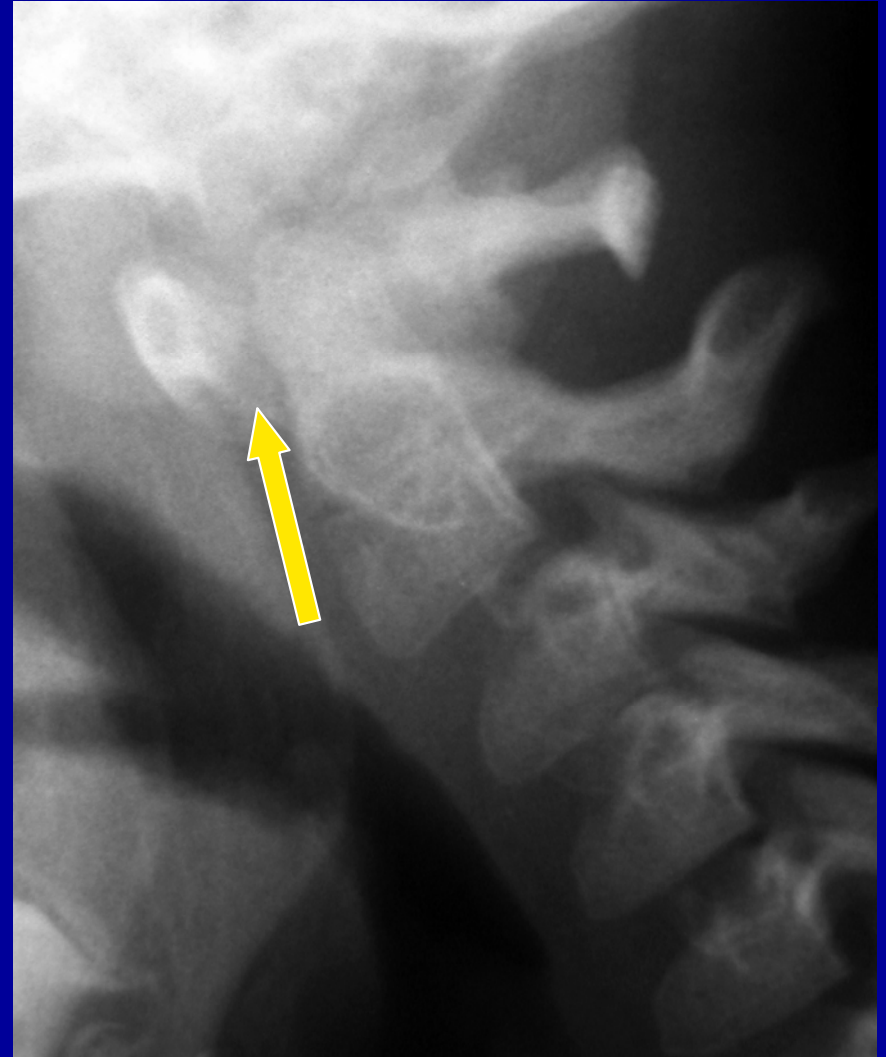
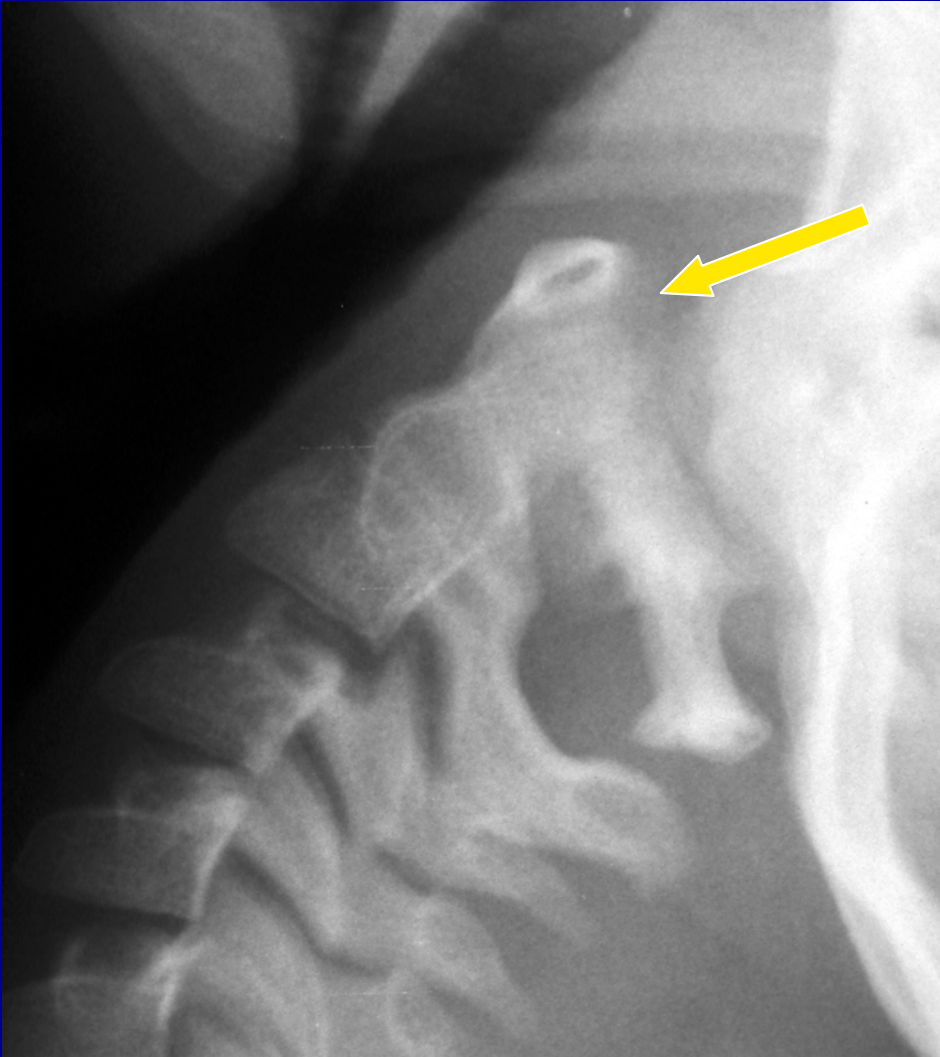


**Normal V-  
shaped  
apophyseal  
joints  
(mild)**

# Anterior Atlantodental Distance

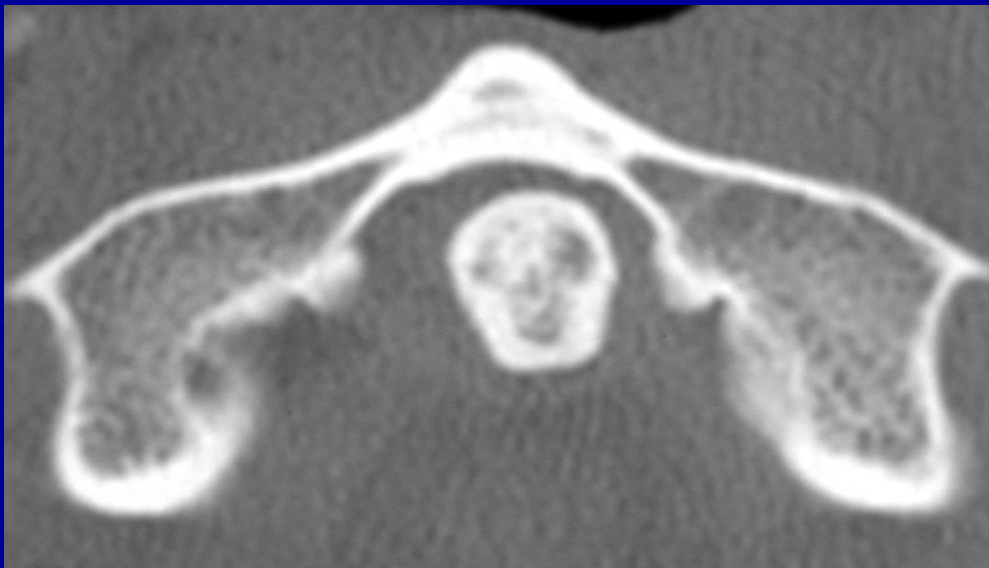
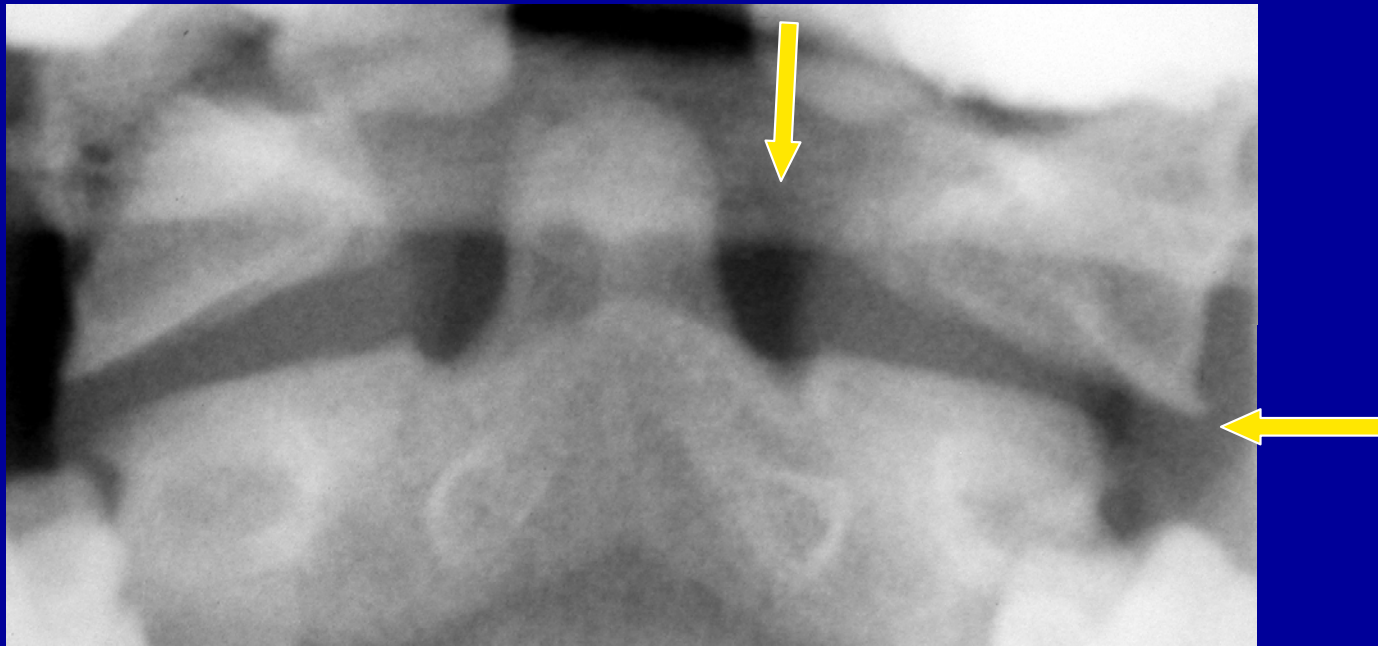
- May be as wide as 4-5 mm





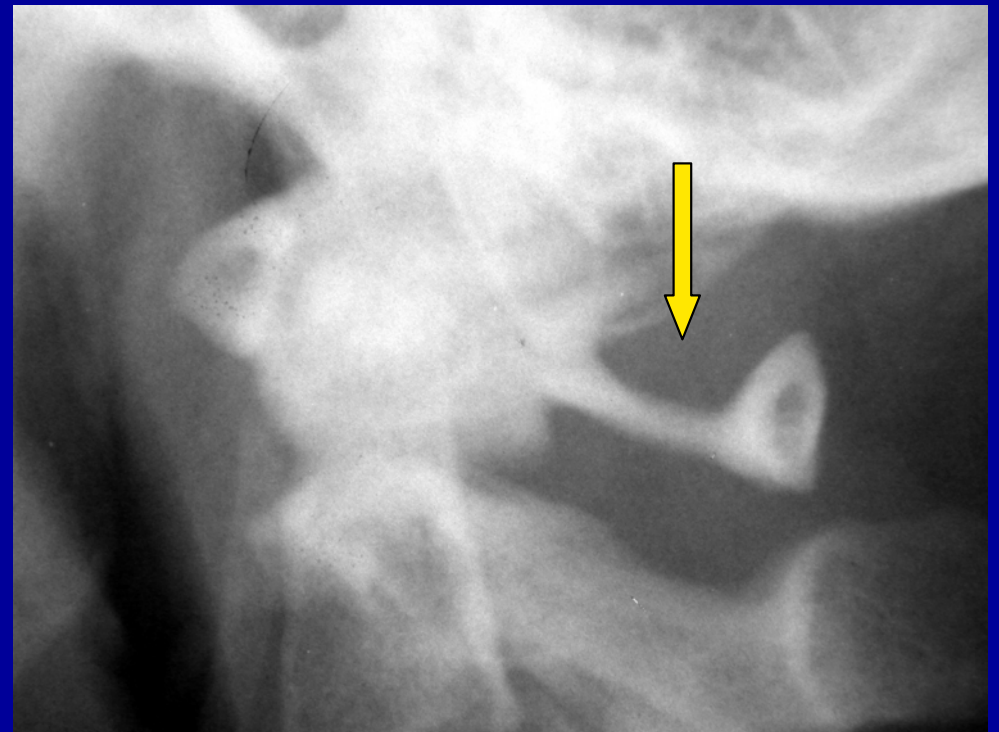
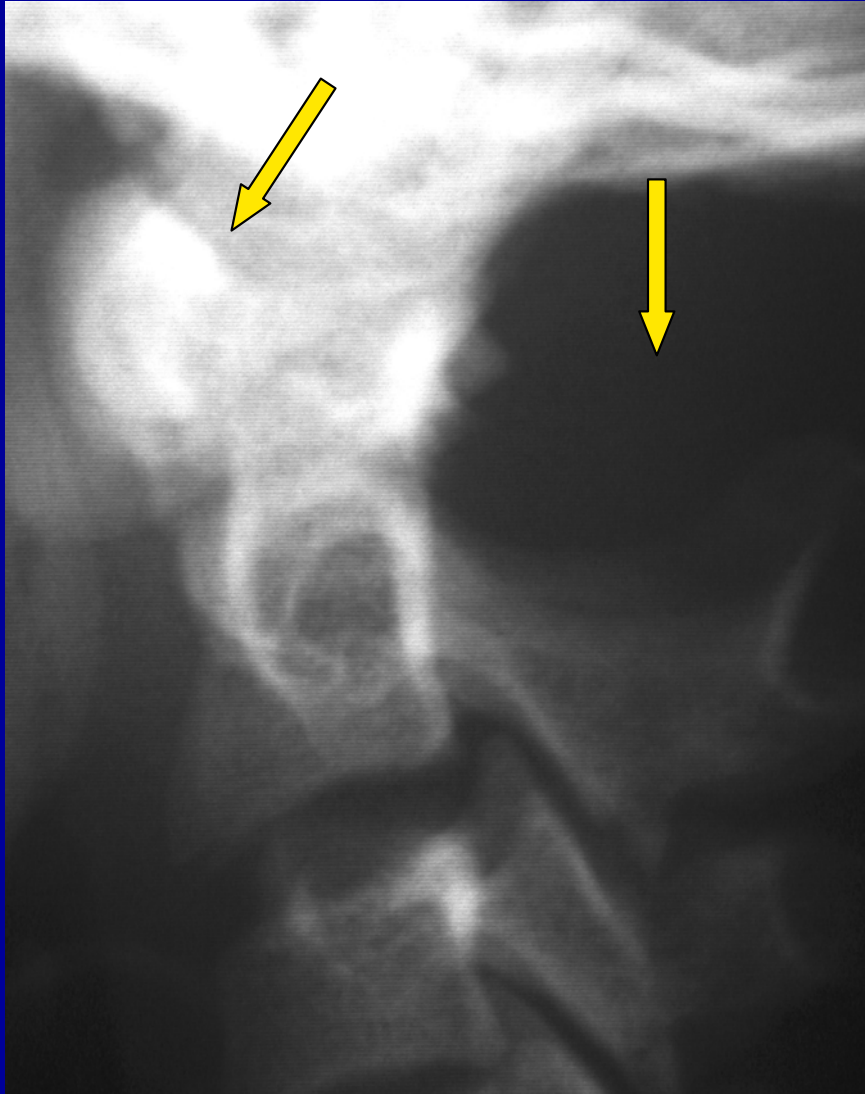
**Change in atlantodens interval of 2mm is normal, with maximum of 5 mm**

# Normal Mild Lateral Motion



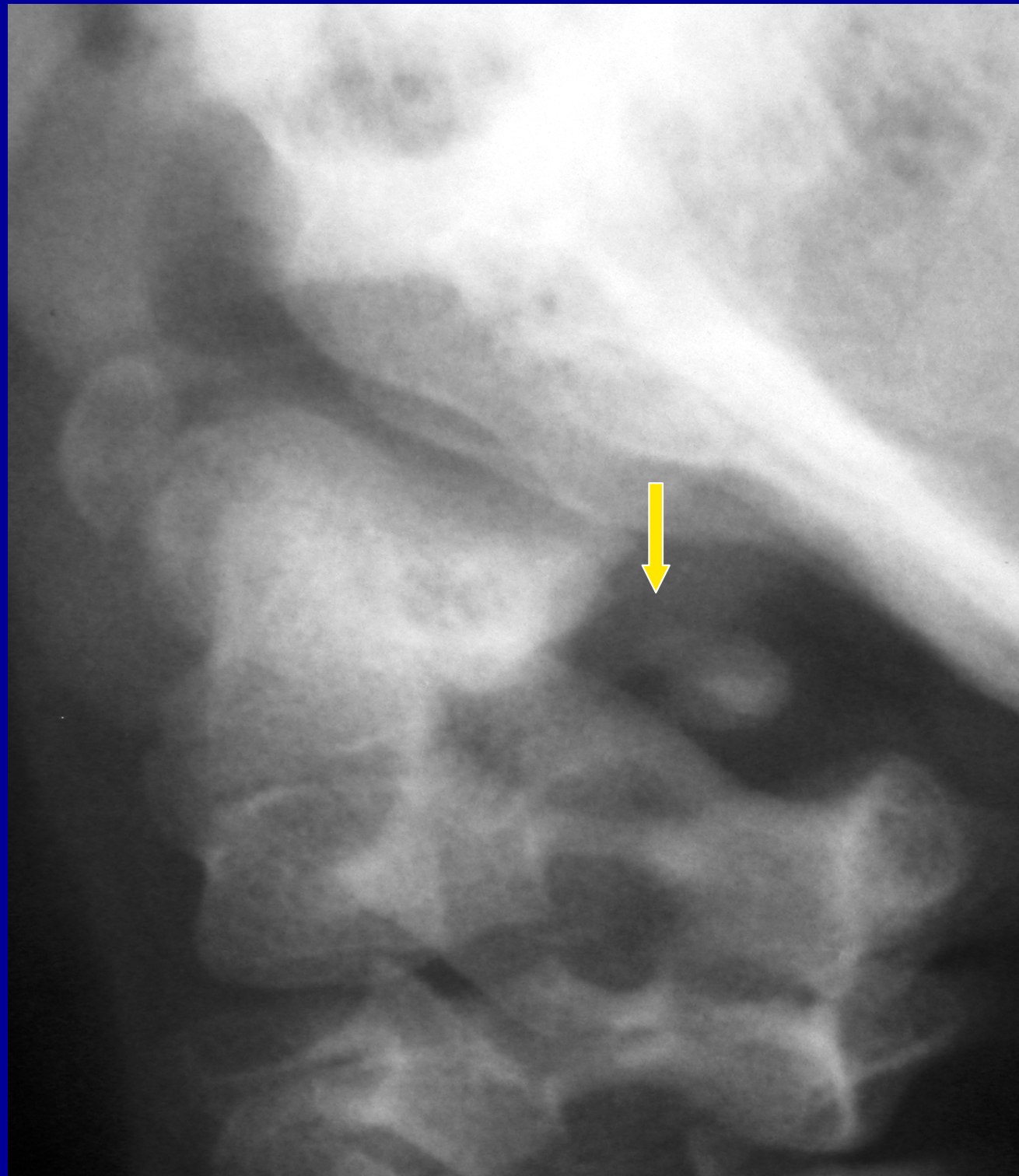
# C1 Anomalies

- Common
- Vary from absent posterior arch to hairline defects



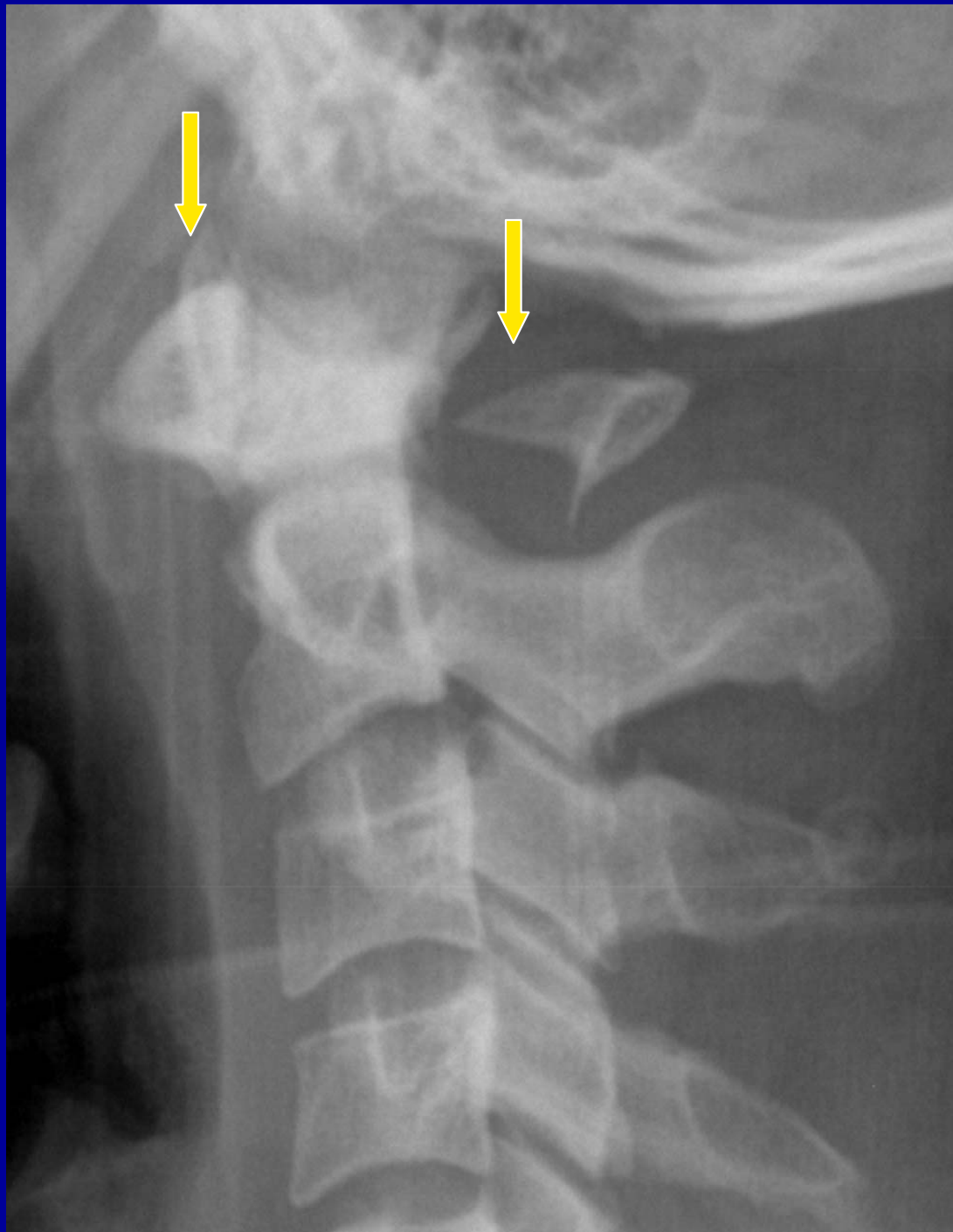
# Congenital Defects of C1

- Stable as long as dens is normal





## Clues to Congenital Defects



- Tapering or rounding of margins
- Hypertrophy of anterior arch

# Patterns of Injury

- **Infantile (before head control)**
  - Birth injuries (traction, torsion)
  - Shaking
  - Stretching may lead to vertebral artery injury
- **Young juvenile (head control-8 yrs)**
  - Usually above C4
  - Fulcrum at C2-3
  - Incomplete development of vertebra complicates assessment



# Patterns of Injury

- Old juvenile  
(greater than 8 yrs age)
  - More like adults
  - Midcervical more common
  - Most ossification centers fused
    - Except for os terminale, ring apophyses, spinous and transverse processes



3

**What initial cervical spine screening exam is used at your facility for children with GCS > 8?**

- 1) None
- 2) C-spine radiographs
- 3) C-spine CT
- 4) C-spine CT if non-verbal
- 5) MRI

# Spine CT in Children

- **Use has increased**
  - Higher in teenagers, at non-Level I Trauma centers Mannix, Acad Emerg Med. 2011 September ; 18(9): 905–911
- **Concerns about radiation dose in children**
  - Dose to thyroid 90-200 X that of multiple xrays  
Excess risk for thyroid CA 2X higher in 0-4 yr olds  
Jiminez, Pediatr Radiol 2008; 38:635-644
  - Adolescents with spine injury get more studies and have cumulative effective dose 3X that of children Lemburg, AJR 2010; 195:1411
- **Osseous injuries usually visible on XRs**
  - 4/147 with CT showed abnormality, all seen on lateral Xray Hernandez, Emerg Radiol 2004 Feb; 10(4):176-8

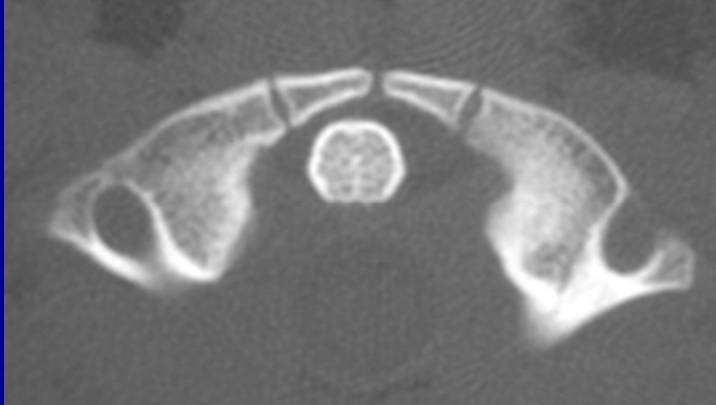
# Are Radiographs An Adequate Screening Exam?

- **Nigrovic, PECARN C-spine study group.**  
Pediatr Emerg Care 2012; 28(5):426-432
- **Multicenter study of 206 children <16 yrs age**
  - 168/186 injuries identified on radiographs
  - Sensitivity 90%
  - Missed 15 fractures and 3 isolated ligamentous injuries
- **Factors showing higher risk:**
  - Abnormal mental status
  - Endotracheal intubation
  - Focal neurologic deficits

# When Is CT Worthwhile?

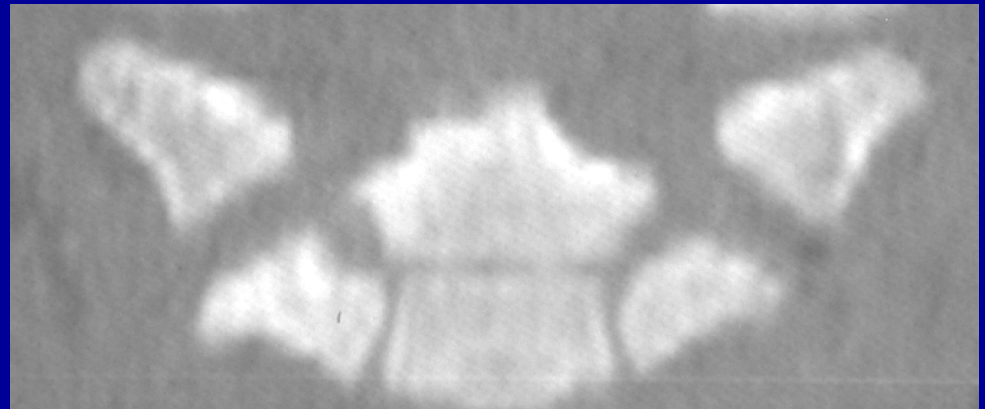
- **Consequences of a missed cervical injury can be devastating**
  - **Error rates (included CT) – false + and -**
    - 8 yrs or less – 24% (4/17)
    - 9 yrs or greater – 15% (3/20)
    - Occiput – C2 most common sites
    - Failure to recognize normal anatomy, normal variants  
Avellino, Childs Nerv Sys (2005) 21:122-127.
- **Ages < 10 years – Should be restricted to problem solving when radiographs are inconclusive**
  - **Natl. Institute of Health and Clinical Excellence(U.K.) –**
    - GCS 8 or less
    - Strong clinical suspicion with normal XR

## C1 Synchondroses



Anterior arch:  
Ossifies by 1 year  
Fuses by age 7

## C2 Synchondroses



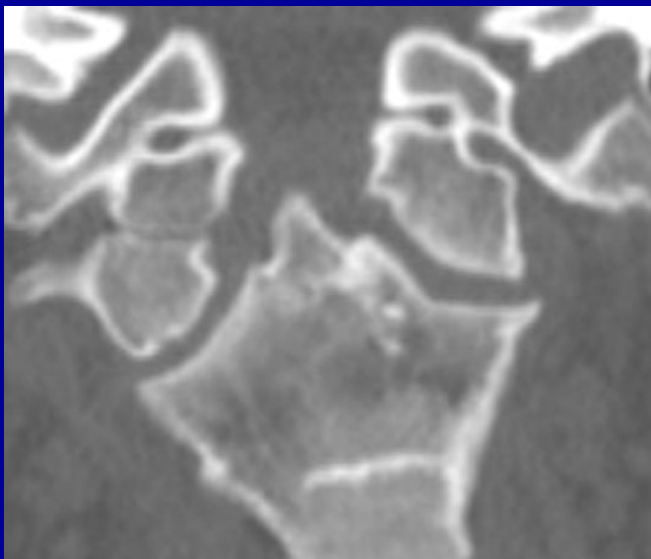
Injuries can occur at  
synchondroses, so be wary of  
asymmetrical widening



# Unilateral Absence of C1

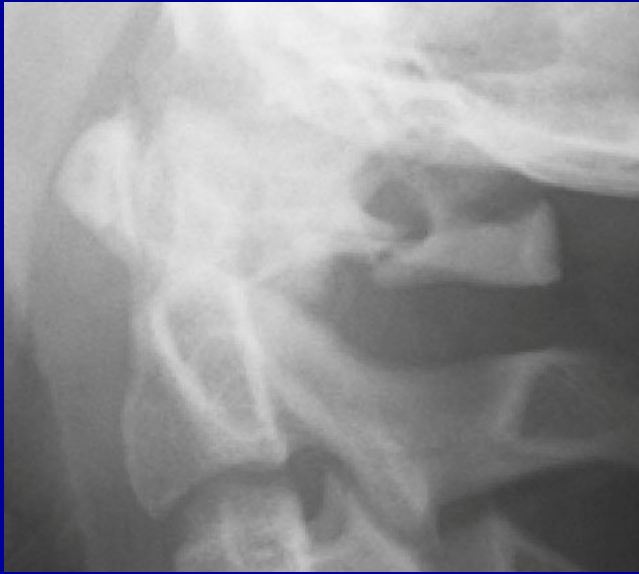


C1-2 anomalies are common, difficult to assess on radiographs

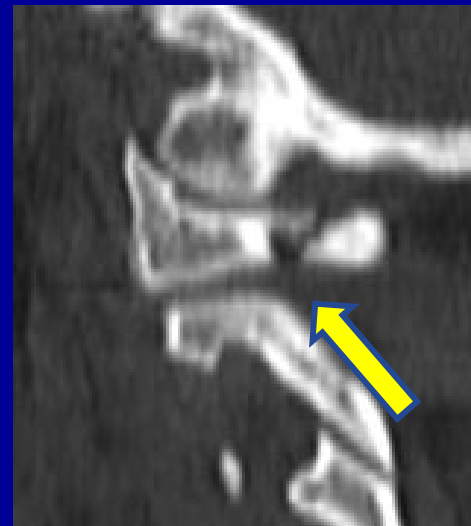


1/3 develop tortocollis and symptoms after birth

# Jefferson Fracture



- Uncommon in children
- Falls on head, diving accidents
- Often not visible on radiographs



# MRI for Pediatric C-spine Injury

- **Highly sensitive for soft tissue injury**
  - Sensitivity 100%, NPV 75%, PPV 100%
  - Relevance of subtle findings not established  
Henry, Childs Nerv Syst (2013) 29:1333–1338
- **Decreases time to clearance and cost**
- **Cost effective in certain patients**
  - Obtunded or non-verbal with severe mechanism of injury
  - Equivocal radiographs
  - Neurologic findings with normal XRs
  - Inability to clear spine within 72 hours  
Frank, Spine 2002; 27(11): 1176-1179
- **Important in patients with unstable injuries**

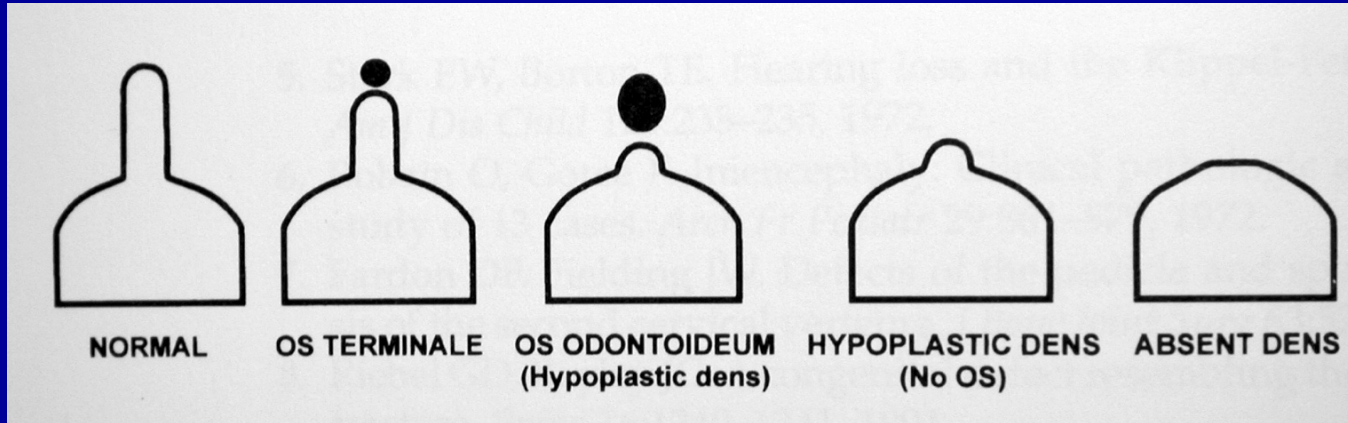


# C-spine MRI Protocols

- **Axial**
  - T2 gradient echo
  - T1
- **Sagittal**
  - T1
  - STIR or T2 fat sat
- **Coronal**
  - STIR

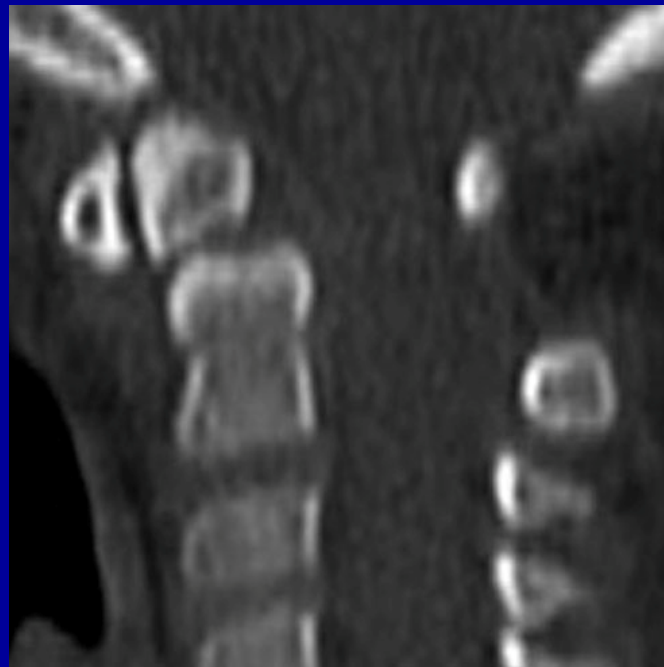
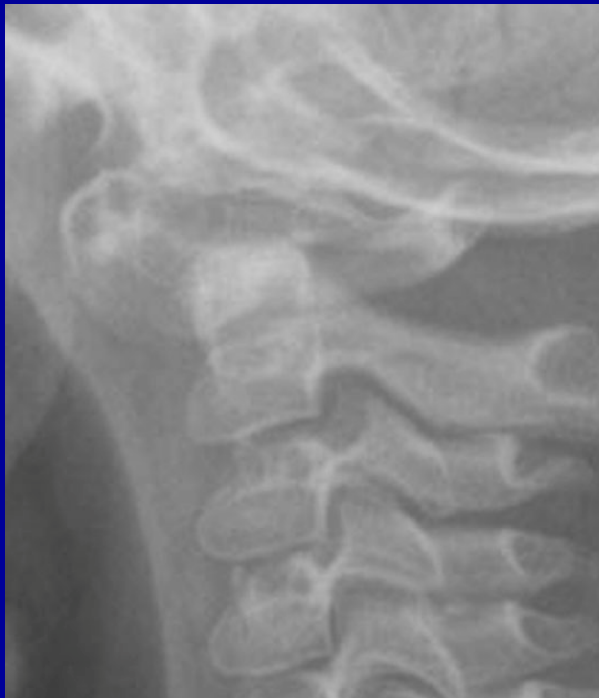


# Dens Anomalies



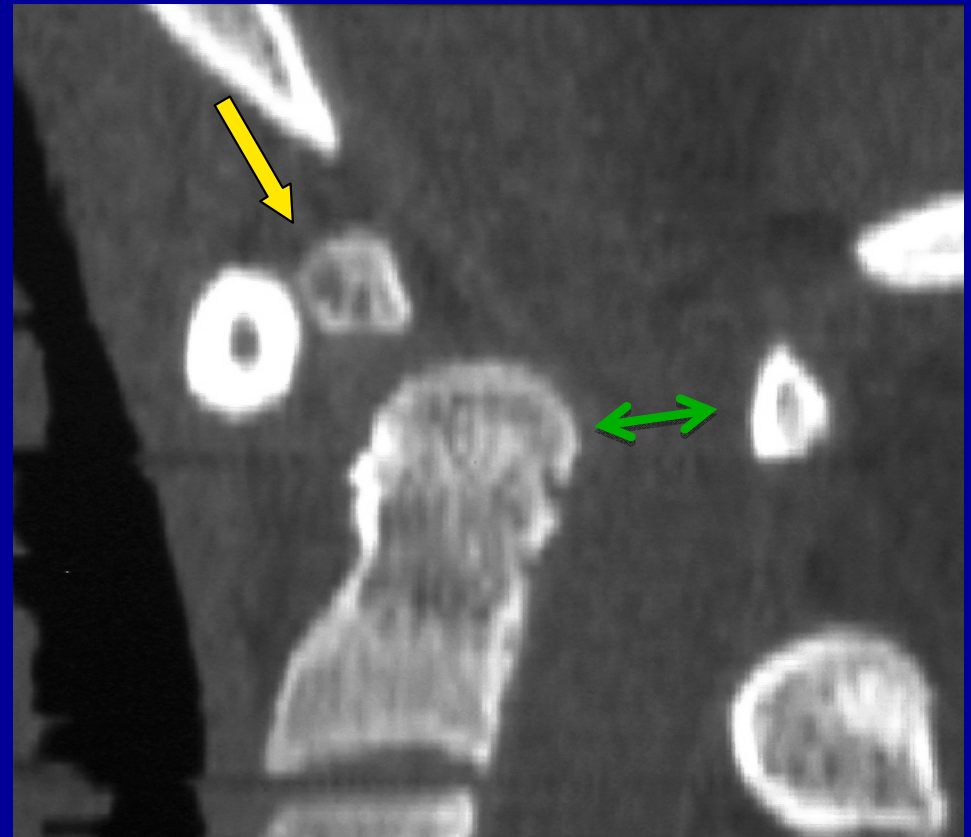
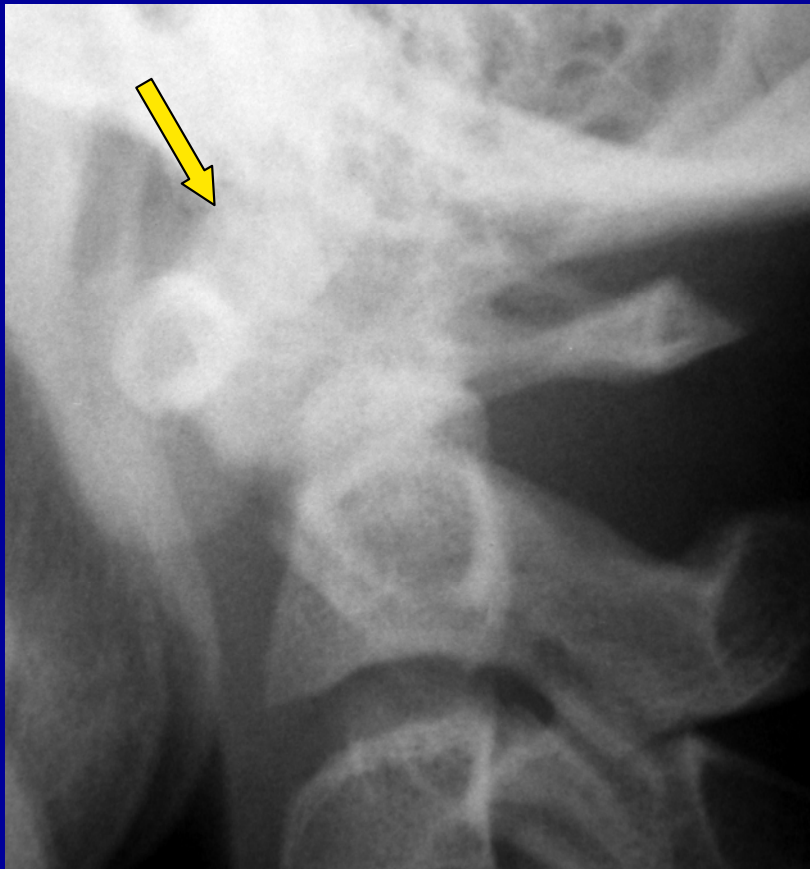
Prone to instability in some patients

Swischuk, Imaging of the Cervical Spine in Children

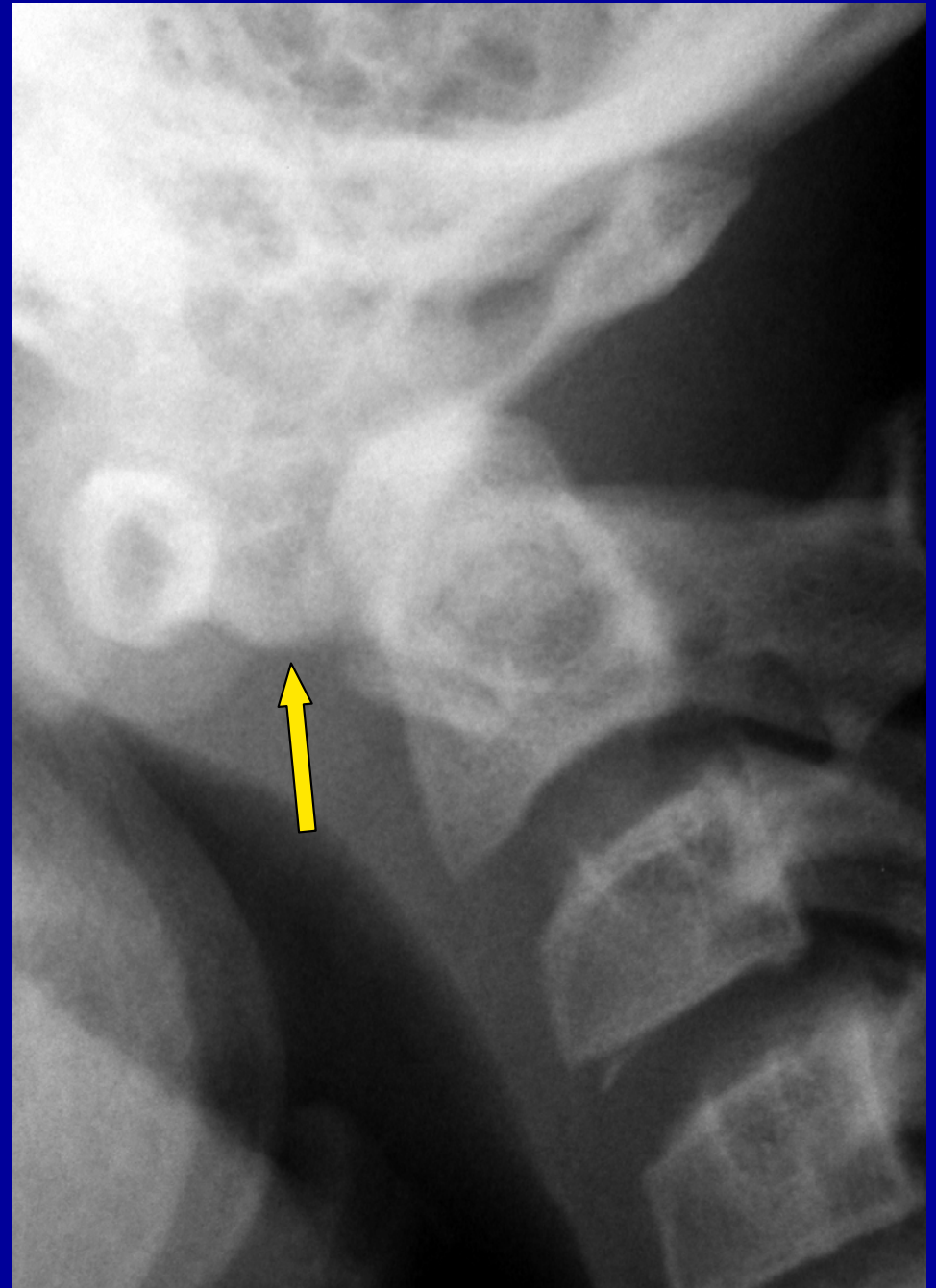


# Os Odontoideum

- Os is often fused to anterior arch of C1 or to basion
- Posterior atlantodental interval more important than AADI



# Controlled flexion/extension under fluoroscopy



# Cinical Implications of Os Odontoideum

- Pain
- Myelopathy –varies from transient to paralysis
- Asymptomatic
  - Cases of sudden injury after minor trauma
- MRI evaluates cord atrophy



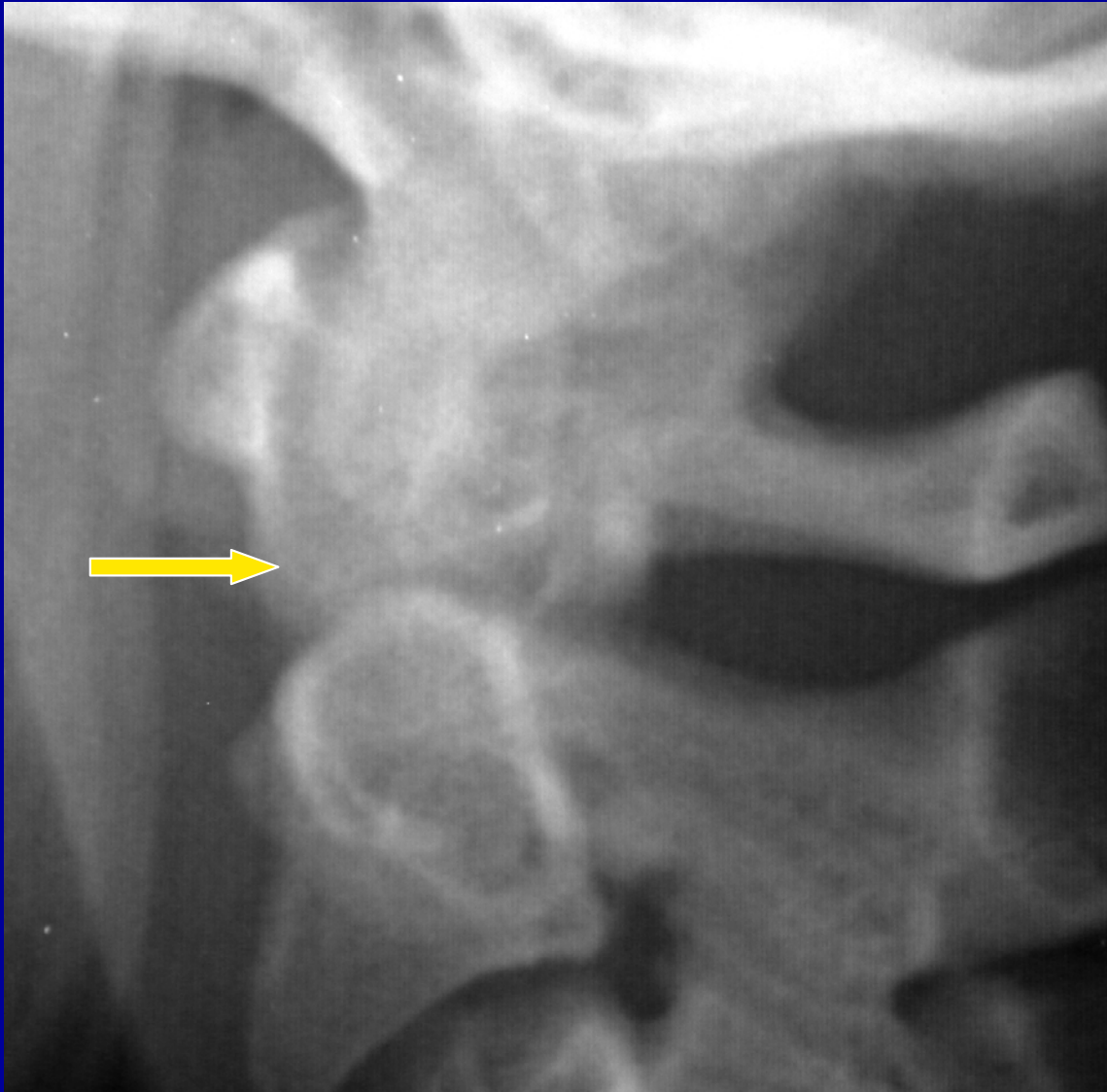


# Odontoid Fractures

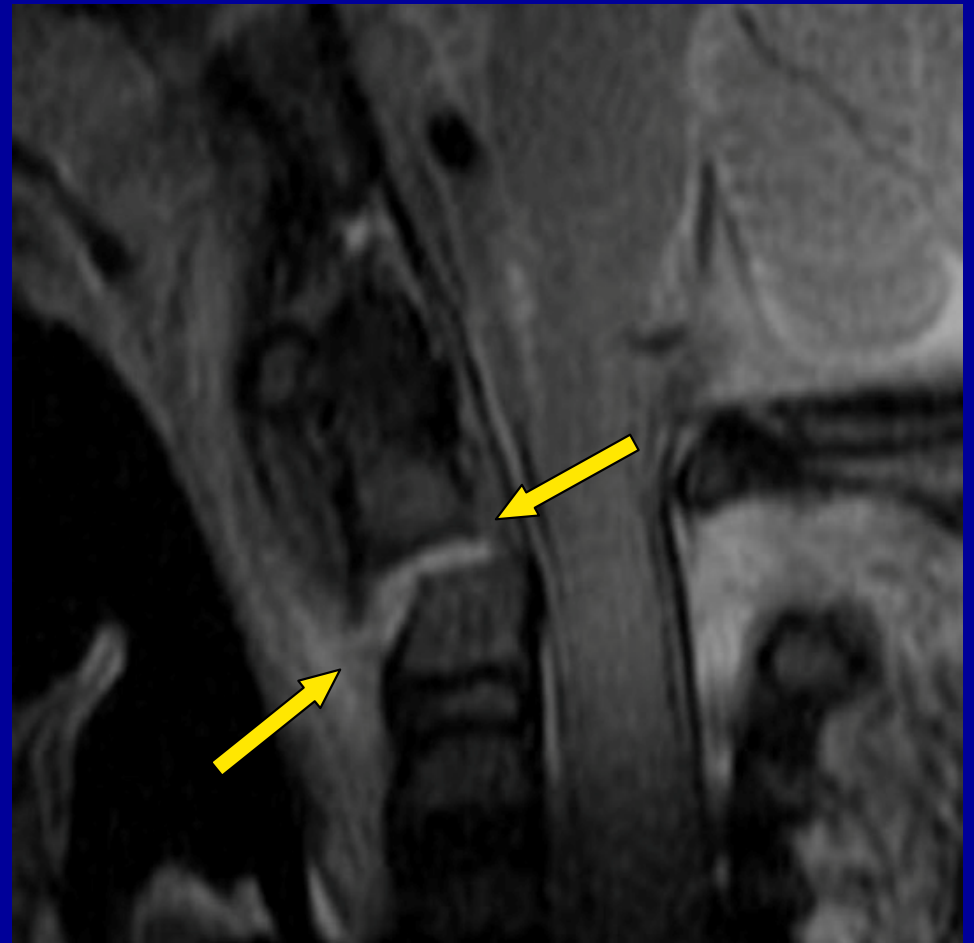
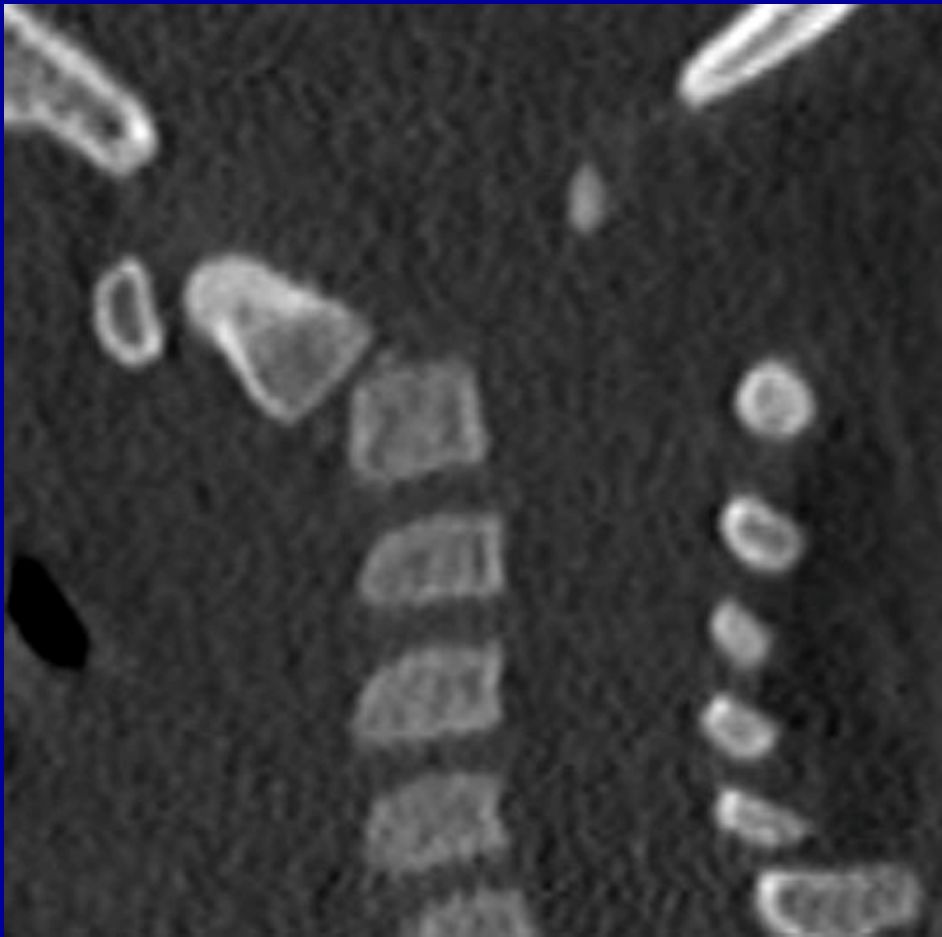
- **Most common pediatric cervical fracture**
- **Most occur through basilar synchondrosis**
  - **Fuses at 5-7 yrs, but remains partially visible until 11**
- **Heal with halo immobilization (6-8 weeks)**

# Type II Dens Fractures

Displacement can be subtle on radiographs

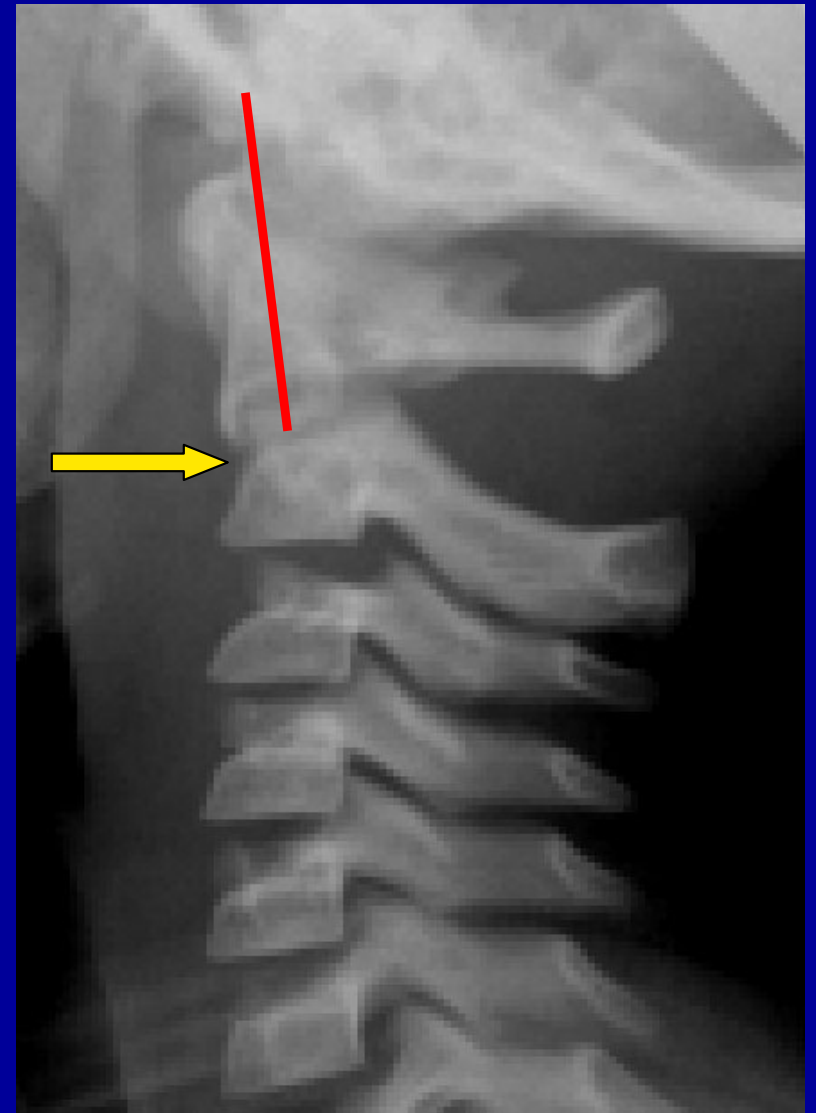
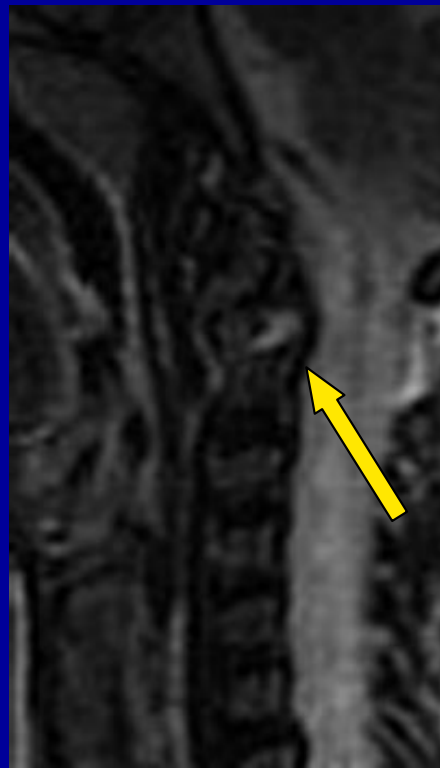


# Fracture at Neurocentral Synchondrosis

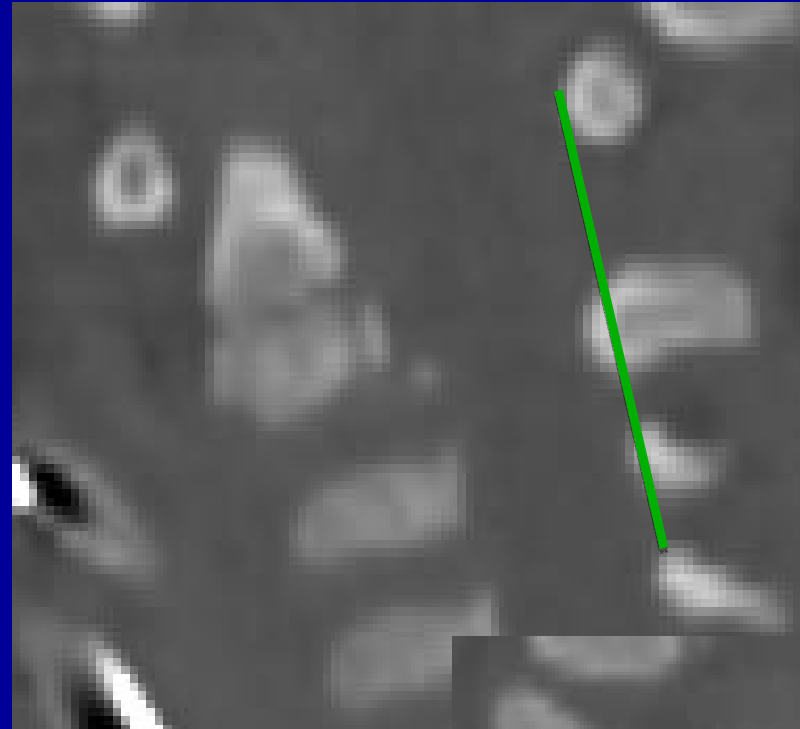
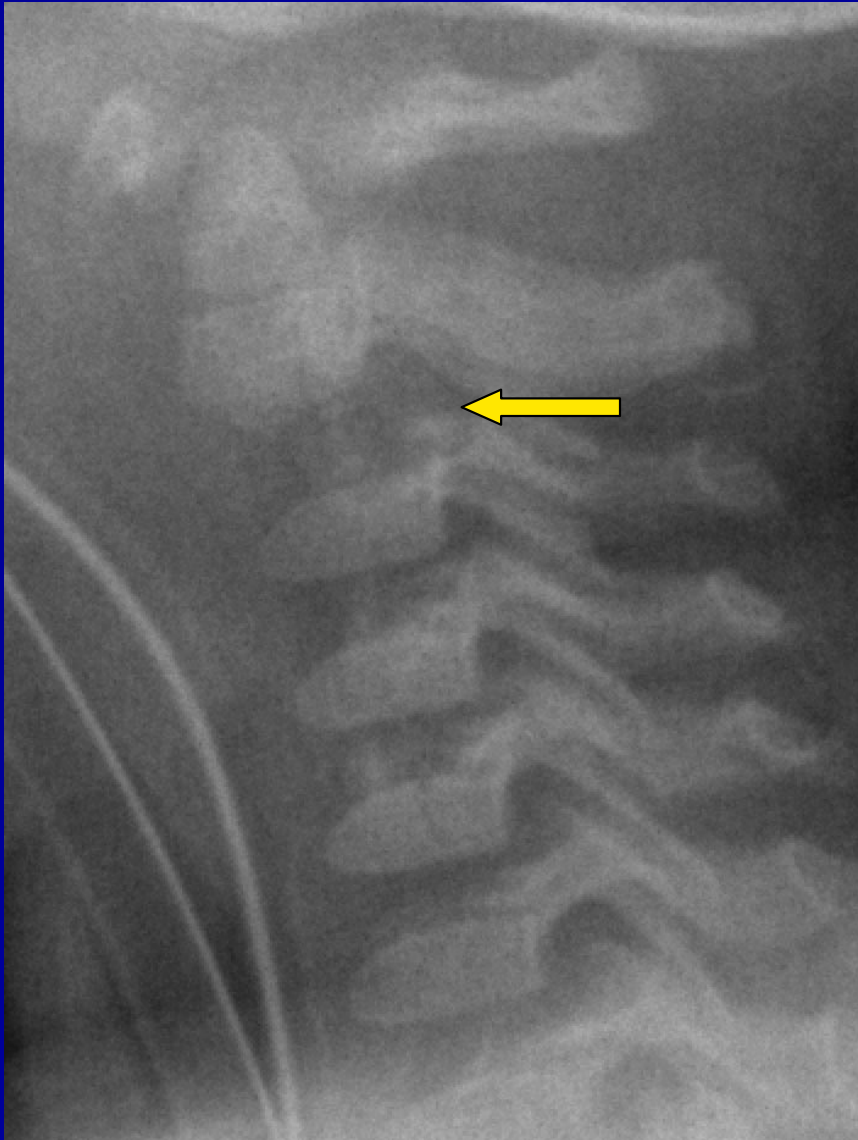


# Fracture at C2 Synchondrosis

- Anterior tilt
- Anterior offset



# Fracture-Subluxation at C2 may resemble physiologic laxity



## **Atlanto-occipital dissociation:**

- 1) Is more common in adults than children.**
- 2) Is fatal in 90% of patients.**
- 3) Can manifest as asymmetry of the AO joint.**
- 4) Cannot be diagnosed reliably with radiographs or CT.**

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# Atlantoccipital Dislocation

- **More common in children than adults**
  - **Small condyles**
  - **More horizontal orientation**
- **High velocity trauma**
- **Survival improving, but neurological deficits are common**



## Basion – dens distance

Should be 12 mm or less



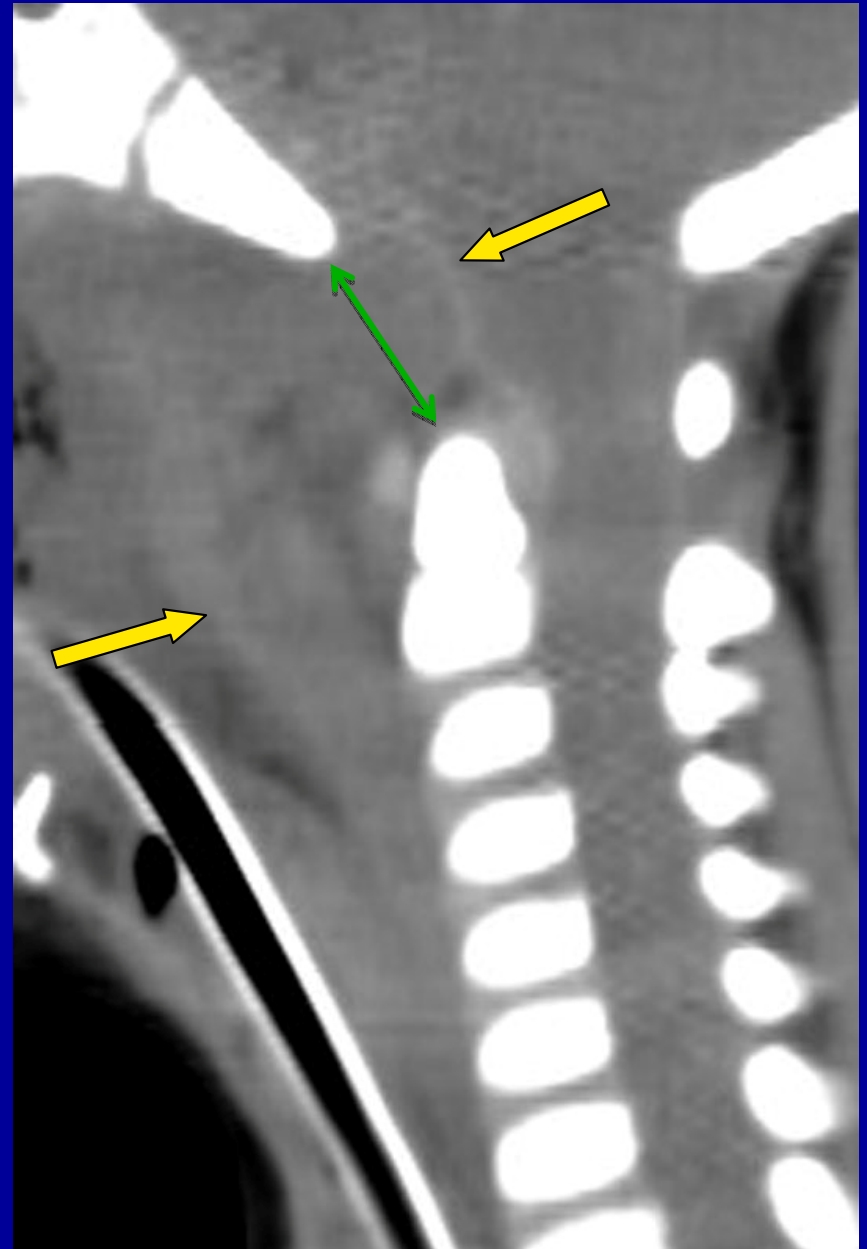
## Powers ratio

Should be less than 1

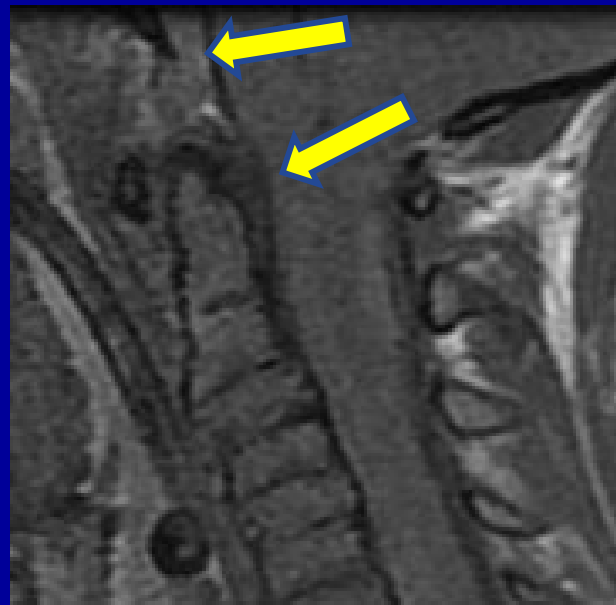
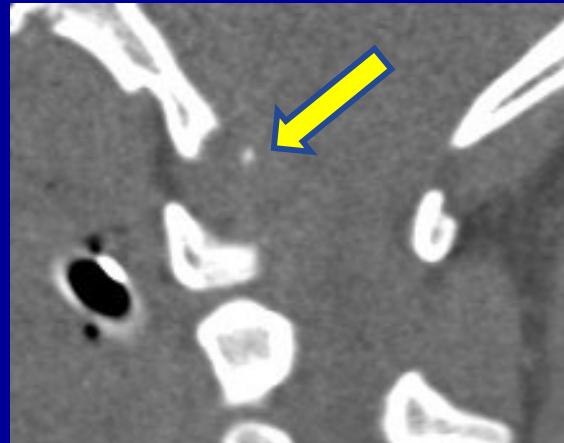
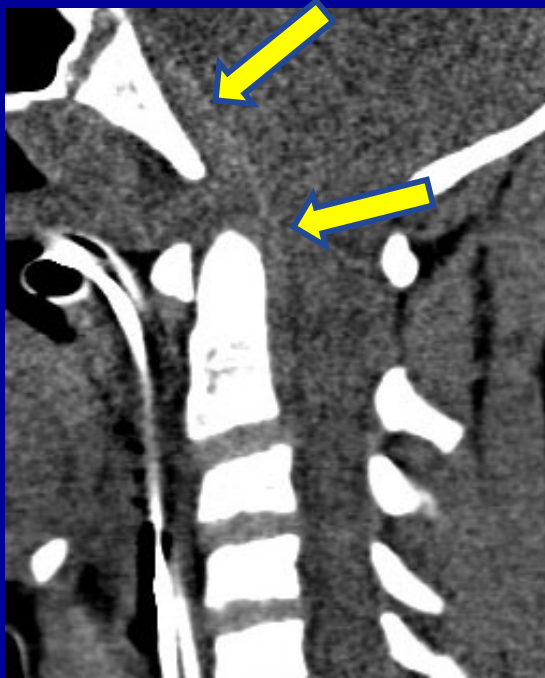


# Atlantoccipital Dissociation

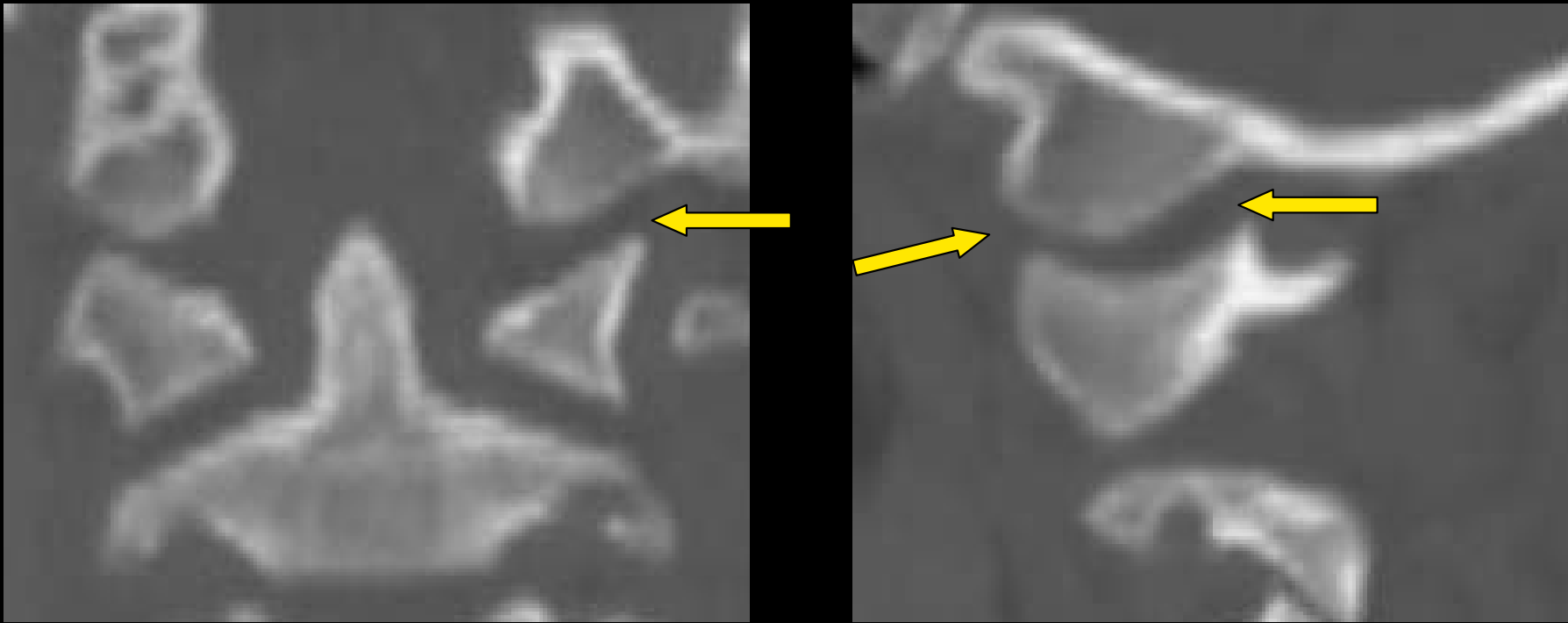
- CT allows more accurate measurement of dens-basion distance
- Soft tissue injuries visible when severe



# Retroclival Hematoma



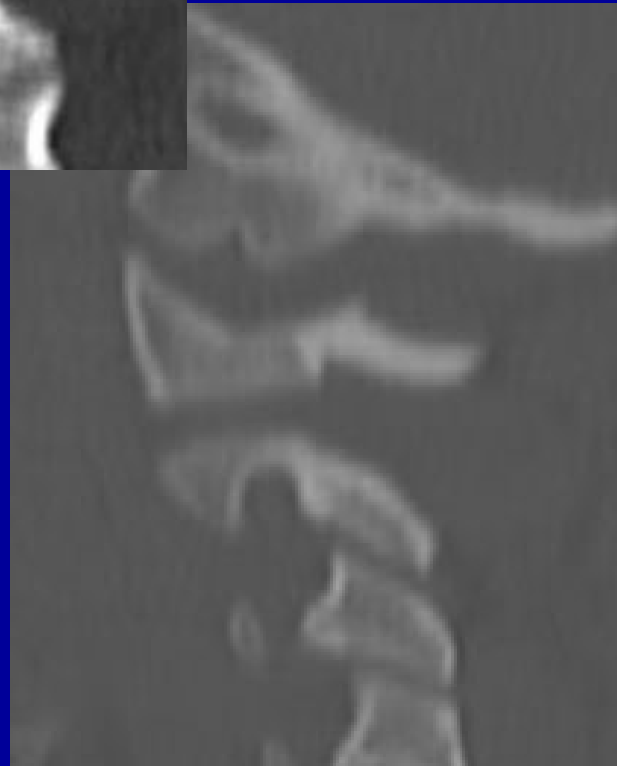
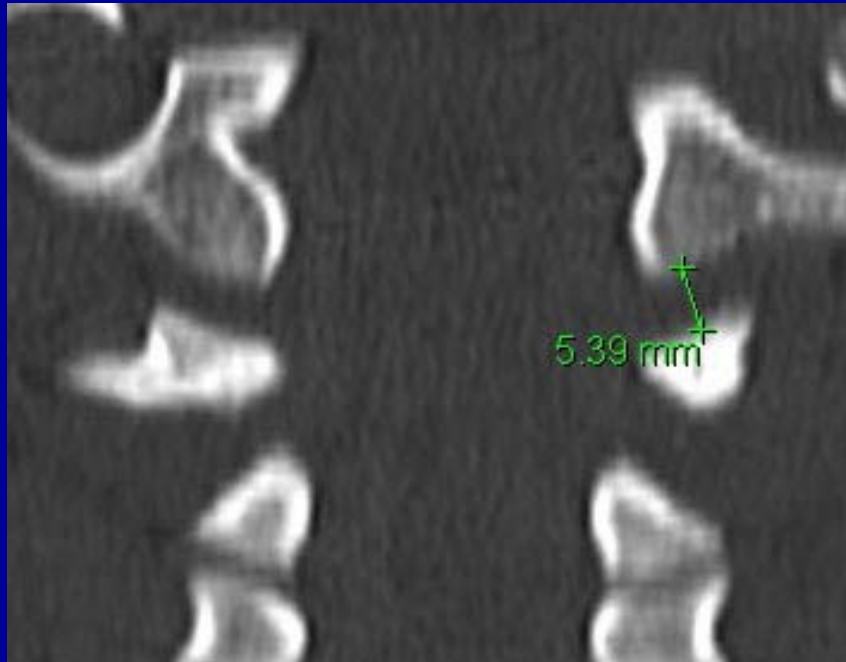
- Rare injury
- Elevated tectorial membrane
- Associated with CC ligamentous injuries
- May be treated conservatively if patient asymptomatic

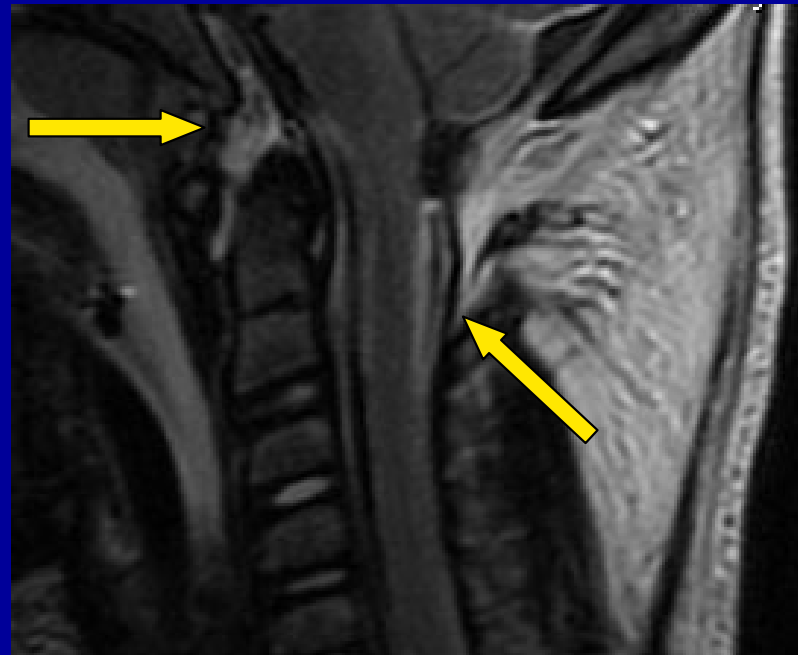
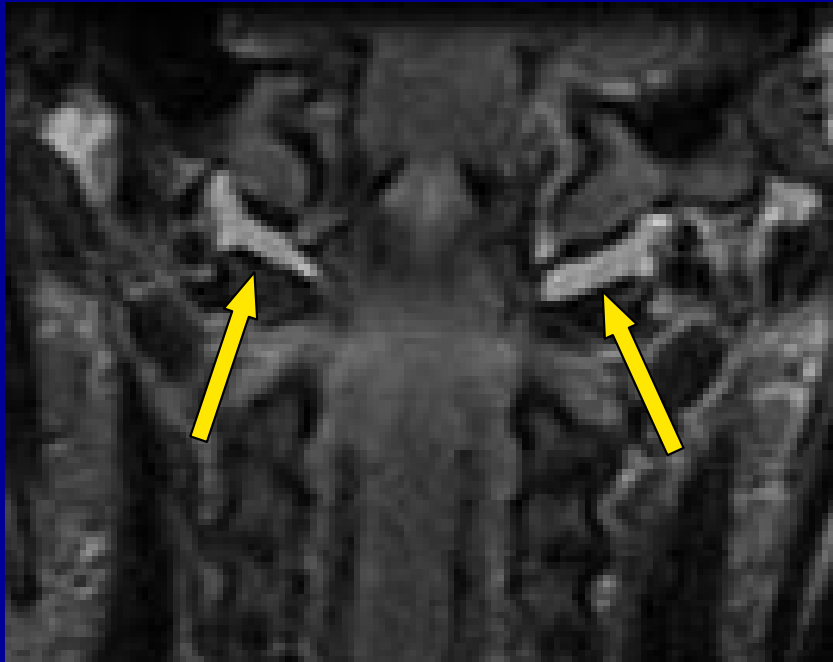


## Condyle – C1 Interval

- Highest sensitivity and specificity for AOD
- 4-5 mm or greater – abnormal
- Asymmetry, offset

# 6 yr old in MVC





# Isolated Ligamentous Injuries

- Rare
- Avulsed fragments difficult to see

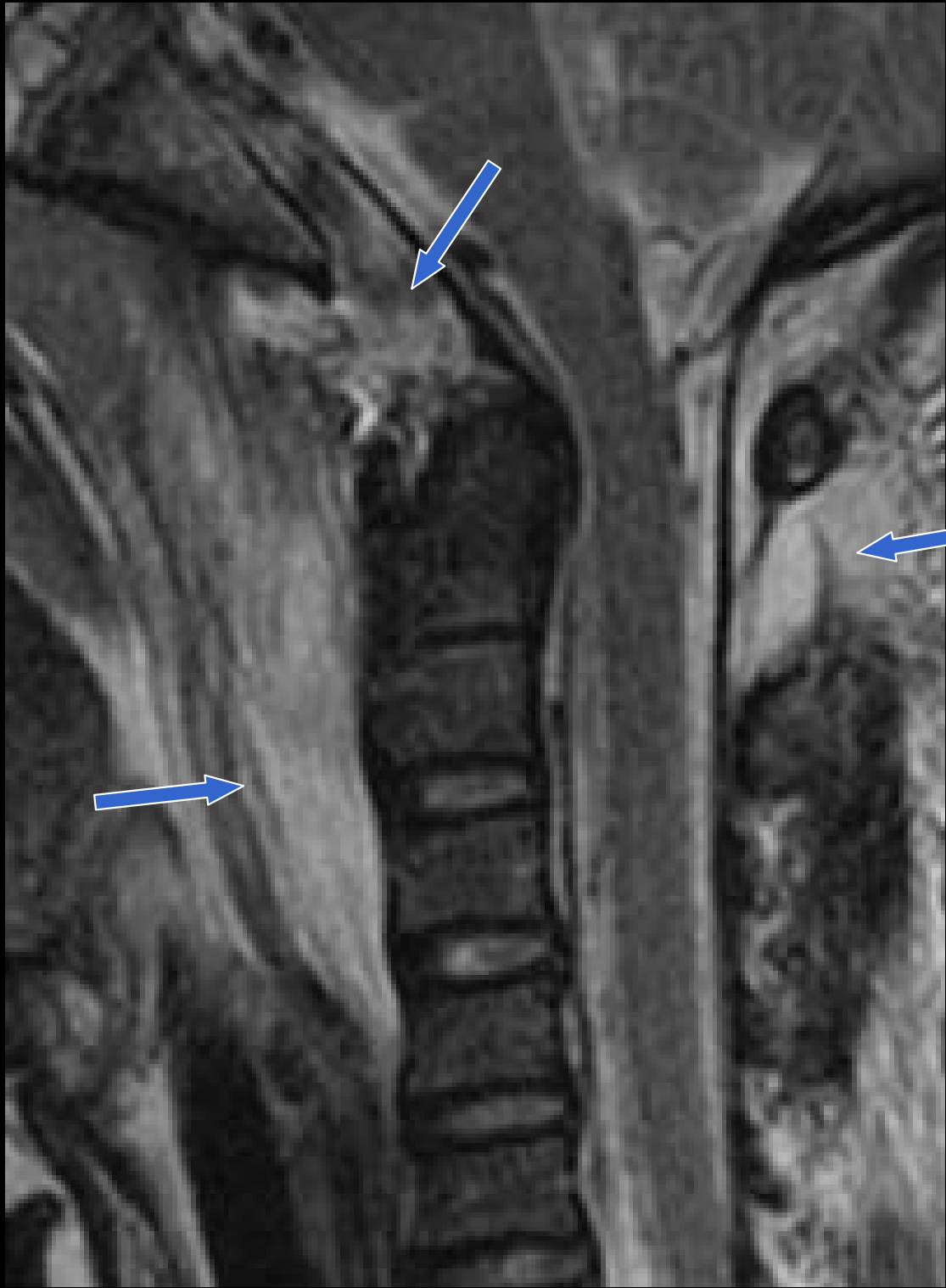


**Transverse Ligament Injury with Avulsion**

# C1-2 Ligamentous Injuries

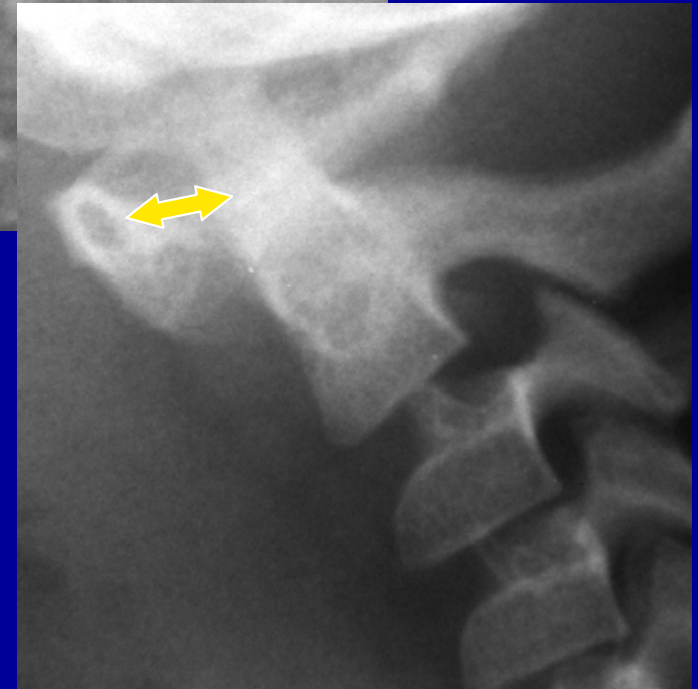
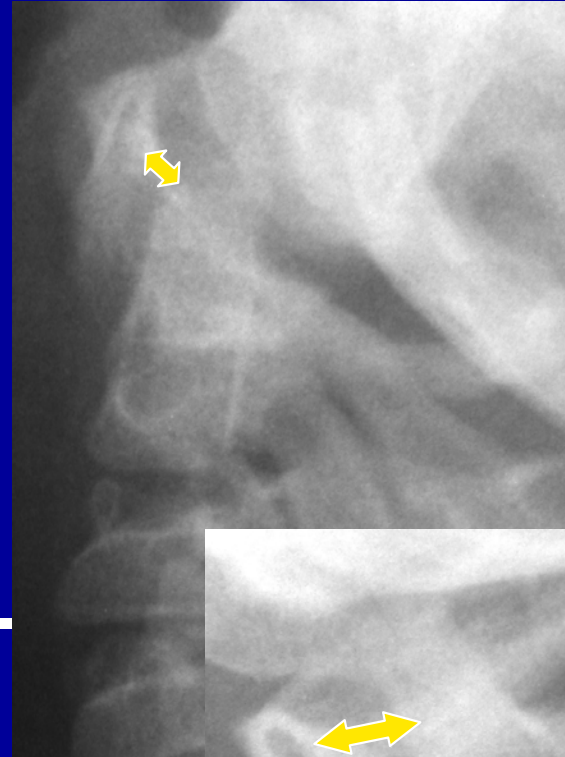






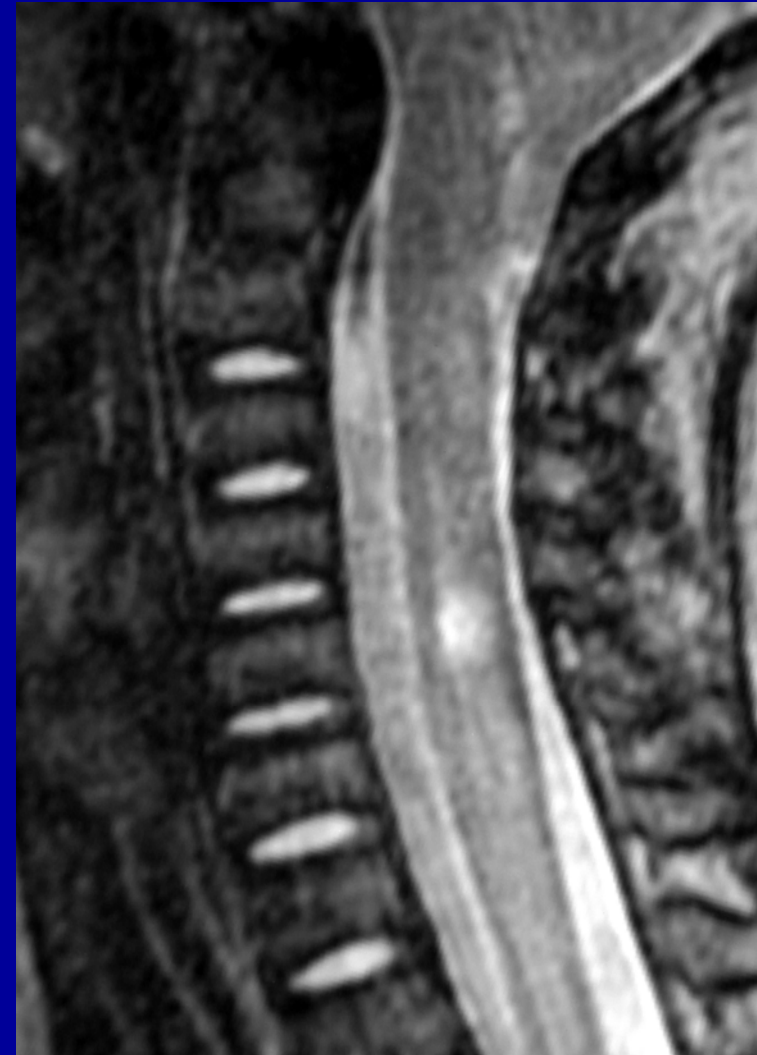
# Cervical Instability – Trisomy 21

- Due to ligamentous laxity
- Can occur at multiple levels
- C1-2 instability – 14-17%
- C1 hypoplasia (posterior)- 26%
- <10% have signs of cervical myelopathy
- CT or MRI not usually needed



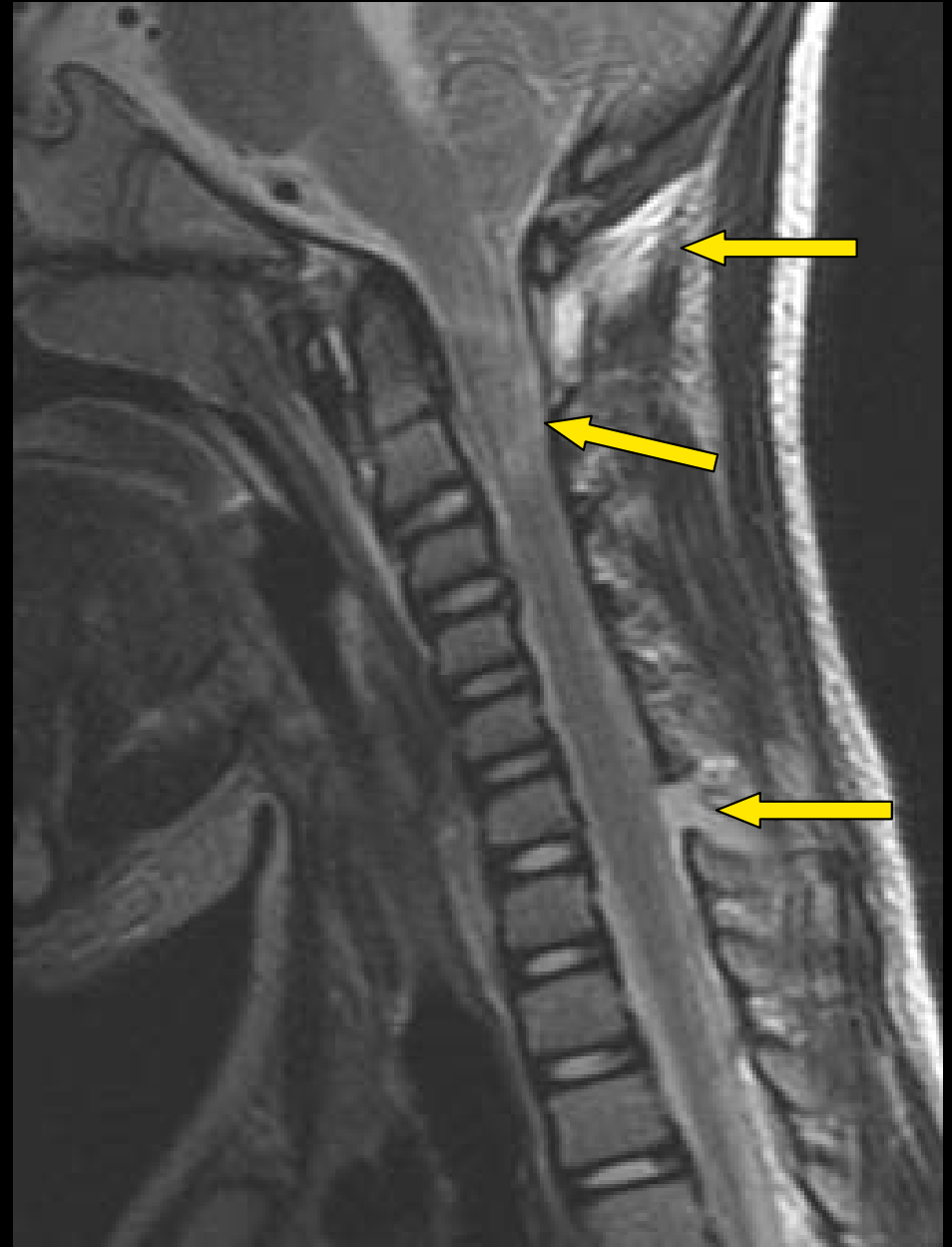
# SCIWORA Injury

- Incidence 6 -20%
- Normal ligamentous laxity allows excess motion without bone injury
- Most common at C5-8
- Spinal column can withstand **2 in.** of distraction (infants) – cord and vessels only **.25 in.**

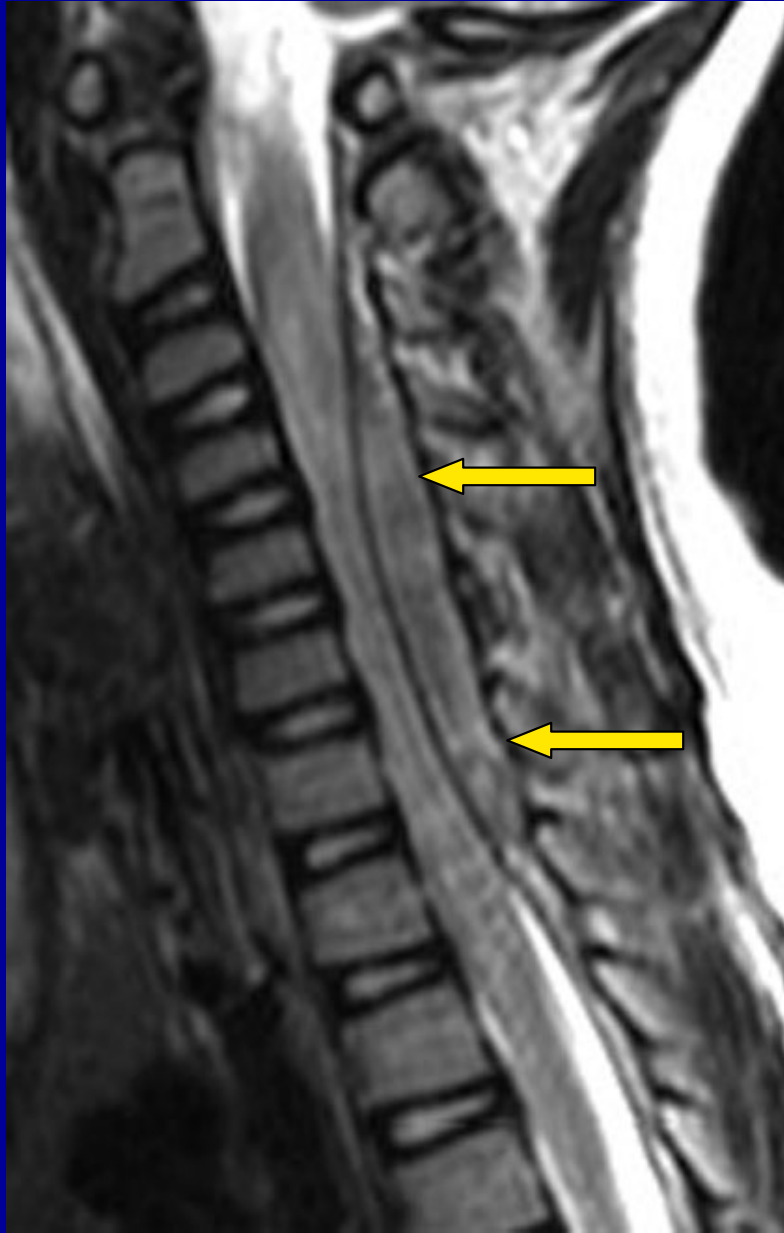


# Pediatric Cervical Injuries without Fracture

- Children under 8 yrs age
  - More severe injuries
  - Upper spine more common
- 52% - delayed paraplegia (up to 4 days)
- Susceptible to reinjury - occult instability?

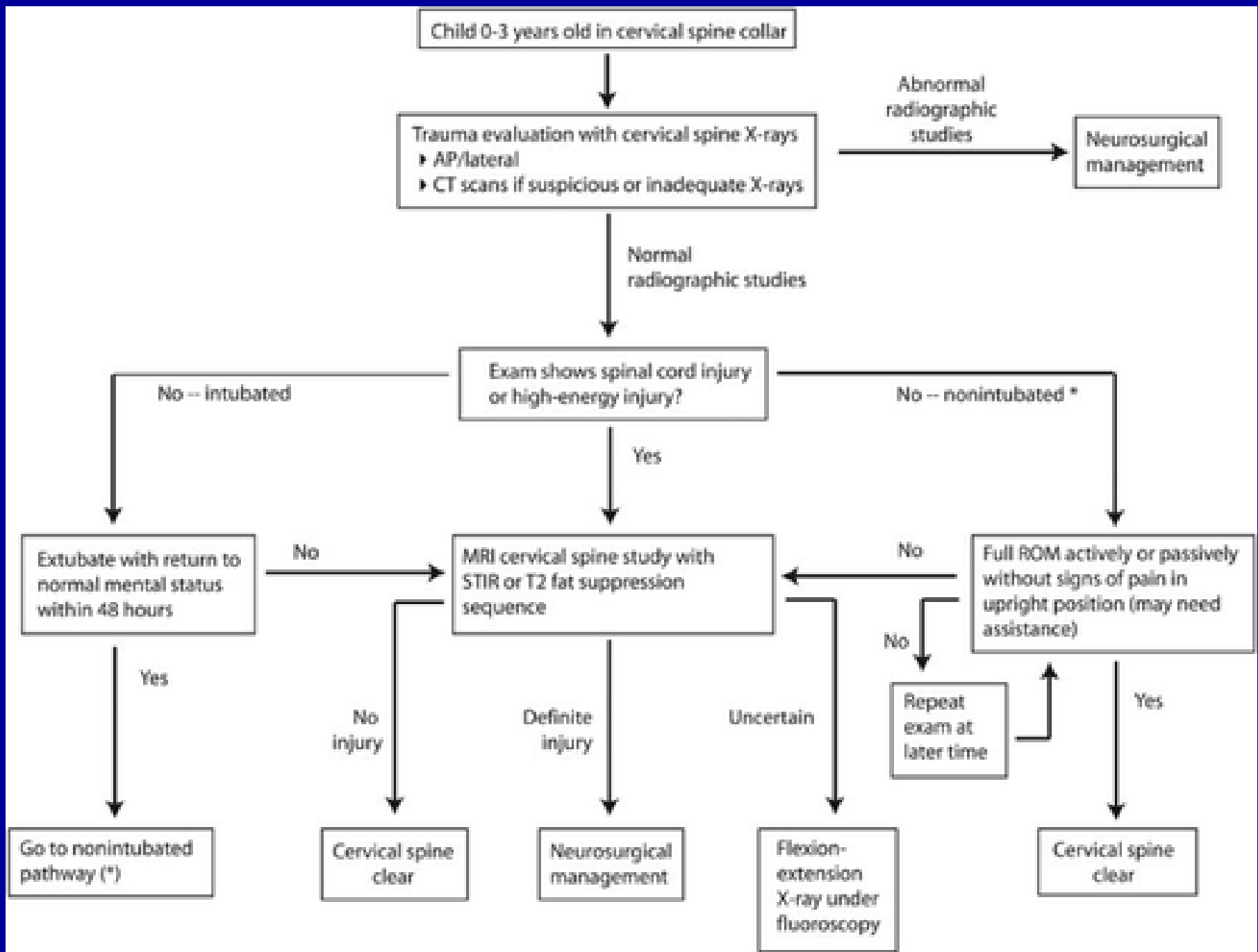


# Cervical Epidural Hematoma



- May result from shearing forces without spine fracture





Anderson, J Neurosurg Pediatr 2010; 5:292.

# Spine Injuries in Children

- **CT best for questionable fractures on radiographs, neurologic symptoms**
- **Mild laxity is normal**
  - **MRI may help identify subtle instability or injuries**
- **Anomalies**
  - **CT for better anatomical definition**
  - **MRI for effects on spinal cord**
- **More cross-sectional imaging may be warranted in infants with NAT**