RC 608 – Spinal Injuries: Stable or Unstable? You make the call

Craniocervical Region

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Sub-dental Cervical Region

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Thoracolumbar Regions

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Disclosures
None
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Learning Objectives
Craniocervical Junction (CCJ)
In ~25+ minutes, you should know

1. What's common & what's commonly missed, and what you can do about it.
2. How stability (clinical instability) is defined.
3. What imaging findings are used to assess stability; & what injuries are typically stable *vs.* unstable.

Question #1:

- Which of the following statements is ***FALSE***?

1. C2 fractures are among the most common fractures of the cervical spine
2. C2 fractures are among the most commonly missed fractures in the cervical spine
3. Spine fractures are more likely to be missed in obtunded patients
4. Occipital condyle fractures are rare

Question #2

- Which of the following statements is ***FALSE***?

1. CCJ distraction injuries include AOD, type 3 occipital condyle fractures, & type 1 dens fractures.
2. "Unstable" Jefferson fractures typically sustain osteoperiosteal disruption of the transverse atlantal ligament.
3. Intrasubstance disruptions of the transverse atlantal ligament lead to delayed healing with stability in over 90% of patients.
4. 50% displaced segmental fractures of the anterior arch of C1 are typically biomechanically unstable.

Question #3

- Which of the following statements is ***FALSE***?

1. The key to assessing biomechanical stability of Hangman fractures is the integrity of the C2–C3 disc space.
2. The biomechanically stable type I Hangman's fracture is the most common variant and is rarely misdiagnosed.
3. With the possible exception of atypical Hangman fractures, all Hangman fractures show bilateral traumatic spondylolysis.
4. Concomitant CCJ fractures occur in 30–40% of patients sustaining high-energy Hangman type fractures.

Question #4

- Which of the following statements is ***FALSE***?

1. The normal range of C1-C2 rotation includes rotational deformities seen in C1-C2 rotary fixation.
2. Torticollis, C1-C2 rotary subluxation, C1-C2 fixation, & Grisel's Syndrome are synonyms.
3. C1-C2 rotary fixation is rarely due to blunt-force trauma.
4. Torticollis, C1-C2 rotary subluxation, & C1-C2 fixation are typically treated "conservatively" & very rarely require surgical correction.

Question #5

- Which of the following statements is ***FALSE***?

1. In the acute setting, clinical instability is present if a patient has sustained an acute radiculopathy or myelopathy due to blunt-force trauma, regardless of imaging findings.
2. It is common for injuries causing acute neurologic debility to be mechanically stable.
3. Patients sustaining SCIWORA are typically biomechanically stable.
4. Vertebral column injuries that predispose to late deformity and pain are considered clinical unstable, despite absence of neurologic disability.

Goal #1

What’s common & what’s commonly missed, and what you can do about it.

What’s commonly missed in Polytrauma?

- Spine fractures ~10%
  - Craniocervical junction
  - Cervicothoracic junction
  - Multiplicity

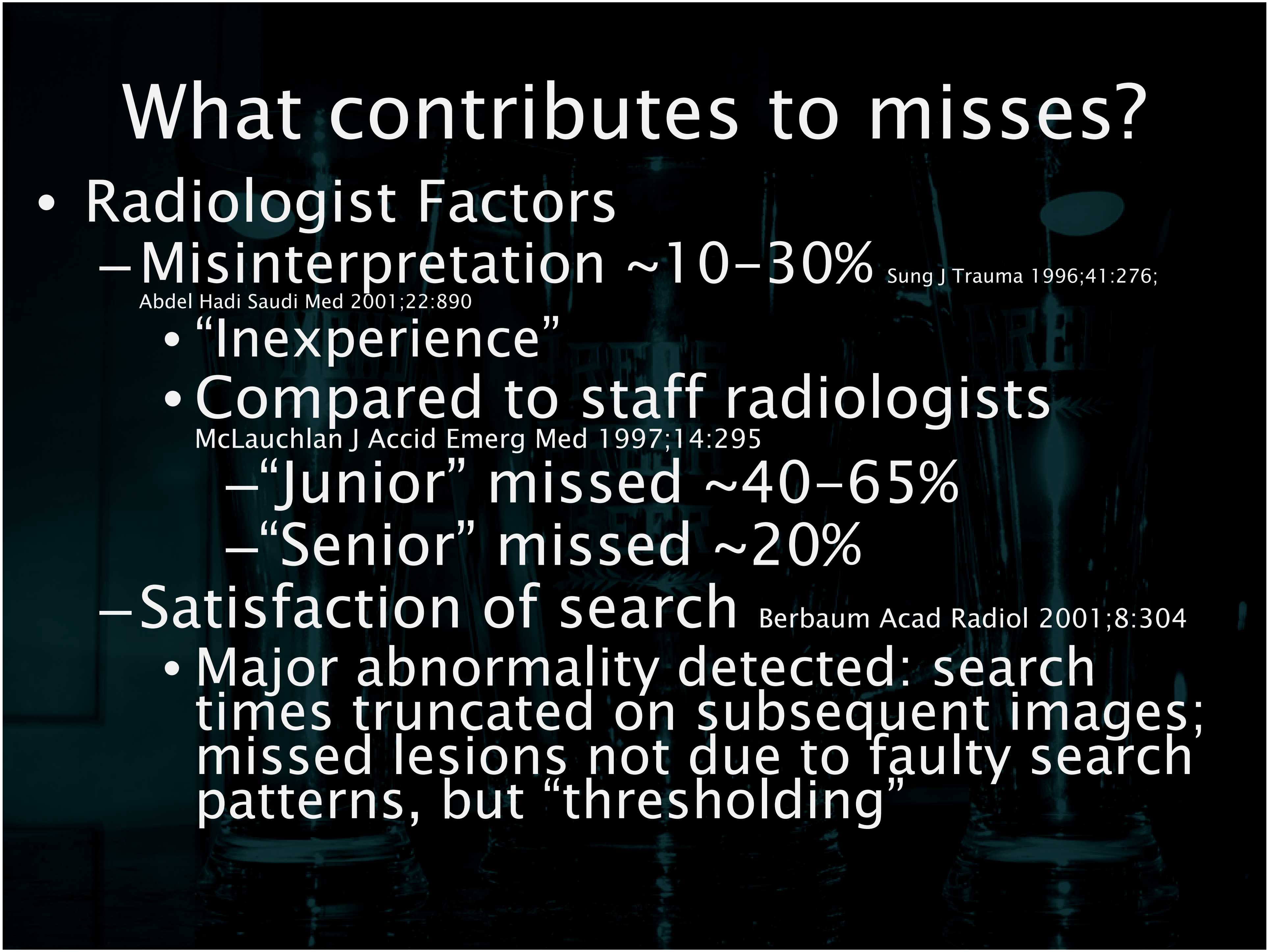
What contributes to misses?

- Patient characteristics
  - Obscured history of trauma (e.g., “found down”, “AOB”) ~10% Sung J Trauma 1996;41:276
  - Multiple, severe injuries Onuora Injury 1993;24:619; Buduhan J Trauma 2000;49:600
  - Distracting injuries: (Copass: unreliable exam if >4mm 2-point discrimination)
  - Decreased level of consciousness
    - Brain injuries ~60% Biffl J Trauma 2003;54:38; Buduhan J Trauma 2000;49:600
    - Intoxication Enderson J Trauma 1990;30:666

What contributes to misses?

- Hemodynamic instability Ward J Orthop Trauma 1991;5:308
  - ED to: Biffl J Trauma 2003;54:38
    - TICU ~55%
    - OR ~25%
- Bulky dressings or splints obscuring less obvious lesion Ward J Orthop Trauma 1991;5:308

- Imaging Tait Injury 1991;22:475; Ward J Orthop Trauma 1991;5:308
  - Failure in clinical examination (not imaging regions with signs or symptoms) Sung J Trauma 1996;41:276
    - "Inexperience" ~15%
  - Incomplete or poor quality ~60% Hirshberg Am J Surg 1994;168:299


What contributes to misses?
• Radiologist Factors
– Misinterpretation ~10-30% Sung J Trauma 1996;41:276; Abdel Hadi Saudi Med 2001;22:890
• "Inexperience"
• Compared to staff radiologists McLauchlan J Accid Emerg Med 1997;14:295
– "Junior" missed ~40-65%
– "Senior" missed ~20%
– Satisfaction of search Berbaum Acad Radiol 2001;8:304
• Major abnormality detected: search times truncated on subsequent images; missed lesions not due to faulty search patterns, but "thresholding"

How can misses be avoided? Mostly….

- Avoidable: 56% Buduhan J Trauma 2000;49:600
- Repeated use of standardized itemized, detailed reviews Stansecu Emerg Radiol 2006;3:119-123
  - Miss reduction ~35%
- Be suspicious….
  - Associated injuries, including *vascular injuries in high-energy C0-C2 fractures*
  - In patients at risk for spine injury, imaging modality matters

Imaging Spine Trauma

- Vertebral Column Trauma
  - Conventional Radiographs: in trauma bay
  - CT: rapidly replacing conventional radiographs
  - MRI: best to evaluate acuity of fracture
- Spinal cord injury (MRI essential)
  - Post-traumatic HNP, epidural hemorrhage, STS
- Spinal nerve injury/avulsion (MRI, CT myelography)
- Vascular injuries
  - CT angiography, catheter angiography

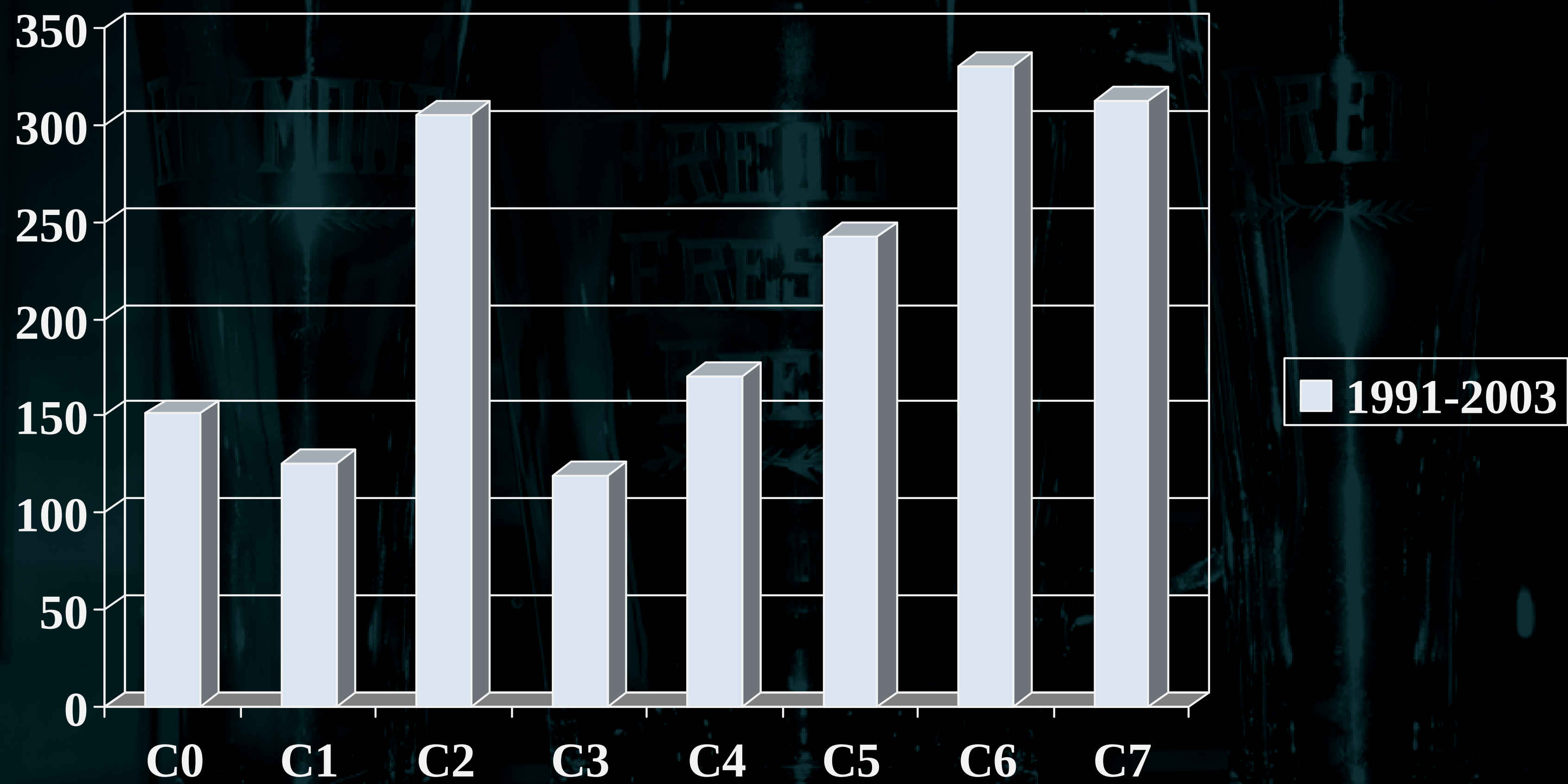
How can misses be avoided?

- MDCT
  - Cervical spine: conventional radiographs miss 40–60% injuries, especially at craniocervical junction Blackmore Radiology 1999;211:759; Hanson AJR 2000;174:713; Schenarts J Trauma 2001;51:663
- MRI
  - Grading cord injuries
  - Unexplained neurologic findings
  - Determining chronologic age of fracture

Image Evaluation

- How to not to miss injuries
  - Know where to look
  - Knowledge of fracture locations
- Knowledge of missed fracture locations
  - Learn from others' mistakes

Where to Look?
Location of Fractures



Linnau KF RSNA 2004;
Neuroimaging Clin N Am 2003; 13(2):283-291

Missed Fractures

- Upper cervical spine 43%
  - Occipital condyle 26%
  - Dens fractures 17%
- Lower cervical spine 57%
  - Posterior column 47%
    - Lamina/pedicle/articular mass/transverse process

Linnau KF RSNA 2004;
Neuroimaging Clin N Am 2003; 13(2):283-291

Goal #2

How stability (clinical instability) is defined

Clinical Instability

- "…loss of the ability of the spine under *physiologic loads* to maintain its pattern of displacement so that there is no initial or additional neurological deficit, no major deformity, and no incapacitating pain."

[White AA, Panjabi MM. Clinical Biomechanics of the Spine, 2nd edition. J.B. Lippincott Co.; 1990: 278]

Defining Stability

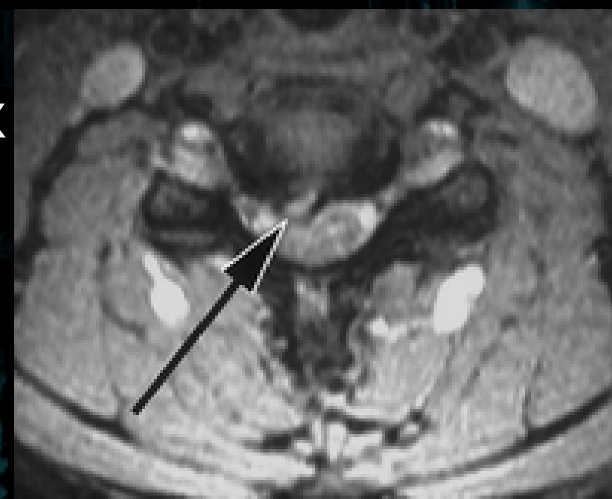
- *Neurologic* – injury will not cause or worsen a neurologic injury under physiologic load
- *Mechanical* – spine able to prevent non-physiologic movement under physiologic load
- Note Bene:
  - To be considered **stable** an injury must not lead to chronic pain, deformity, neurologic damage if untreated
  - Most mechanically unstable injuries are neurologically unstable. (Exceptions… low grade Jefferson & Hangman fractures)

Imaging Stability

- Patient with any *acute* ***neurologic deficit*** *presumed* ***mechanically unstable*** until proven otherwise.
- Stability ***inferred*** from static imaging; verified by physiologic stress.

"Normal" cervical spine with deficit "SCIWORA"

- Neurologic deficit present
- No vertebral fracture or residual subluxation (radiography, CT)
- Consider
  - disc- osteophyte complex
  - acute soft disc herniation
  - epidural hematoma
  - spontaneous realignment



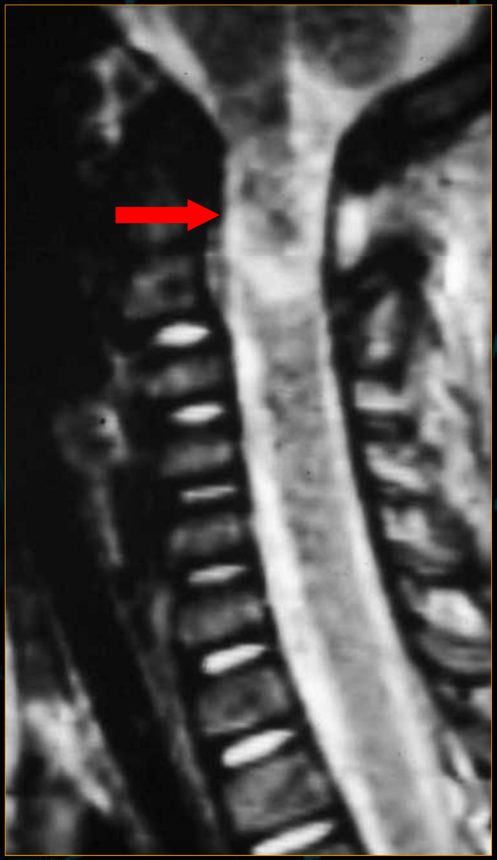
- Perform MRI
- Regarded as stable unless contradicted by MRI

Direct MRI Findings for 1^{o} & 2^{o} Spinal Cord Injury with “fixed” neurologic deficits

- Rupture (laceration)
- Hemorrhage
  - –> 1 vertebra height
- Edema
  - –> 2 vertebrae height

Value of GRE Imaging in SCI

T1



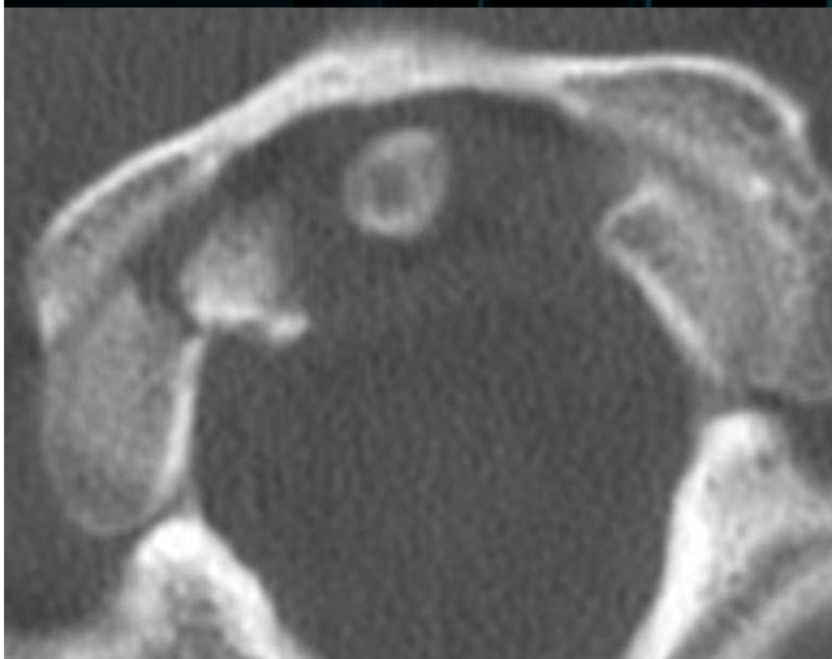
T2-FSE

GRE

Goal #3

What imaging findings are used to assess stability; & what injuries are typically stable *vs.* unstable.

Case #1



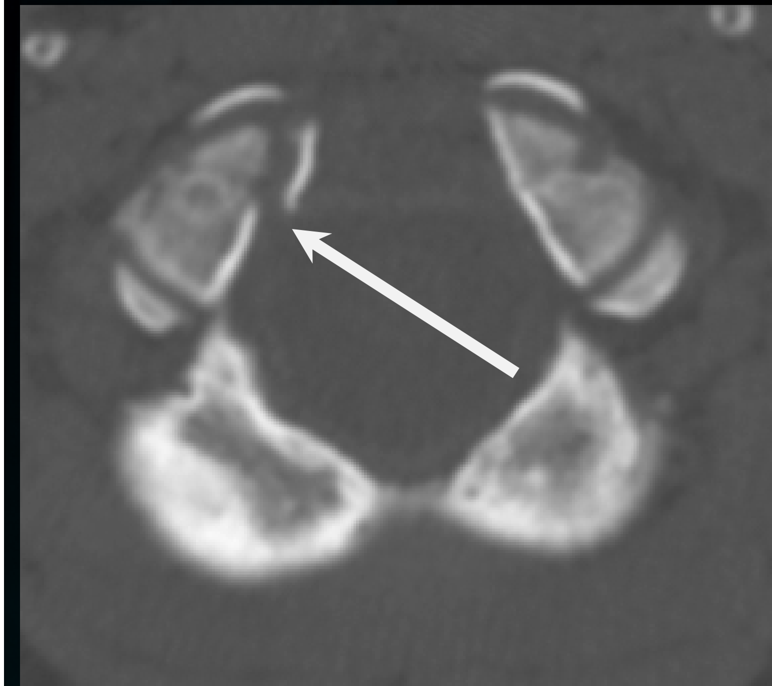
Which of the following is the ***correct*** diagnosis?

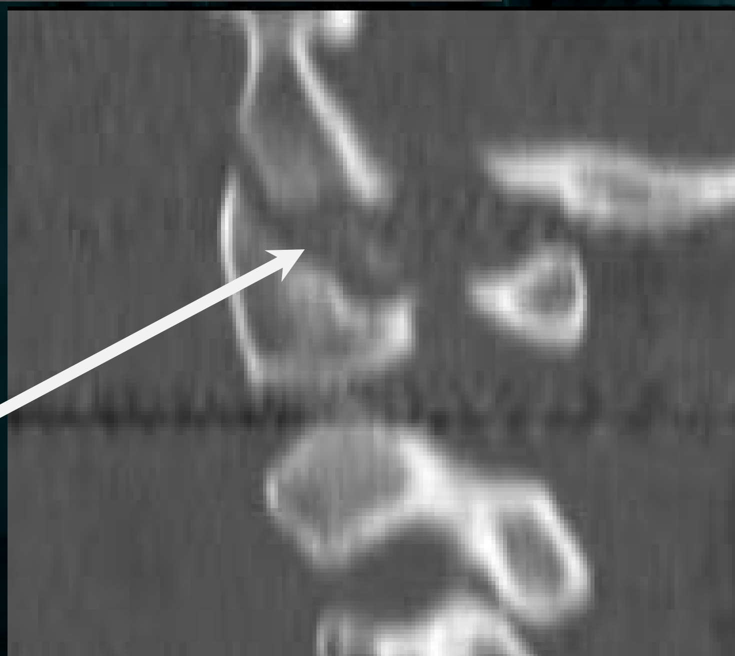
1. Occipital condyle fracture, type 1
2. Occipital condyle fracture, type 2
3. Occipital condyle fracture, type 3
4. None of the above

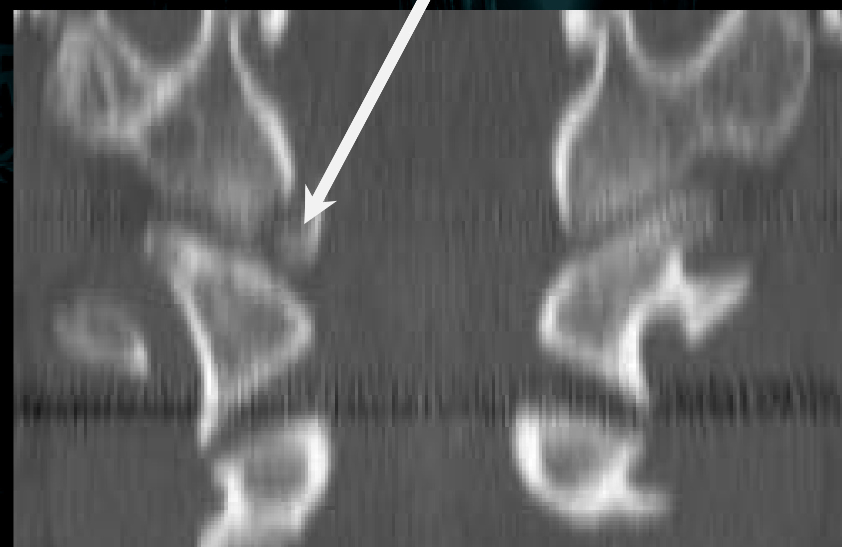
Occipital Condyle (C0) Fracture

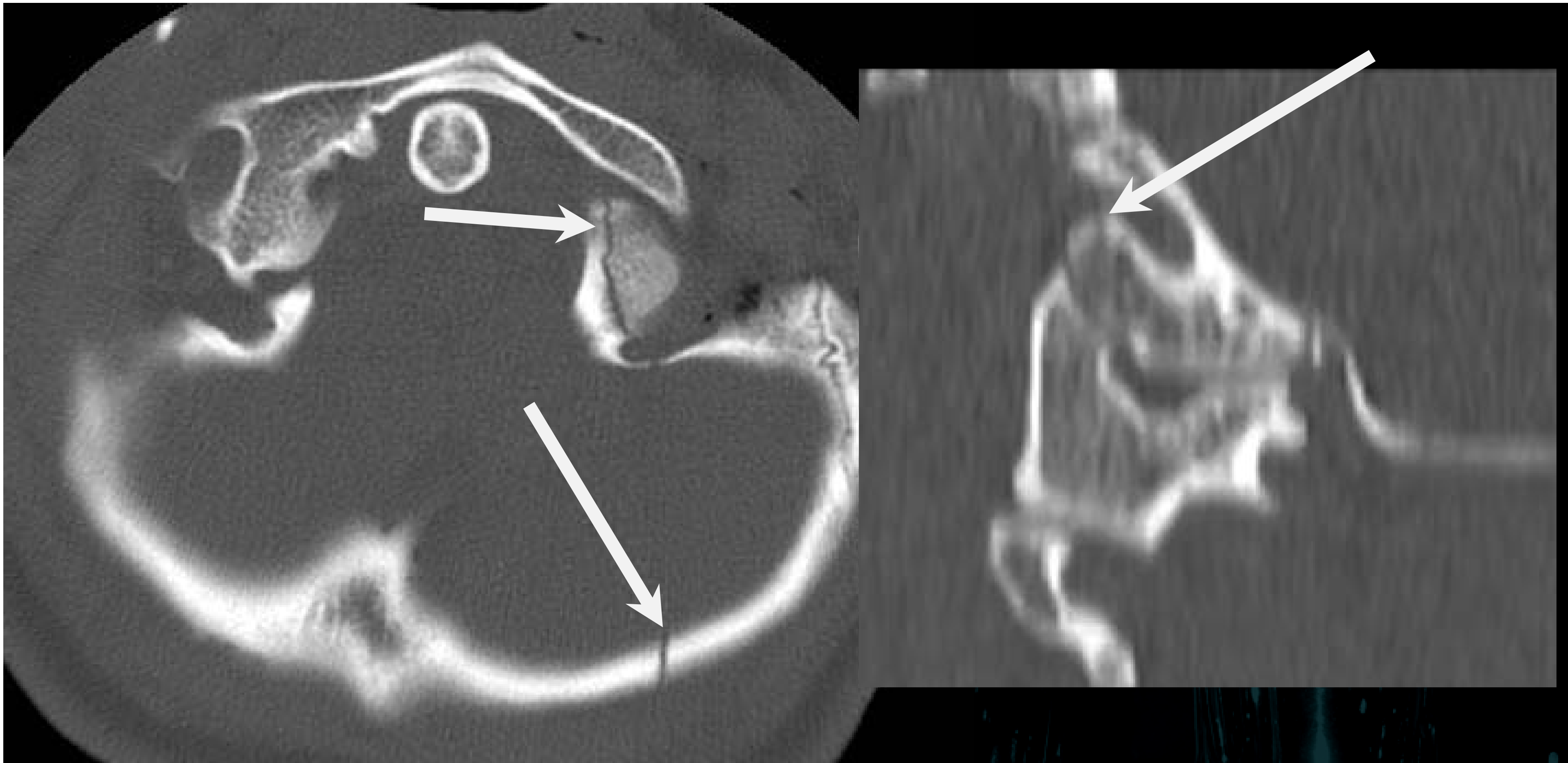
- Type 3, non-displaced
  - "Unstable" if displaced > 3mm
- Classification (Anderson, et al)
  - Type 1: Burst fracture
  - Type 2: Extension from basilar fracture
  - Type 3: Avulsion
    - Alar ligament

Occipital Condyle Type 1 (Burst Fracture)

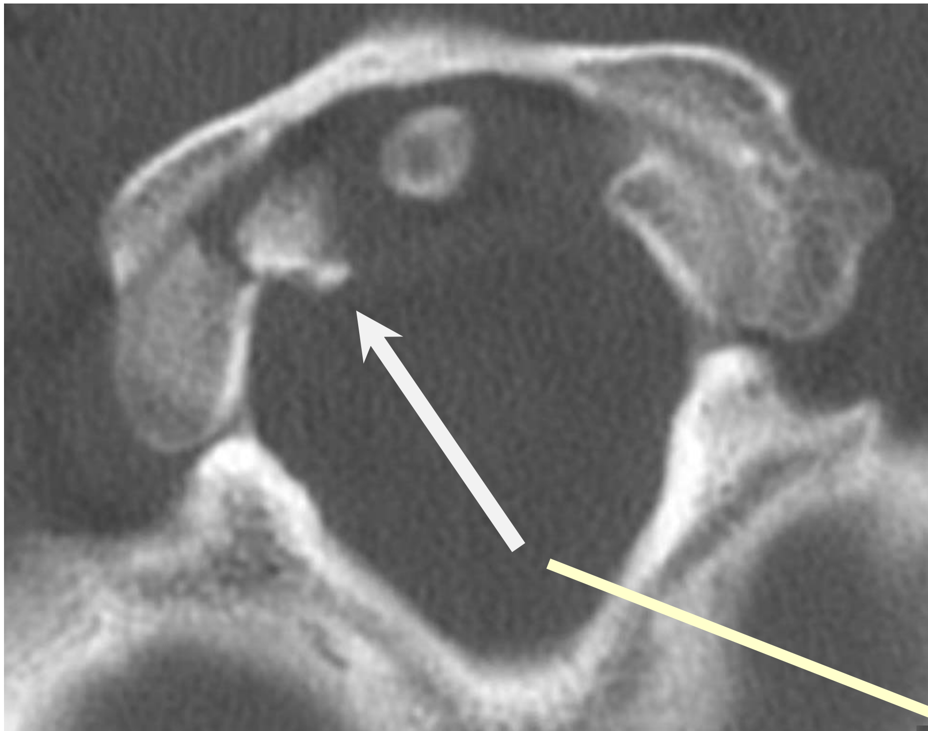






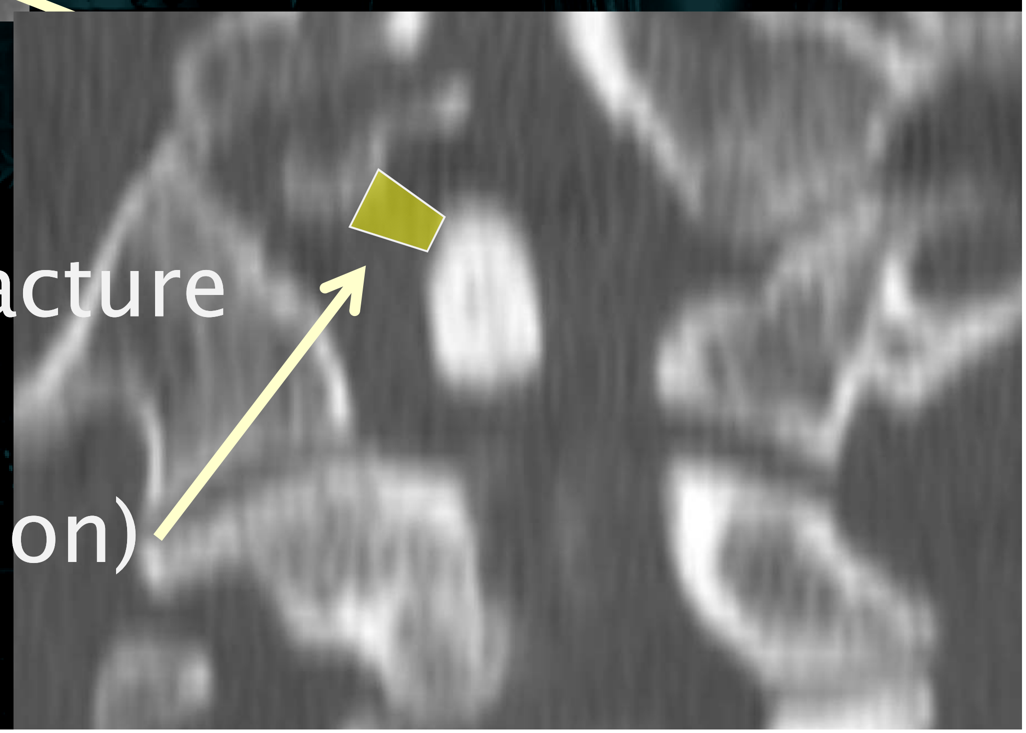


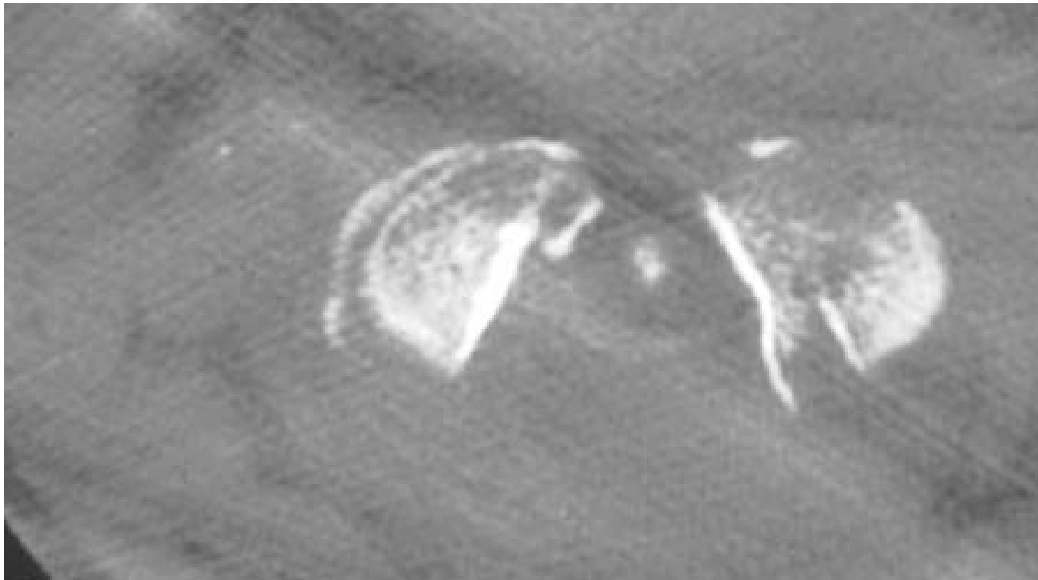
Occipital Condyle Fracture
Type 2
(Extension From Occiput)

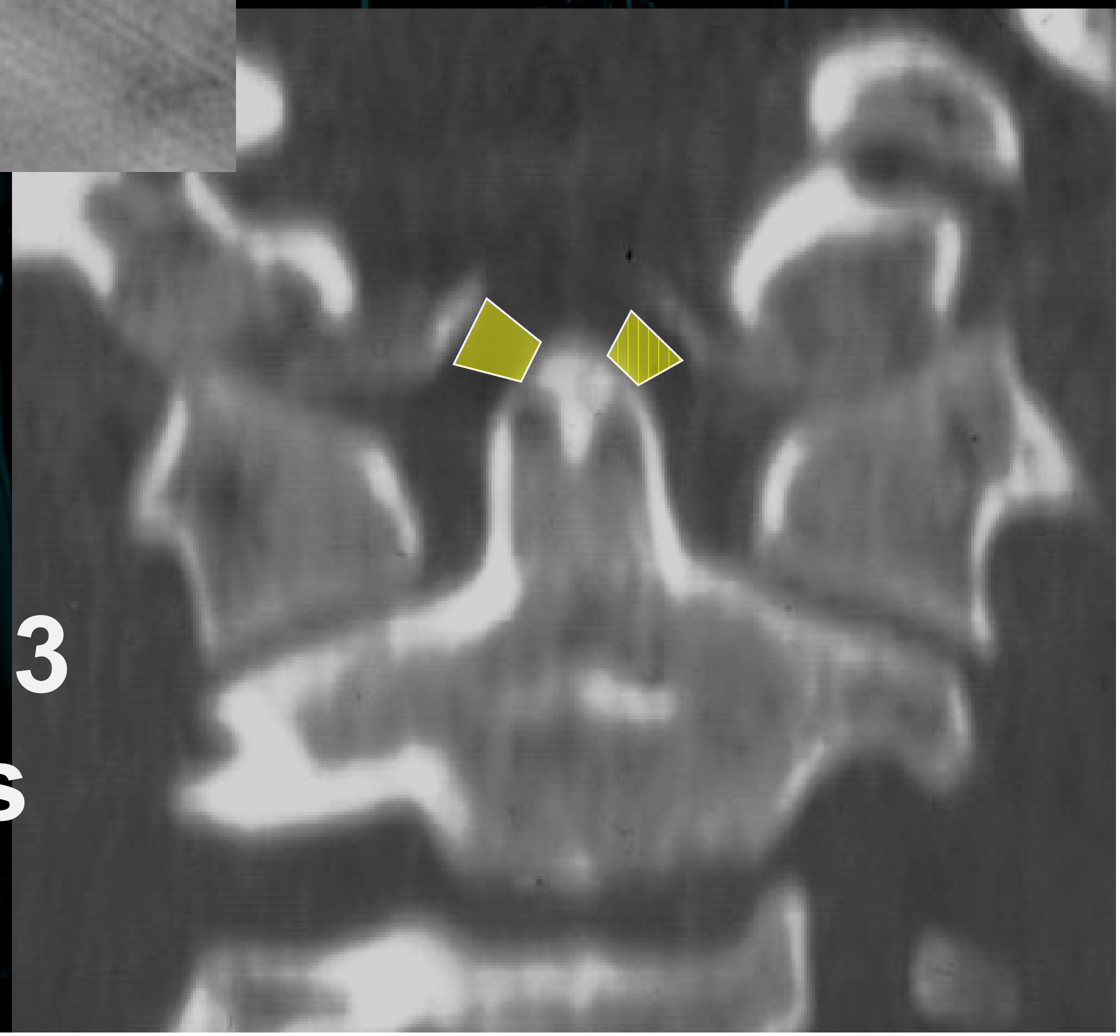


≥ 3mm displacement
= instability

Occipital Condyle Fracture
Type 3
(Avulsion-Distraction)





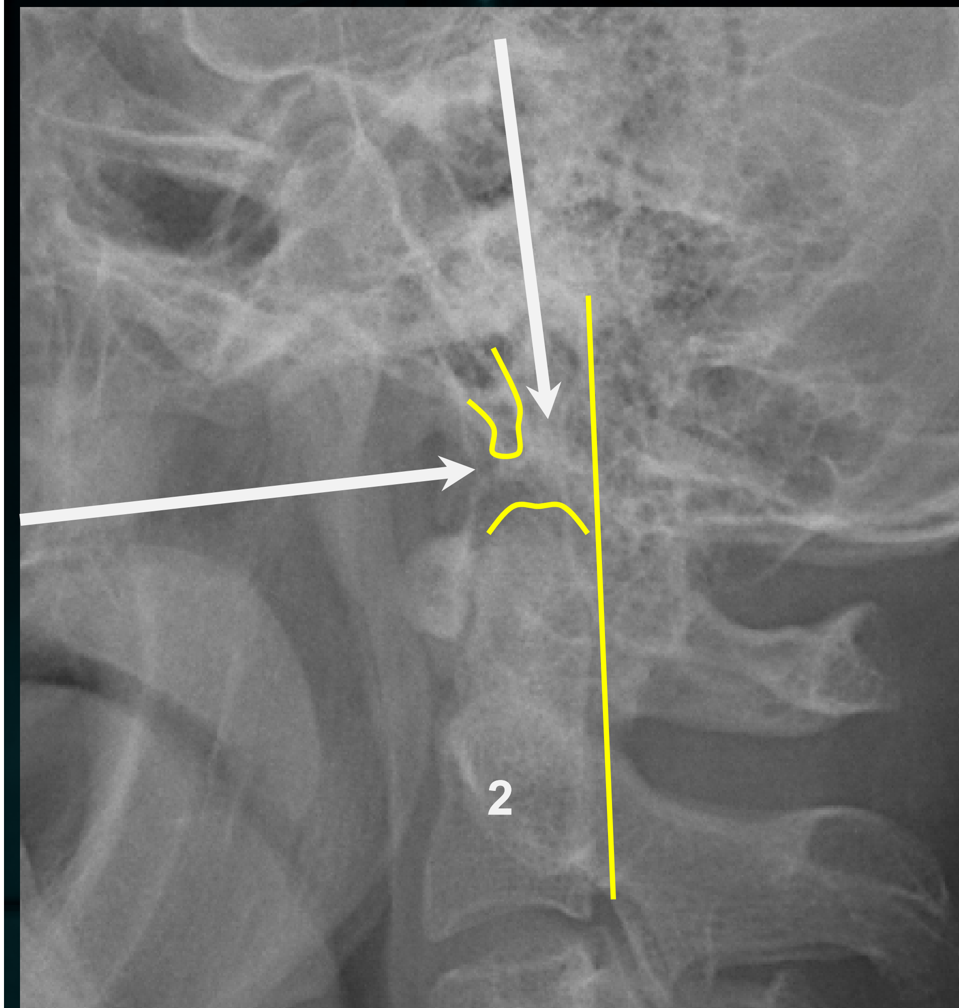


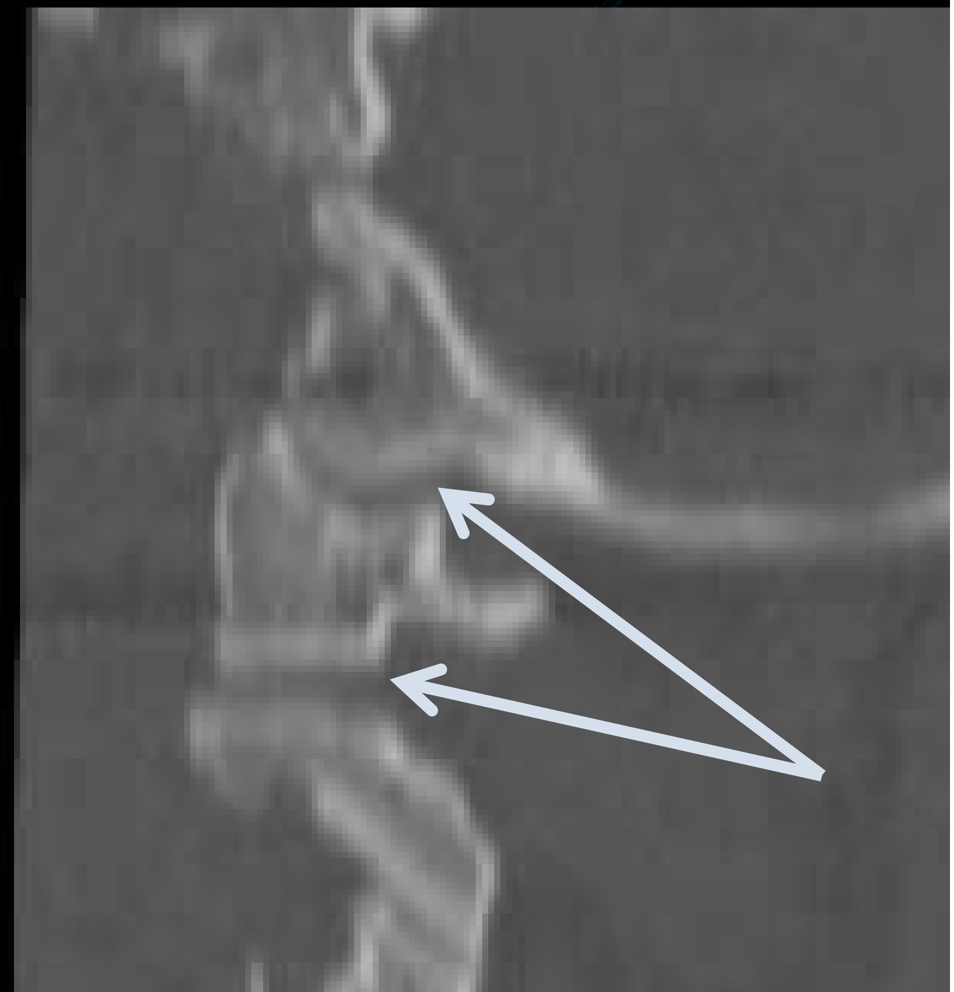
Bilateral type 3 OC Fractures

Assessing C0-C2 Distraction Injuries

- Radiographs
  - Harris' Distances
    - Dens-Basion
    - Posterior Axial Line - Basion
  - C1-C2 Intervals
    - Lateral ADI
    - C1-C2 joint space height
    - C1-C2 interlaminar distance
  - Wackenheim line
  - Lee's X
  - Power's Ratio

C0–C2 Alignment

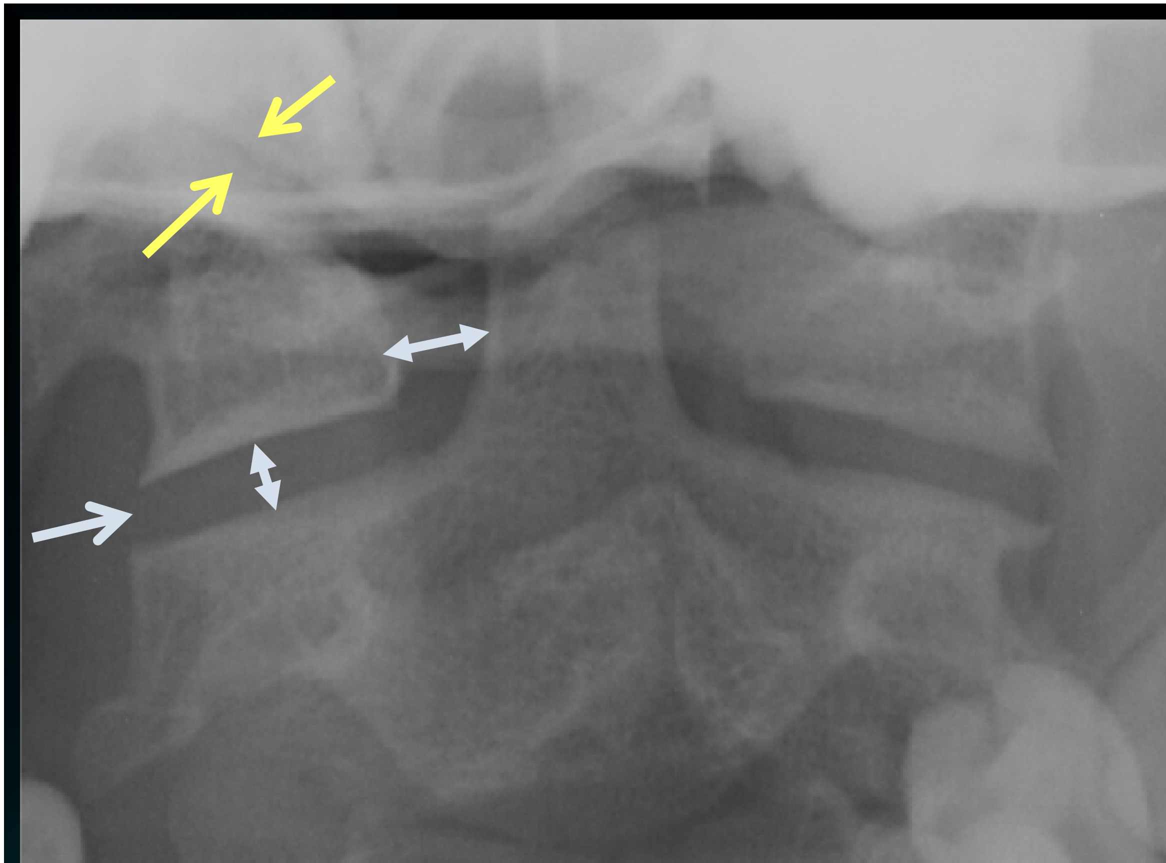




BD ≤ 12mm

PAL-D: -4 mm – 12 mm

Harris J Radiology 2001;218:337–351
AJR 1994;162:881–886



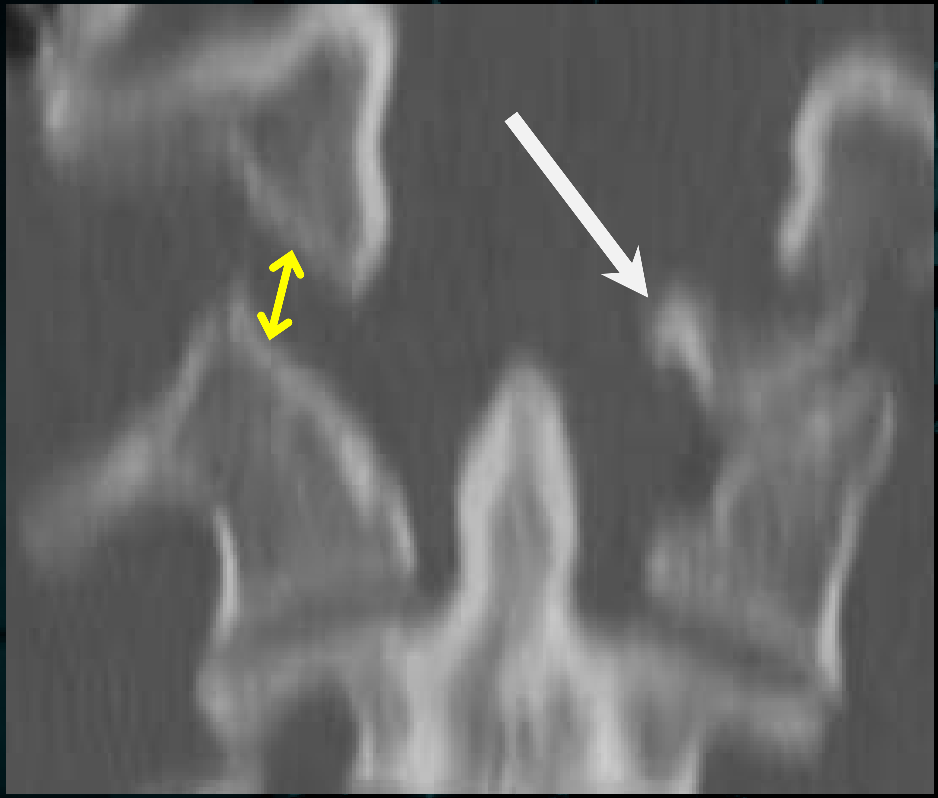
C0-C1 space:
Adult: 2-3mm
Infants: < 10mm

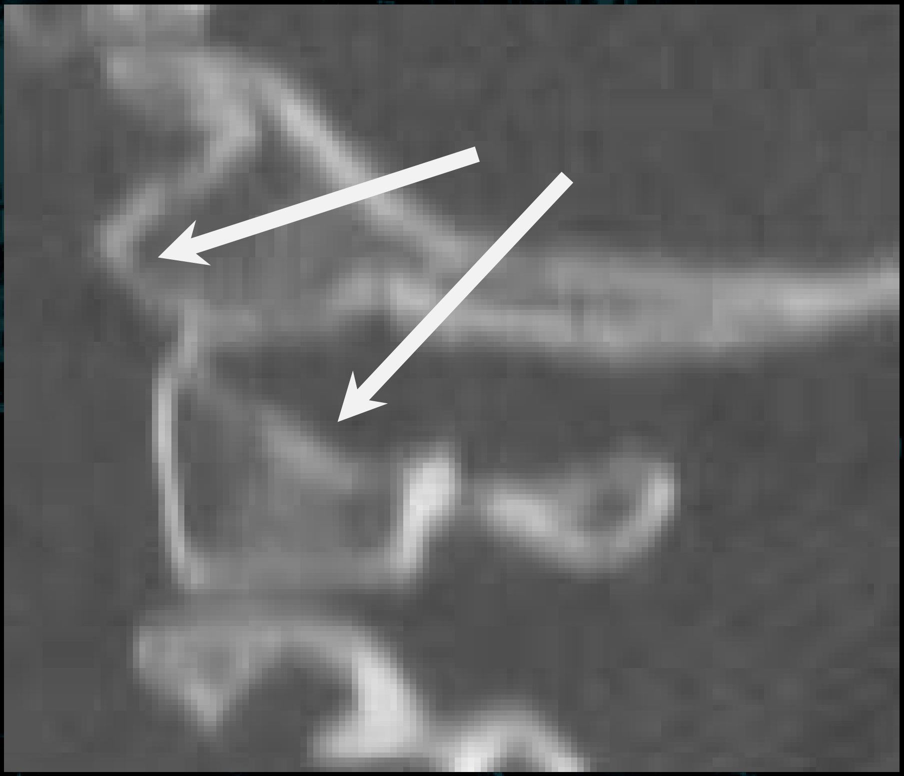
LADI:
Not reliable

C1-C2 lateral mass joint space:
Adult ≤ 3.5 mm
Pediatric: ≤ 4.5 mm

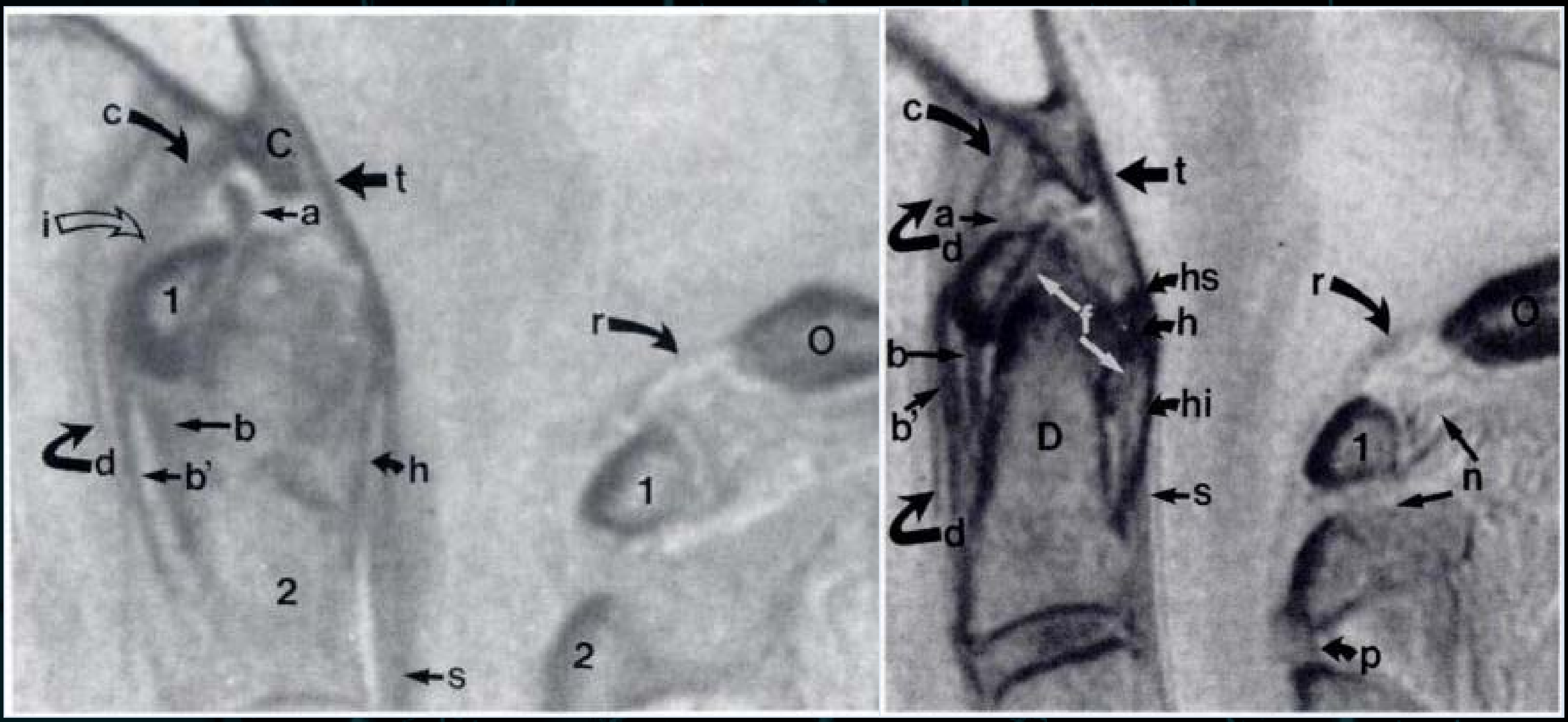
Rojas CA AJR 2009;193:1388-1392

Occipital Condyle Fracture, Type 3 Atlanto-Occipital Dissociation (AOD)



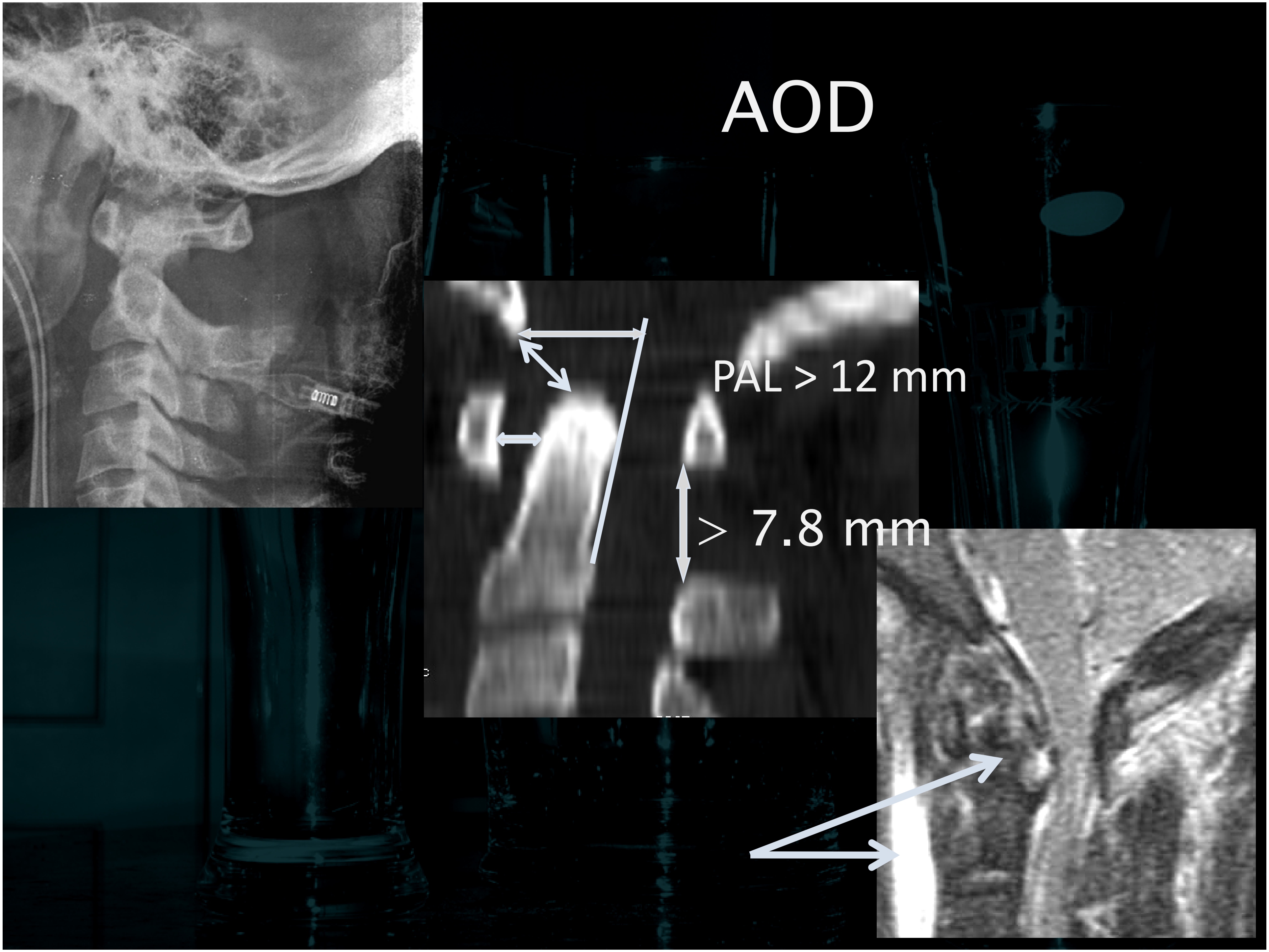


Atlanto-occipital ligaments
Tectorial membrane is KEY



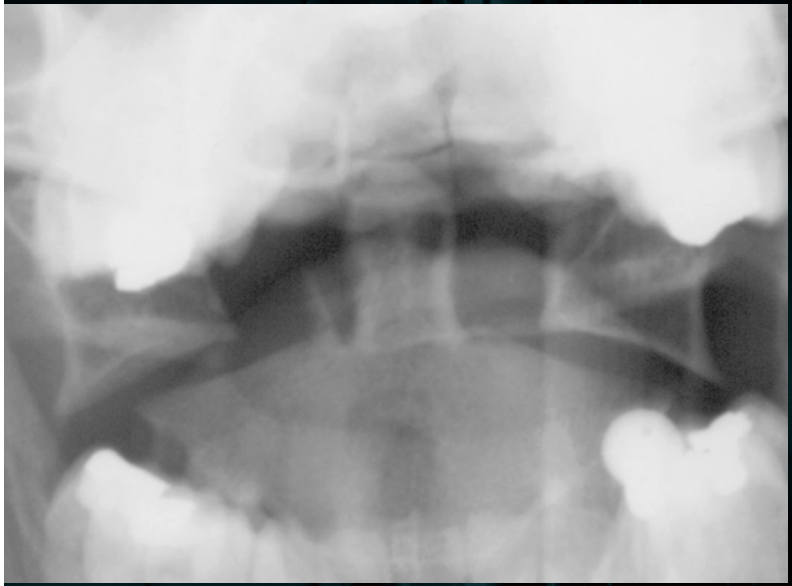
Schweitzer ME AJR 1992;158:1087-1090

Mirvis SE RSNA 2007


AOD
PAL > 12 mm
> 7.8 mm

Case #2

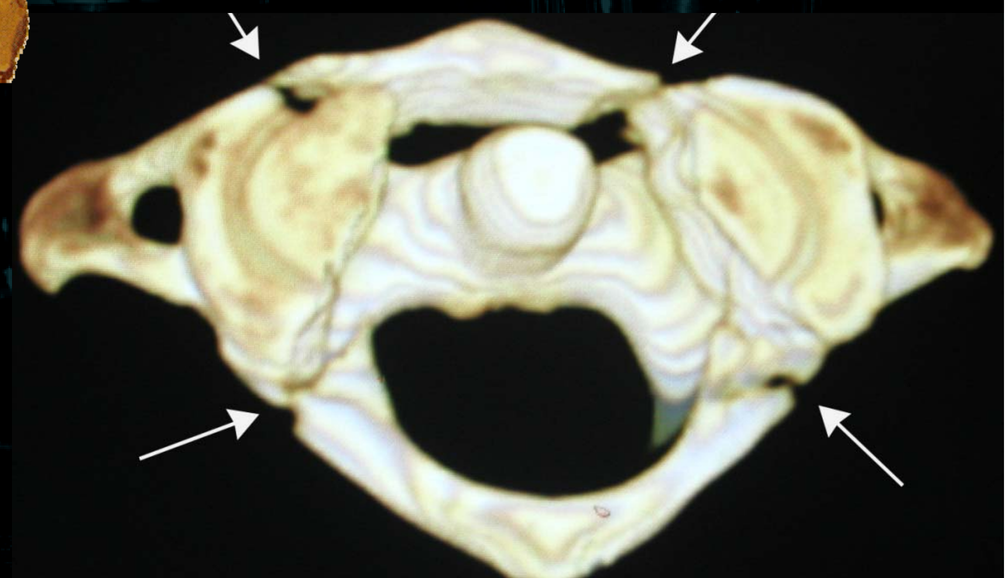
Which of the following is the ***correct*** diagnosis?



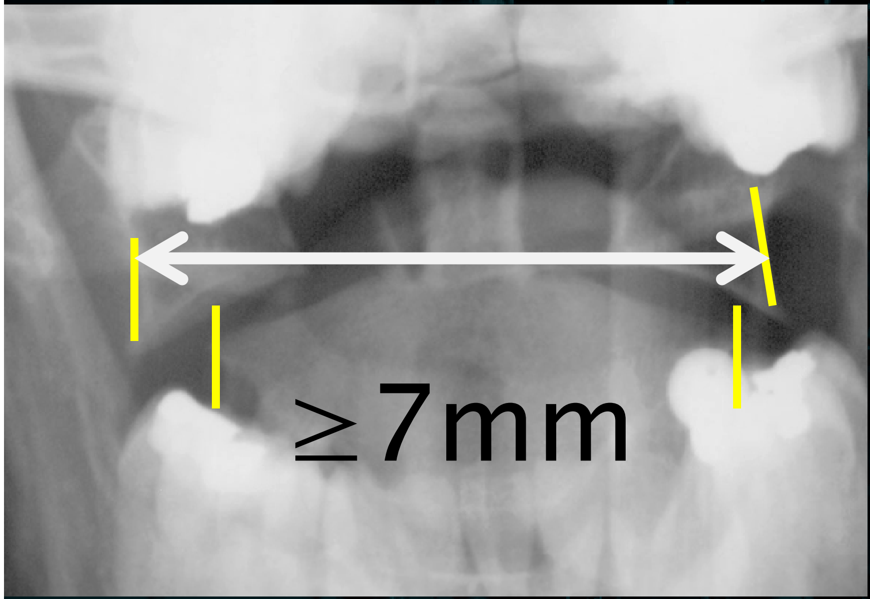
1. Jefferson burst fracture, unstable
2. C1 lateral mass fracture
3. Bilateral C1 posterior arch fractures
4. Normal variant

Axis (C1) Fractures

- Jefferson "burst" fracture
  - Extra-articular, typically 3 > 4 parts



Axis (C1) Fractures



Jefferson "burst" fx

- Extra-articular, typically 3 > 4 parts
- Transverse atlantal ligament (TAL) integrity
  - Intact: "Stable"
  - Disrupted: "Unstable"
    - Total lateral displacement ≥ 7 mm
    - Osteoperiosteal fragment

Axis (C1) Fractures

- Jefferson “burst” fx
- Lateral mass fx
  – Intra-articular
  – Ipsilateral, typically 2 part
  – No TAL injury

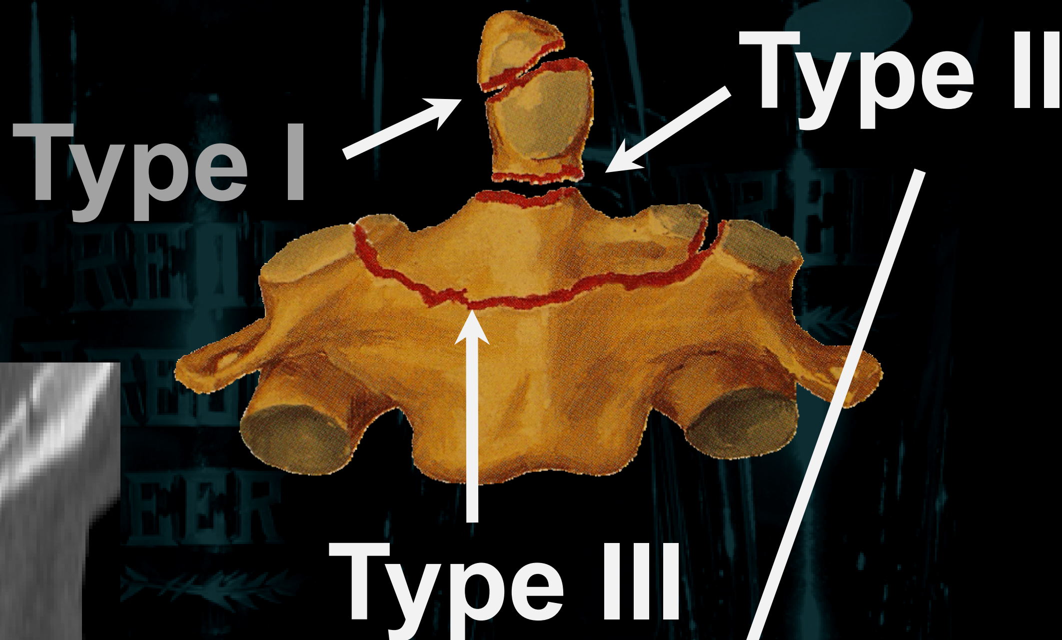
Case #3

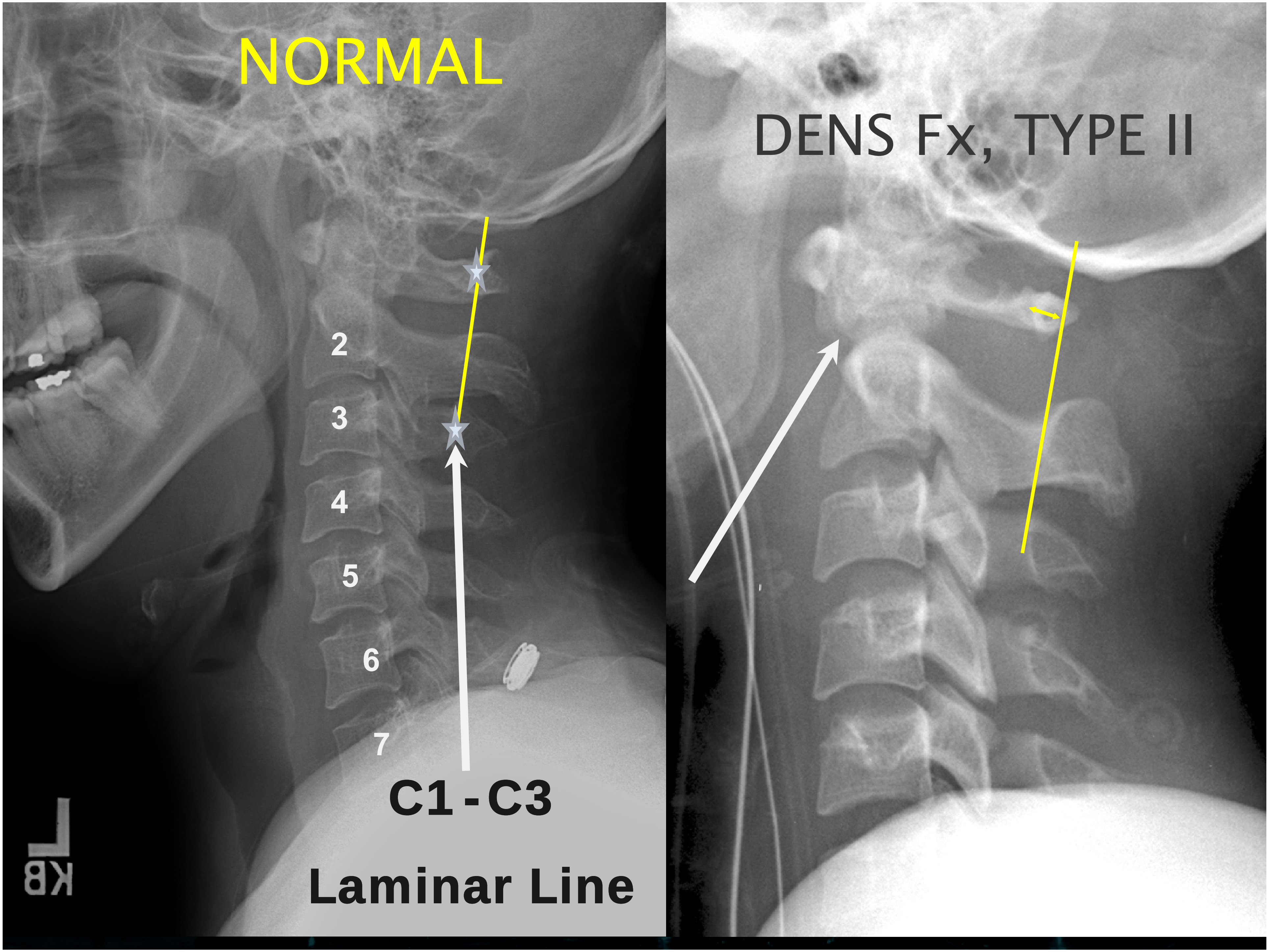
Which of the following is the ***correct*** diagnosis?

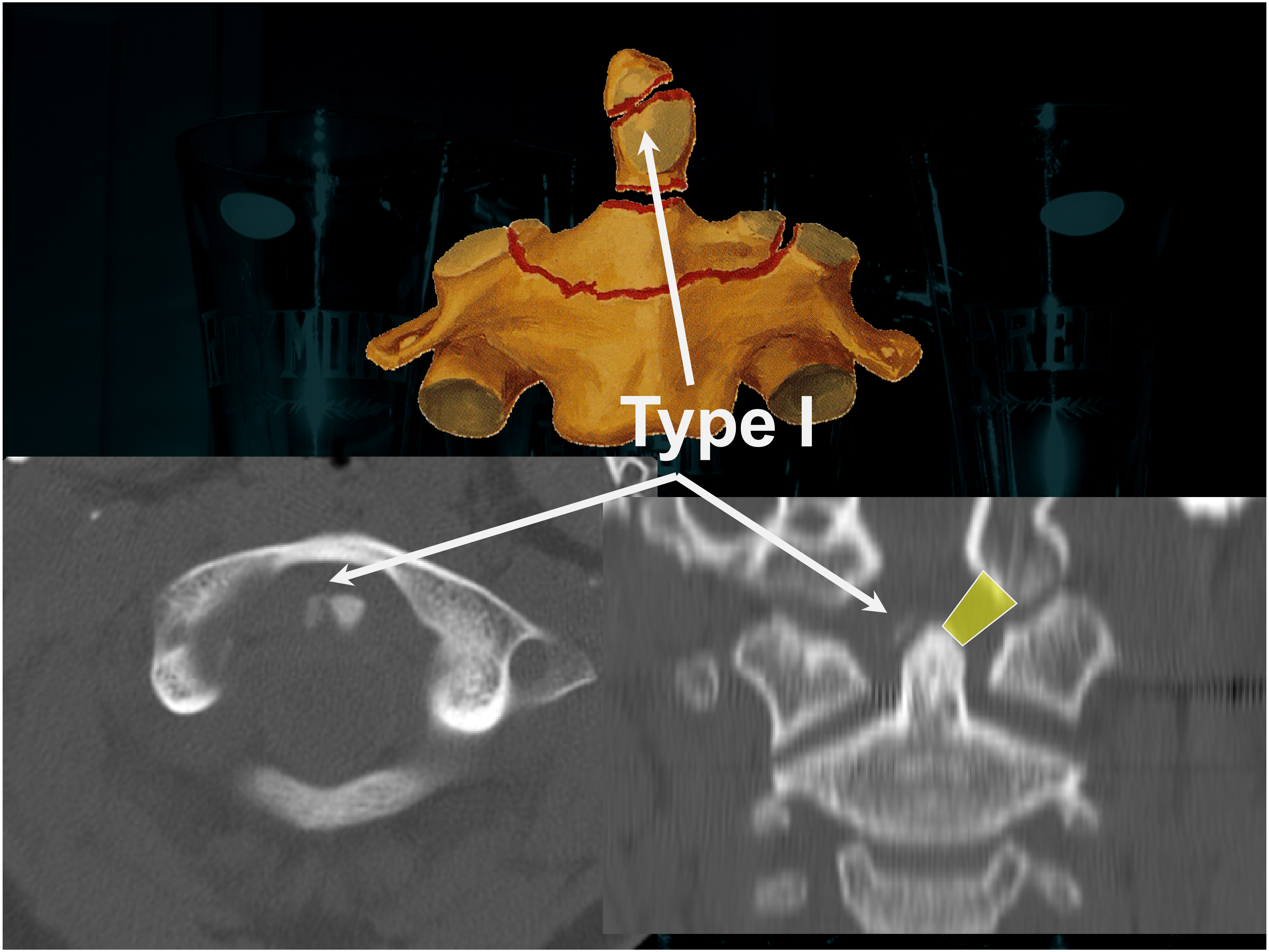
1. Transverse Atlantal Ligament Rupture
2. Dens fracture, type 1
3. Dens fracture, type 2
4. Dens fracture, type 3
5. “Plough” fracture

Dens Fractures

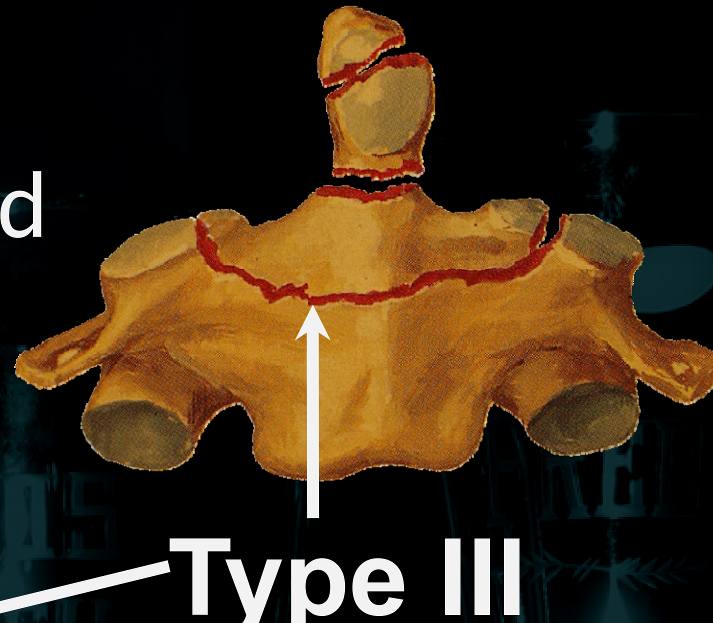
- Dens fracture
  - Type 2
  - displaced

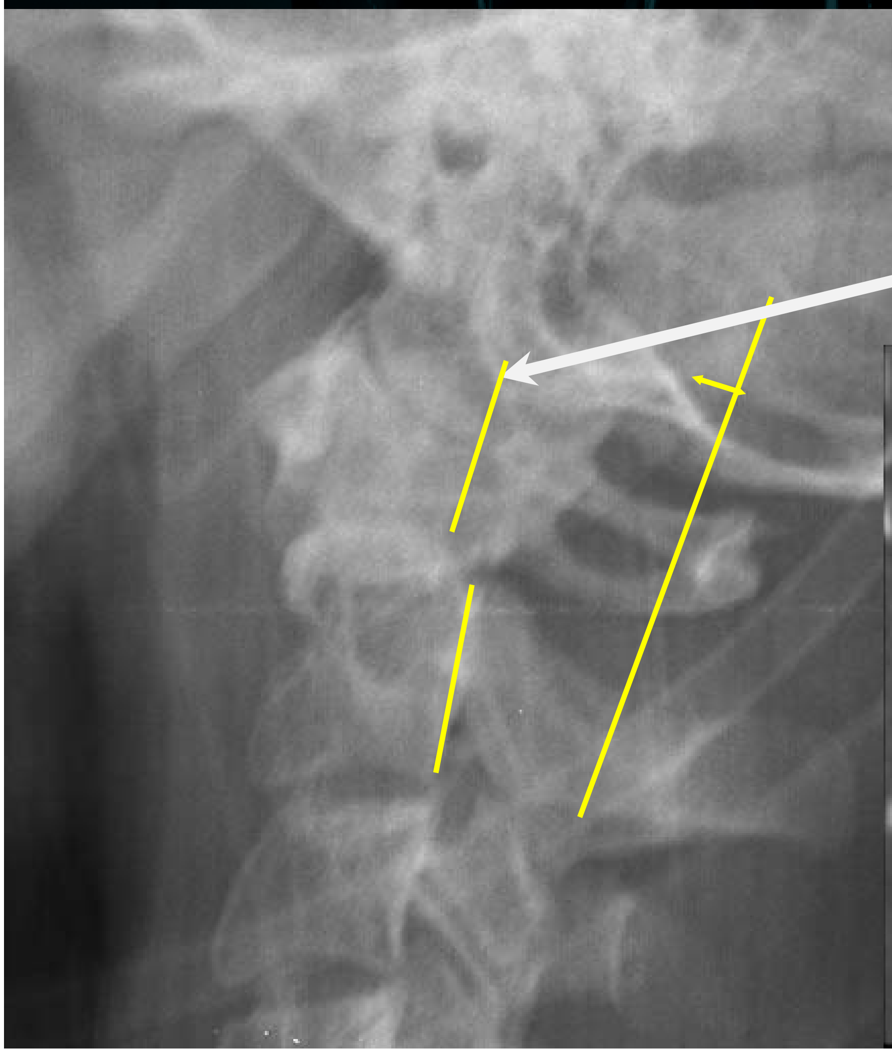



NORMAL
2
3
4
5
6
7
C1 - C3
Laminar Line
L
KB
DENS Fx, TYPE II


Type I

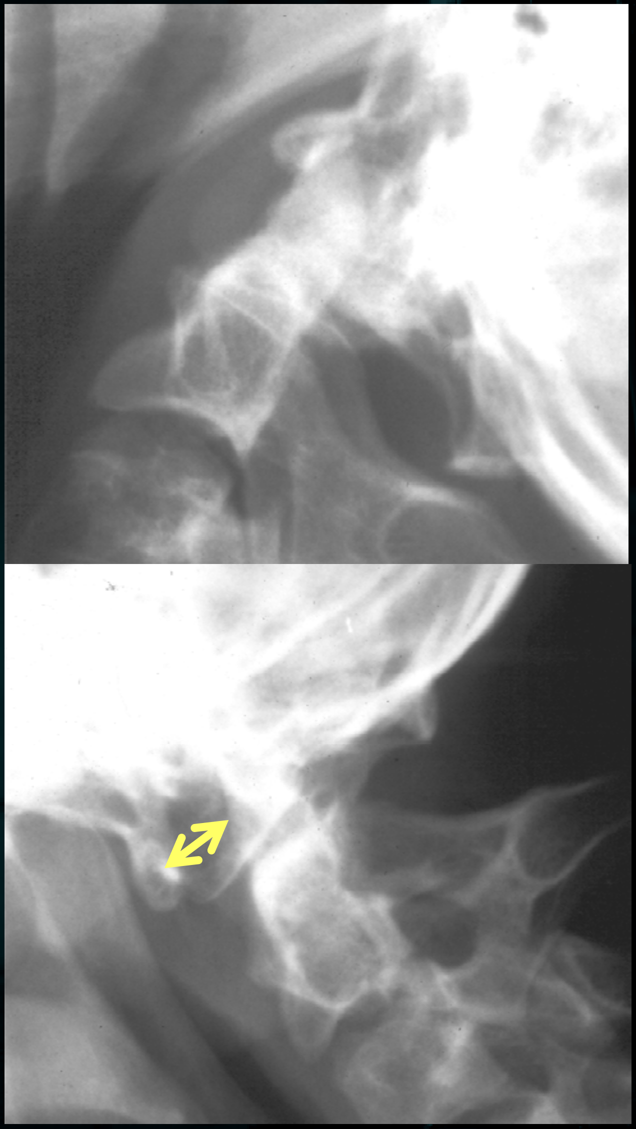
Generally “stable”
Except > 50% displaced





Displaced Type 3 Dens Fractures

C1-C2 Horizontal Instability

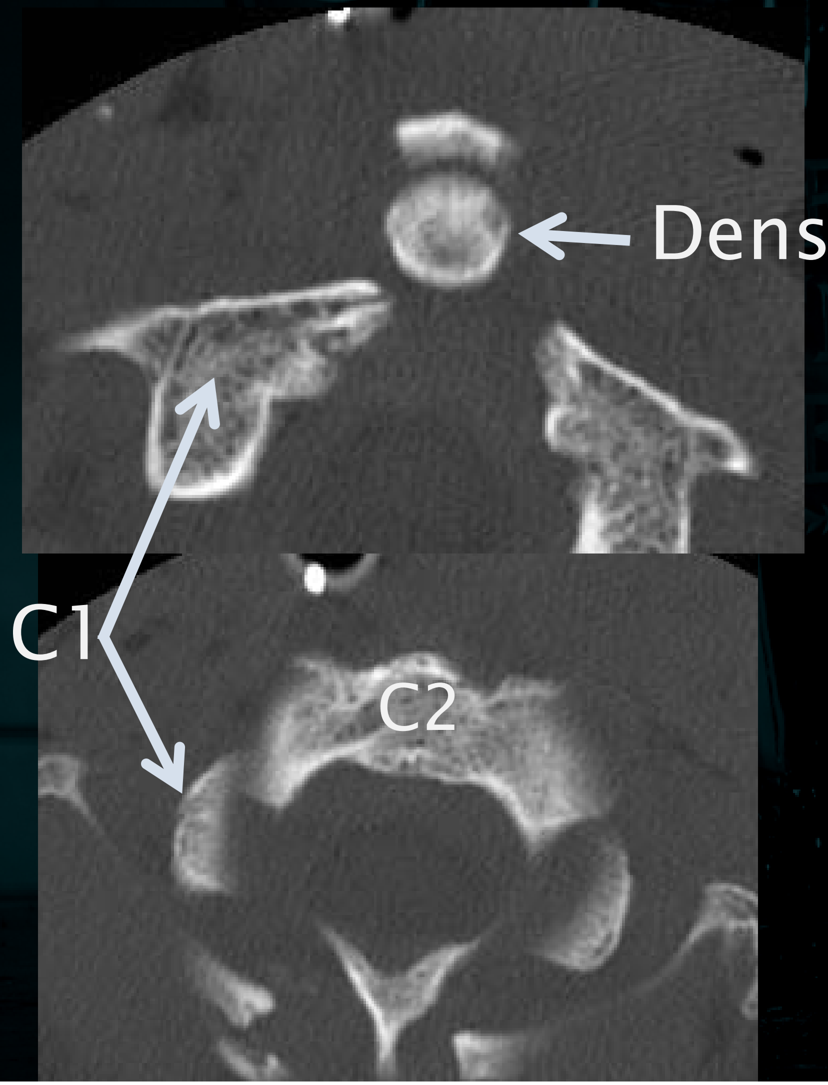


Transverse Atlantal Ligament (TAL) Rupture

•Osteoperiosteal ruptures typically heal (“stable”)
•Intrasubstance ruptures typically do NOT heal (“unstable”) Dickman Neurosurgery 1996;38:44-50
•Commonly “missed” by CT

Displacement > 5 mm means accessory ligaments torn
Displacement > 11 mm means alar ligaments torn

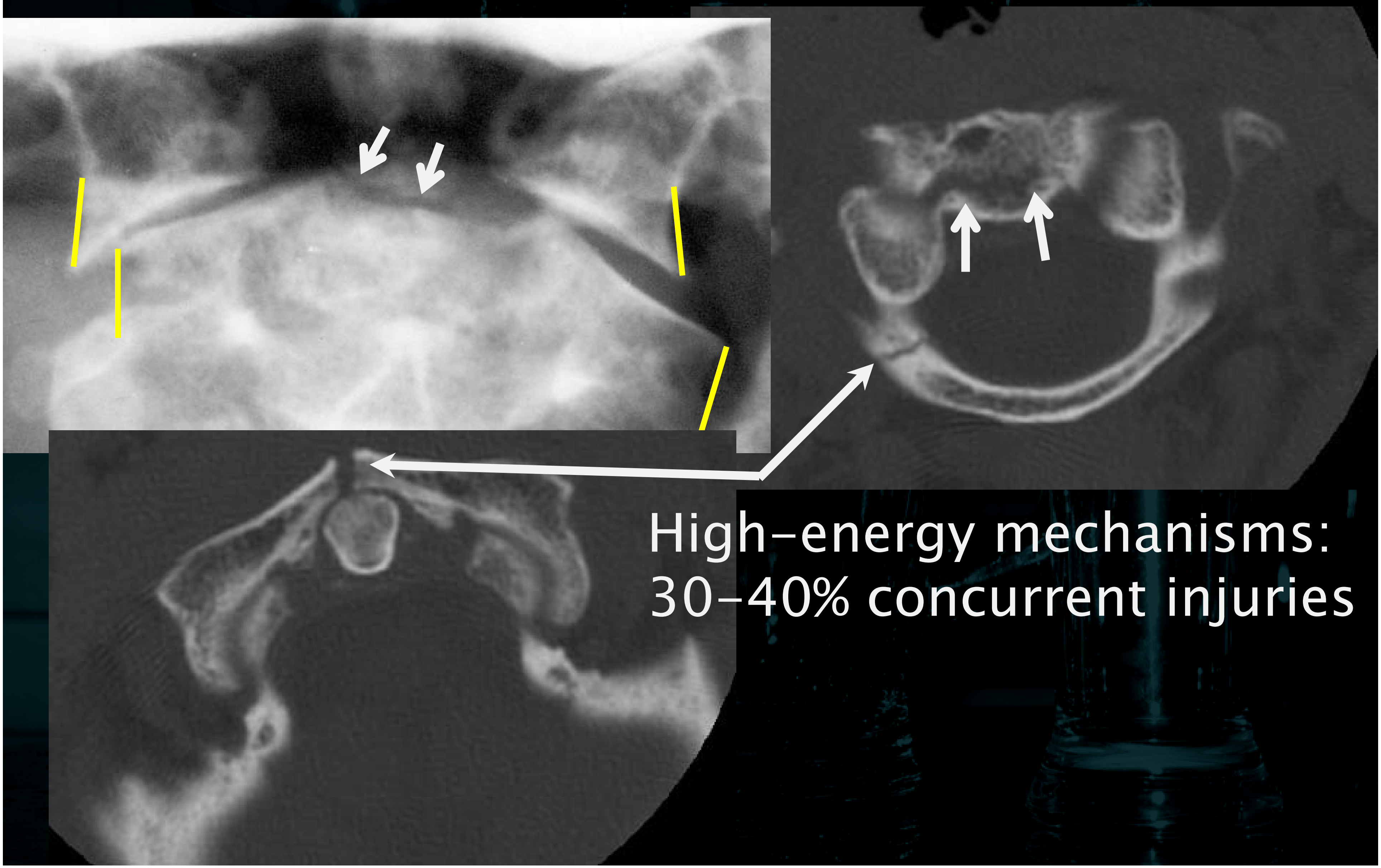
C1-C2 Horizontal Instability



"Plough" Fracture:

- >50% offset of anterior cortex consistent with periosteal disruption = "unstable"
- Note: C1-C2 dislocation

C1-C2 complex fracture combinations



High-energy mechanisms:
30–40% concurrent injuries

Case #4

Which of the following is the *correct* diagnosis?

1. Hangmans fracture, type 1
2. Hangmans fracture, type 2
3. Hangmans fracture, type 3
4. Hangmans fracture, atypical variant
5. Extension teardrop fracture

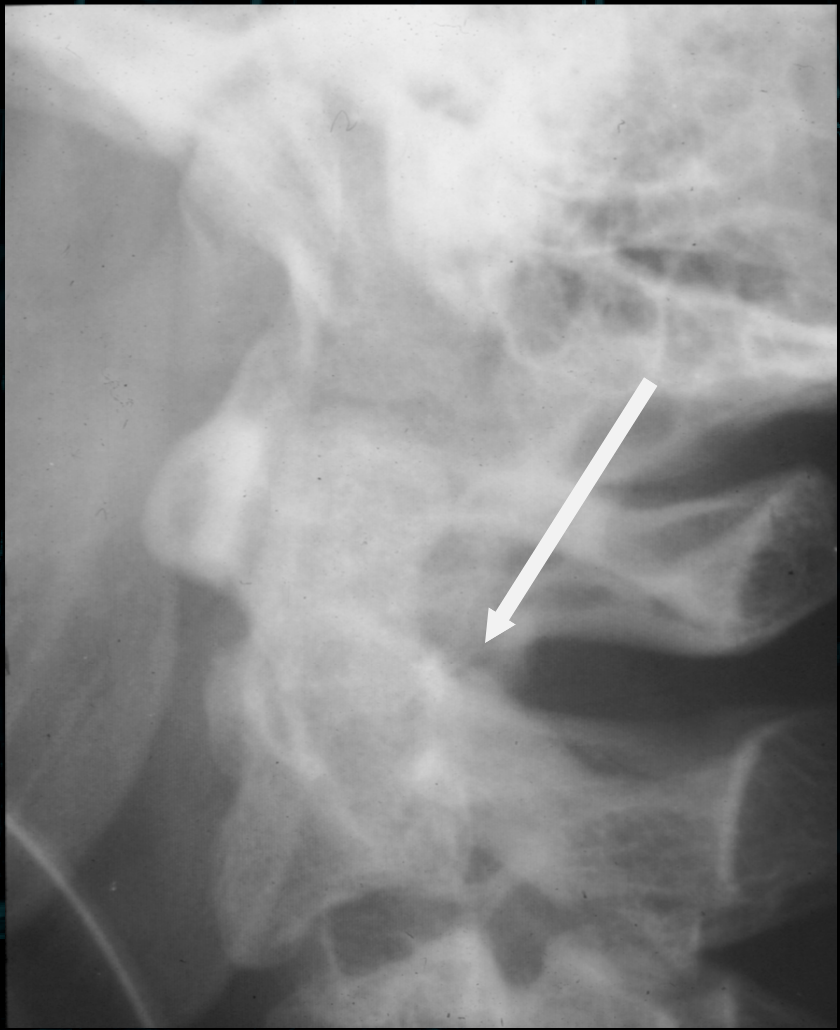
“Hanged-man” Fracture

- Type II Hangman’s Fracture
- Bilateral traumatic spondylolysis
- Frequency: 5-25%
- Myelopathy: < 25%
- Mechanism
  - Varies by subtype
  - Extension-Distraction (Judicial)
- SLIC concepts germane

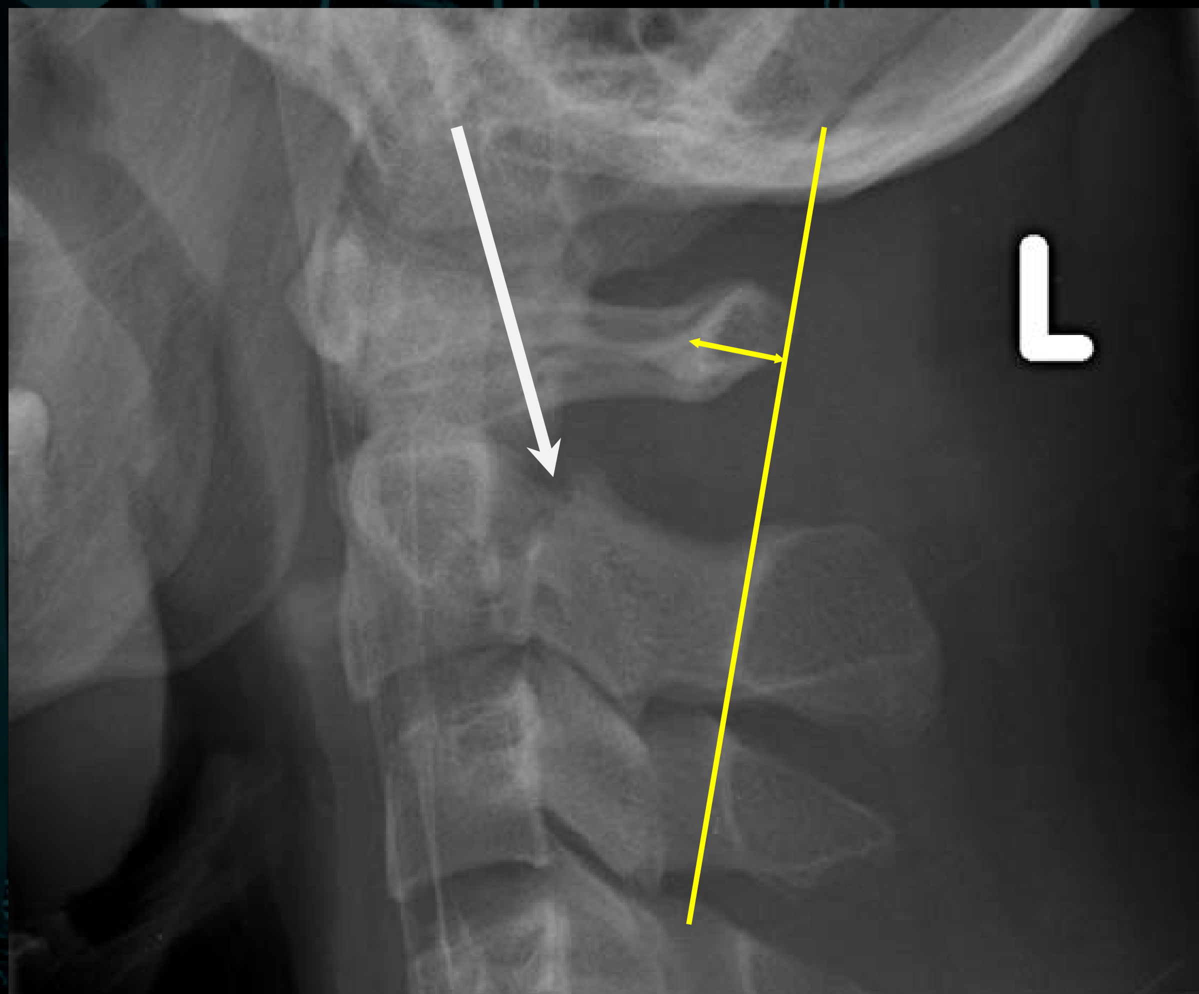
Hangman's Fracture Levine Classification

- Adults; not applicable to children
- Type I:
  - < 3 mm translation, no angulation
  - Type II:
    - Most common subtype
    - >3 mm translation & >10^0 angulation
    - C2-3 disk and posterior longitudinal ligament are disrupted
  - Type IIa
    - Fracture more oblique than vertical with greater angulation &/or translation
    - Posterior C2-C3 disc space widened
  - Type III:
    - Features of Type 2 plus facet dislocation (fracture-dislocation)

Hangmans Fracture, Type 1 (non displaced)

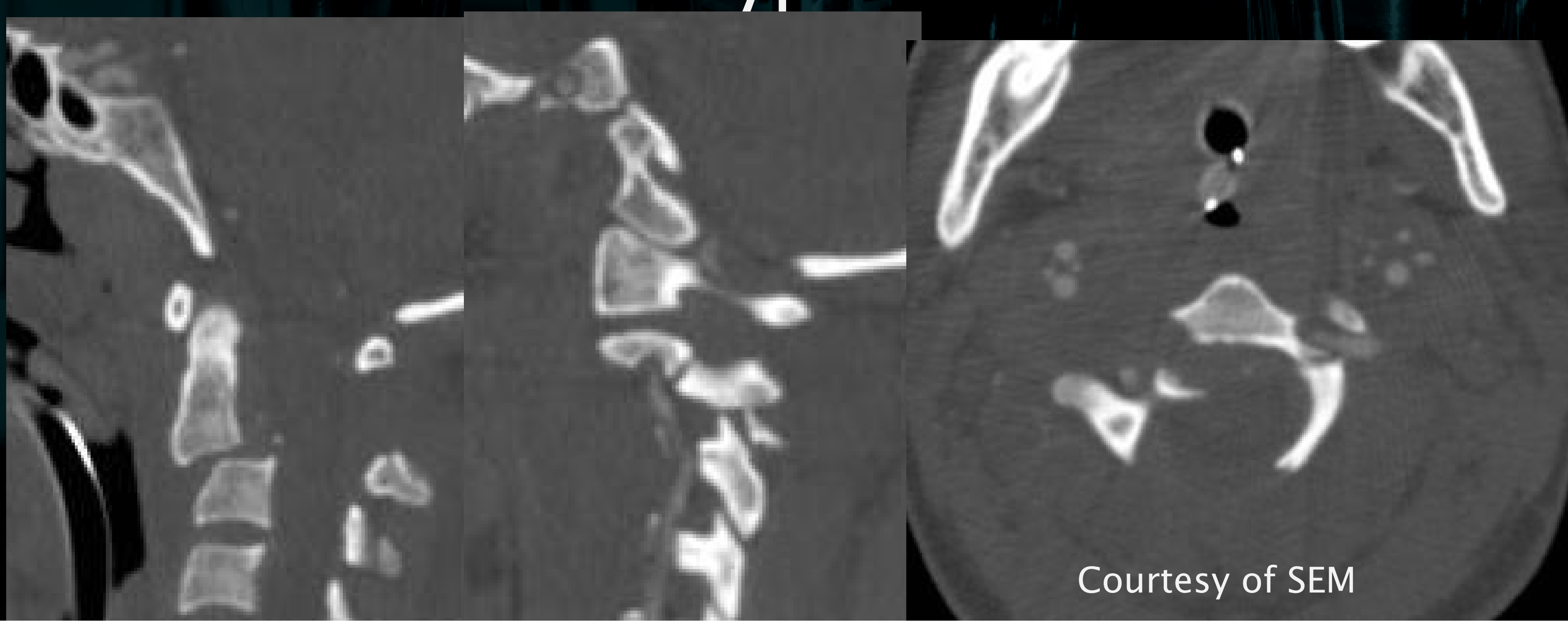


Hangman Fracture Type II



Type IIa

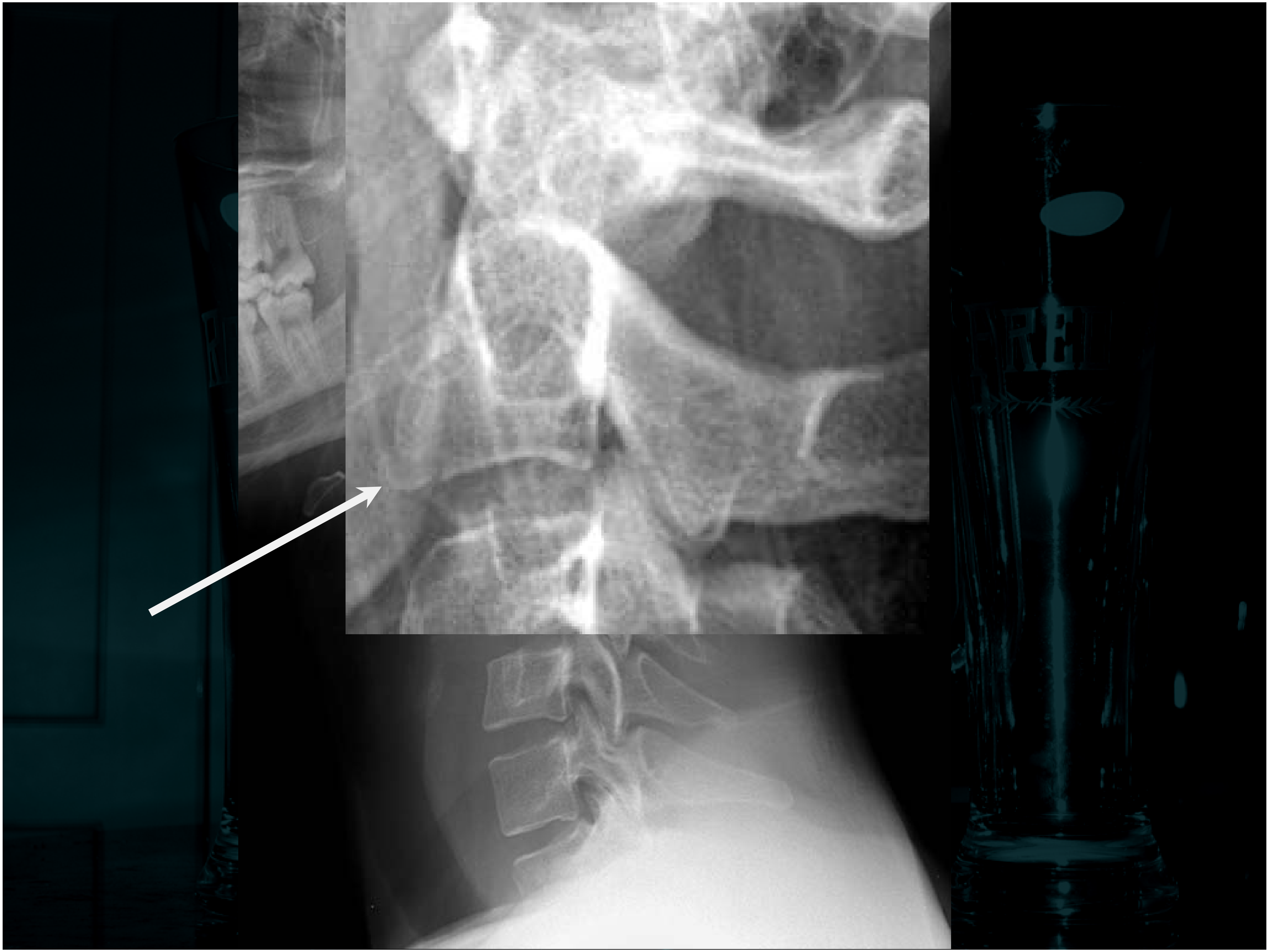
Type III



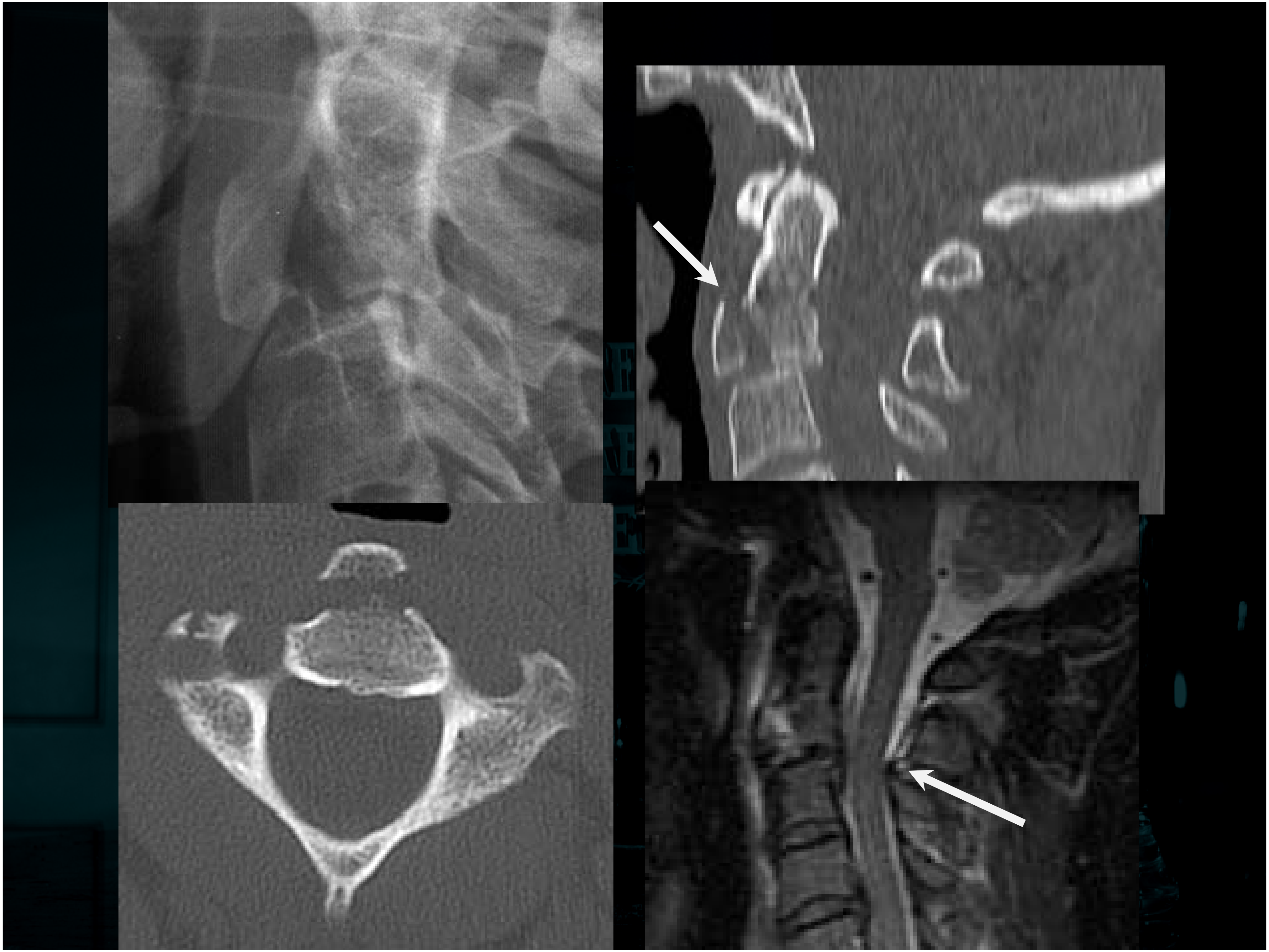
Hangman's Fracture
Type II Variant

Typical Hangman's

Variant :posterior cortex



C2 Hyperextension Teardrop Fx



Which of the following is the *__correct__* diagnosis?

Case #5

1. Grisel's Syndrome
2. Torticollis
3. C1-C2 subluxation
4. Positional
5. Insufficient information for diagnosis

C1–C2 Rotation

- Need clinical context
- What's normal range of rotation at C1–C2?
  - Rotation: ±50º (total rotation 90-100º) Monckeberg Spine 2009;34:1292–1295; White AA, Panjabi MM. Clinical Biomechanics of the Spine, 2nd edition. J.B. Lippincott Co.; 1990: 278
  - Articular contact loss with rotation: 40–90% Monckeberg Spine 2009;34:1292–1295
- Symantics
  - Atlantoaxial subluxation: Avoid confusion
    - vertical, horizontal, rotational
  - Subluxation, Dislocation
  - Fixation = Grisel's Syndrome (="subluxation")
    - Chronic fixation
  - Torticollis

C1–C2: Rotary Fixation

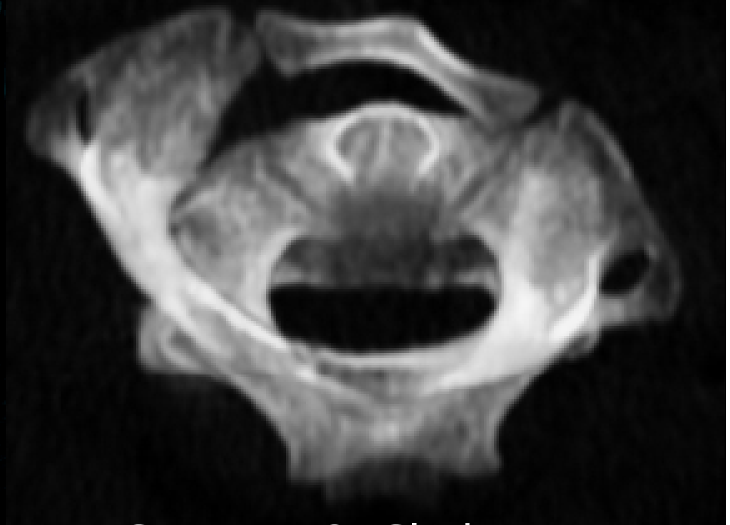
- Not "Unstable" unless acute neurological deficit (extremely rare)
- Frequency
  - Younger than 16-yo:< 5%
  - Older than 20-yo: Rare*
- Mechanism poorly understood
  - Post-inflammatory in youth
  - Low-energy over-rotation

Imaging

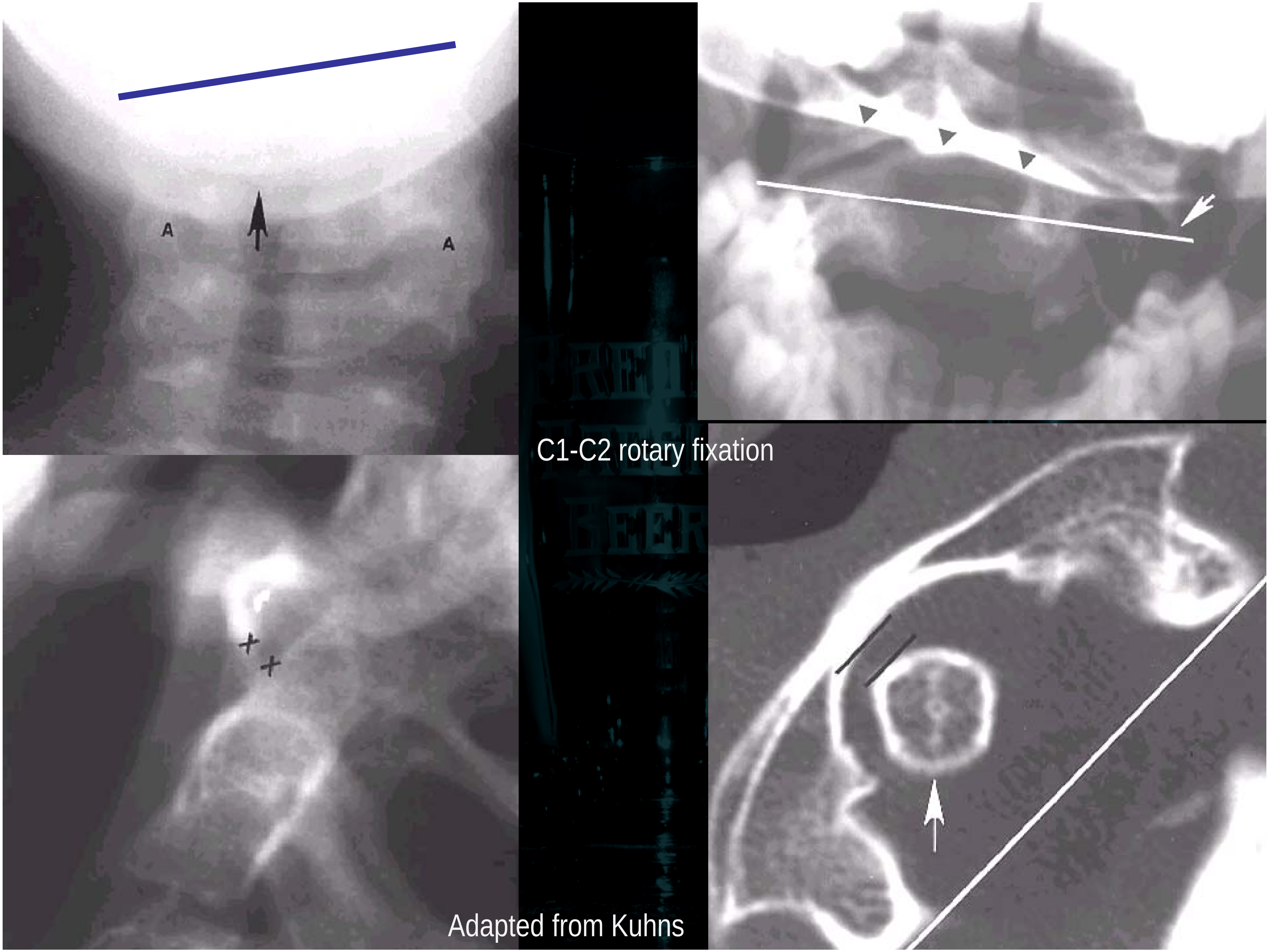
- *C1-C2 rotational displacement
  - AP: “cock-robin” position
  - Lateral: ⬆ Anterior ADI (apparent)
- Patient cannot actively reduce.
  - Functional CT Kowalski AJR 1987;149:595-600
    - “As is”
    - Maximal active rotation to opposite side
  - Predictors of reduction failure
    - Deformity to superior C2 facet
    - >20º lateral inclination (tilt) C1c/w C2 Ishii J Neurosurg Spine 2006;5:385-391

C1-C2 Rotary ***Fixation***

- Unable to *voluntarily* turn across midline
- Usually post-URI
    - Rarely traumatic



Courtesy O. Clark West, MD



C1-C2 rotary fixation

Adapted from Kuhns

CCJ Instability Summary
Potentially "unstable" injuries

- Atlanto-Occipital Distraction (AOD)
- Occipital condyle fracture, type 3 (AOD component)
- Atlanto-axial dislocation (transverse ligament)
- Odontoid fractures
  - Type 1 (AOD component)
  - Type 2 (especially displaced)
- Hangman's grades 2, 2a and 3 (flexion-extension)

Question #1:

- Which of the following statements is ***<u>FALSE</u>***?

1. C2 fractures are among the most common fractures of the cervical spine
2. C2 fractures are among the most commonly missed fractures in the cervical spine
3. Spine fractures are more likely to be missed in obtunded patients
4. <u>Occipital condyle fractures are rare</u>

Question #2

- Which of the following statements is ***FALSE***?

1. CCJ distraction injuries include AOD, type 3 occipital condyle fractures, & type 1 dens fractures.
2. “Unstable” Jefferson fractures typically sustain osteoperiosteal disruption of the transverse atlantal ligament.
3. **Intrasubstance disruptions of the transverse atlantal ligament lead to delayed healing with stability in over 90% of patients.**
4. 50% displaced segmental fractures of the anterior arch of C1 are typically biomechanically unstable.

Question #3

- Which of the following statements is ***FALSE***?

1. The key to assessing biomechanical stability of Hangman fractures is the integrity of the C2-C3 disc space.
2. **The biomechanically stable type I Hangman's fracture is the most common variant and is rarely misdiagnosed.**
3. With the possible exception of atypical Hangman fractures, all Hangman fractures show bilateral traumatic spondylolysis.
4. Concomitant CCJ fractures occur in 30-40% of patients sustaining high-energy Hangman type fractures.

Question #4

- Which of the following statements is ***FALSE***?

1. The normal range of C1–C2 rotation includes rotational deformities seen in C1–C2 rotary fixation.
2. **Torticollis, C1–C2 rotary subluxation, C1–C2 fixation, & Grisel's Syndrome are synonyms.**
3. C1–C2 rotary fixation is rarely due to blunt-force trauma.
4. Torticollis, C1–C2 rotary subluxation, & C1–C2 fixation are typically treated "conservatively" & very rarely require surgical correction.

Question #5

- Which of the following statements is ***FALSE***?

1. In the acute setting, clinical instability is present if a patient has sustained an acute radiculopathy or myelopathy due to blunt-force trauma, regardless of imaging findings.
2. It is common for injuries causing acute neurologic debility to be mechanically stable.
3. Patients sustaining SCIWORA are typically biomechanically stable.
4. Vertebral column injuries that predispose to late deformity and pain are considered clinical unstable, despite absence of neurologic disability.

Learning Objectives
Hopefully, you have refreshed your familiarity with

1. What's common & what's commonly missed, and what you can do about it.
2. How stability (clinical instability) is defined.
3. What imaging findings are used to assess stability; & what injuries are typically stable *vs.* unstable.


And, now here's Clark!
FRED'S
FRESH
BEER
FRED
Thank-you

O. Clark West, MD FACR
Professor and Vice Chair
The University of Texas Medical School at Houston

SPINAL INJURIES: STABLE OR UNSTABLE? YOU MAKE THE CALL LOWER CERVICAL REGION

Learning Objectives

1. Analyze MDCT of lower cervical spine employing an efficient, systematic pattern.
2. Learn soft tissue signs of disc and ligament injury that may be detectable by MDCT.
3. Classify lower cervical spine injuries into morphological patterns useful for prognosis and therapy.

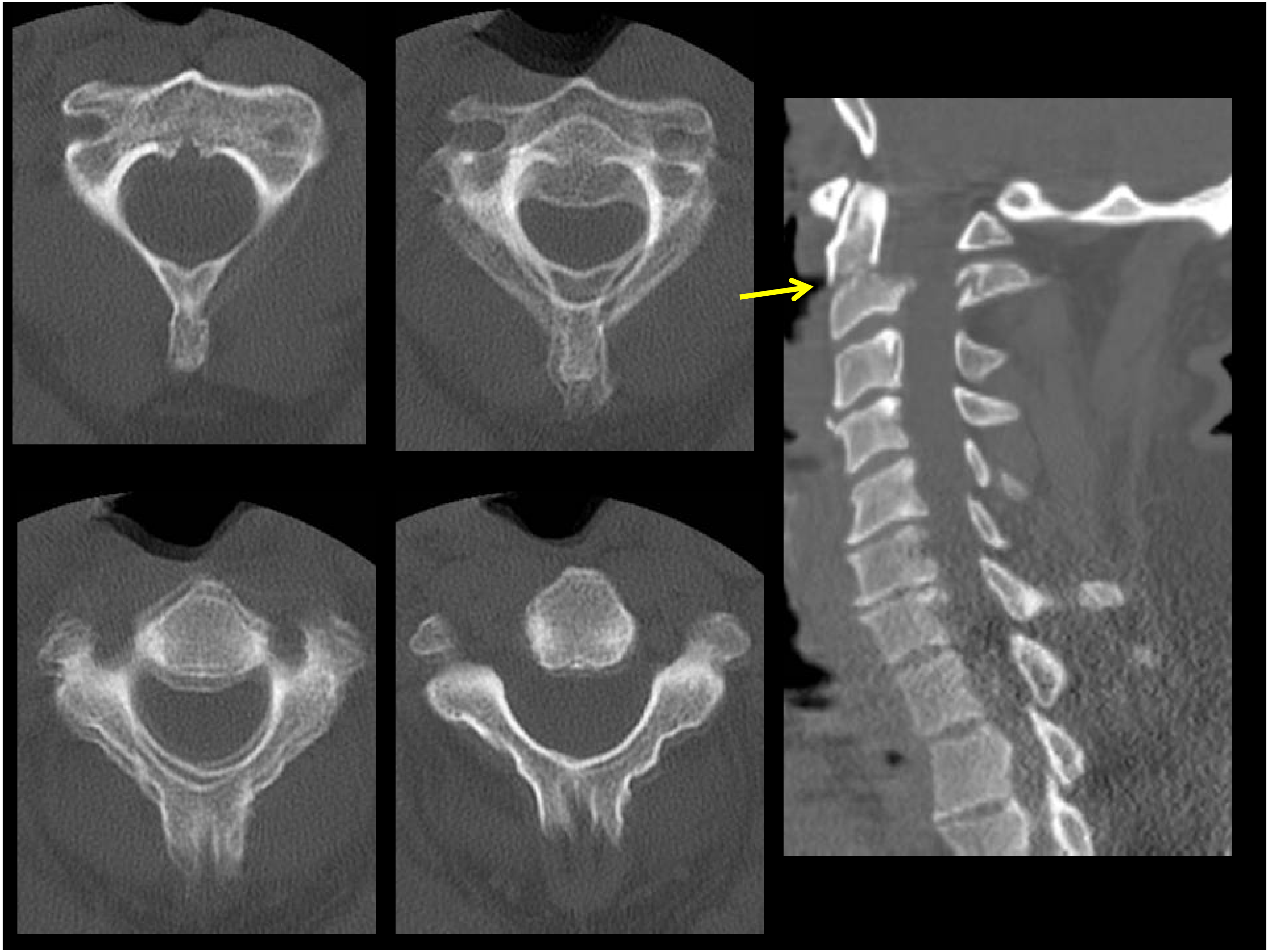
2 mm bone and soft algorithm

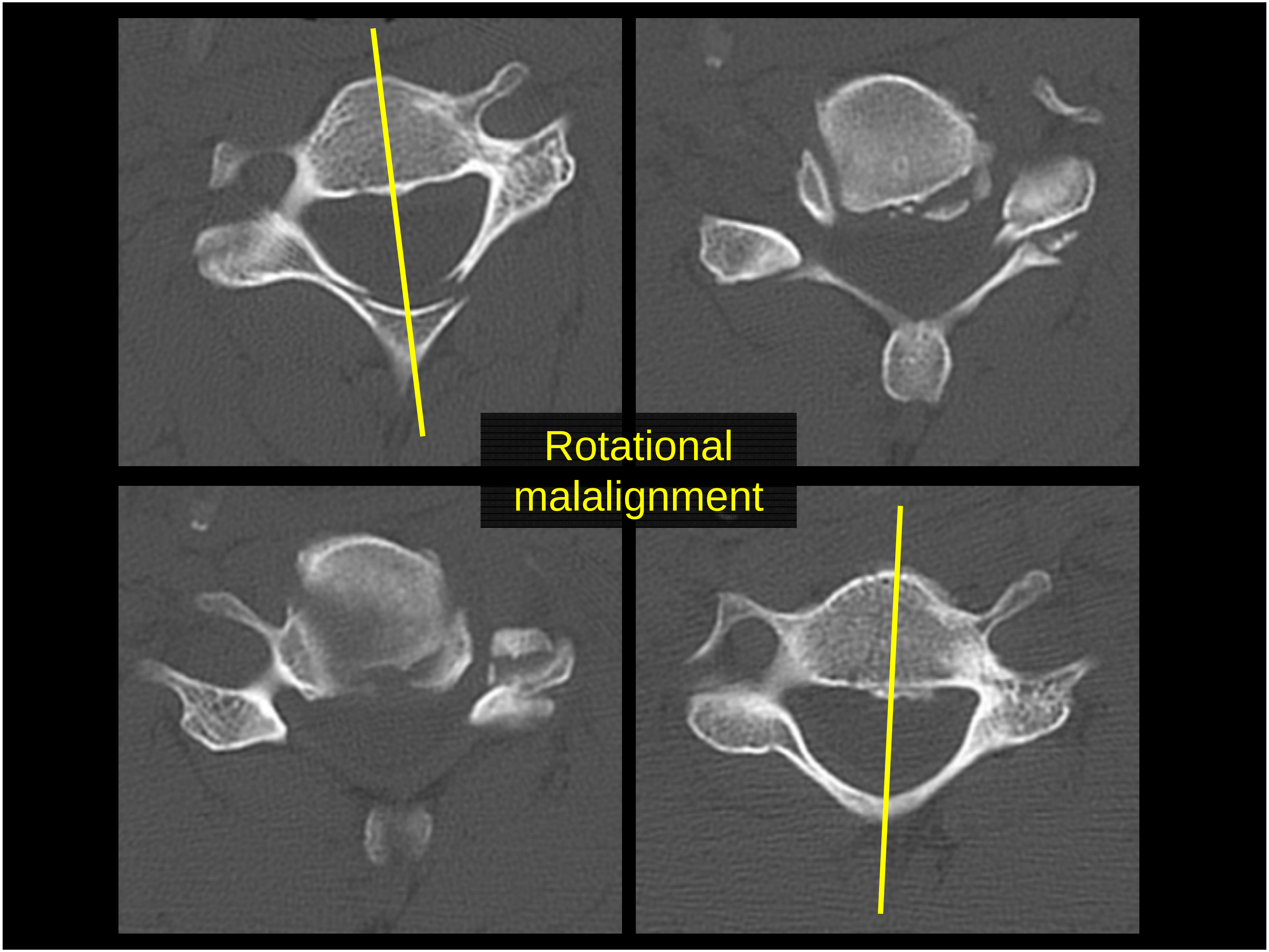
transverse, sagittal, coronal

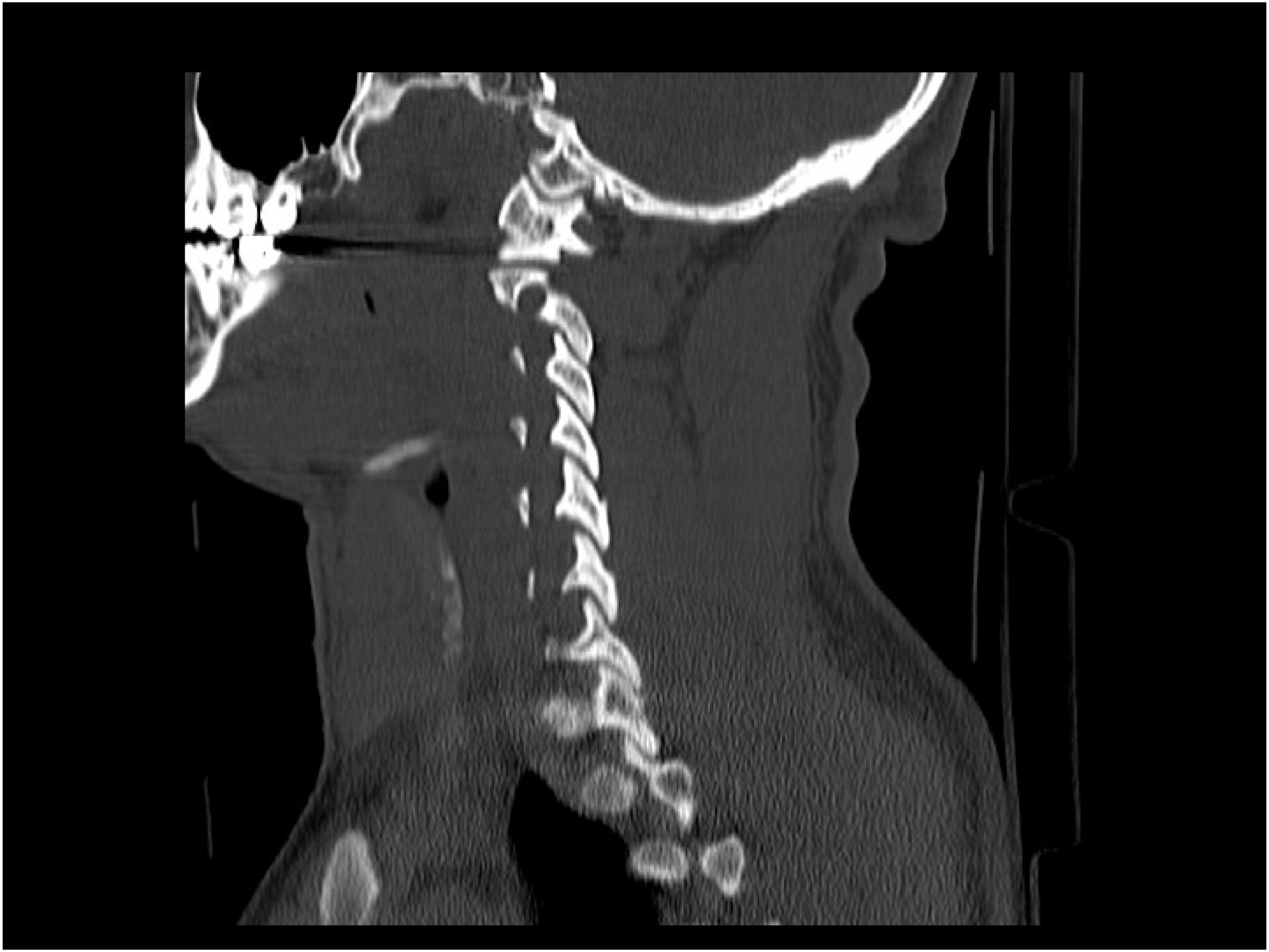
KEY IMAGES
approach to a 400 image cervical spine MDCT

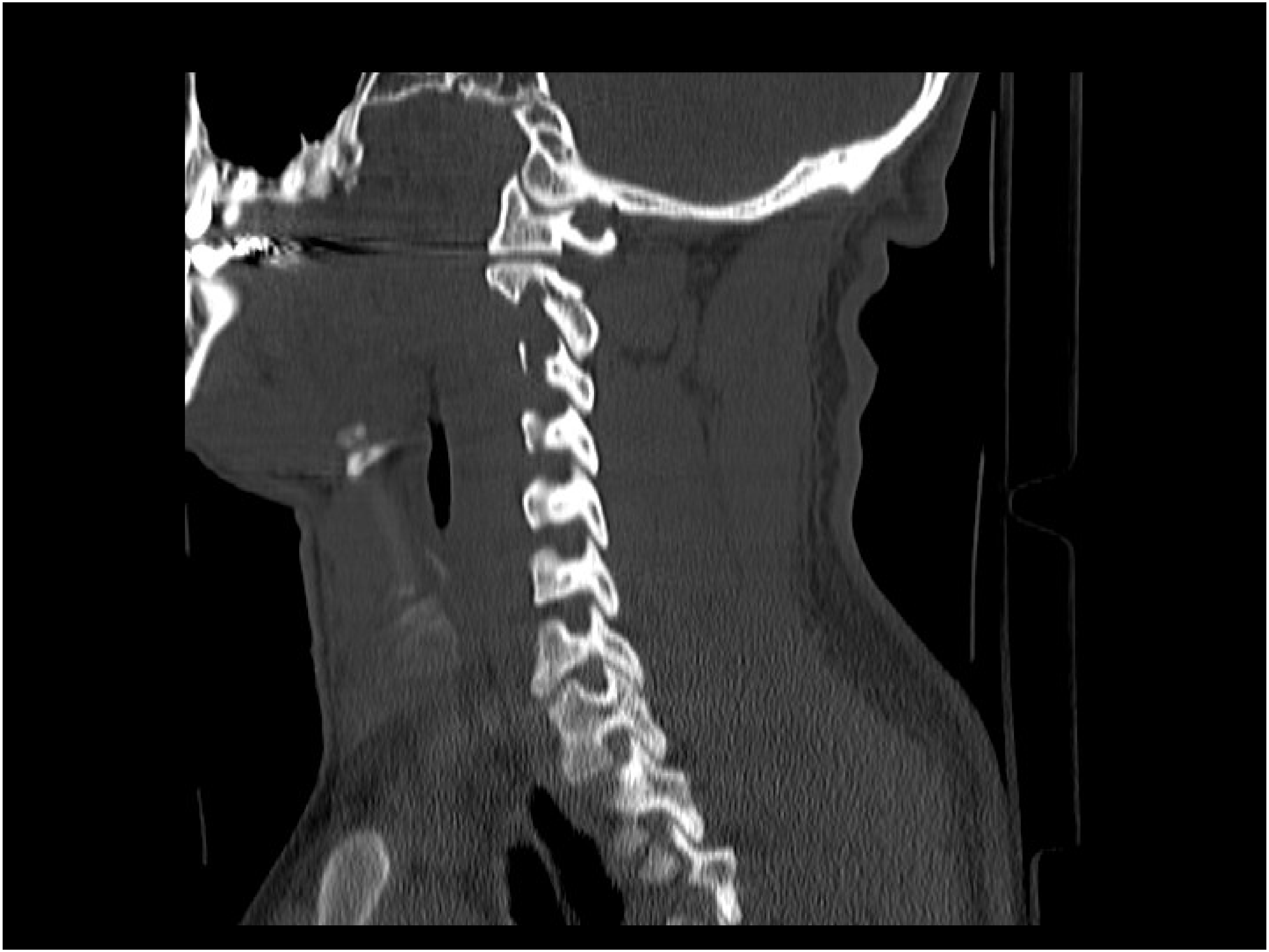
Analyze using efficient, systematic pattern

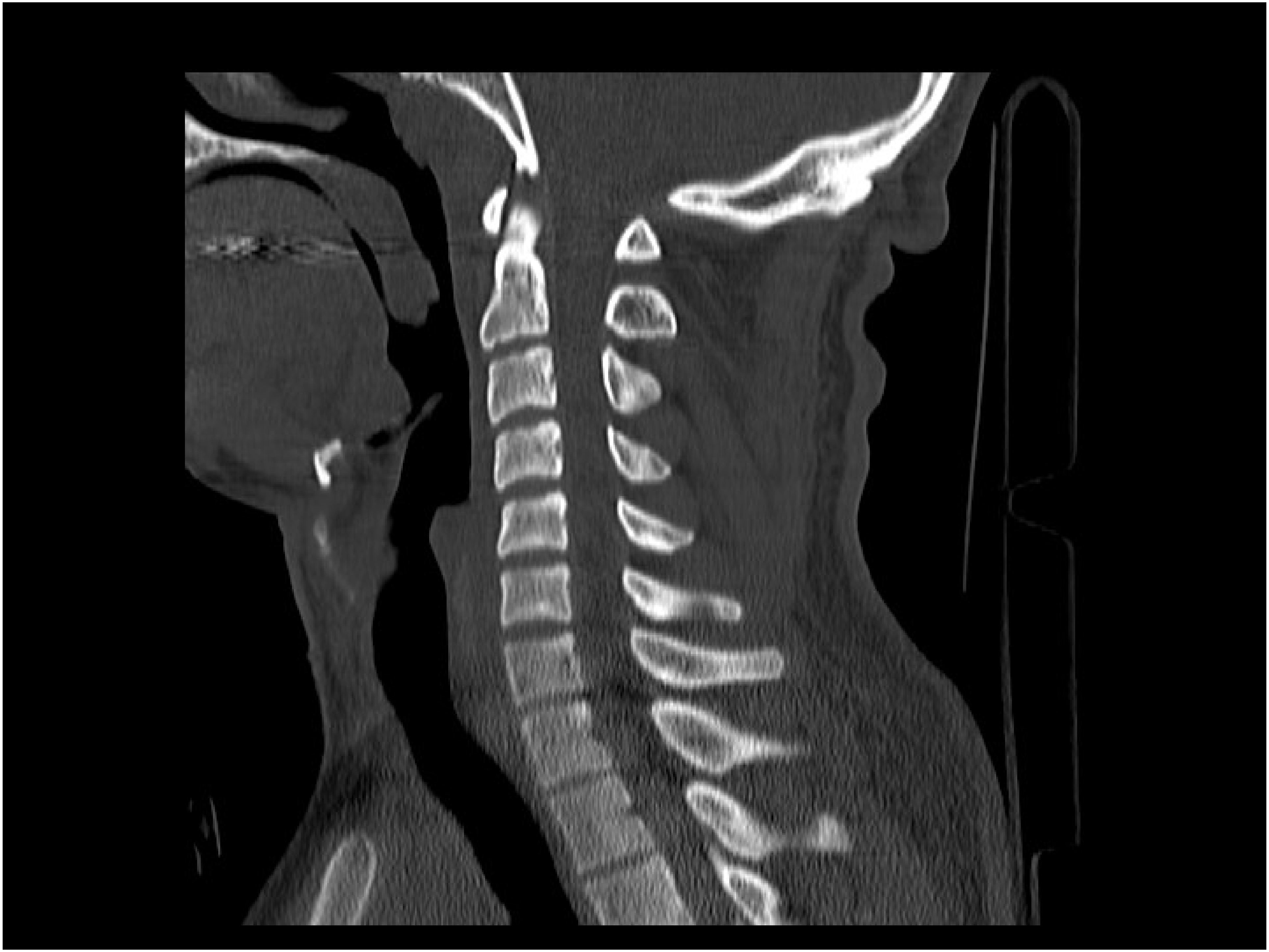
1. Assess for adequate coverage
2. Assess for artifacts and major injuries (transverse)
3. Count the vertebrae (transverse + sagittal)
4. Analyze cranio-cervical region in 3 planes
5. Analyze lower cervical spine on sagittal images with reference to transverse and coronal

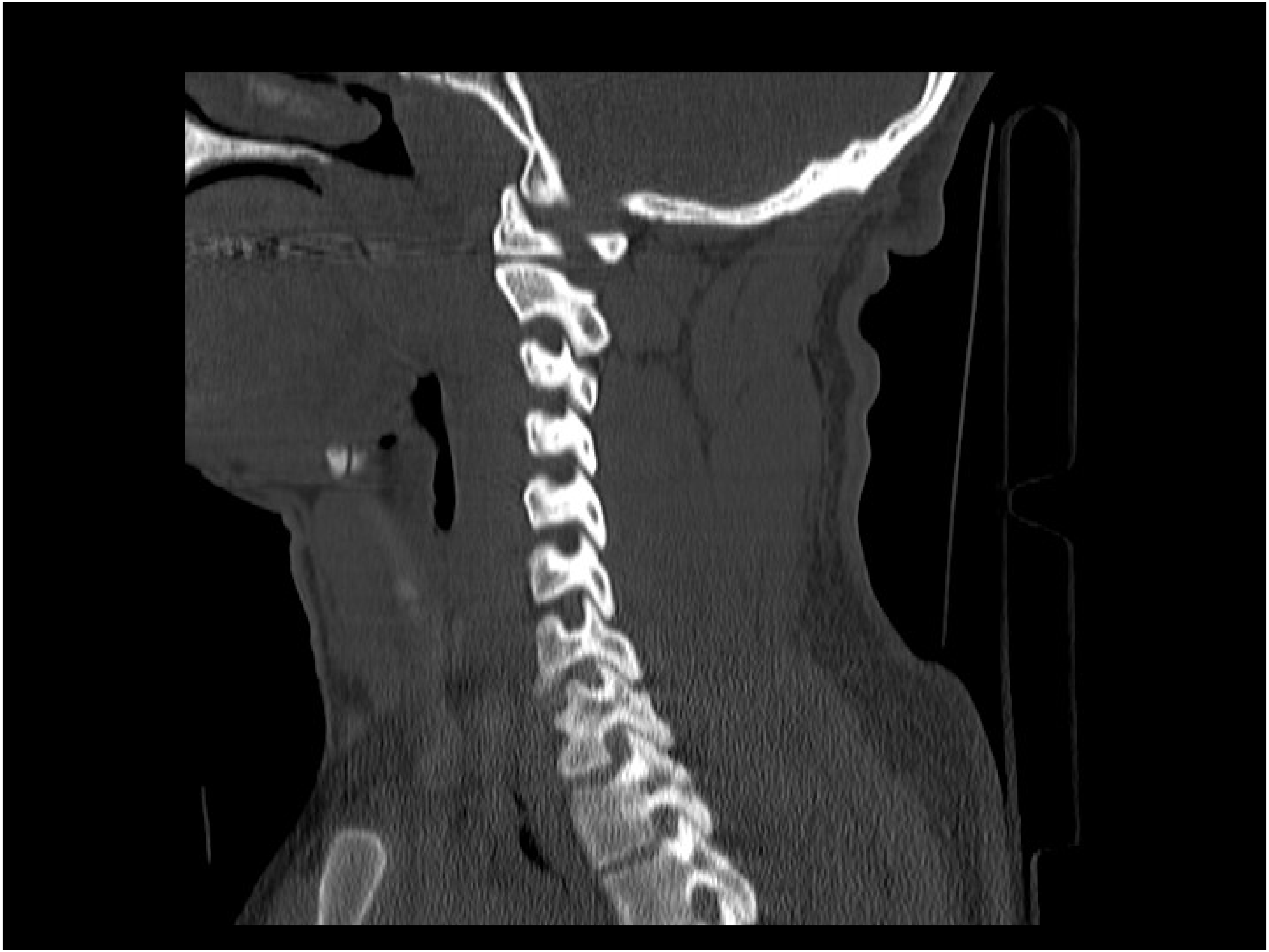


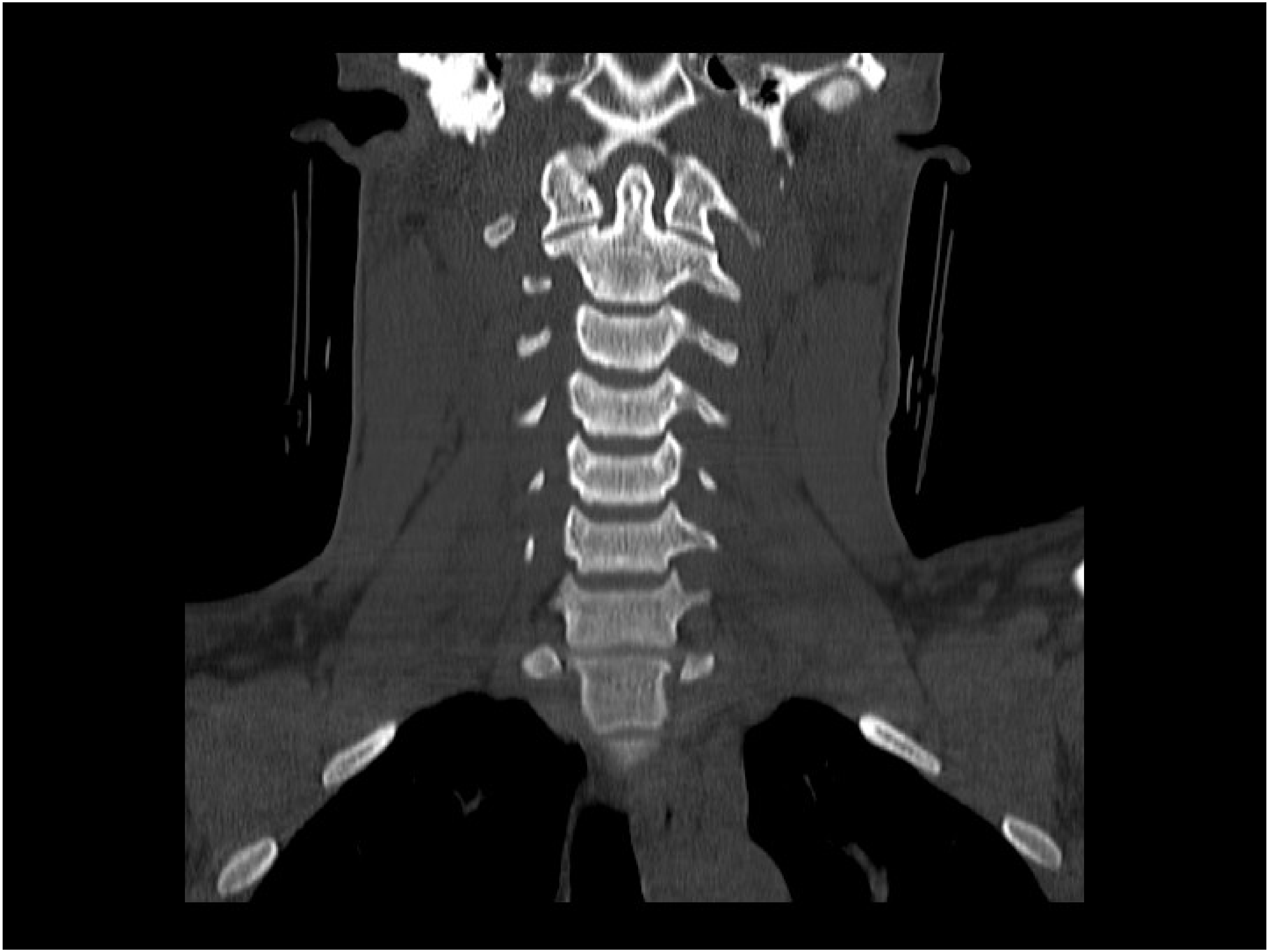

Rotational
malalignment

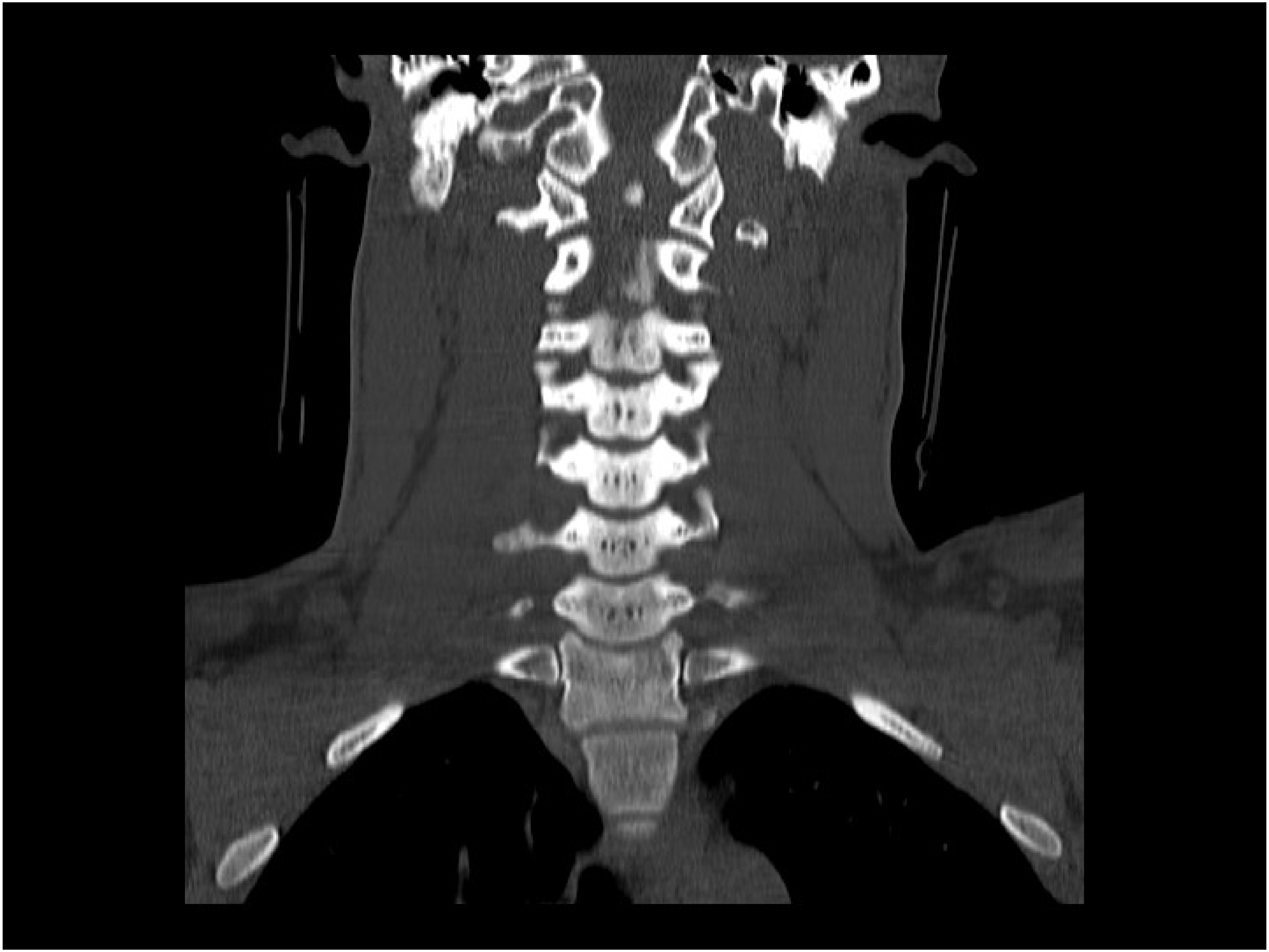


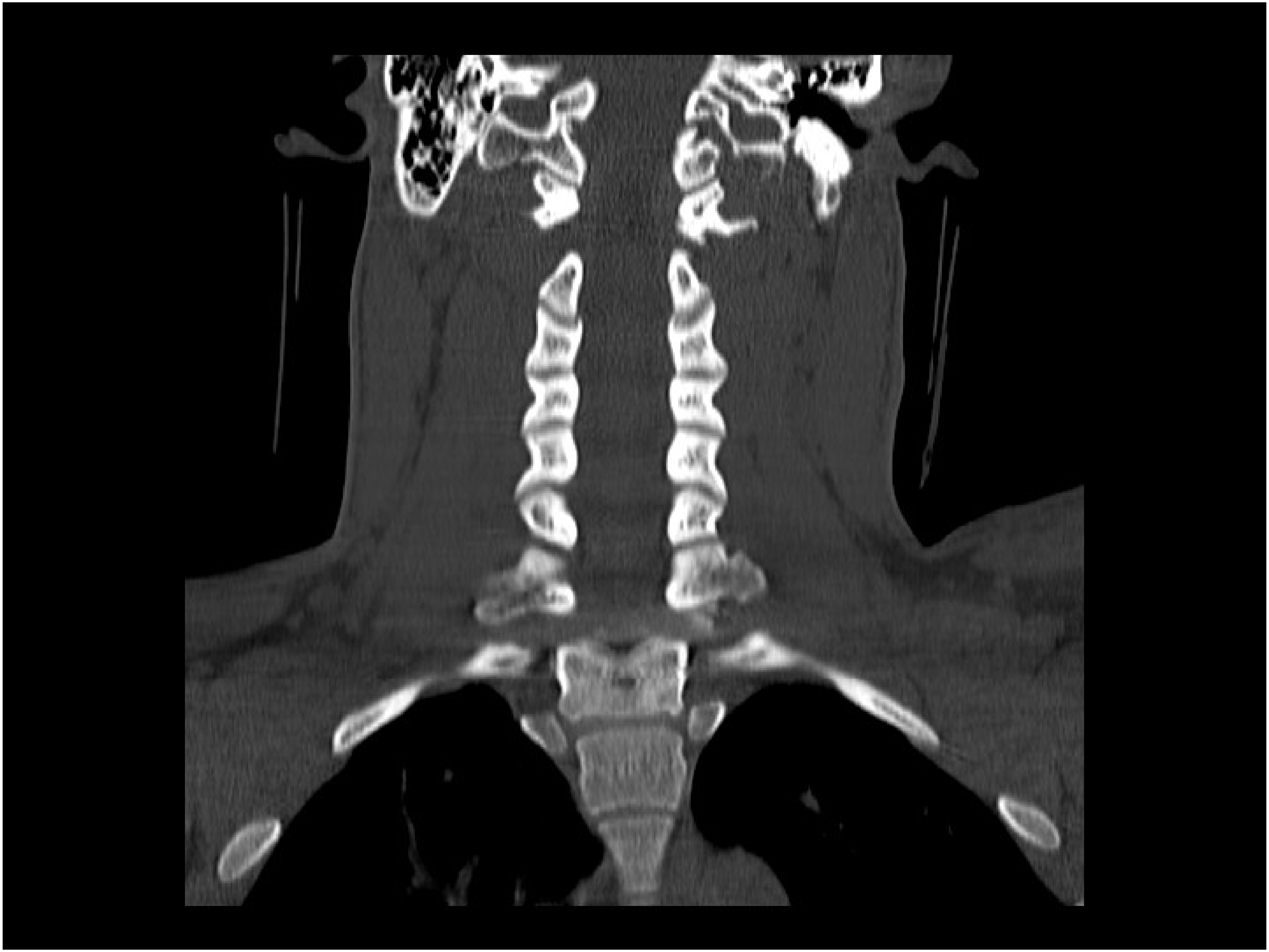


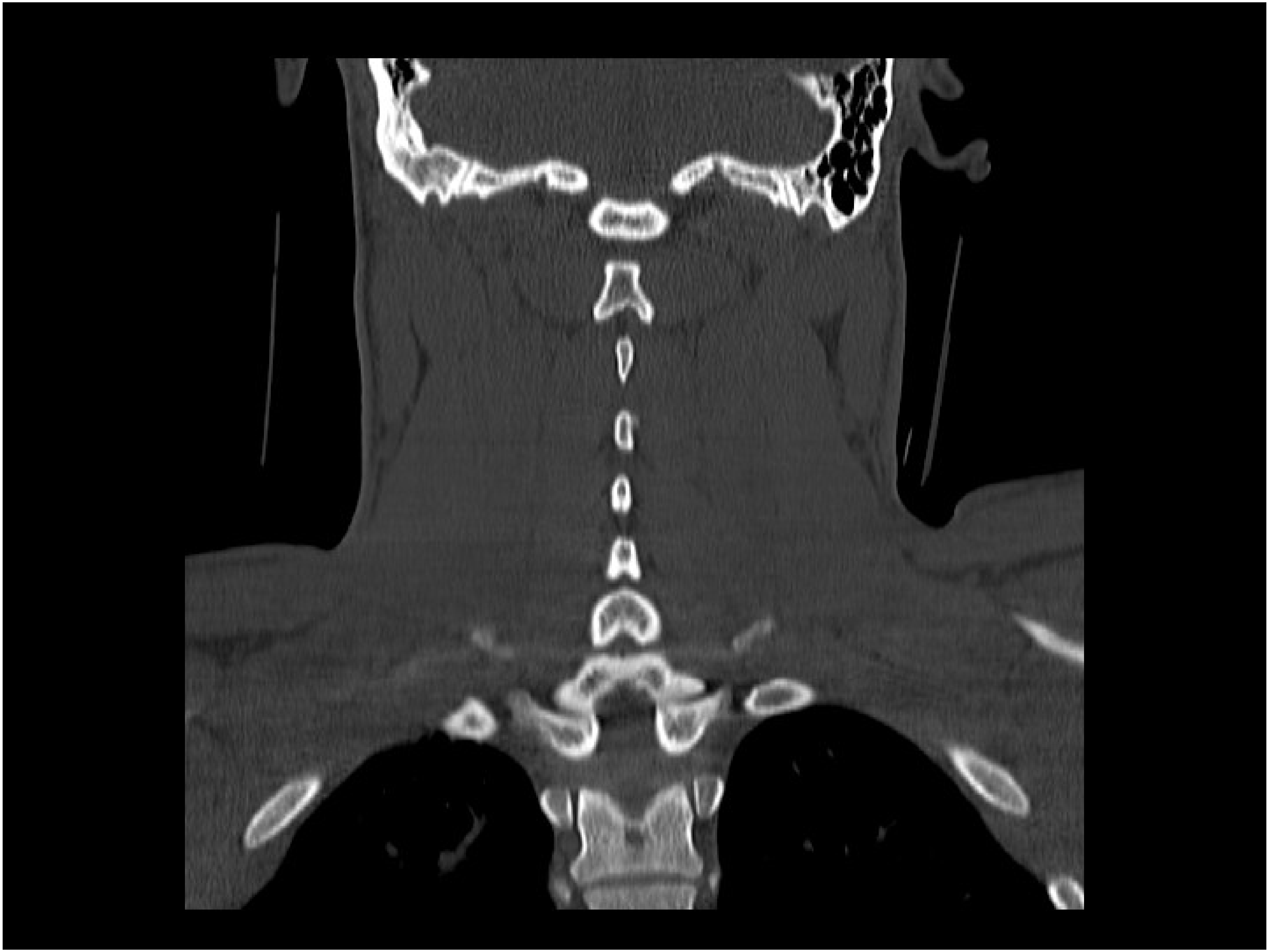


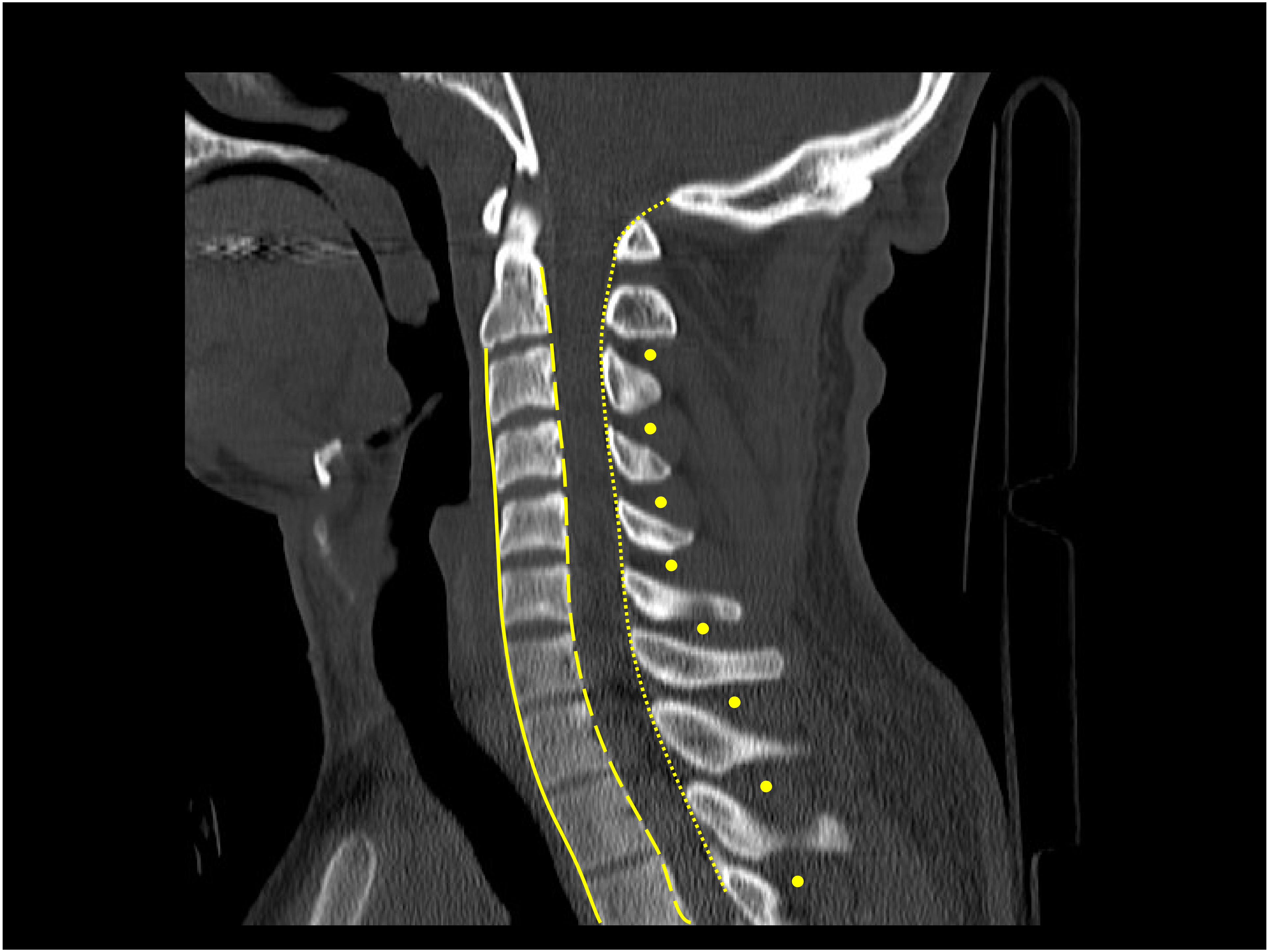


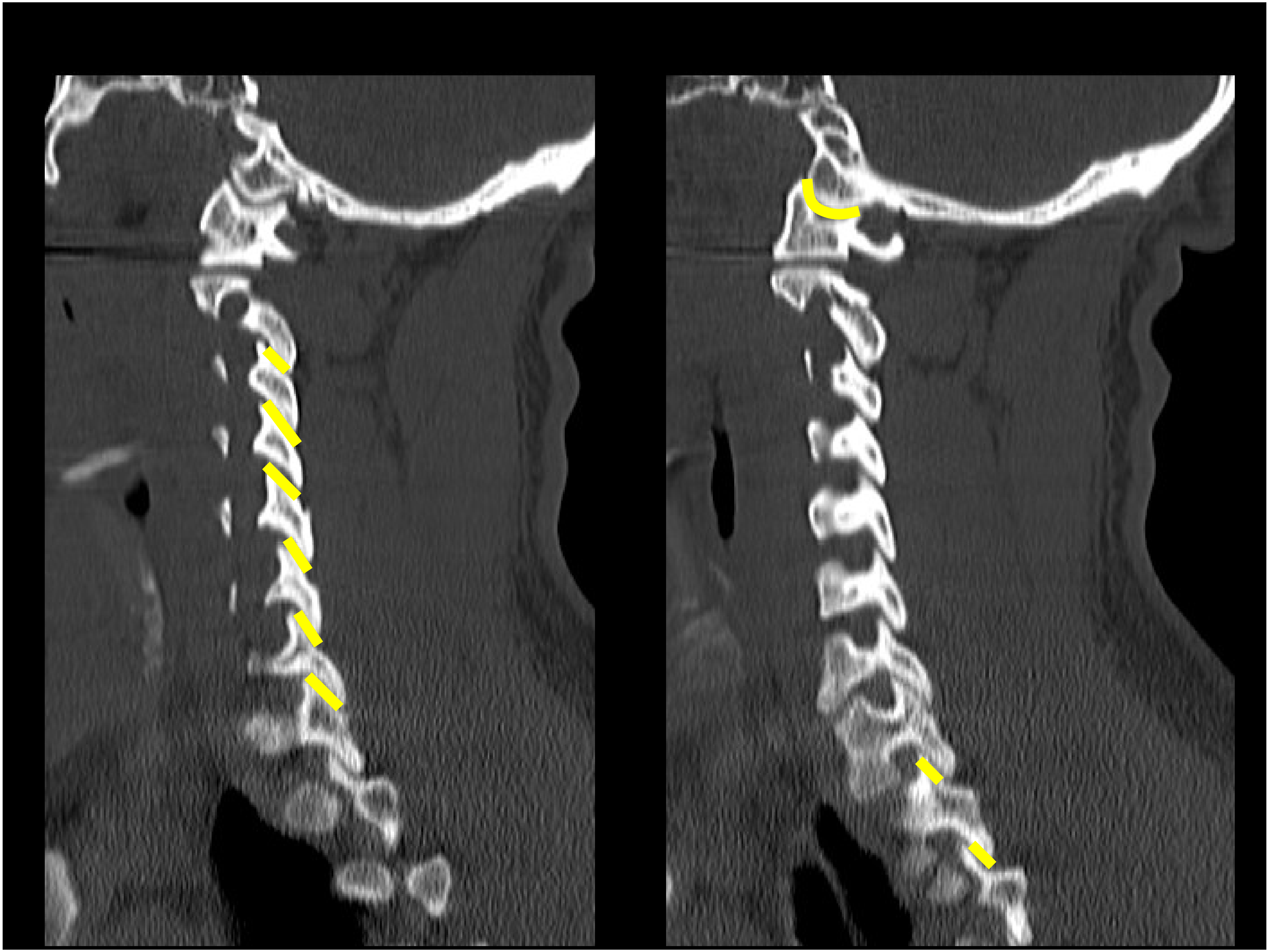










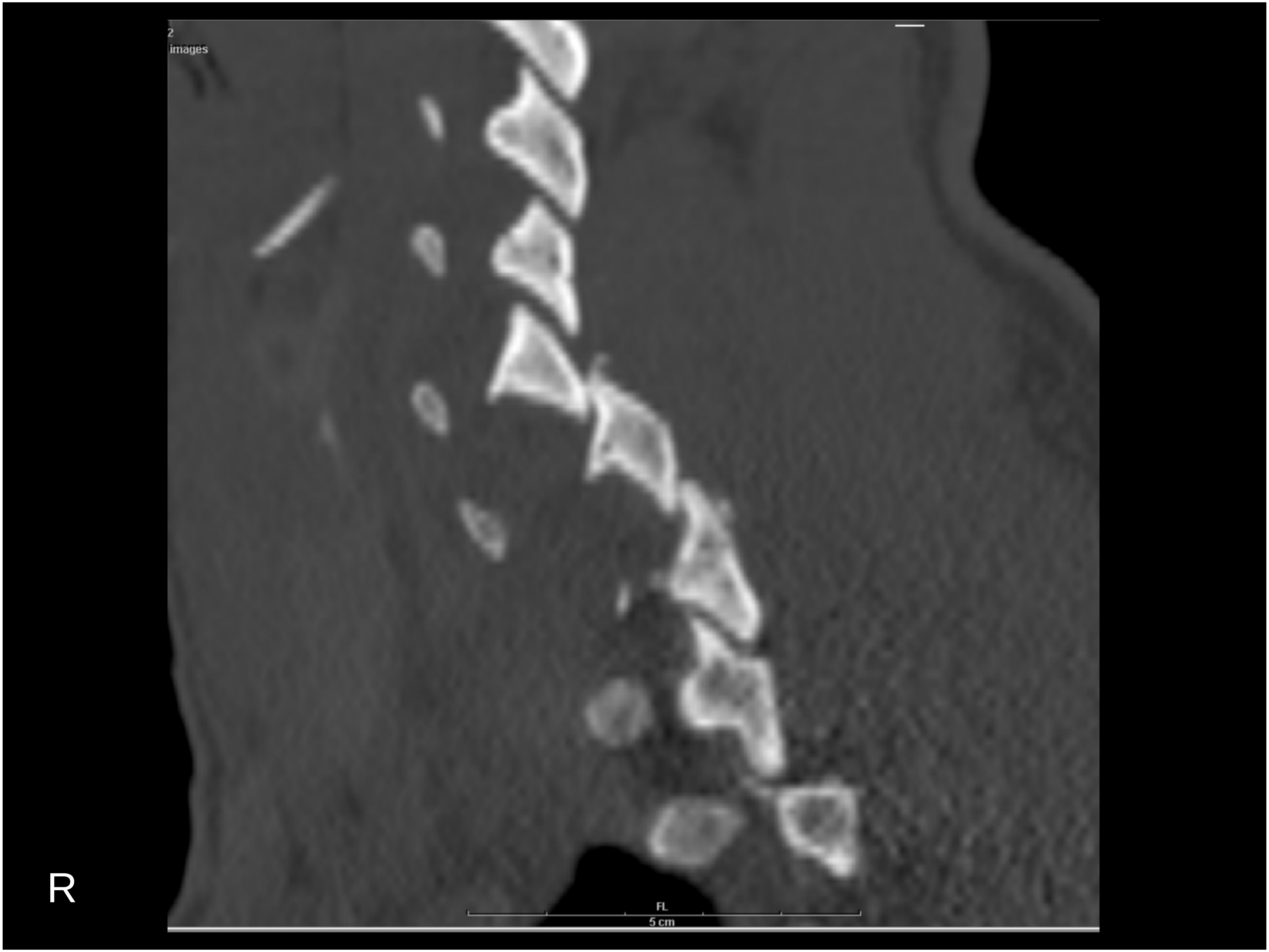


Summary: Sagittal images

- Mid sagittal alignment
  - Anterior translation
  - Kyphosis
- Disc space widening
- Vertebral bodies for compression fracture
- Interspinous or interlaminar widening
- Facet joints for fracture or subluxation
- Spinous process for missed fracture

Analysis of injuries


MID
5 cm


2
images
FL
5 cm
R

Mid


2
images
FL
5 cm
L

2
images
FL
5 cm
L

Stable or unstable?

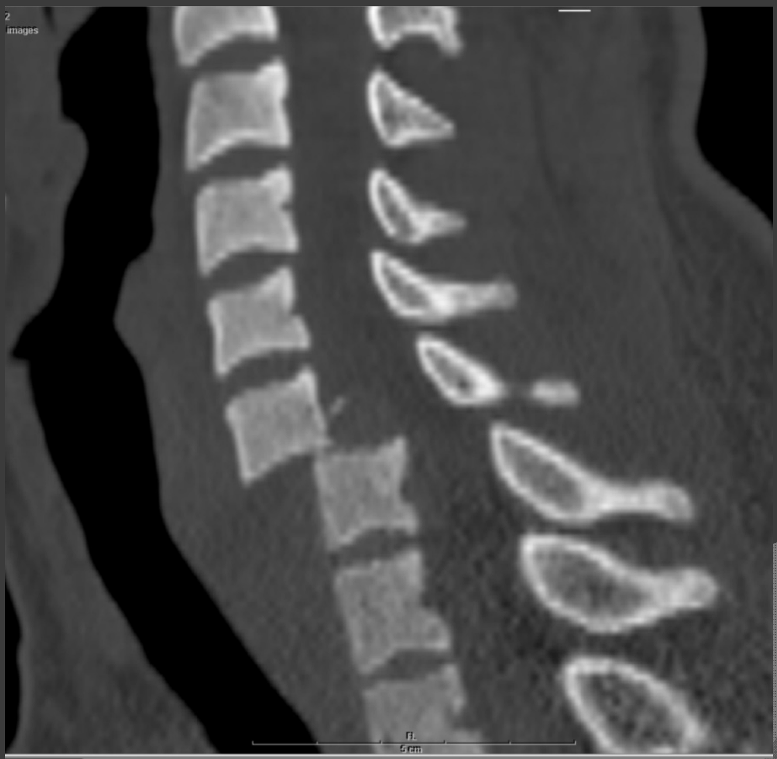
1. Stable
2. Unstable
3. Uncertain

Stable or unstable?

1. Stable
2. Unstable
3. Uncertain

Which injury morphology from the SLIC system BEST describes this injury?

1. Compression
2. Distraction
3. Translation/Rotation
4. Never heard of the SLIC system



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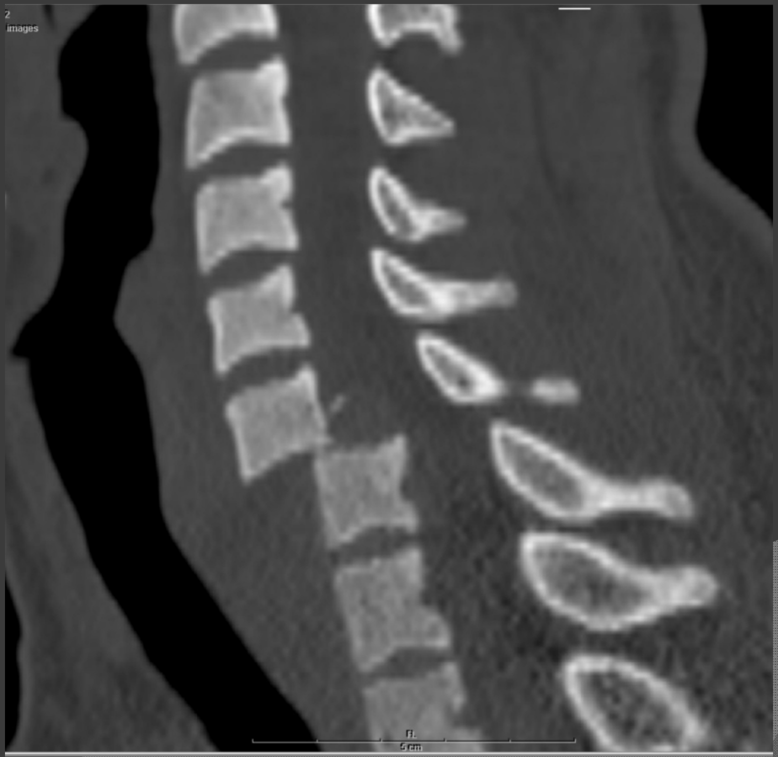
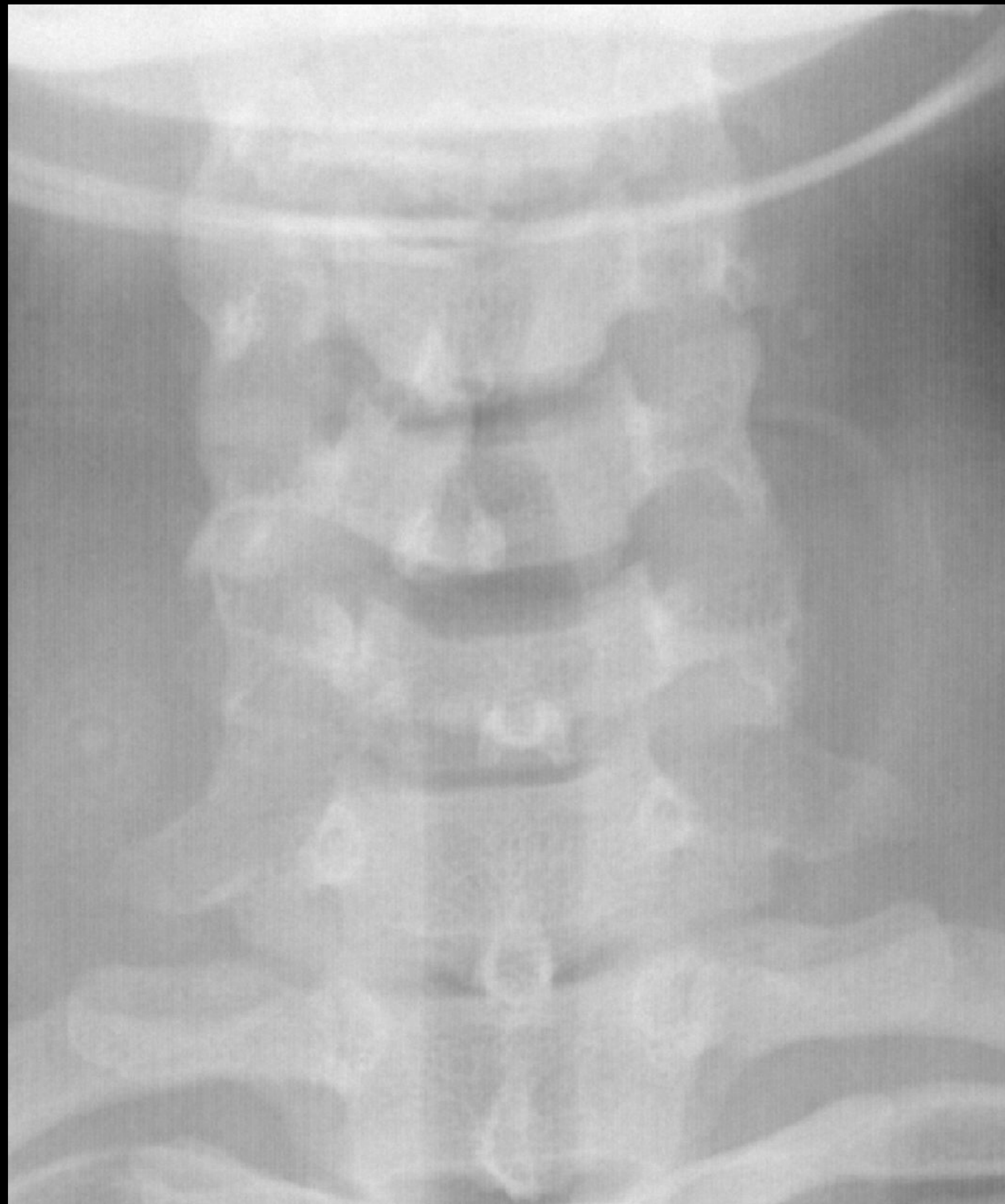
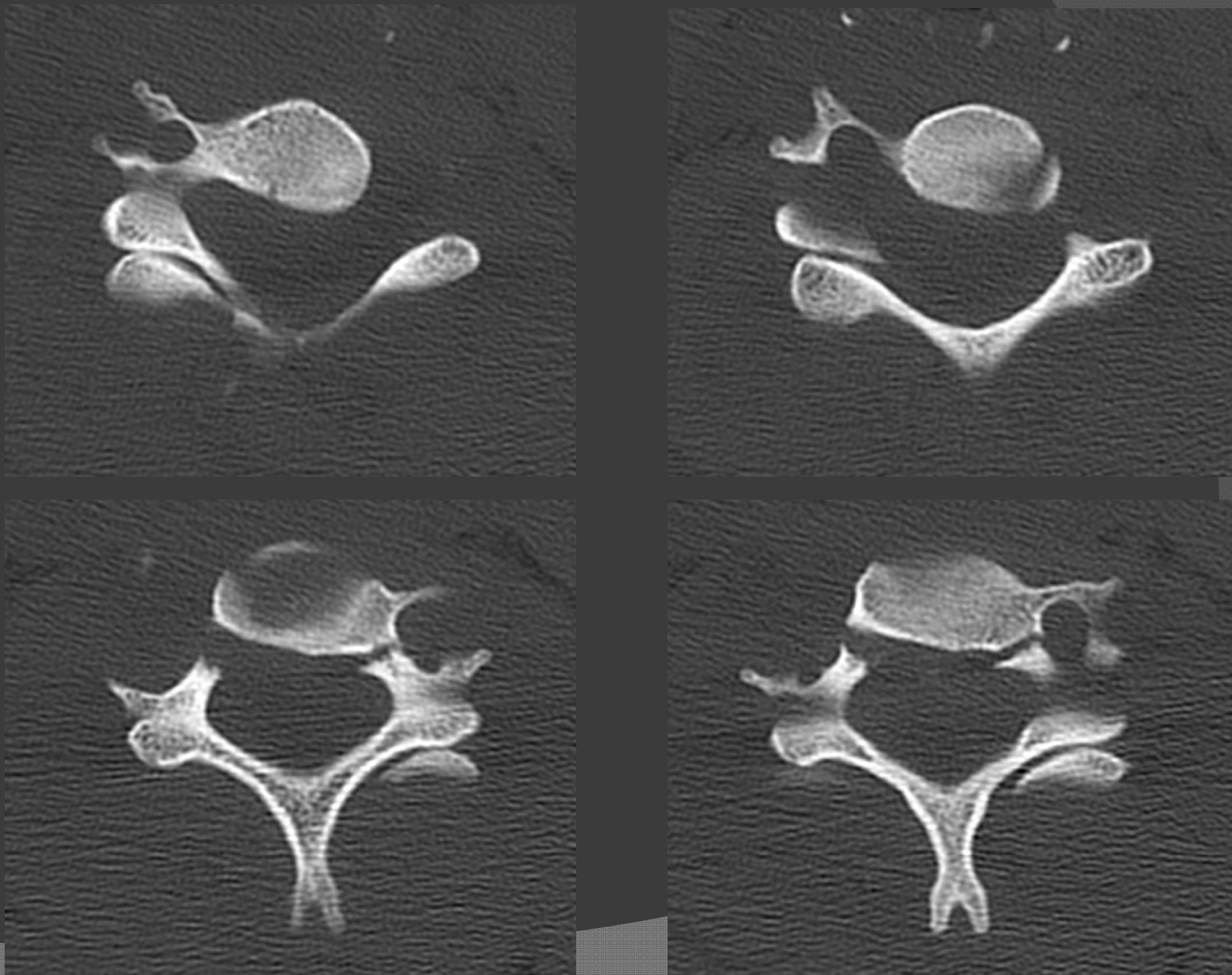
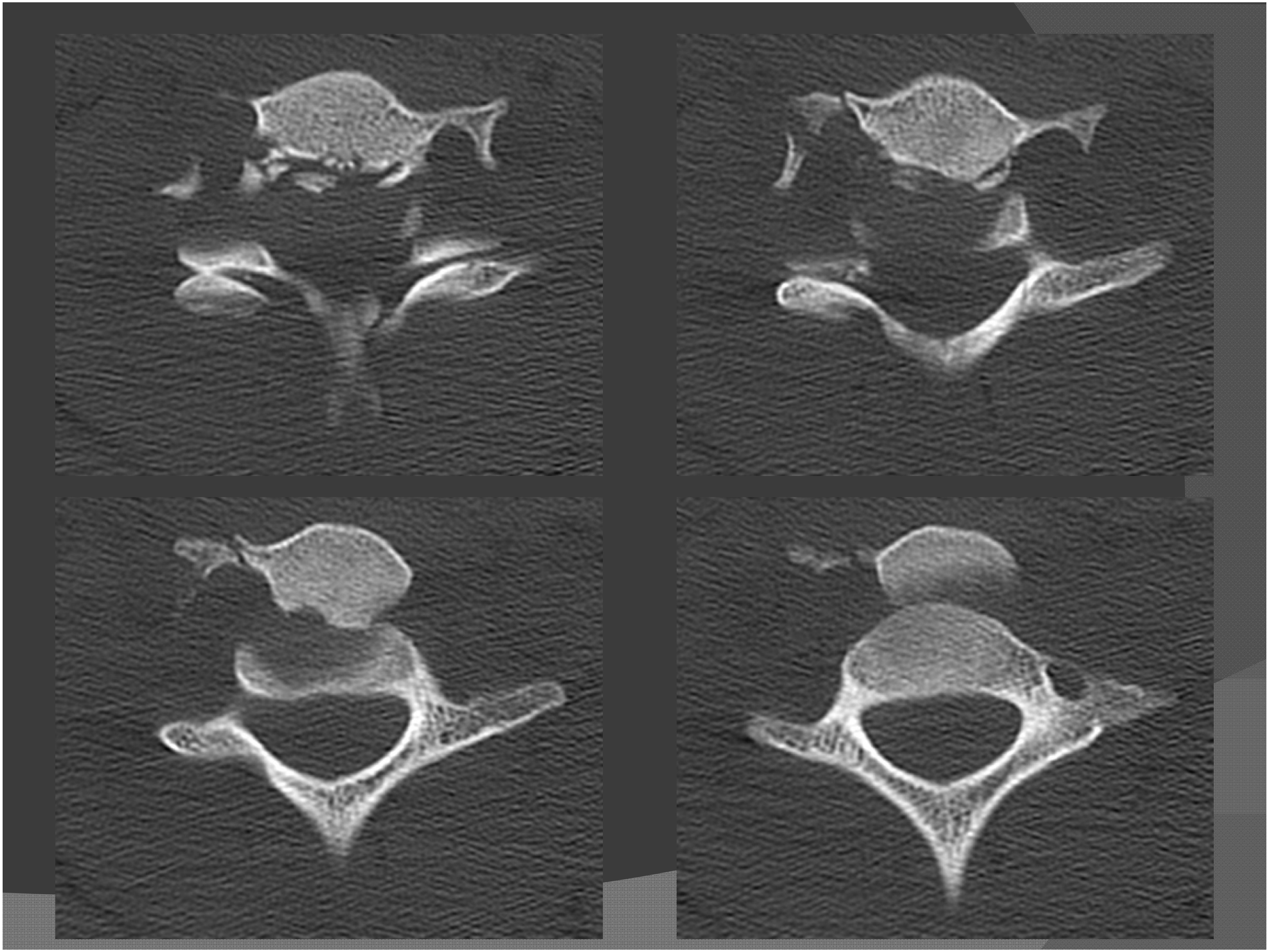






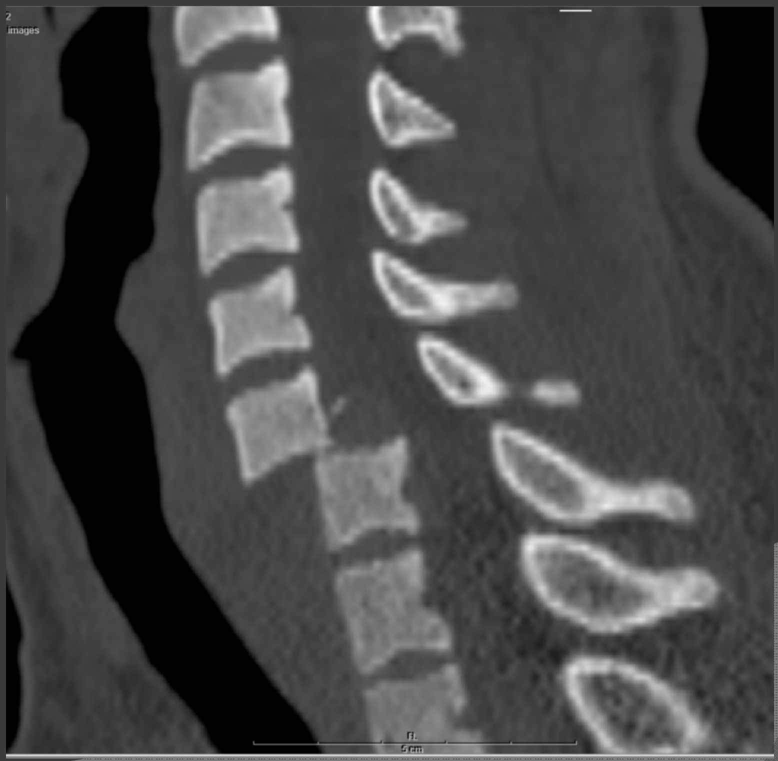


Translation/Rotation

- Radiographic evidence of horizontal displacement of 1 part of the subaxial cervical spine with respect to the other
- Any visible translation unrelated to degenerative causes is considered a translation morphology
- Typified by unilateral and bilateral facet fracture-dislocations
- Fracture separation of the lateral mass (“floating” lateral mass, pedico-laminar fracture)
- Bilateral pedicle fractures

Which injury morphology from the SLIC system BEST describes this injury?

1. Compression
2. Distraction
3. Translation/Rotation
4. Never heard of the SLIC system



The Subaxial Cervical Spine Injury Classification System (SLIC)

SPINE Volume 32, Number 21, pp 2365–2374

The Subaxial Cervical Spine Injury Classification System

A Novel Approach to Recognize the Importance of Morphology, Neurology, and Integrity of the Disco-Ligamentous Complex

Alexander R. Vaccaro, MD,* R. John Hulbert, MD,† Alpesh A. Patel, MD,‡
Charles Fisher, MD,§ Marcel Dvorak, MD,§ Ronald A. Lehman, Jr., MD,||
Paul Anderson, MD,¶ James Harrop, MD,* F. C. Oner, MD, PhD,# Paul Arnold, MD,**
Michael Fehlings, MD, PhD, MD,†† Rune Hedlund, MD,‡‡ Ignacio Madrazo, MD, DSc,§§
Glenn Rechtine, MD,|||| Bizhan Aarabi, MD,¶¶ Mike Shainline, MS,## and the
Spine Trauma Study Group

Three major injury characteristics

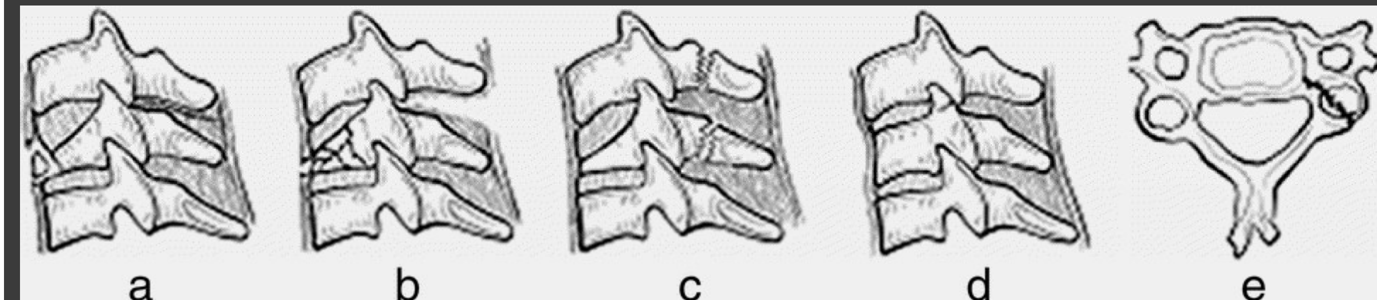
1. Injury morphology as determined by the pattern of spinal column disruption on available imaging studies
2. Integrity of the disco-ligamentous complex (DLC) represented by both anterior and posterior ligamentous structures as well as the intervertebral disc
3. Neurologic status of the patient

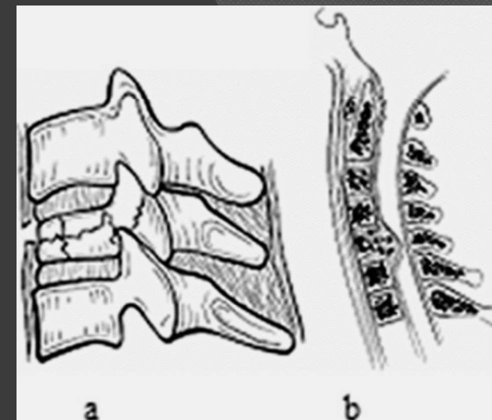
Simplifies injury morphology

- compression injuries
- distraction injuries
- rotational/translational injuries

Burst

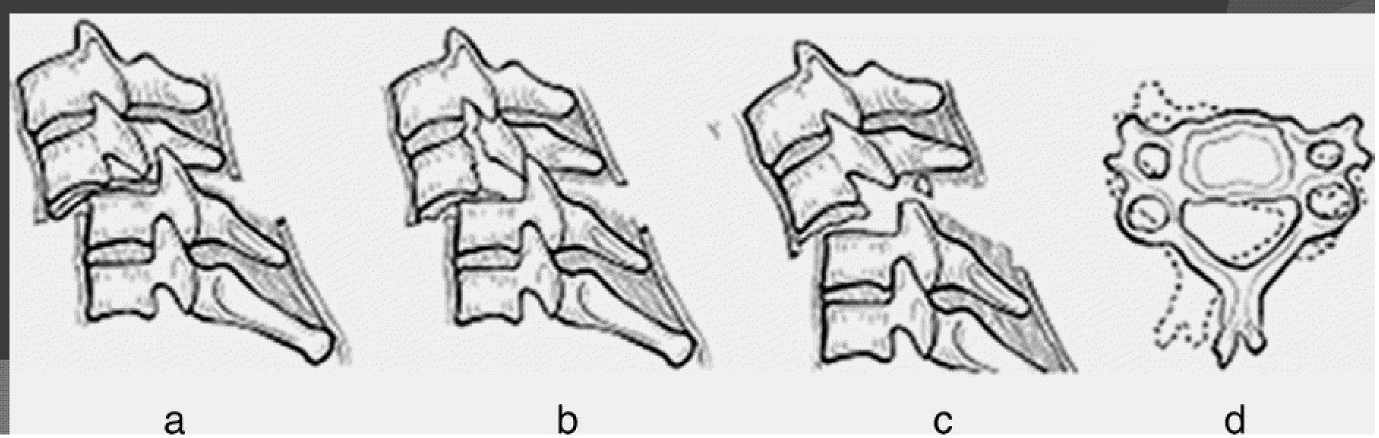
Compression





Distraction

Translation/ Rotation

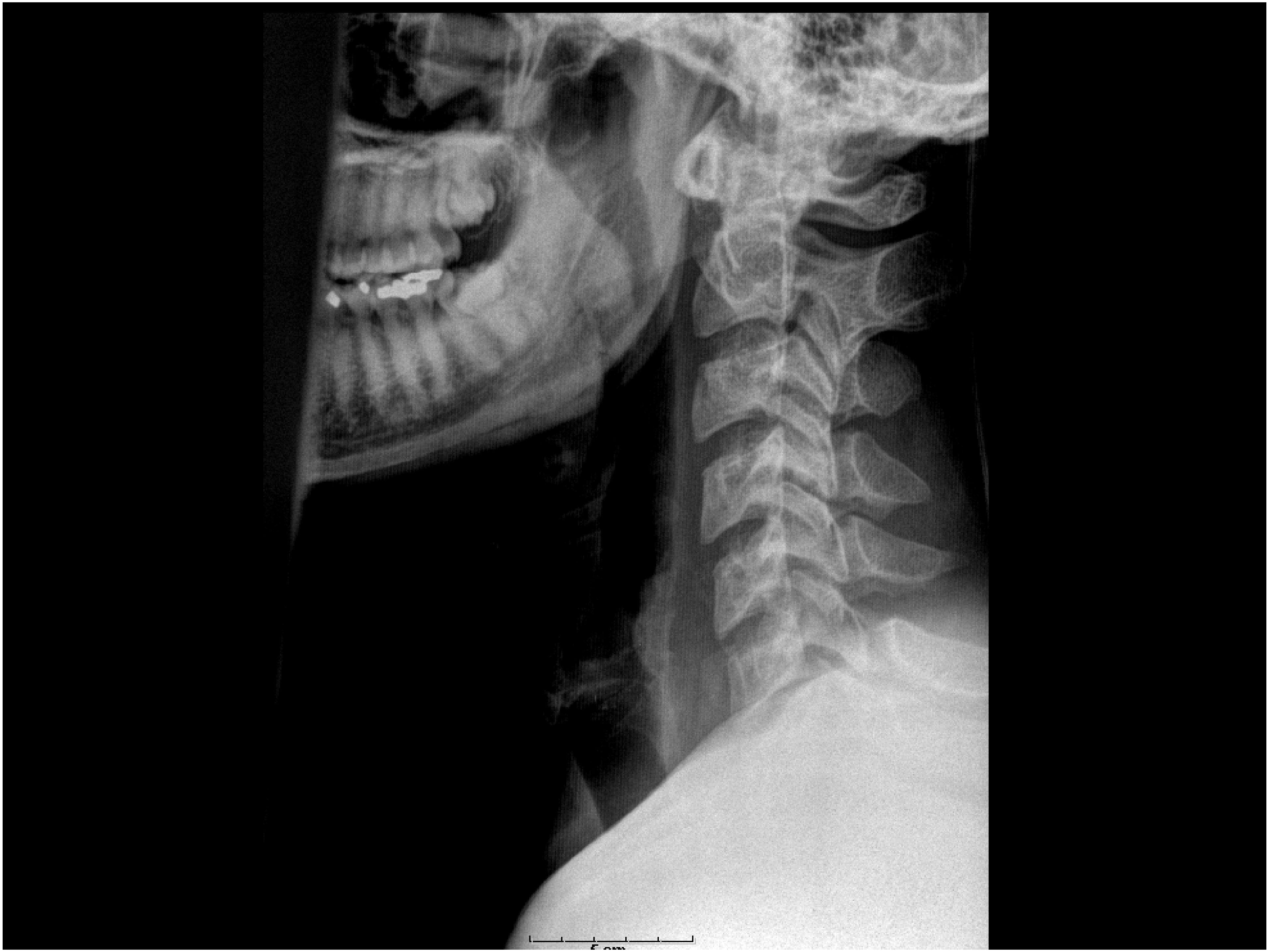


Vaccaro: Spine, Volume 32(21). October 1, 2007. 2365-2374

1. Compression
2. Distraction
3. Translation/Rotation
4. Never heard of the SLIC system

Distraction

- Primarily identified by evidence of anatomic dissociation in the vertical axis
- Most commonly involves ligamentous disruption propagating through the disc space or through the facet joints
- Facet subluxation or dislocation (without fracture and translation or rotation)
- Hyperextension injury disrupting the anterior longitudinal ligament and widening the anterior disc space



Which injury morphology from the SLIC system BEST describes this injury?

1. Compression
2. Distraction
3. Translation/Rotation
4. Still don’t understand the SLIC system

Which injury morphology from the SLIC system BEST describes this injury?

1. Compression
2. Distraction
3. Translation/Rotation
4. Still don't understand the SLIC system

Which injury morphology from the SLIC system BEST describes this injury?

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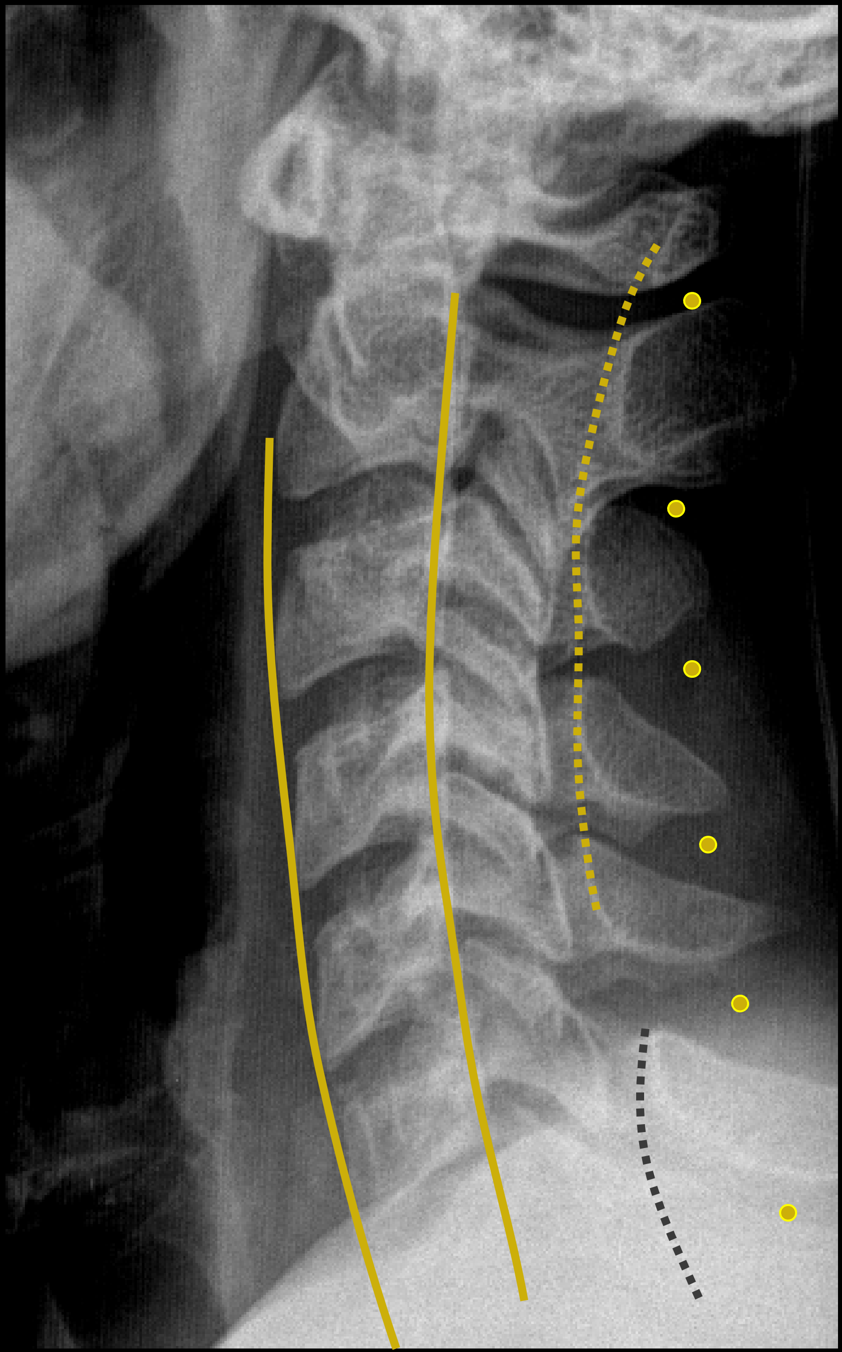
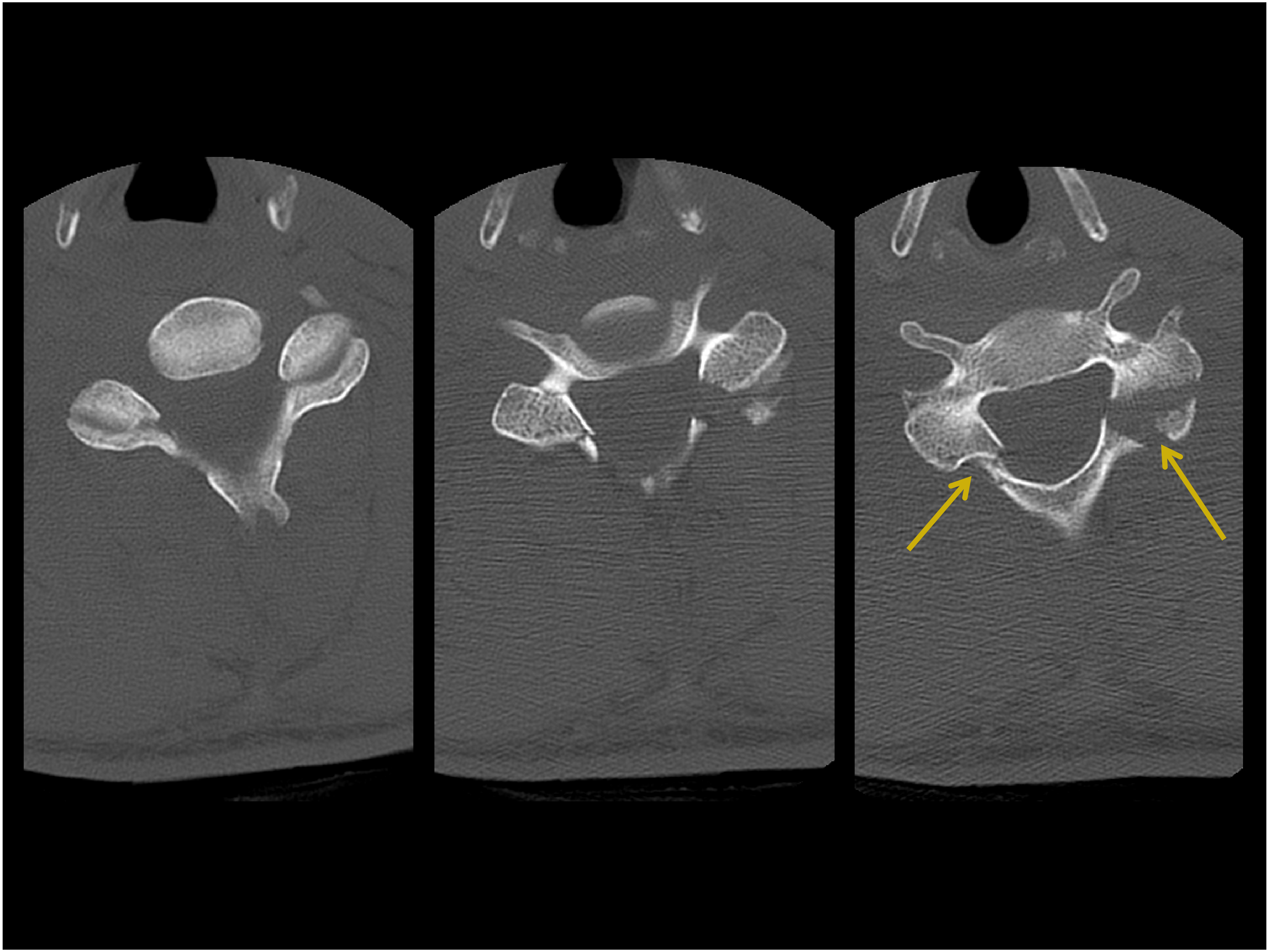
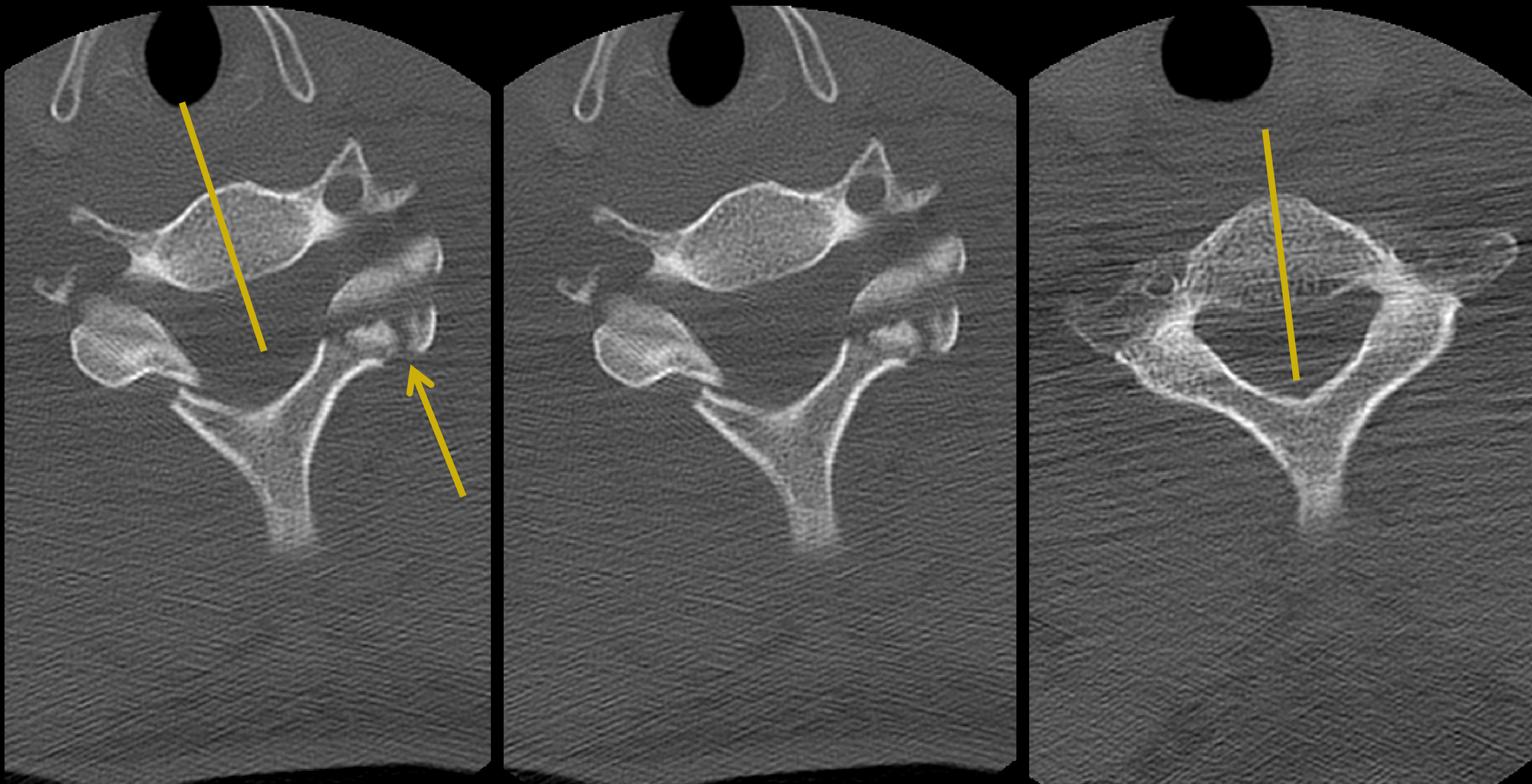
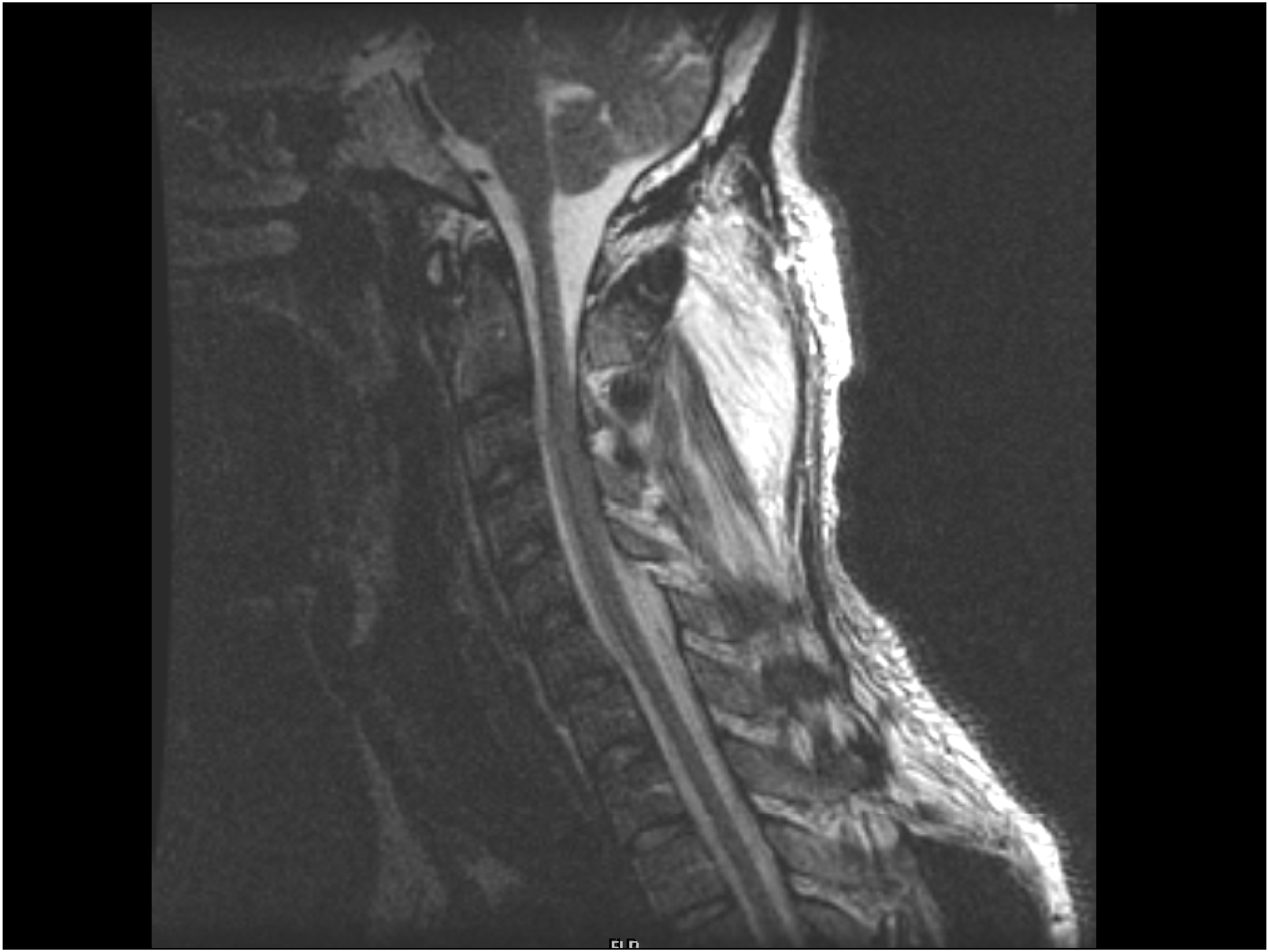


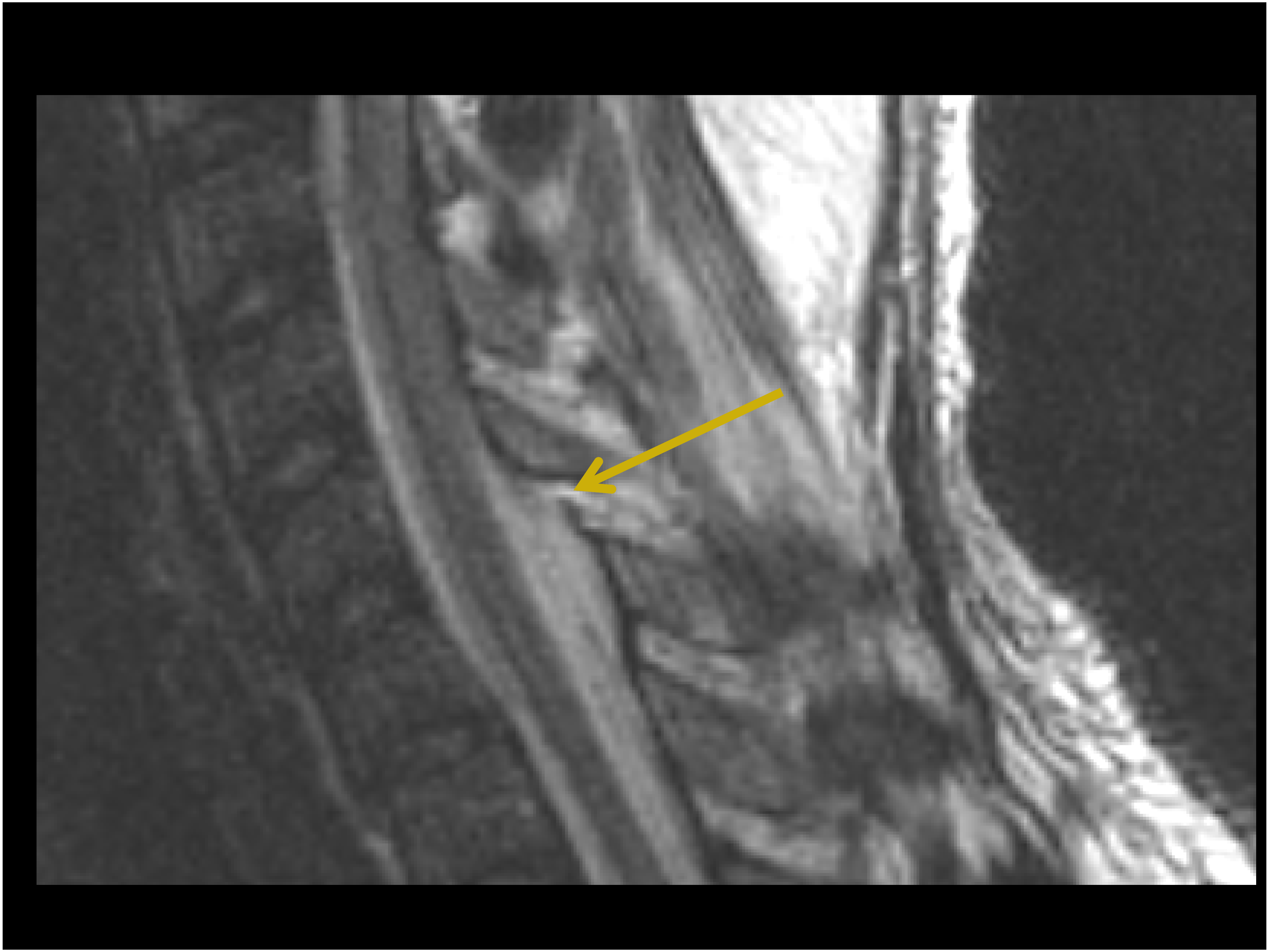




Rotational malalignment on transverse images


FR
FR





Disco-Ligamentous Complex

- Intervertebral disc
- Anterior and posterior longitudinal ligaments
- Ligamentum flavum
- Interspinous and supraspinous ligaments
- Facet capsules

Absolute indicators of DLC disruption

- Abnormal facet alignment (articular apposition 50% or diastasis 2 mm through the facet joint)
- Abnormal widening of the anterior disc space either on neutral or extension radiographs
- Highly suggestive of disc and annulus disruption
  - High signal intensity seen horizontally through a disc involving the nucleus and annulus on a T2 sagittal MRI

Less absolute

- Isolated interspinous widening
  - indicates DLC incompetence only if lateral flexion radiographs demonstrate abnormal facet alignment or a relative angulation of 11° at the involved vertebral interspace
- Hyperintense signal through ligamentous regions on T2-weighted images
  - indeterminate for ligamentous injury

	Points
Morphology	
No abnormality	0
Compression	1
Burst	+1 = 2
Distraction (*e.g.*, facet perch, hyperextension)	3
Rotation/translation (*e.g.*, facet dislocation, unstable teardrop or advanced staged flexion compression injury)	4
Disco-ligamentous complex (DLC)	
Intact	0
Indeterminate (*e.g.*, isolated interspinous widening, MRI signal change only)	1
Disrupted (*e.g.*, widening of disc space, facet perch or dislocation)	2
Neurological status	
Intact	0
Root injury	1
Complete cord injury	2
Incomplete cord injury	3
Continuous cord compression in setting of neuro deficit (Neuro Modifier)	+1

Vaccaro: Spine, Volume 32(21). 2365-2374

	Points
Morphology	
No abnormality	0
Compression	1
Burst	+1 = 2
Distraction (*e.g.*, facet perch, hyperextension)	3
Rotation/translation (*e.g.*, facet dislocation, unstable teardrop or advanced staged flexion compression injury)	4
Disco-ligamentous complex (DLC)	
Intact	0
Indeterminate (*e.g.*, isolated interspinous widening, MRI signal change only)	1
Disrupted (*e.g.*, widening of disc space, facet perch or dislocation)	2

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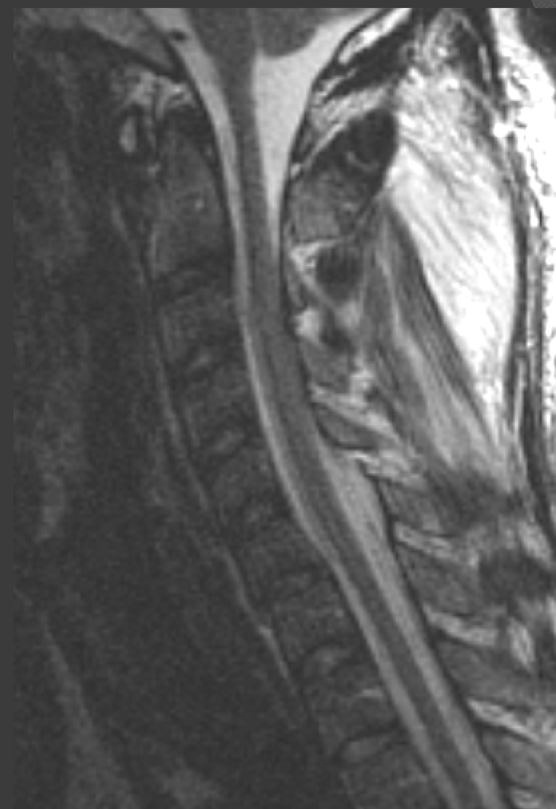
Composite score



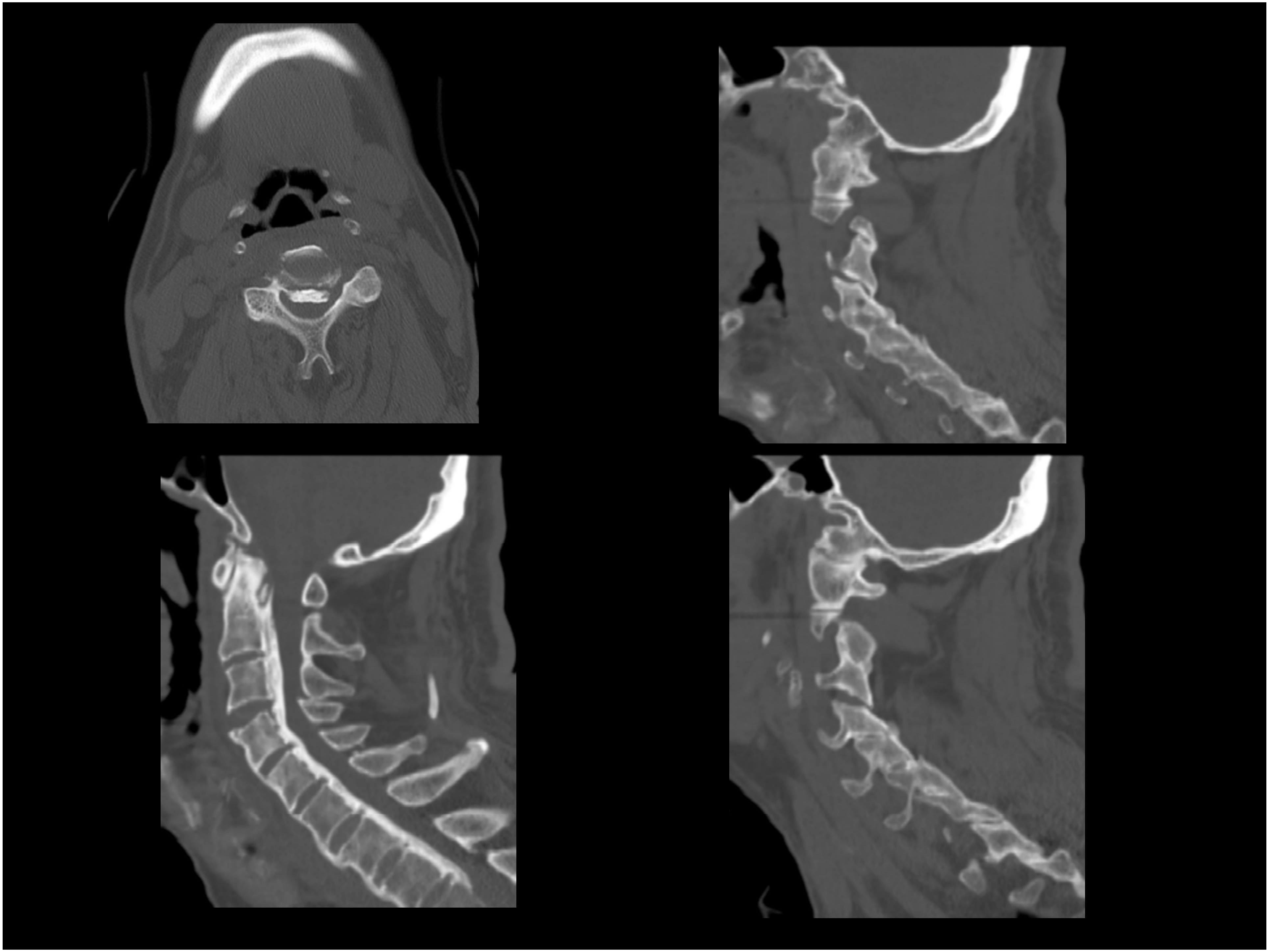
Injury morphology:
rotation – 4 points

DLC: MRI “indeterminant”
– 1 point

Which injury morphology?

1. Compression
2. Distraction
3. Translation/Rotation


MWT



Which injury morphology?

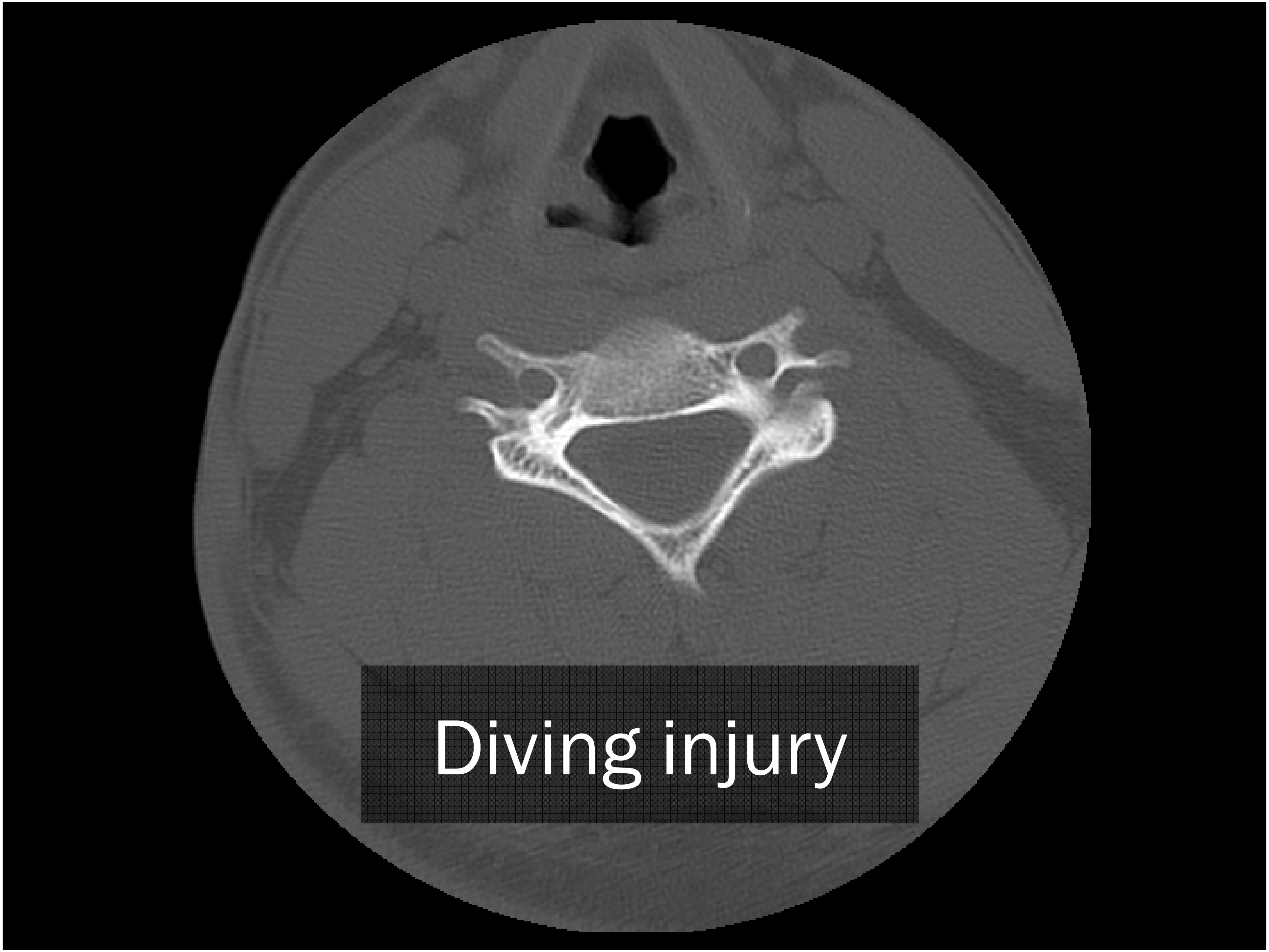
1. Compression
2. Distraction
3. Translation/Rotation

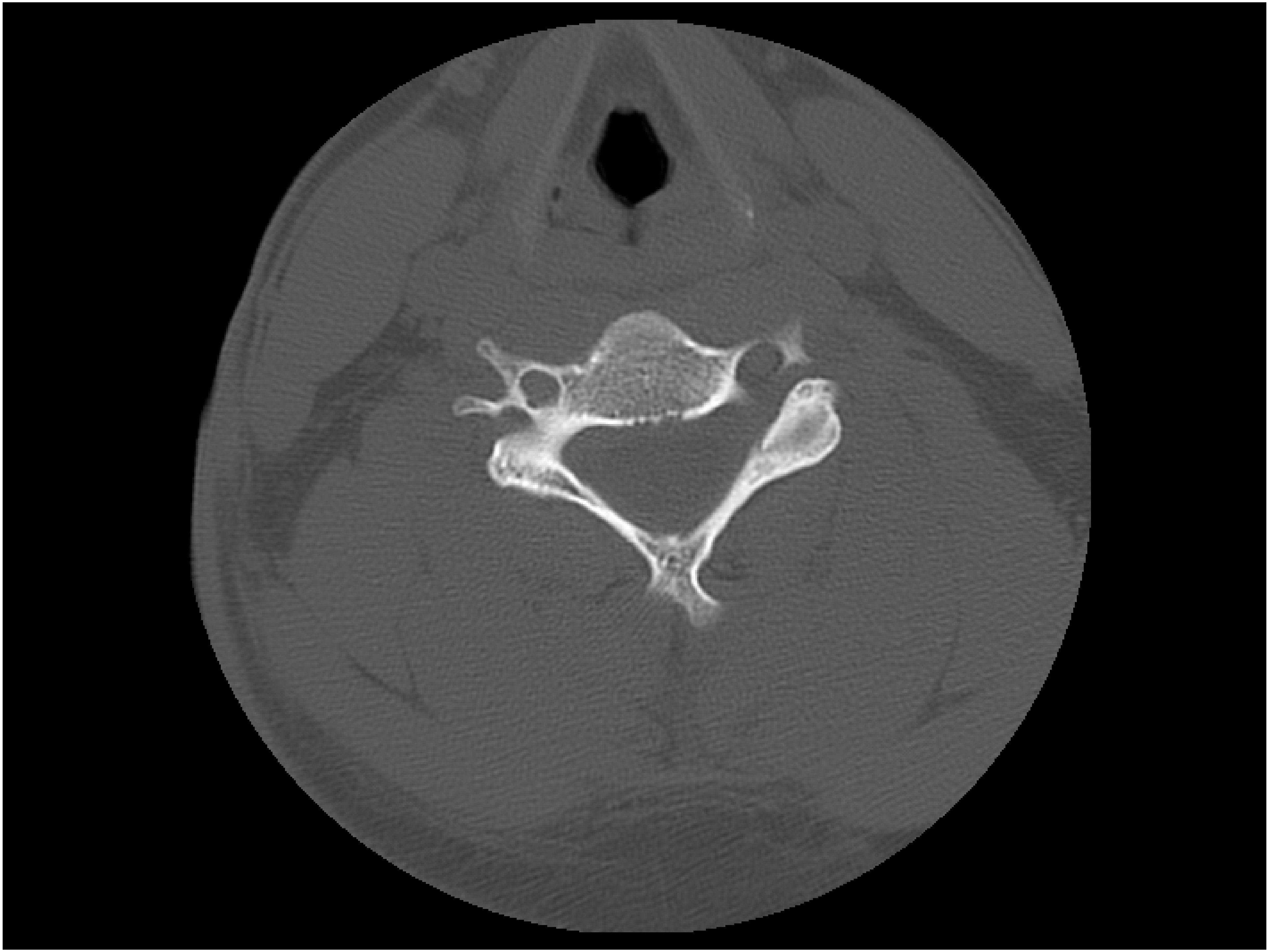
Complete assessment

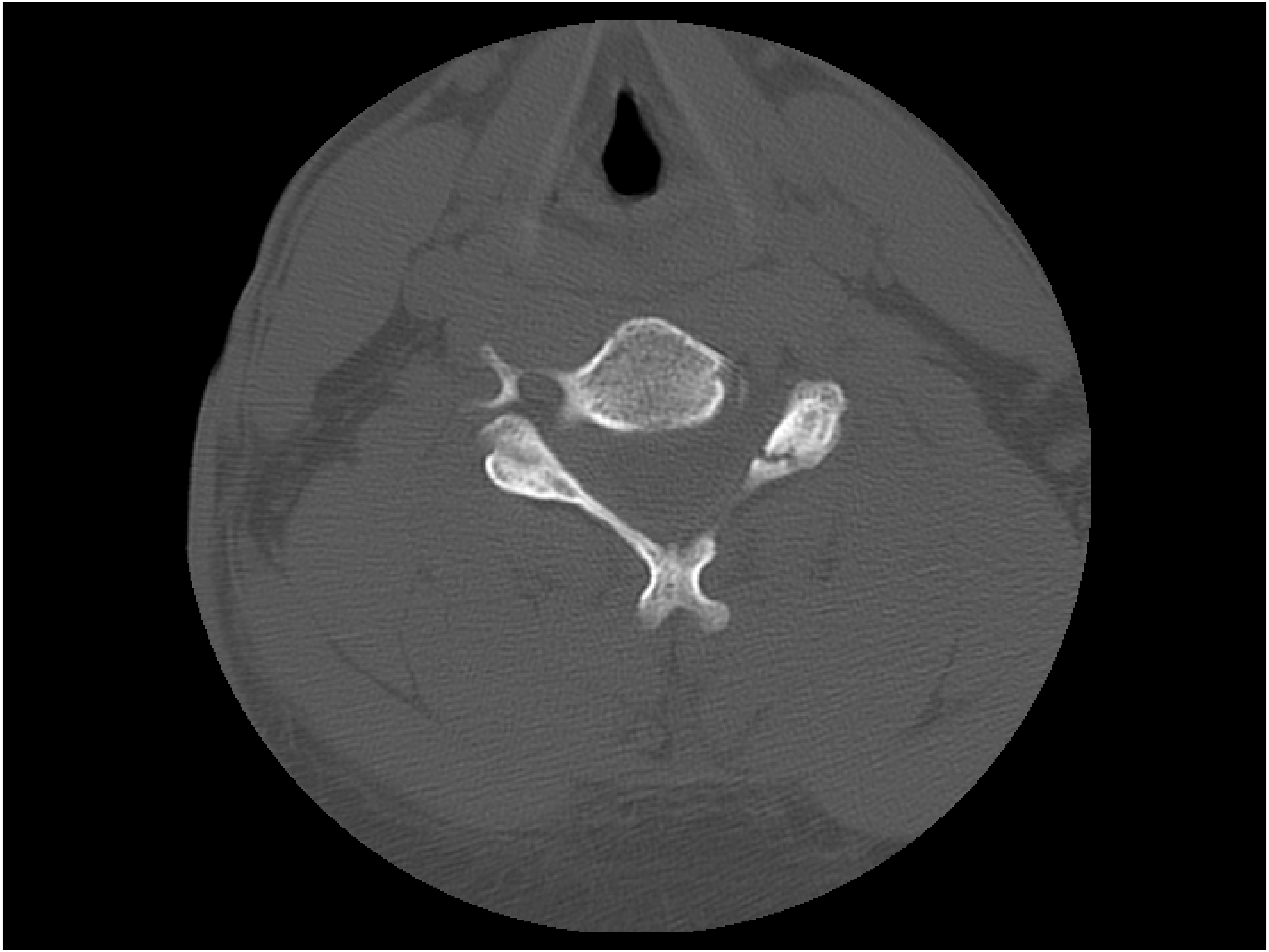
1. Spinal level
2. Injury level morphology
3. Bony injury description
4. Status of DLC
5. Neurology
6. Confounders

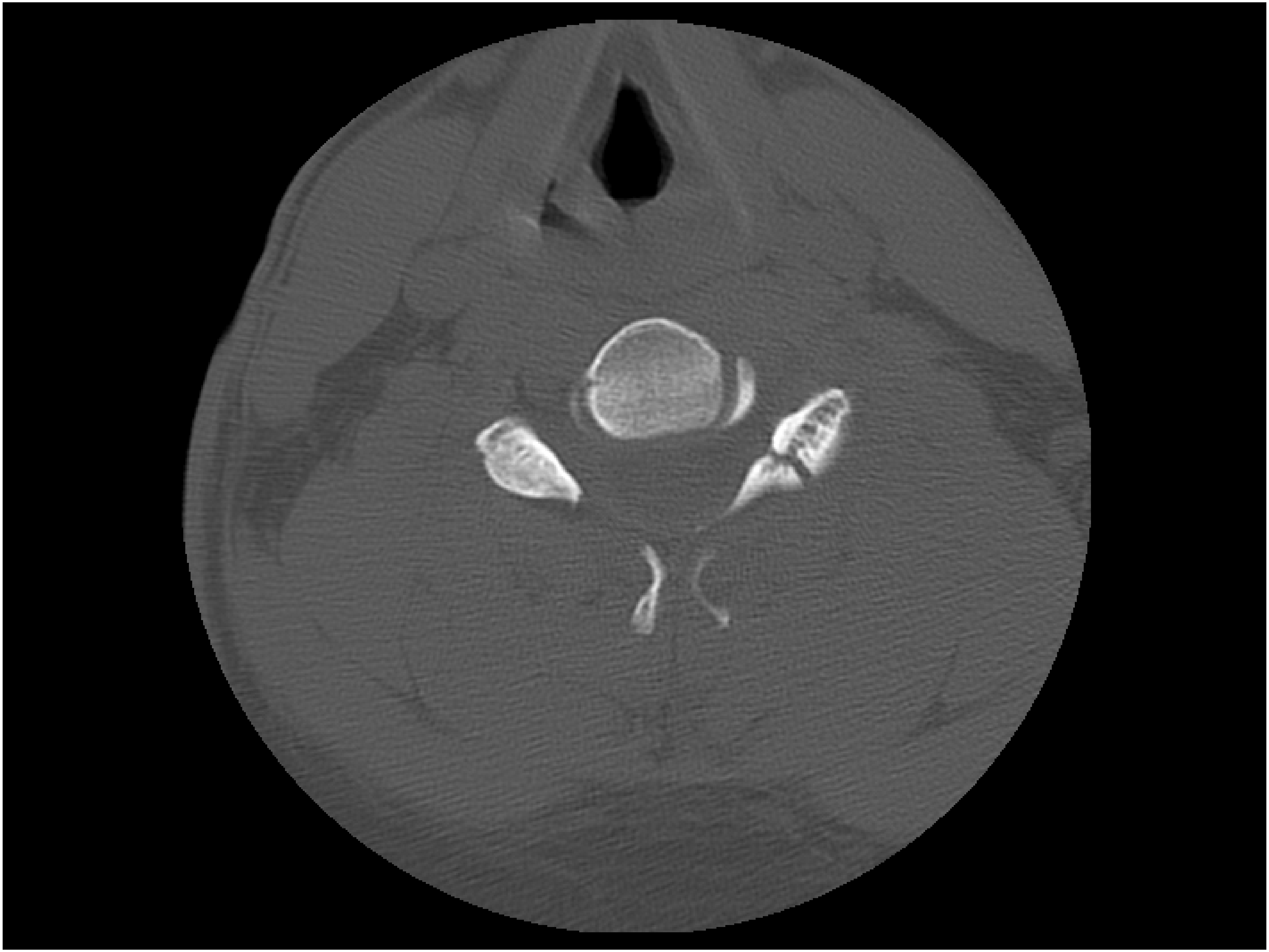
1. C3-C4
2. Distraction (3)
3. Hyperextension of spondylotic spine
4. Disrupted disc (2)
5. Acute quadriparesis (3)
6. OPLL

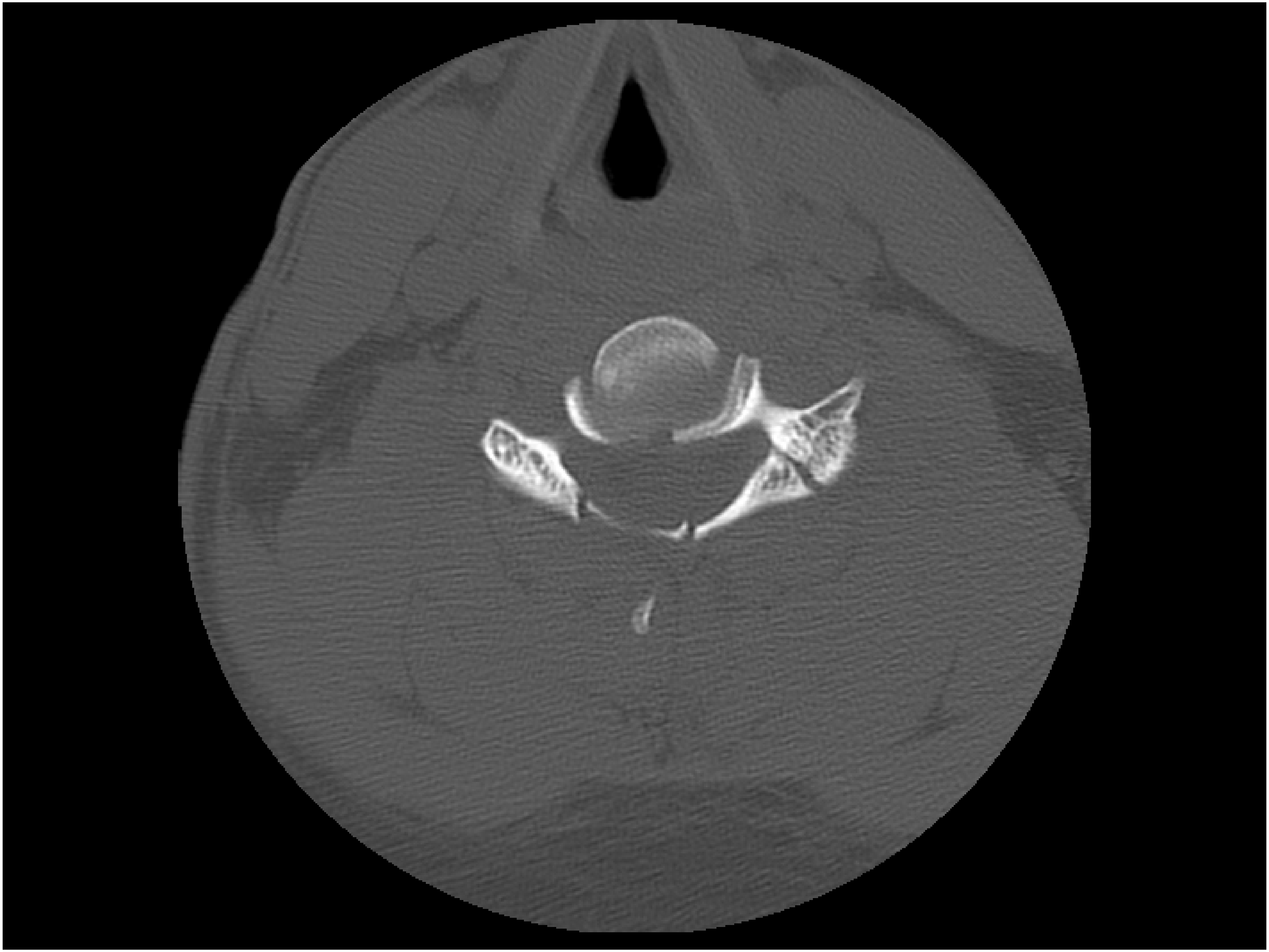
3 + 2 + 3 = 8 points

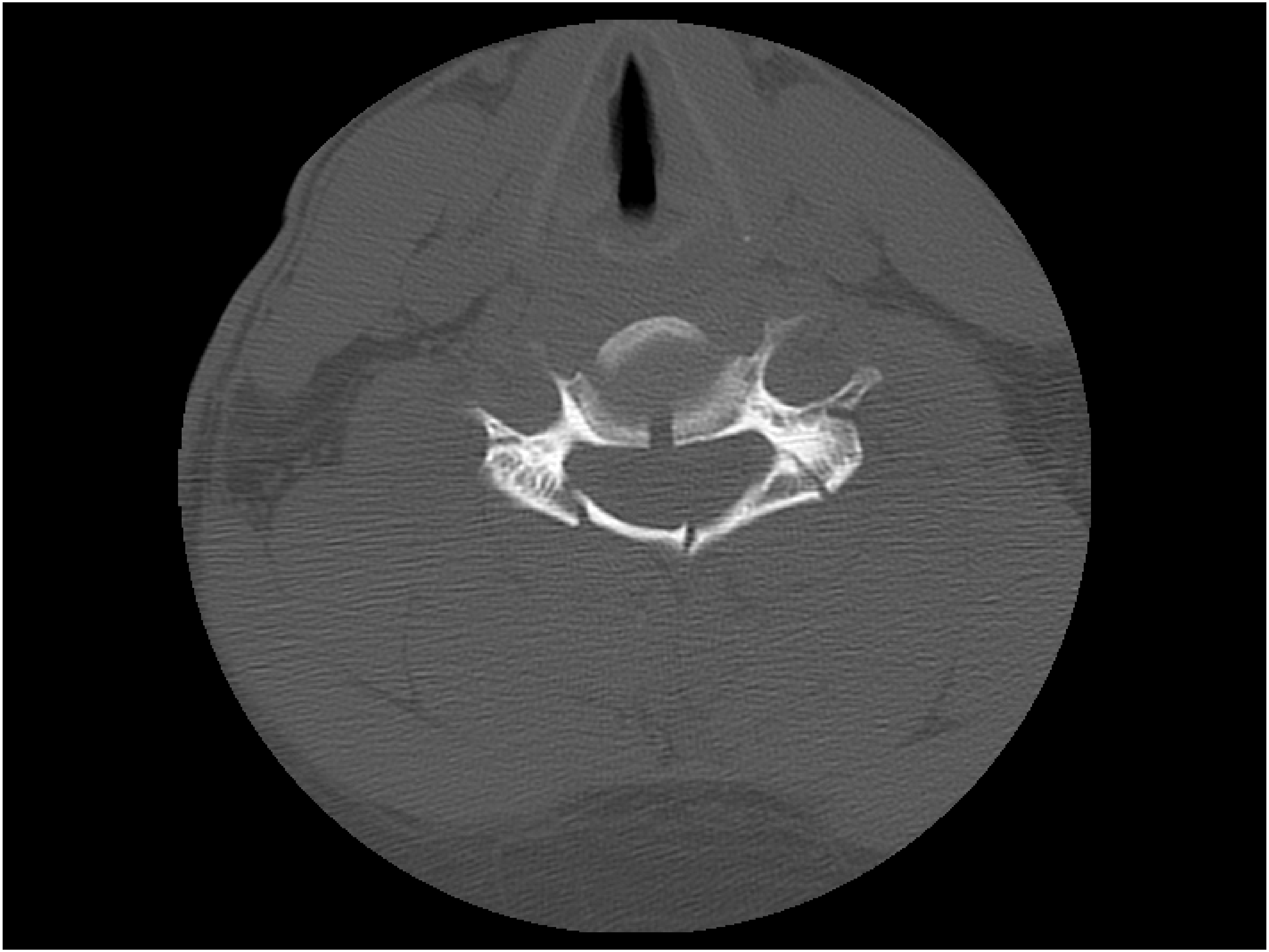

Diving injury

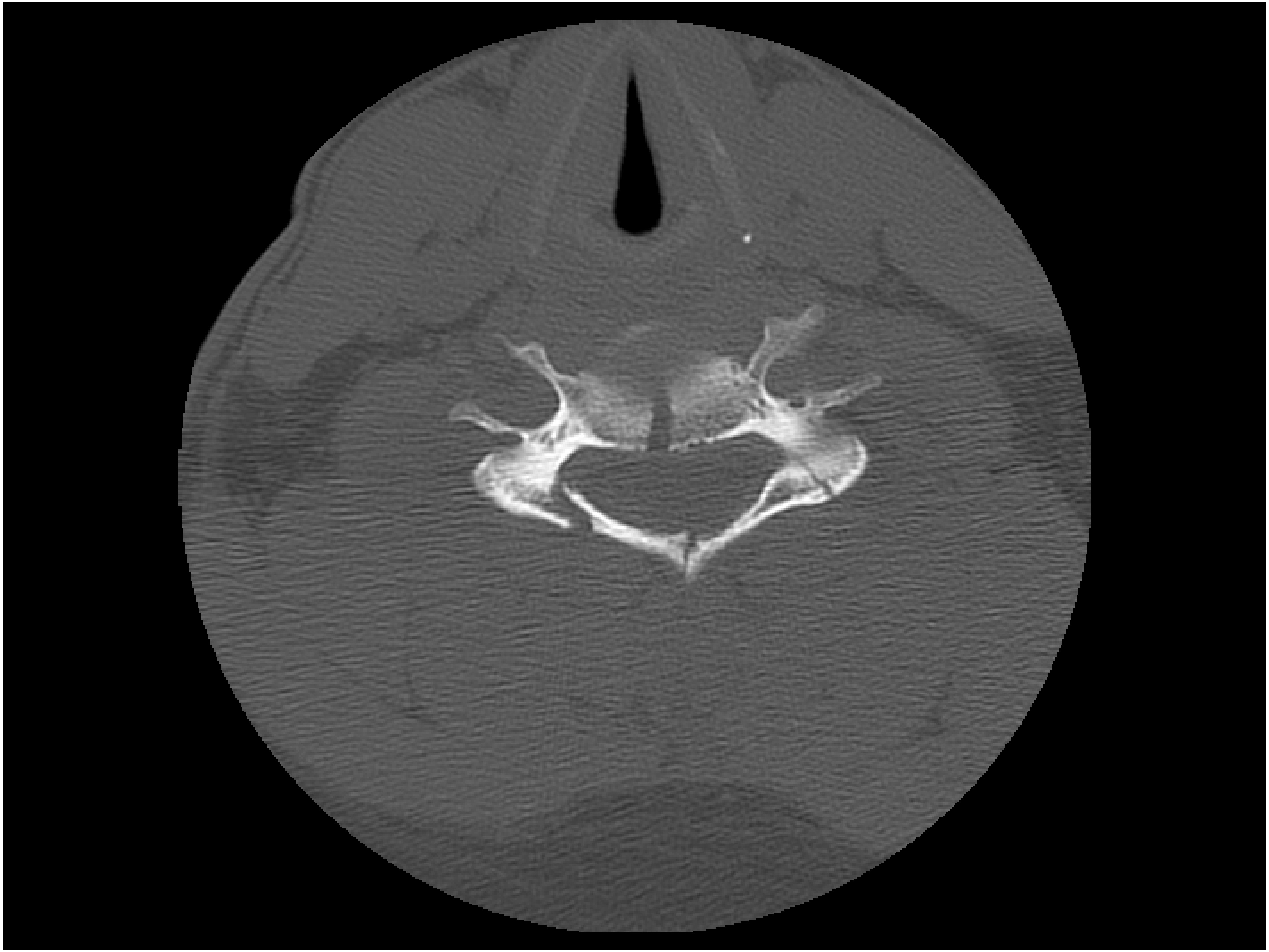


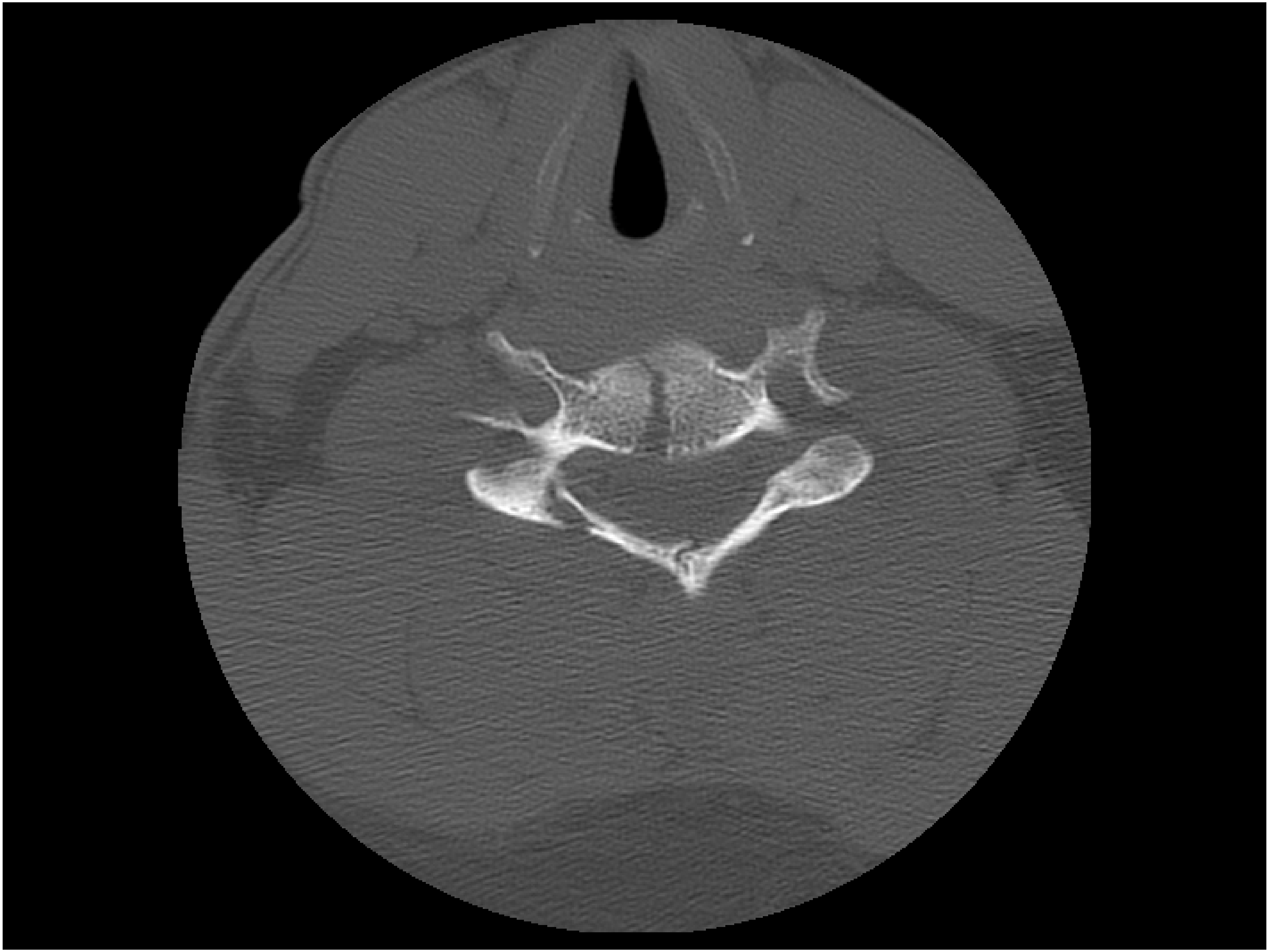


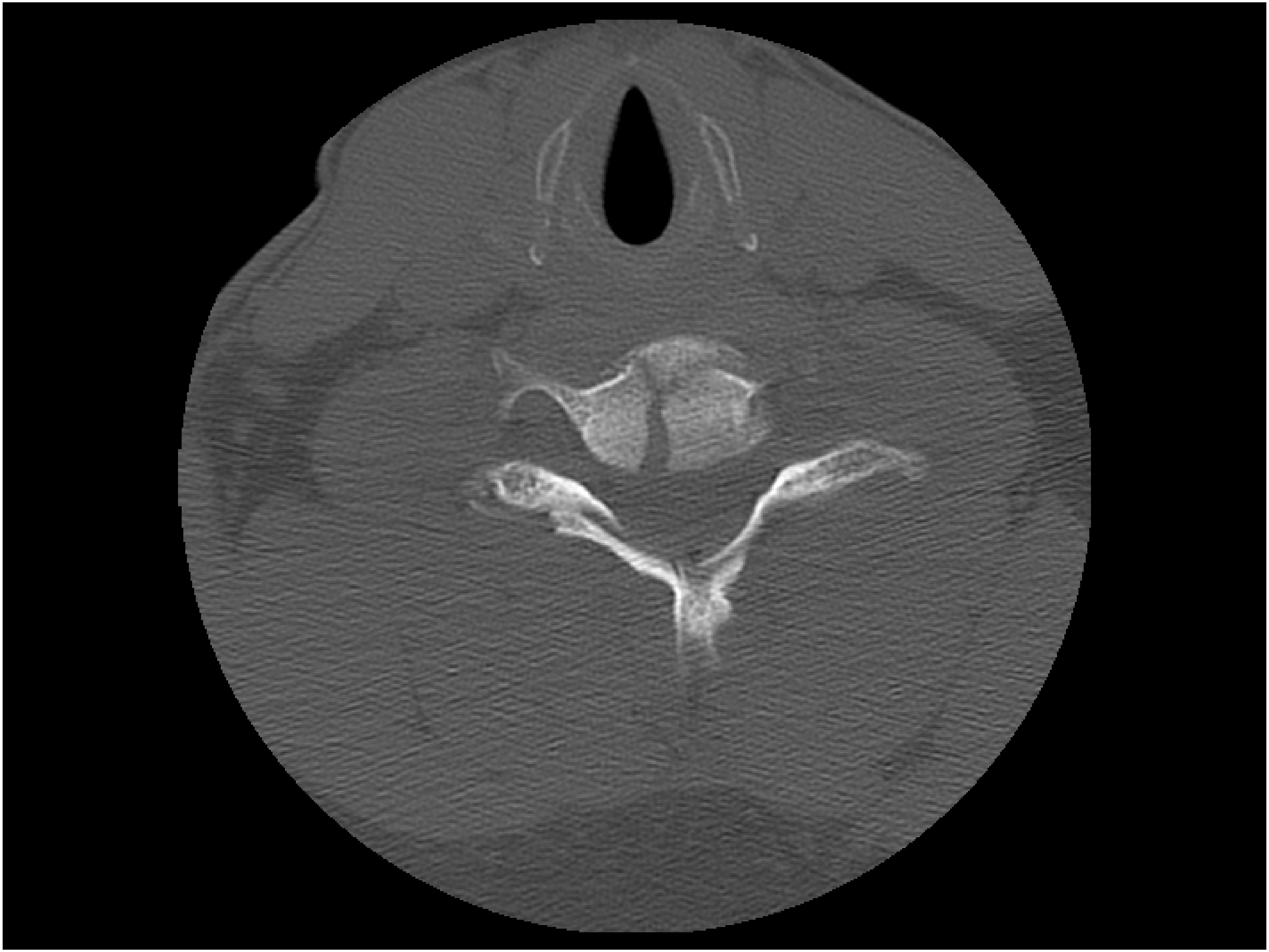


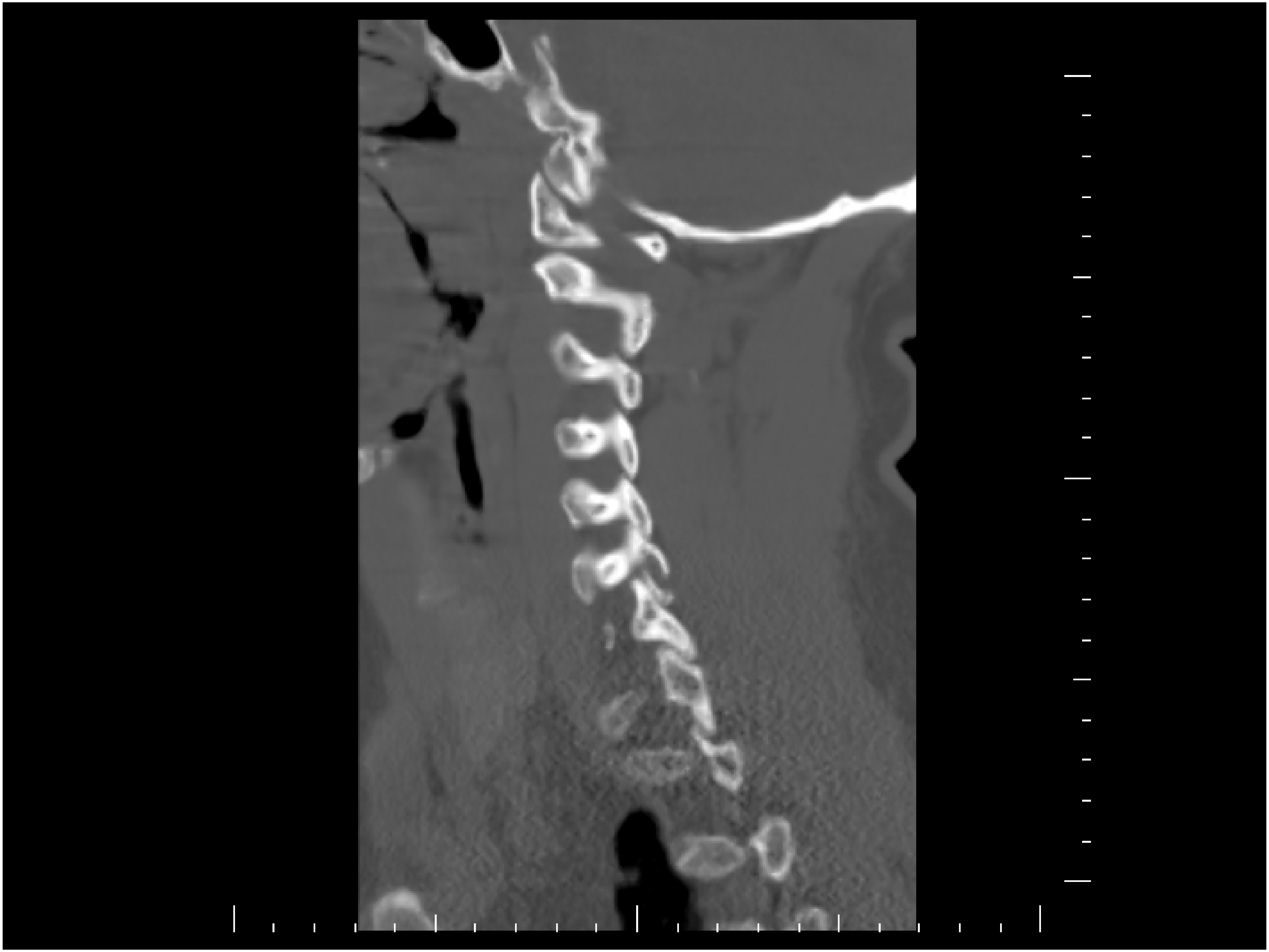


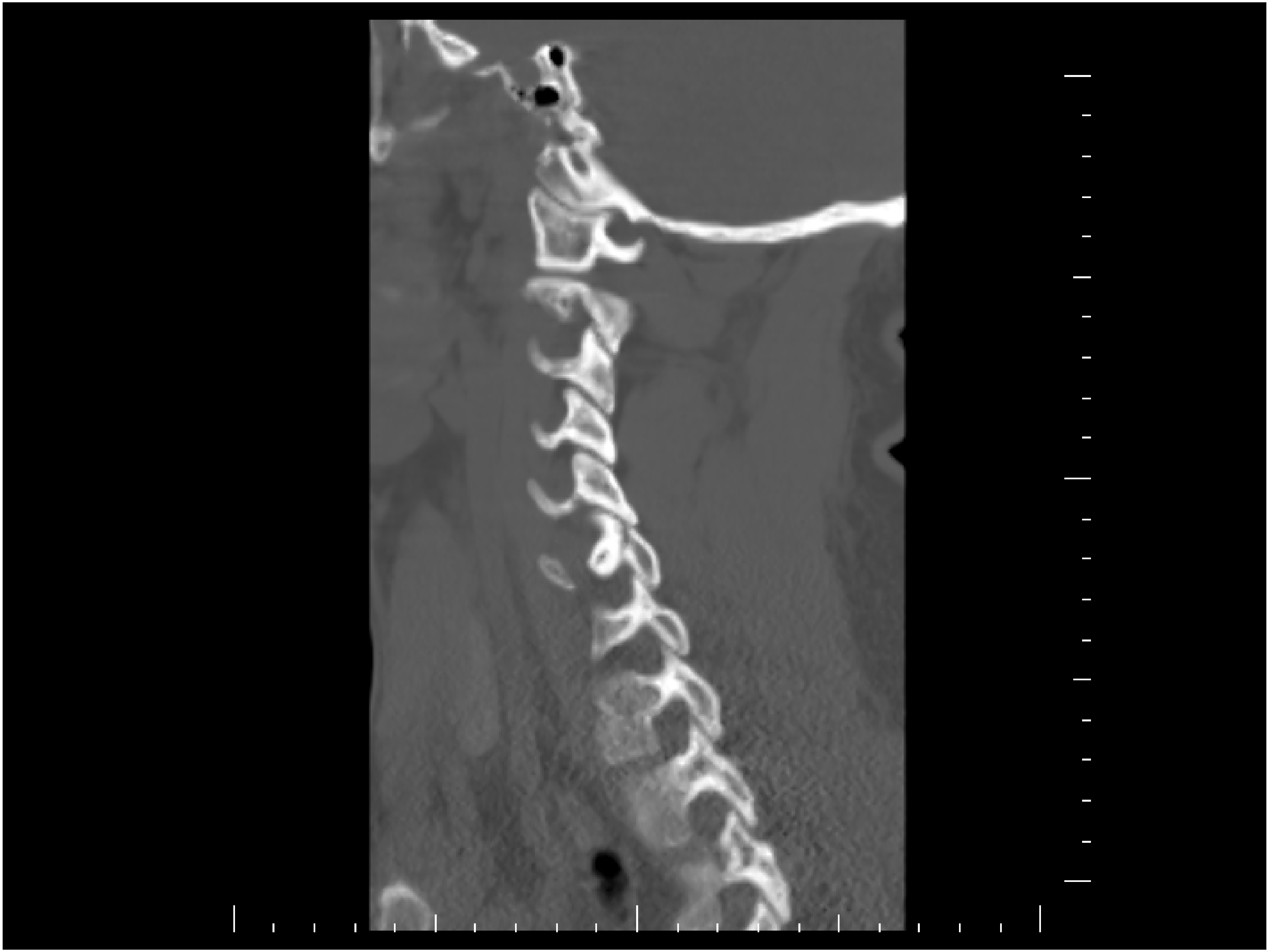


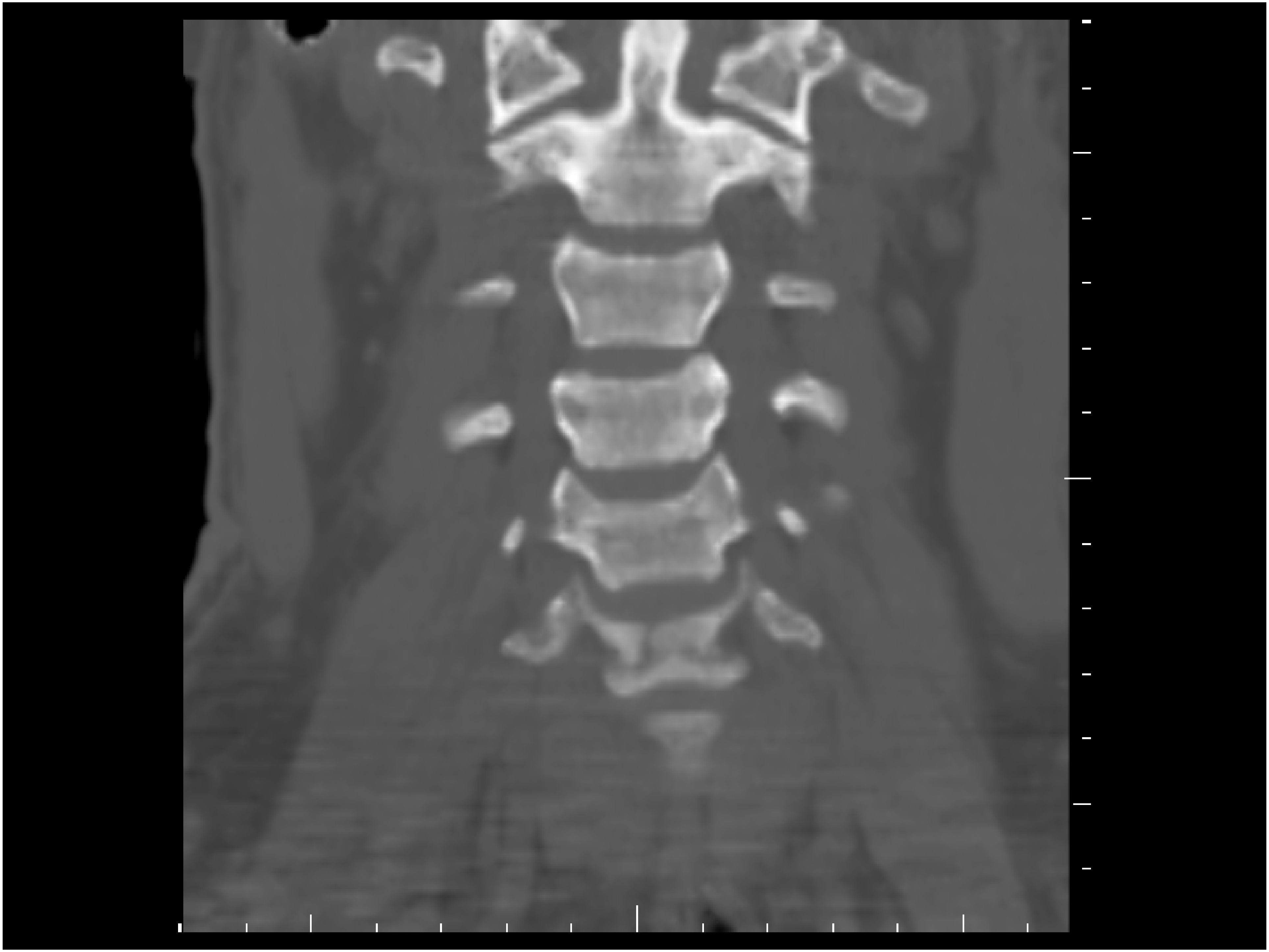


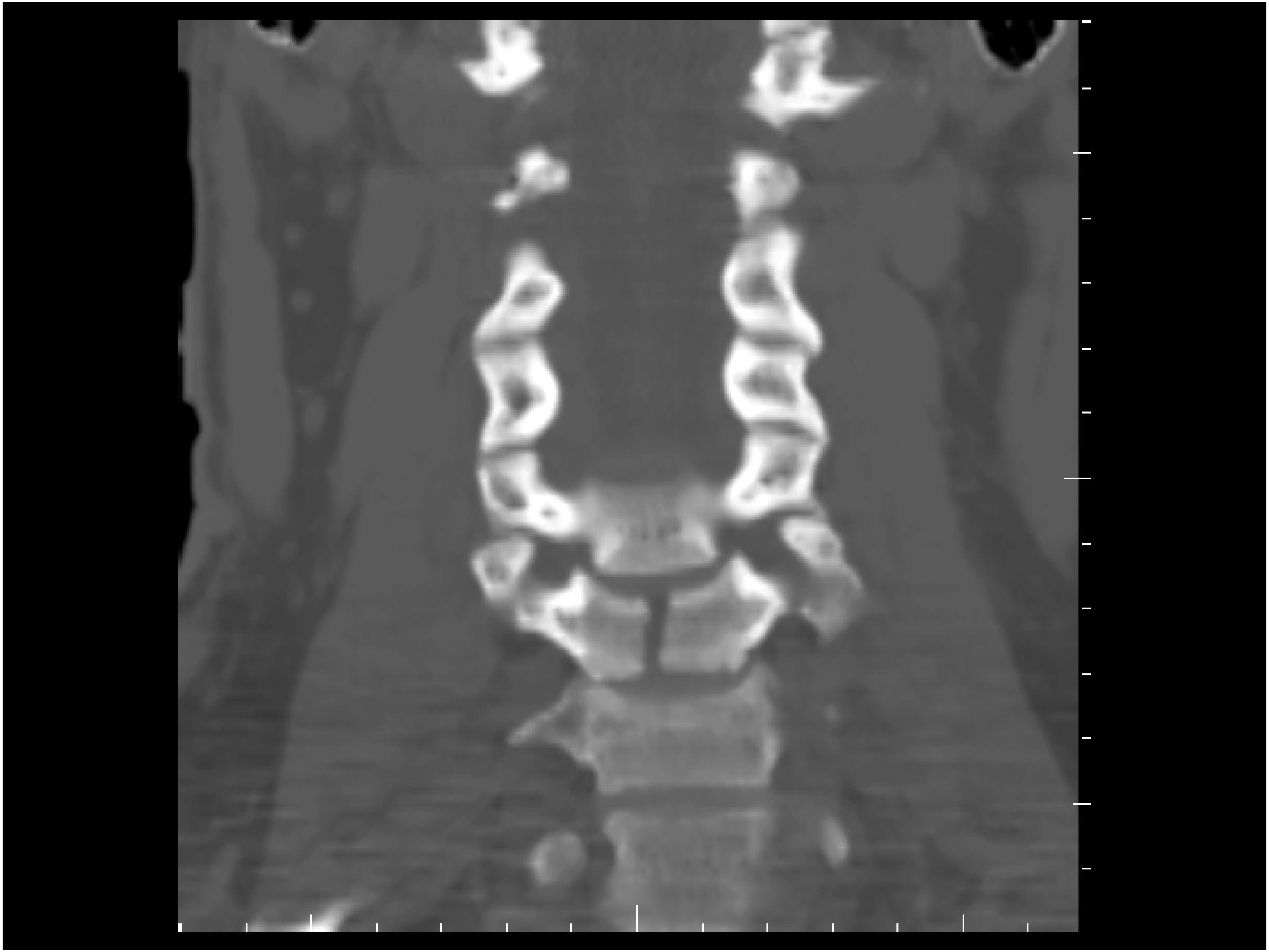


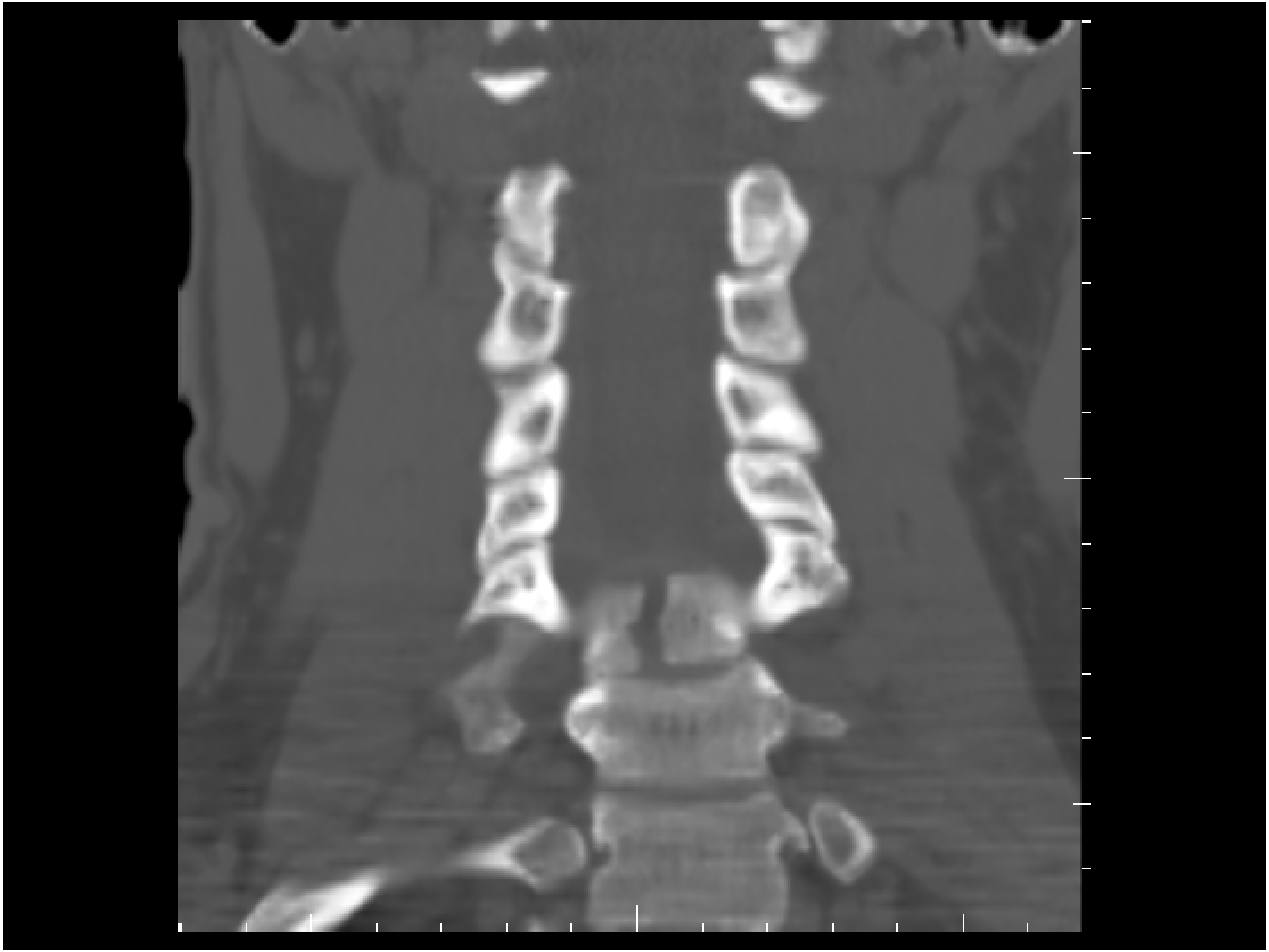


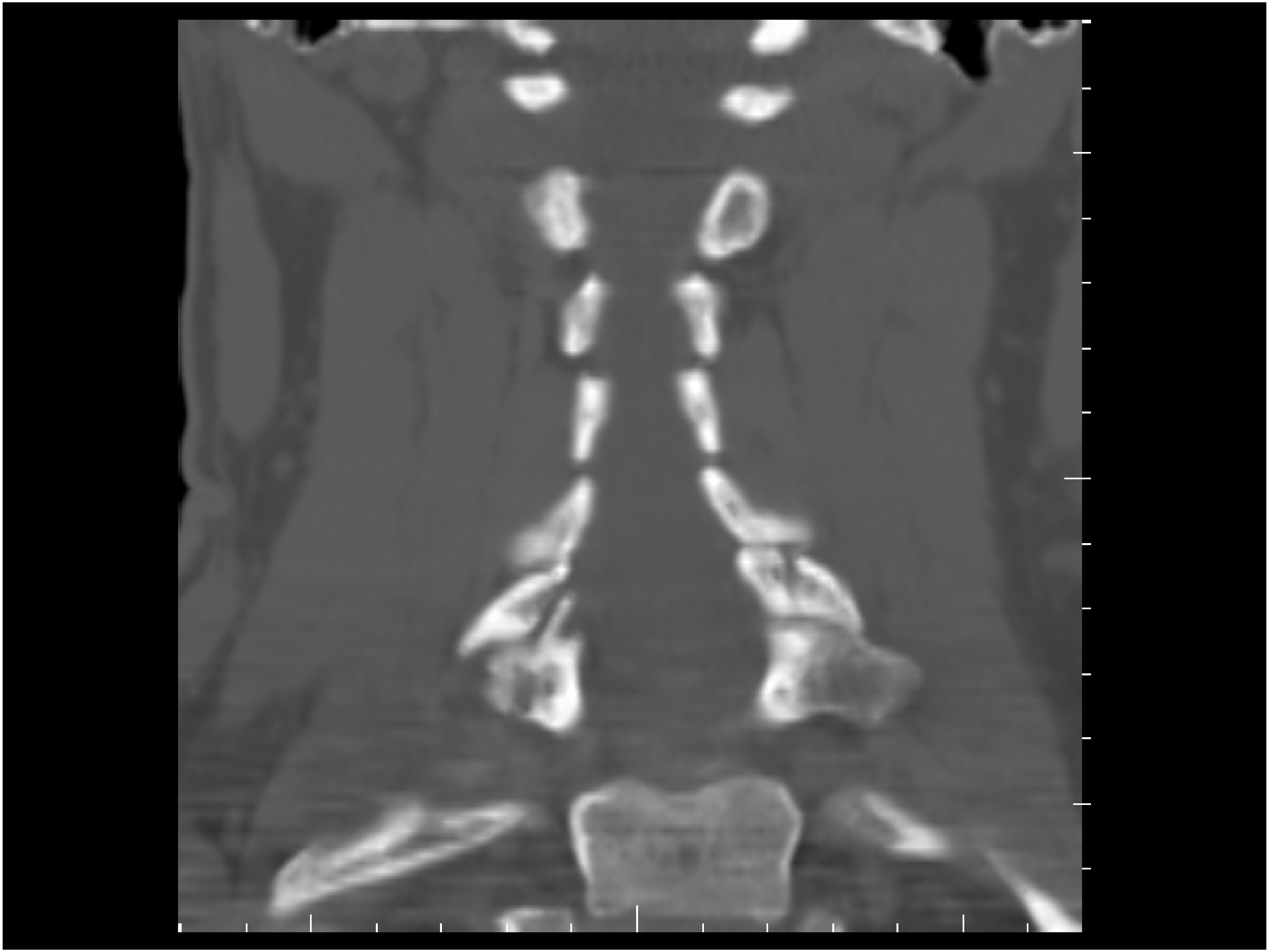


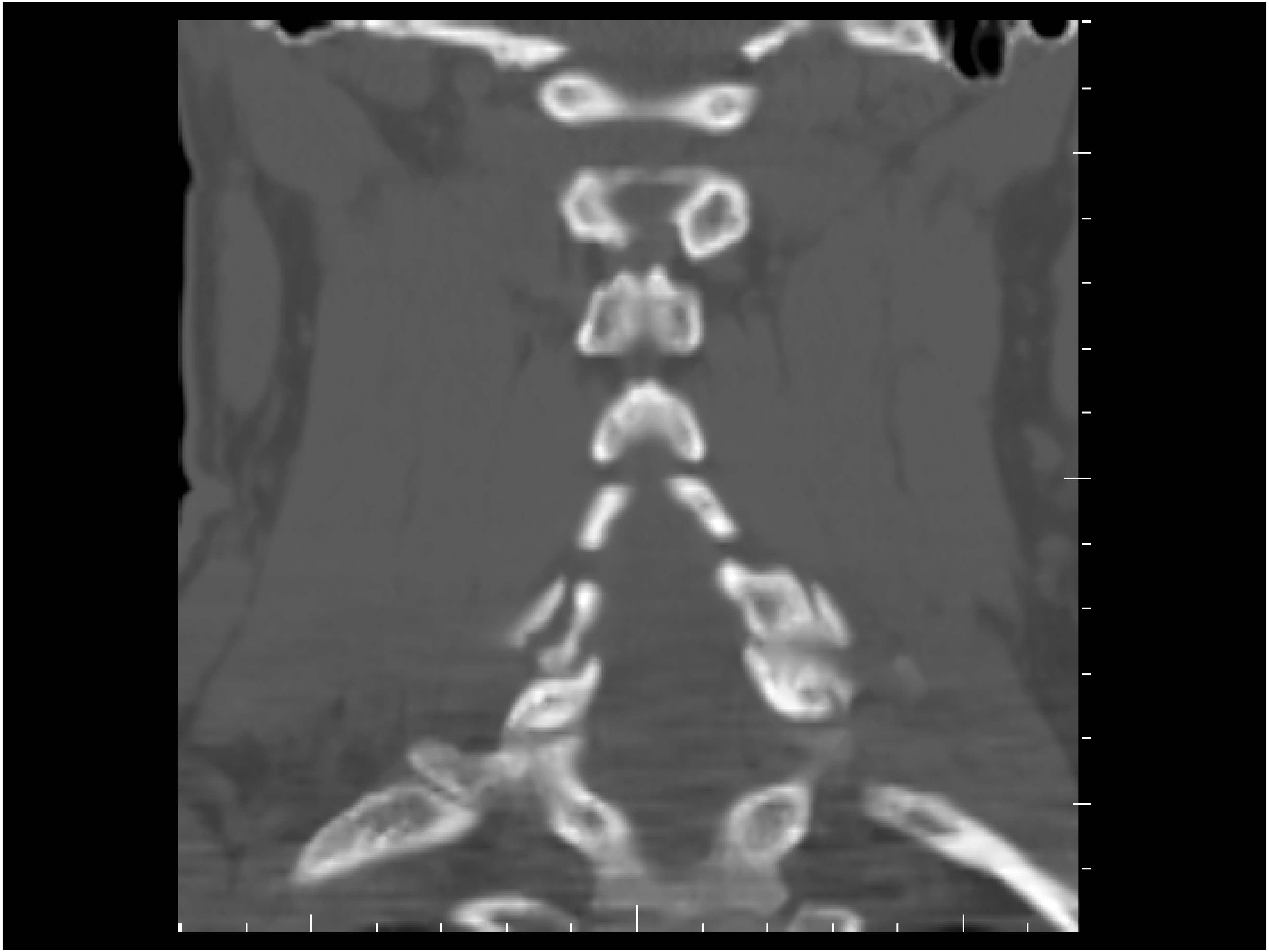


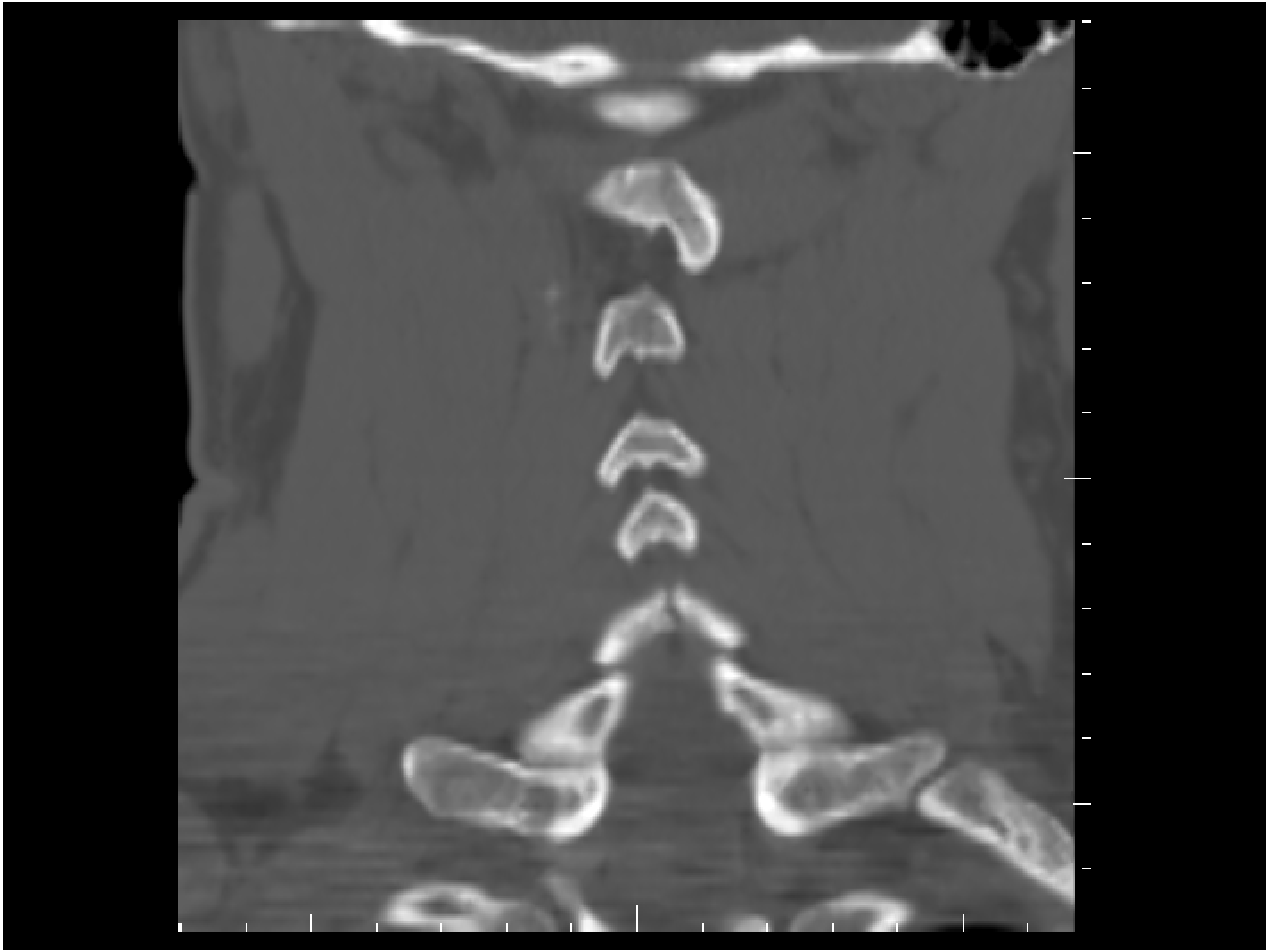












Which injury morphology BEST describes this C6 injury?

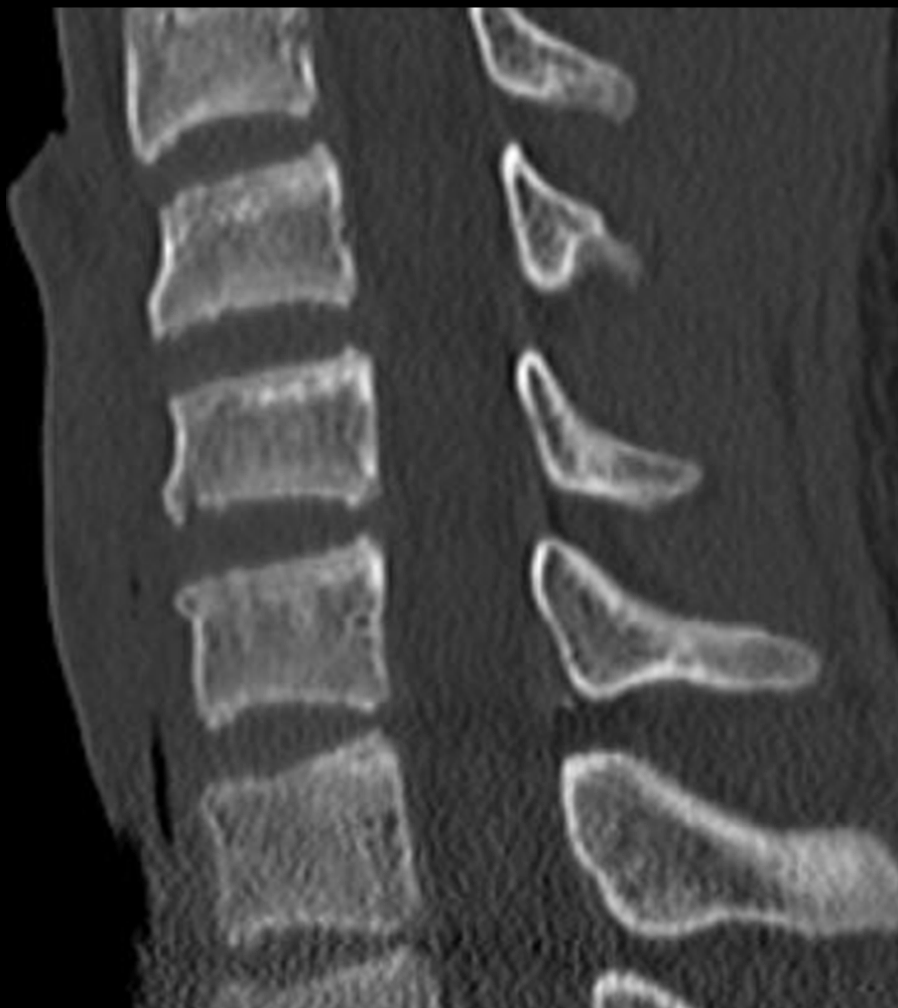
1. Compression
2. Distraction
3. Translation/Rotation

Which injury morphology BEST describes this C6 injury?

1. Compression
2. Distraction
3. Translation/Rotation

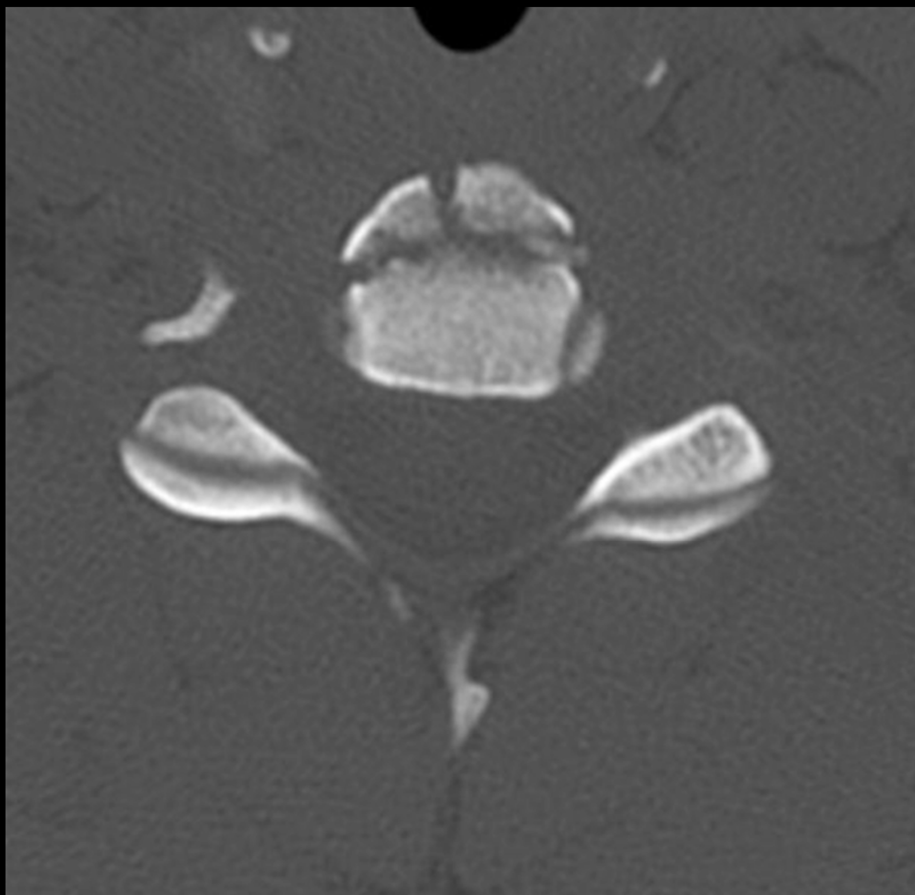
Compression

- Both traditional compression fractures and burst fractures
- Sagittal or coronal plane fractures of the vertebrae
- “tear-drop” or flexion compression fractures primarily involving the vertebral body
- Concomitant fractures of the posterior cervical elements may exist
- Undisplaced or minimally displaced lateral mass and/or facet fractures…unless visible translation is noted between vertebral levels



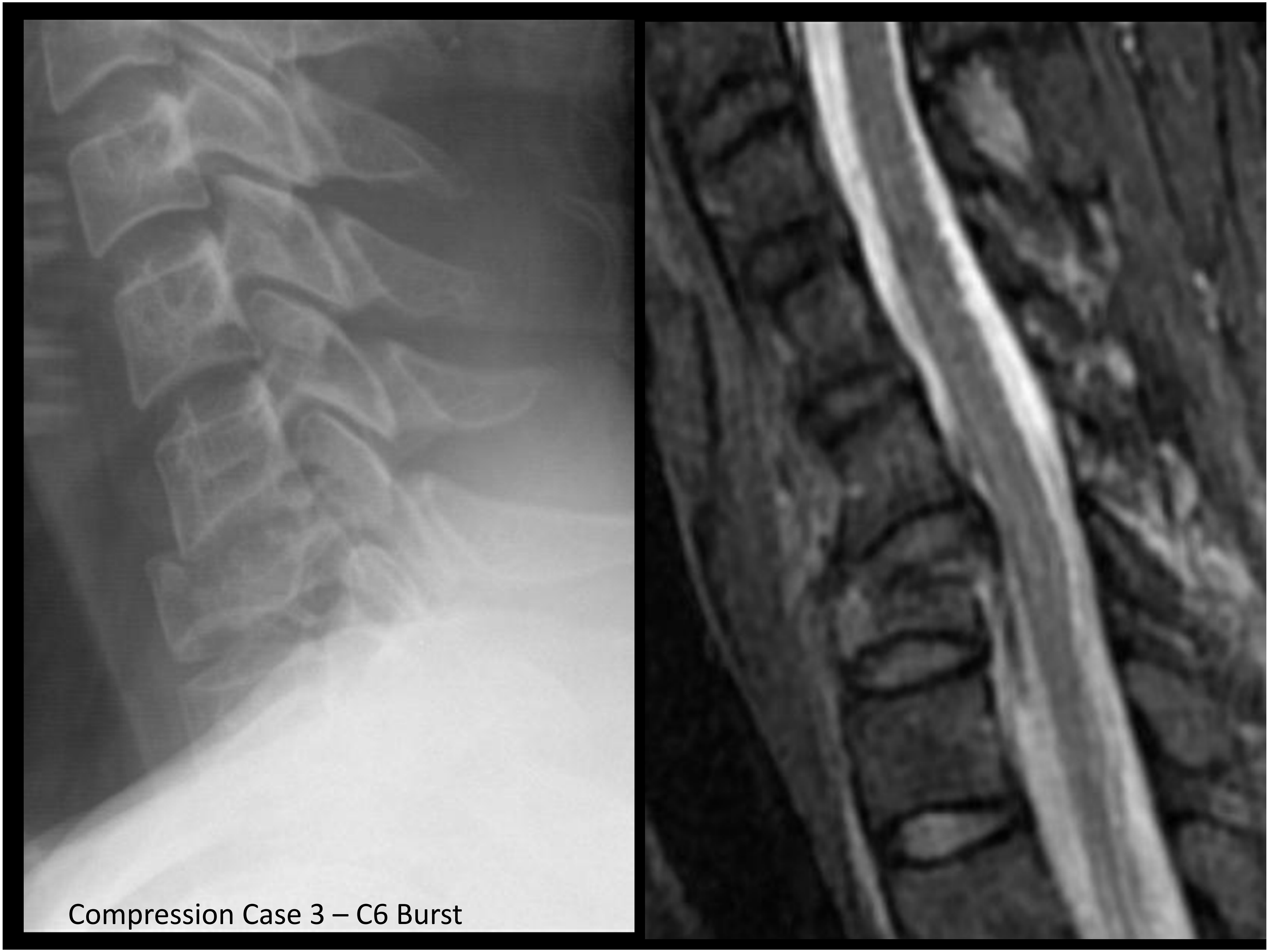

Compression Case 1 – C5 & C6

Compression Case 2 – C5

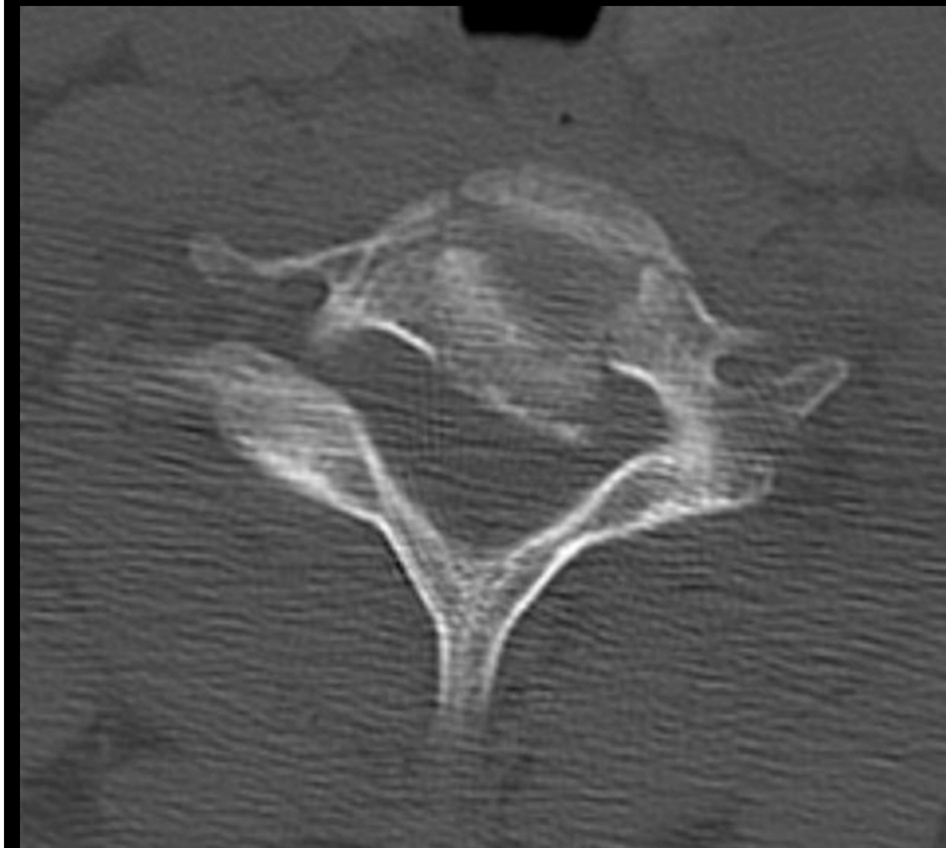


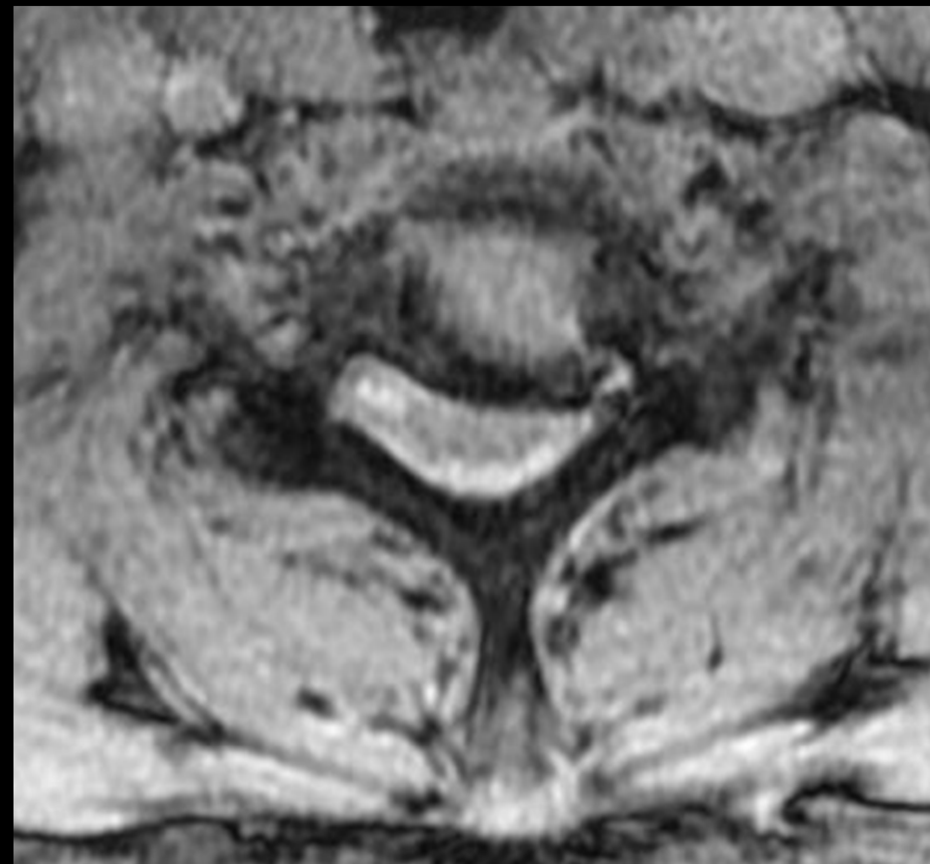
Compression Case 2 – C5


Compression Case 3 – C6 Burst

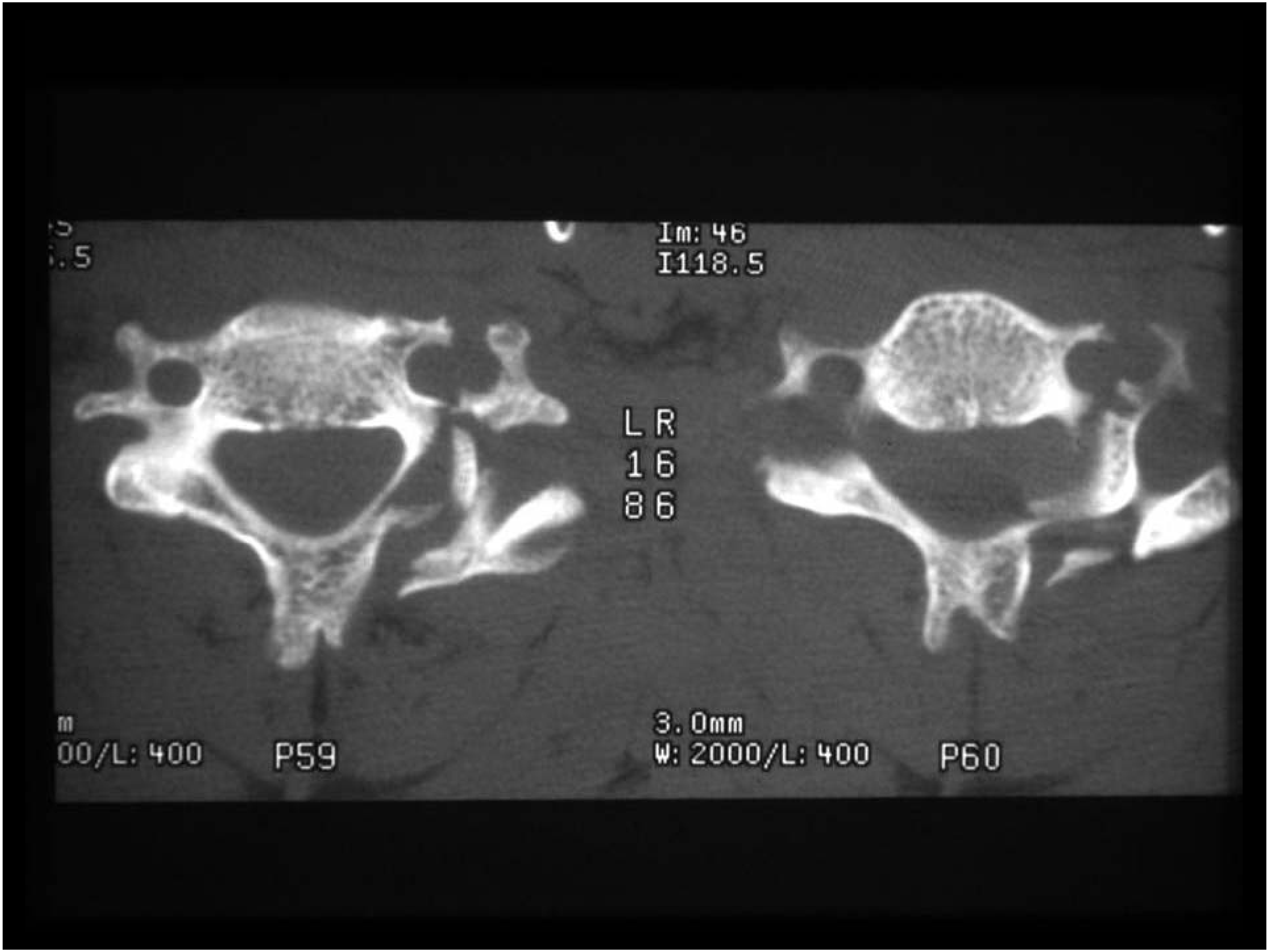


Compression Case 3 – C6 Burst





Compression Case 3 – C6 Burst



.5
Im: 46
I118.5
L R
1 6
8 6
m
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W: 2000/L: 400
P60


Im: 49
I127.5
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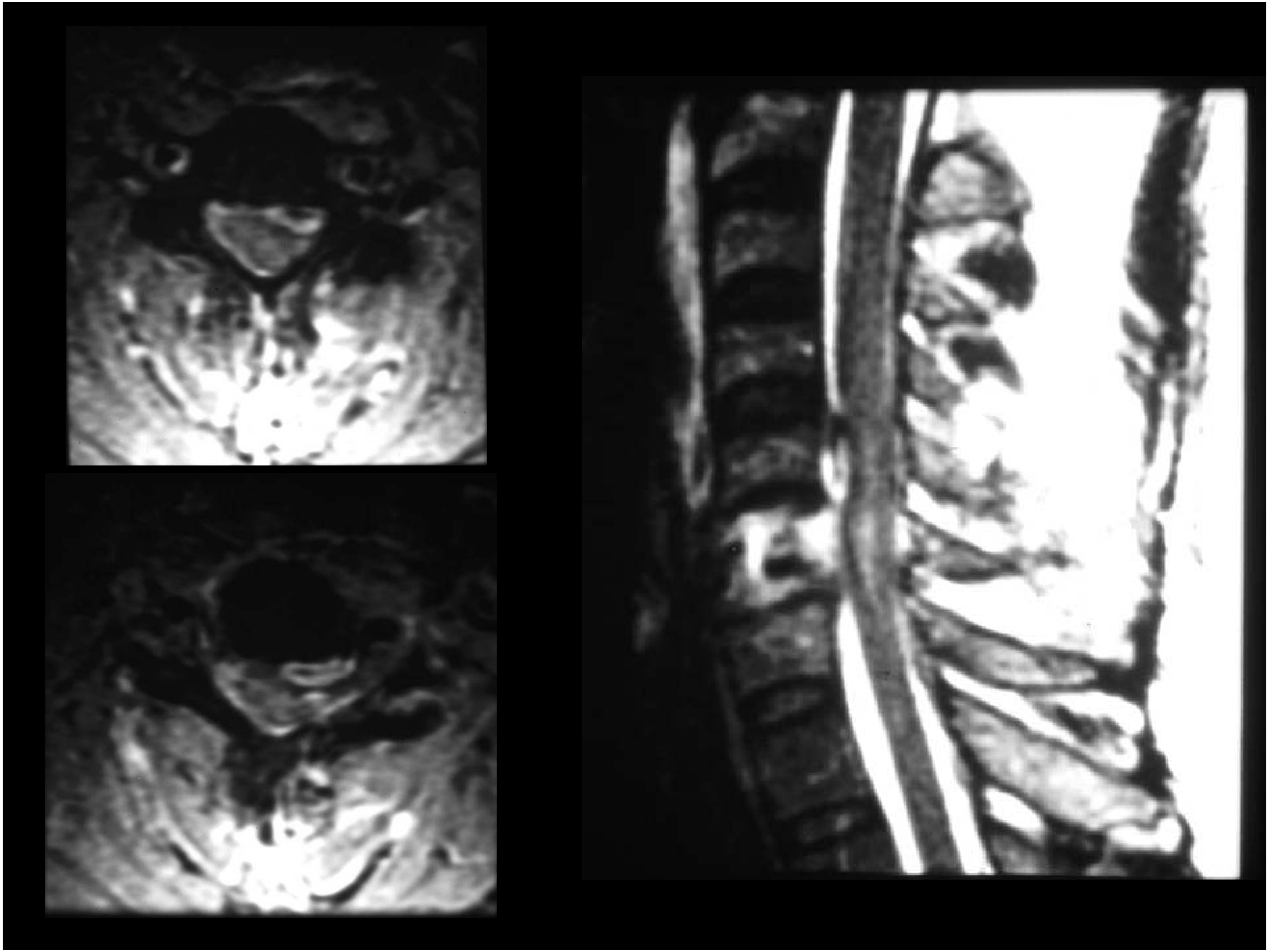
5
3.0mm

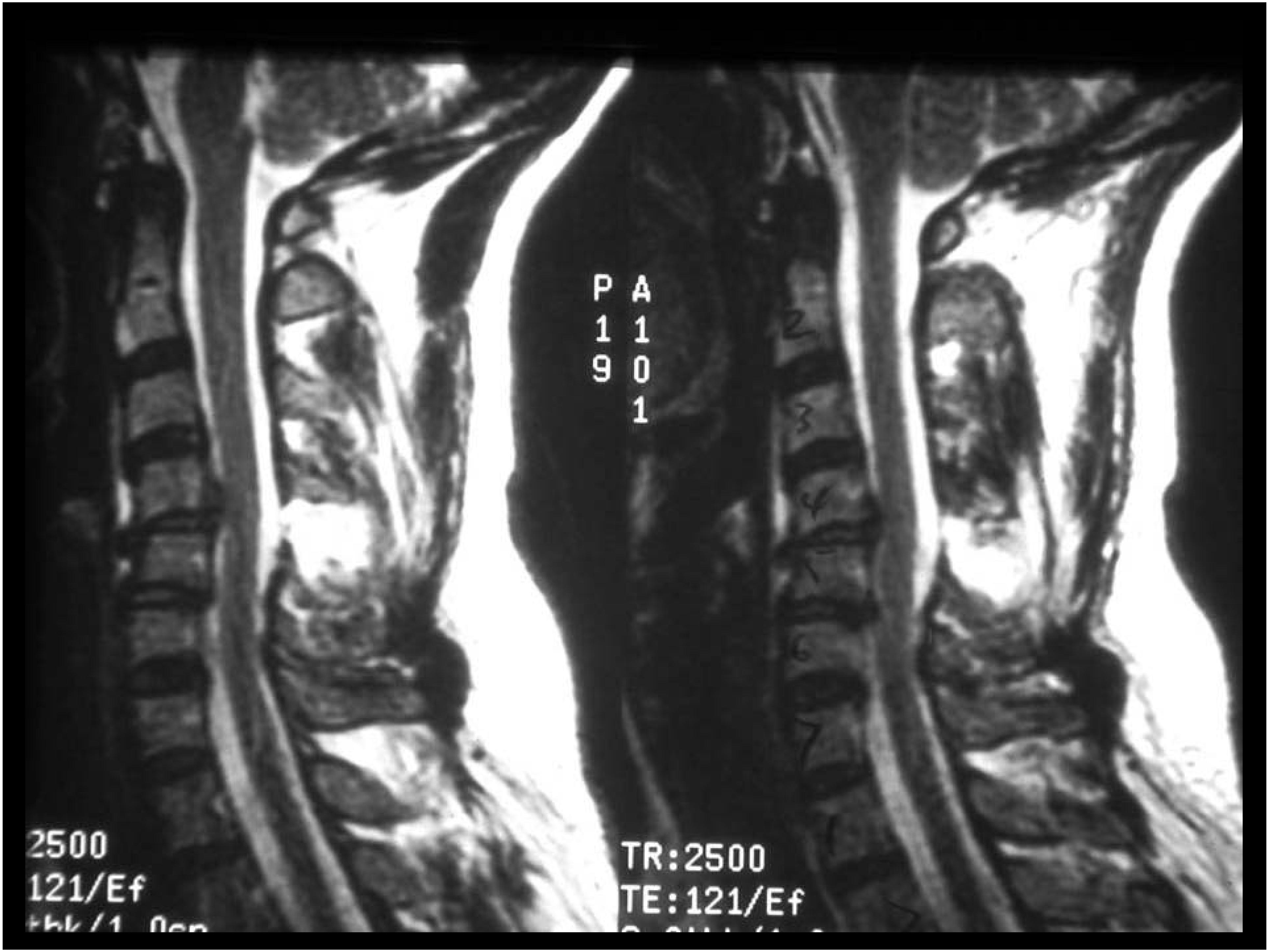


Complete assessment

1. Spinal level
2. Injury level morphology
3. Bony injury description
4. Status of DLC
5. Neurology
6. Confounders

1. C6
2. Translation (4)
3. Markedly displaced burst fracture
4. Disrupted disc – cord impingement (2)
5. Case too old
6. None

4 + 2 + ? = 6+ points


P A
1 1
9 0
1
2500
121/Ef
TR:2500
TE:121/Ef

Complete assessment

1. Spinal level
2. Injury level morphology
3. Bony injury description
4. Status of DLC
5. Neurology
6. Confounders

1. C4-C5
2. Distraction (3)
3. Hyperflexion sprain
4. Disrupted disc & posterior ligaments (2)
5. Quadriplegia (2)
6. None

3 + 2 + 2 = 7 points

The bottom line on SLIC

- Easy to apply
- Fewer categories to remember
- Explicitly defines disc and ligamentous injuries
- May provide the basis for
  - …improved radiology reports
  - …more effective communication with spine surgeons

Summary

- Reviewed an efficient pattern approach to assessment of the lower cervical spine CT.
- Introduced the disco-ligamentous complex and discussed its assessment on CT and MRI.
- Applied the new SLIC system to detailed analysis of lower cervical spine injuries.

RSNA 2009

Thoracic and Lumbar Spine Injuries: Stable or Unstable

Wayne S. Kubal, M.D.
University of Arizona

Learning Objectives

- Discuss the optimal use of radiography, CT, and MR to assess thoracolumbar spine (TLS) injury in the context of a busy ER practice
- Understand the patterns of injury most commonly encountered in the TLS

Learning Objectives

- Recognize on CT and MR, the typical findings of TLS injury
- Apply the knowledge of TLS injury patterns and the imaging findings to the determination of spinal stability in the acutely injured patient

Epidemiology of TLS Fxs

- TLS fractures are not uncommon
  - 4.4% of patients with major trauma
- Acute neurologic injury is common
  - 19-50% of TLS fractures
- Early diagnosis is vital
  - Prompt dx: 1.4% persistent neurologic deficit
  - Delayed dx: 10.5% persistent neurologic deficit

Diaz et al, J of Trauma 2007
Reid et al, J of Trauma 1987

Criteria for Imaging

- Back pain / midline tenderness
- Abnormal neurologic exam
- GCS less than 15
- Intoxication
- Distracting injury
- In reality: part of a "Pan Scan"

Hsu et al, Injury 2003
Holmes et al, J of Emergency Med 2003

Plain Film vs Reformatted CT

- Reformat spine images from a "Pan Scan" of chest, abdomen, and pelvis
- Reformat CT more sensitive than plain film
  - 97% vs 62% in T-spine
  - 95% vs 86% in L-spine
- Dedicated CT not necessary even when fracture is present

Sheridan et al, J of Trauma 2003
Roos et al, AJR 2004

Criteria for MRI

- MRI offers improved sensitivity for:
  - Ligament or cord injury
  - Traumatic disc extrusion
  - Epidural hematoma
  - Acute vs chronic fracture
- Ligament injury without bony injury is extremely rare
- MRI is indicated
  - Neurologic deficit
  - Abnormal CT
  - High clinical suspicion for unstable injury

Diaz et al, J of Trauma 2007

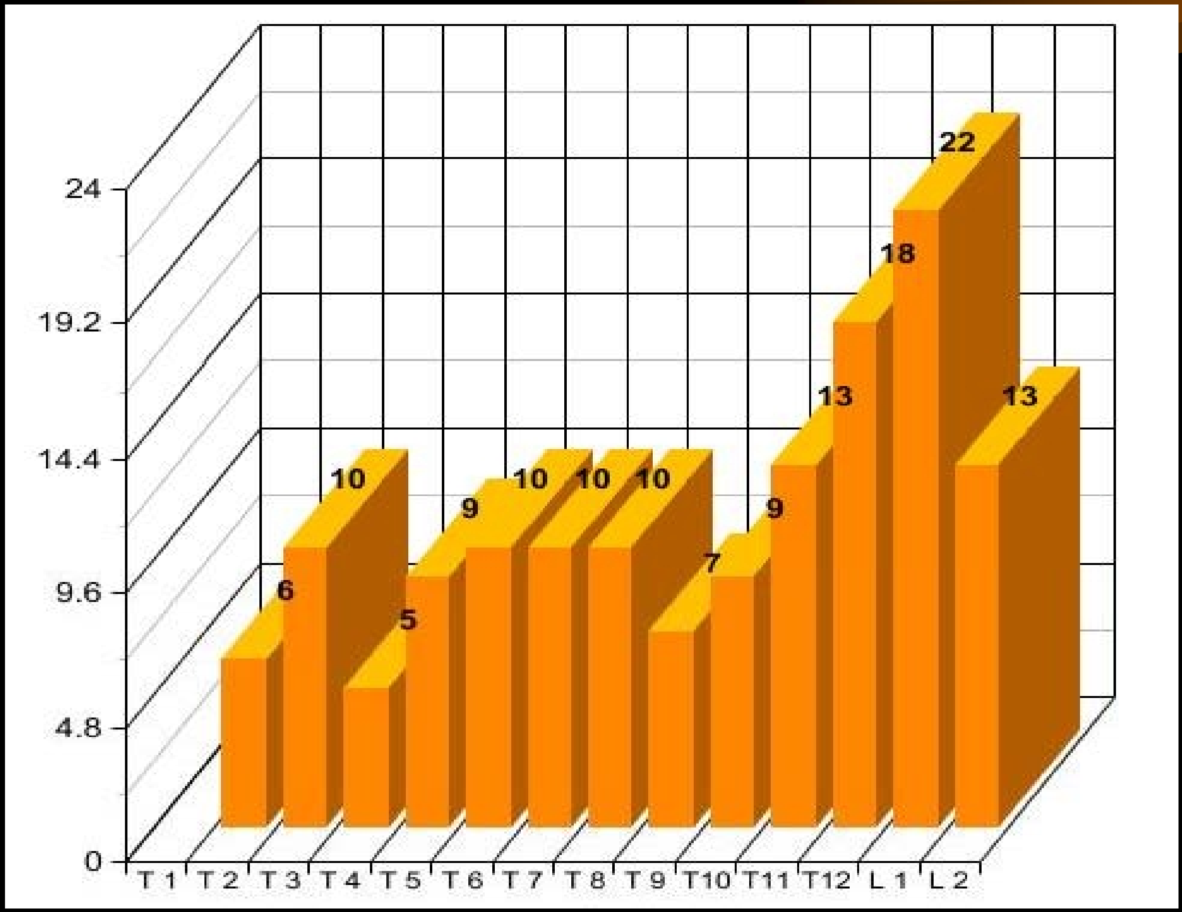
Distribution of T-L Fractures

- Most common at T-L junction (T11-L2)
  - Transitional anatomy
- Less common in T spine (T1-T10)
  - Stabilized by by ribs
- Least common below L2

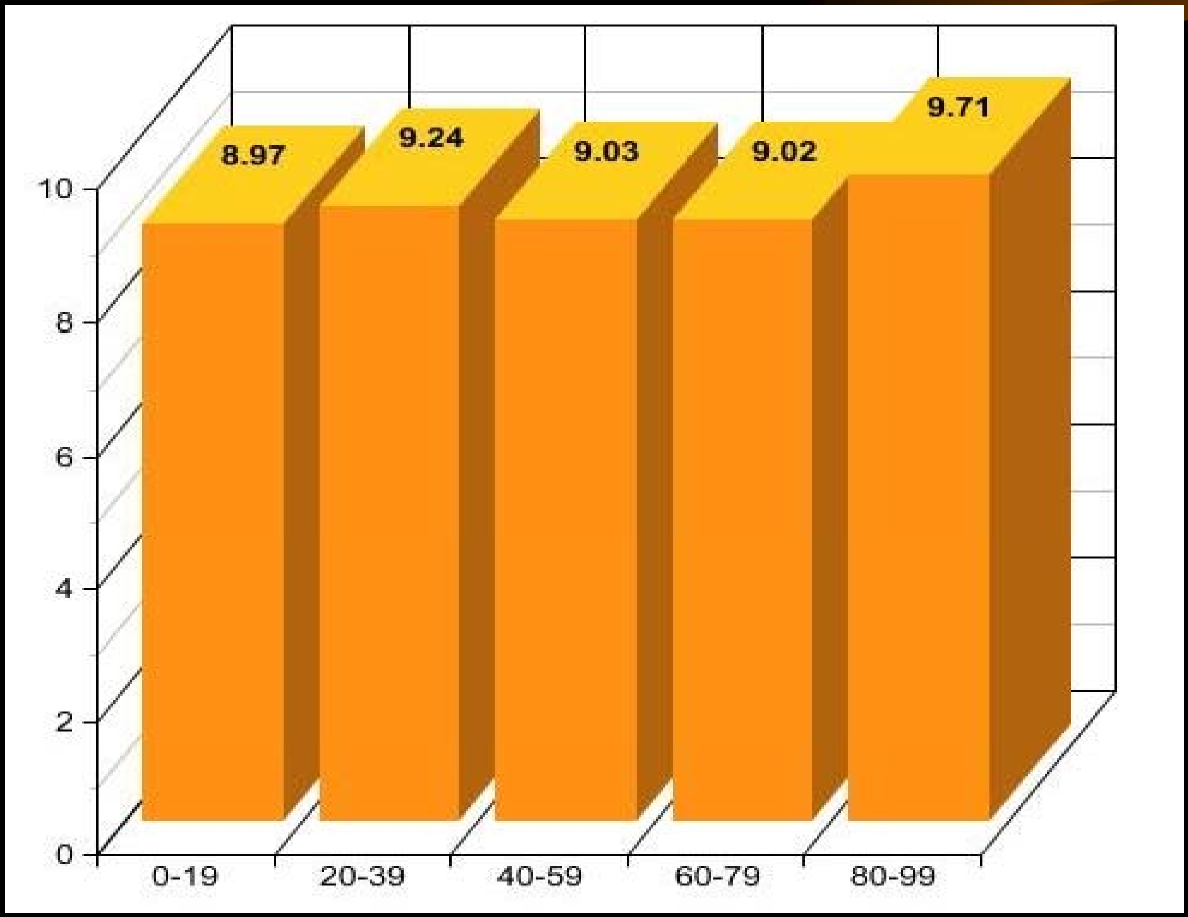
Holmes et al, Academic Emerg Med 2001

Daffner, Imaging of Vertebral Trauma 1996

Fracture Levels: n=152



Fracture Level by Age



Thoracic Spine Fracture

- The patient is neurologically intact.
- Anterior wedge fracture or flexion teardrop fracture?
- PLL and PLC appear intact on CT, but we do not want to miss an unstable injury

Thoracic Spine Fracture

- T2 weighted STIR
- Fat is suppressed
- We note high SI of three vertebral bodies c/w subtle fractures
- Intact ligaments appear black
- PLL and PLC appear intact on MR

What Does the ER Doc Want?

- Can you “clear the spine”?
  - Is there a fracture and/or subluxation?
  - Is it acute or chronic?
- Is it “stable”?
- What should we do next?

Acute vs Chronic Fracture

- Multiple vertebral deformities
- Thoracic deformities are sclerotic
- L1 deformity is lucent

Acute Burst Fracture L1

- Comminuted fracture
- Sharply defined cortical breaks consistent with acute fracture
- Retropulsion causing minimal canal stenosis

Acute / Chronic Fractures

- A = T1 MR
- B = PD MR
- C = Radiograph

- Acute fracture
- Schmorl's node
- Chronic fracture

VandeBerg et al, Radiol Clinics NA 2000

Fracture Pitfalls

- Schmorl's nodes
- Physiologic wedging
  - Lower thoracic spine
  - Anterior height 80% (m) / 87% (f) < posterior height
- Scheuerman's disease
  - Young adults, irregular endplates, narrowed disc spaces, wedging (> 5 degrees)
- Sickle cell disease
  - Depression of central endplates

Lauridsen et al, Acta Radiol 1984

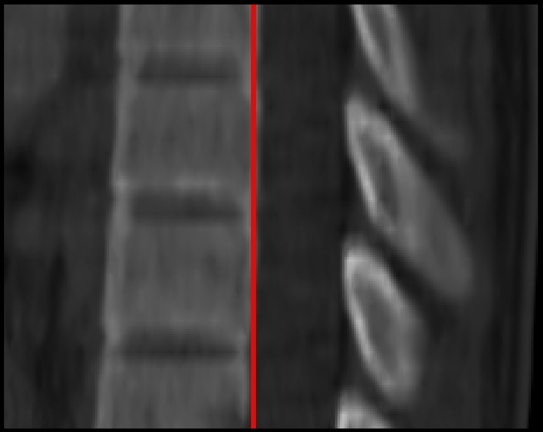
Spinal Instability

"A loss in the ability of the spine under physiologic loads to maintain relationships between vertebrae in such a way that there is neither damage nor subsequent irritation to the spinal cord or nerve roots. In addition there is no development of incapacitating deformity or pain due to structural changes."

White & Panjabi, Clinical Biomechanics of the Spine 1978

Two Column Model

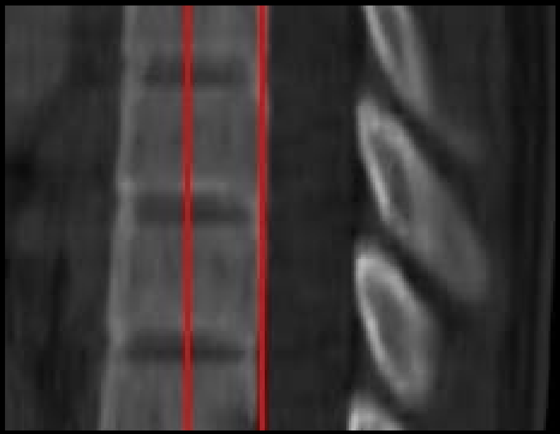
- Holdsworth 1970’s
- Posterior column necessary for stability
  - Posterior ligamentous complex
  - Facet joints
  - Pedicles & laminae
- Problem with comminuted burst fractures



Holdsworth, J Bone & Joint Surg 1970

Three Column Model

- Denis 1980's
- Two of three columns necessary for stability
- Middle column necessary for stability
  - Posterior half of vertebral body
  - Posterior half of intervertebral disc
  - Posterior longitudinal ligament
- Oversimplified view



Denis, Spine 1983

Degrees of Instability

- Denis 1980's
- Neurologic instability
- Mechanical instability
  - Potential for delayed kyphosis
- Both neurologic and mechanical instability
  - Consider both present and future

Denis, Spine 1983

TLS Fracture Classification

- Axial Load
  - Burst fracture
- Flexion/Compression
  - Anterior wedge fracture, flexion teardrop fracture
- Flexion/Rotation
  - Facet fracture/dislocation
- Flexion/Distraction
  - Chance fracture
- Extension
- Shear

Axial Load Injuries: Burst Fx

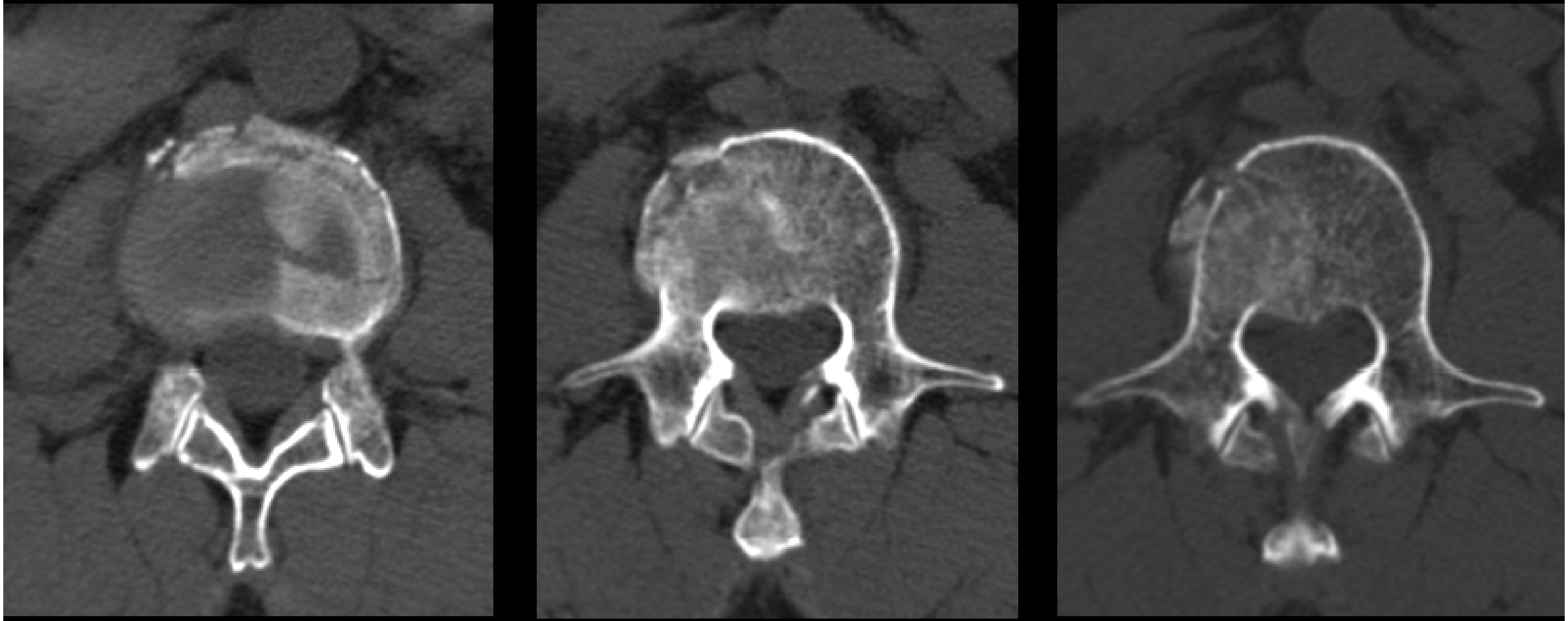
- Retropulsion of vertebral body
- PLL may be intact
- At minimum, 2/3 columns involved
  - Is a two column burst fx unstable?
- Classify stable & unstable burst fractures
- Load sharing classification of “stability” depends on the degree of comminution, apposition of fragments, and deformity

McAfee et al, J Bone Joint Surg 1983
McCormack, Spine 1994

Burst Fracture

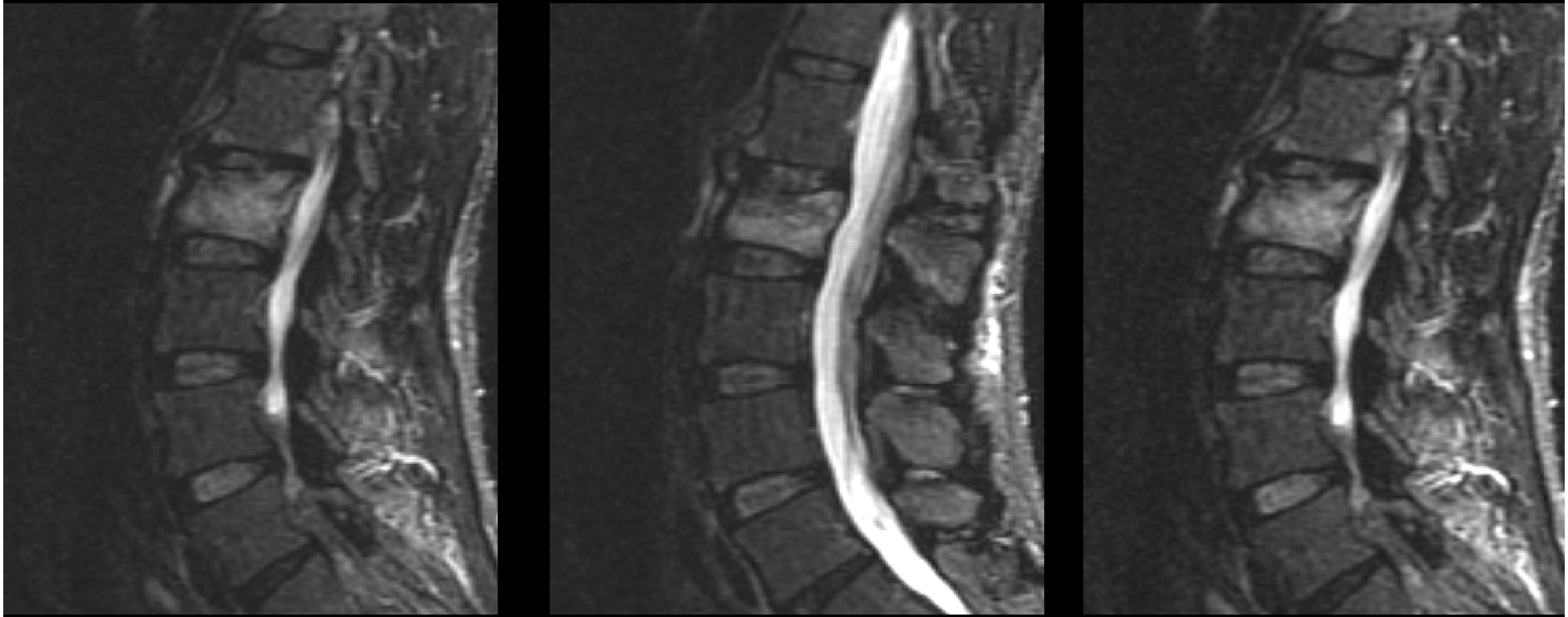
Typical location at TL junction

Burst Fracture



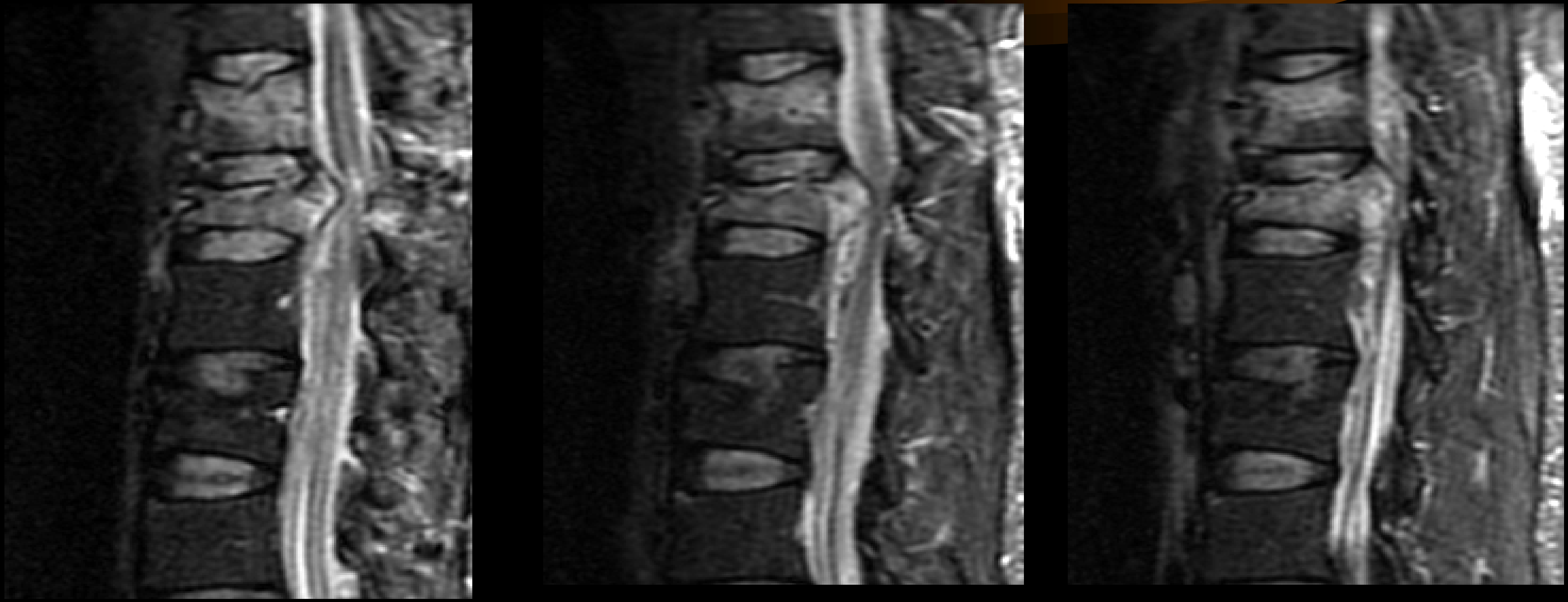
Stable ?

Burst Fracture



PLL appears intact. Stable ?

Burst Fractures

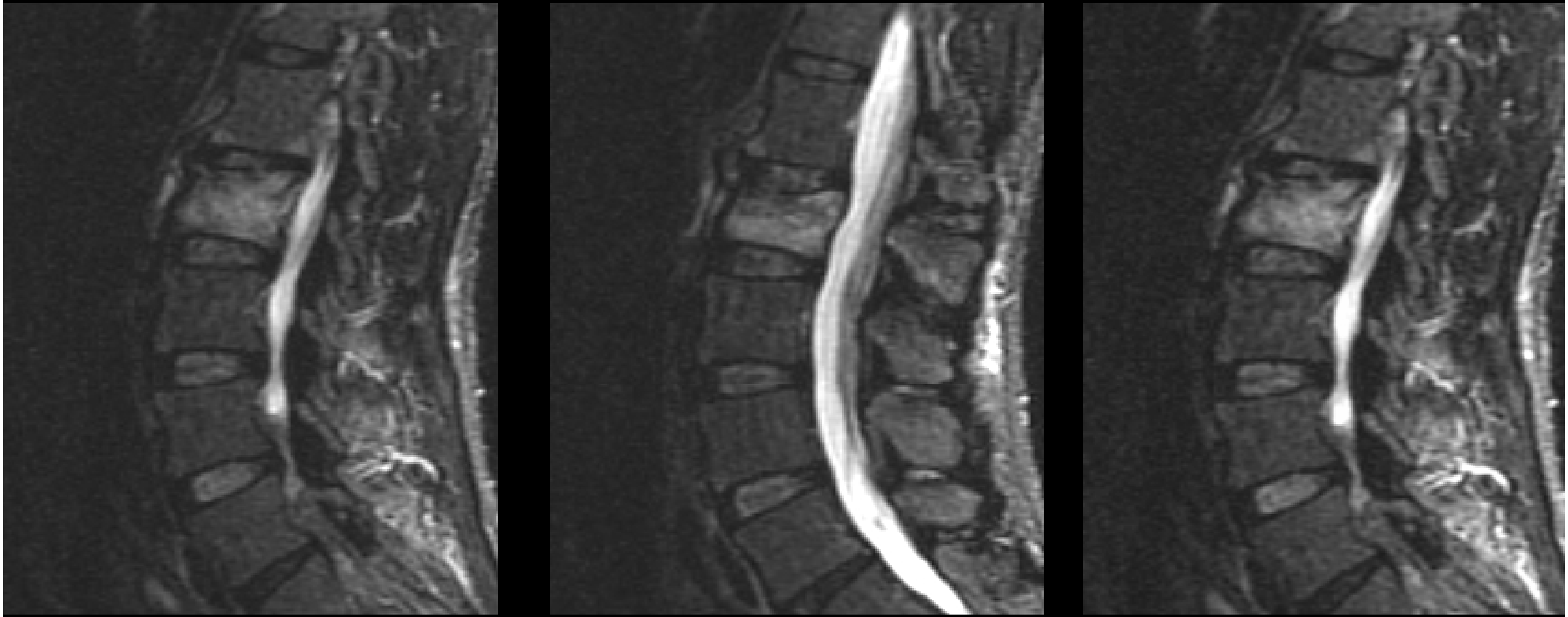


Stable ?

Burst Fracture Stability

- Assess loss of vertebral stature (>50%)
- Assess for kyphosis (>20 degrees)
- Assess canal compromise (>50%)
  - Neurologic compromise
- Assess for multilevel fractures
- Fractures may extend posteriorly to involve pedicles and/or laminae
- Conservative vs. operative management of burst fractures is controversial

Burst Fracture



PLL appears intact. Stable ?   YES!

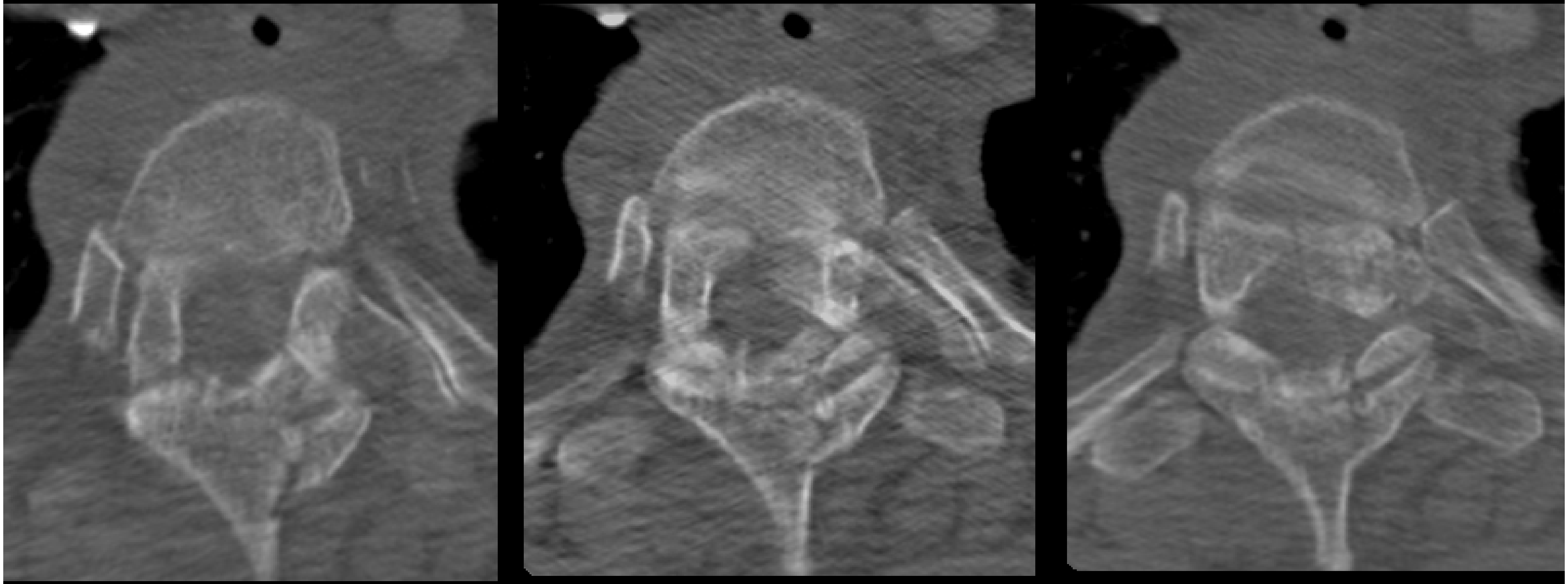
Burst Fractures

Stable ?   NO!   Significant loss of stature and significant compromise of the spinal canal

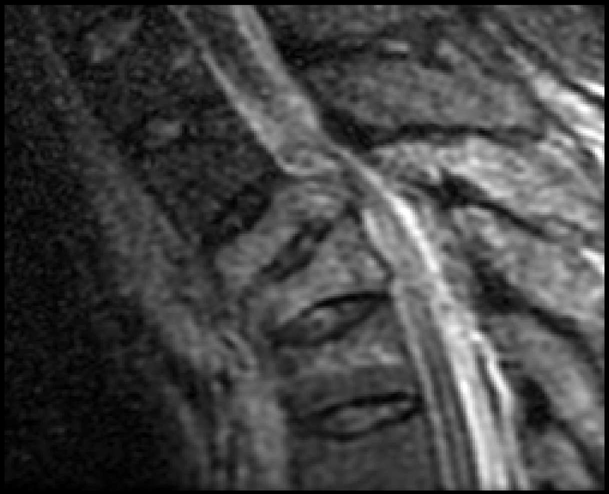
Burst Fracture ?



Burst Fracture ?



Burst vs. Wedge Fracture



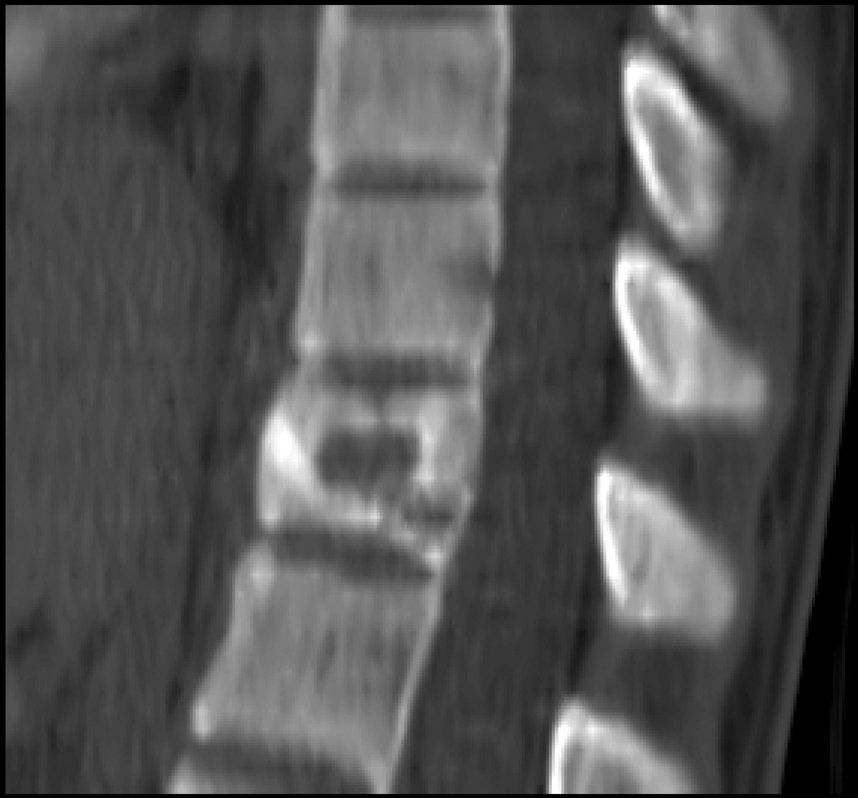
Posterior column involvement, canal compromise, loss of stature: Unstable

Flexion Injuries

- Flexion/Compression
  - Anterior wedge
  - Posterior ligament integrity: mechanical stability ?
- Flexion/Compression
  - Flexion teardrop: mechanical instability
- Flexion/Rotation
  - Facet dislocation
- Flexion/Distraction
  - Chance fracture

Anterior Wedge Fracture

No obvious ligament injury



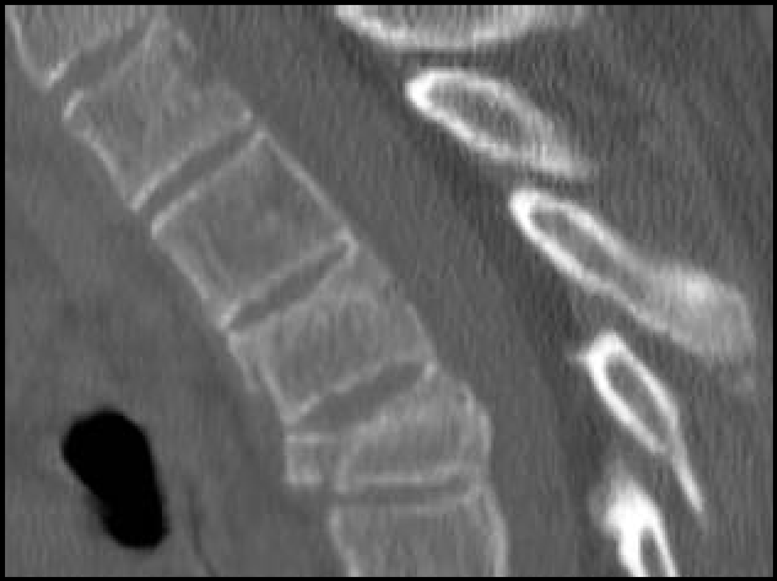
Anterior Wedge Fracture

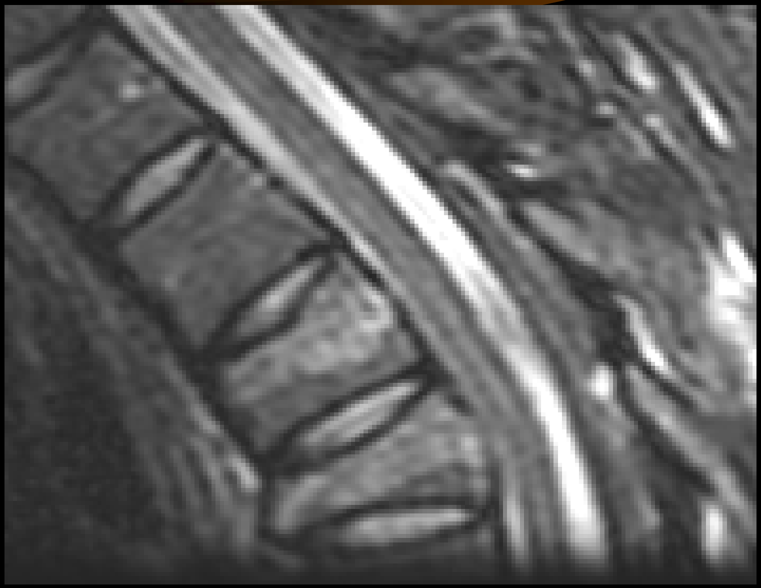
STIR sequence, PLL & PLC appear intact: Stable

Anterior Wedge Fracture

Middle column involved on CT

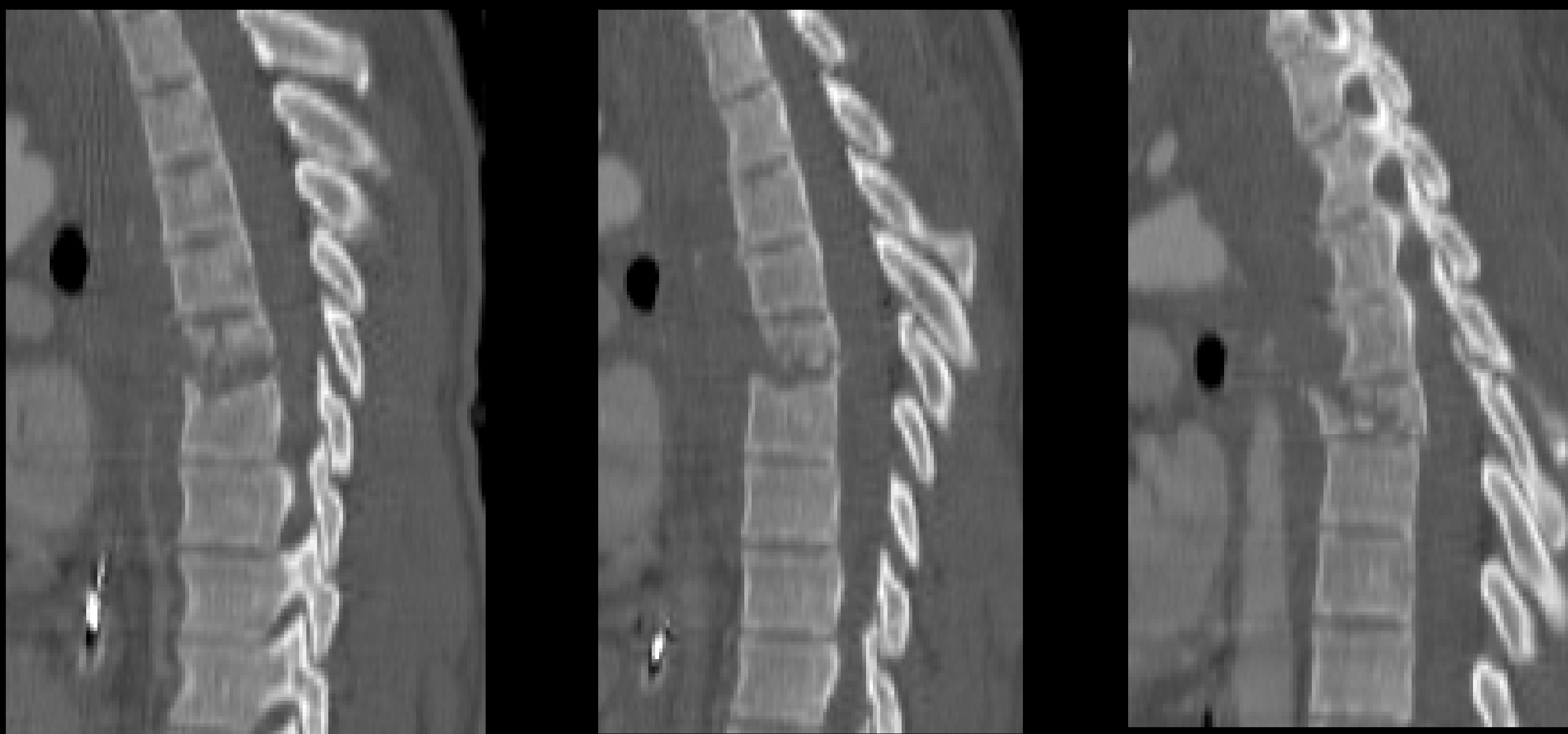
Anterior Wedge Fracture





Middle column & PLL involved on CT & MR (STIR)
PLC appears intact: Mechanically stable?
Surgery may be indicated: kyphosis

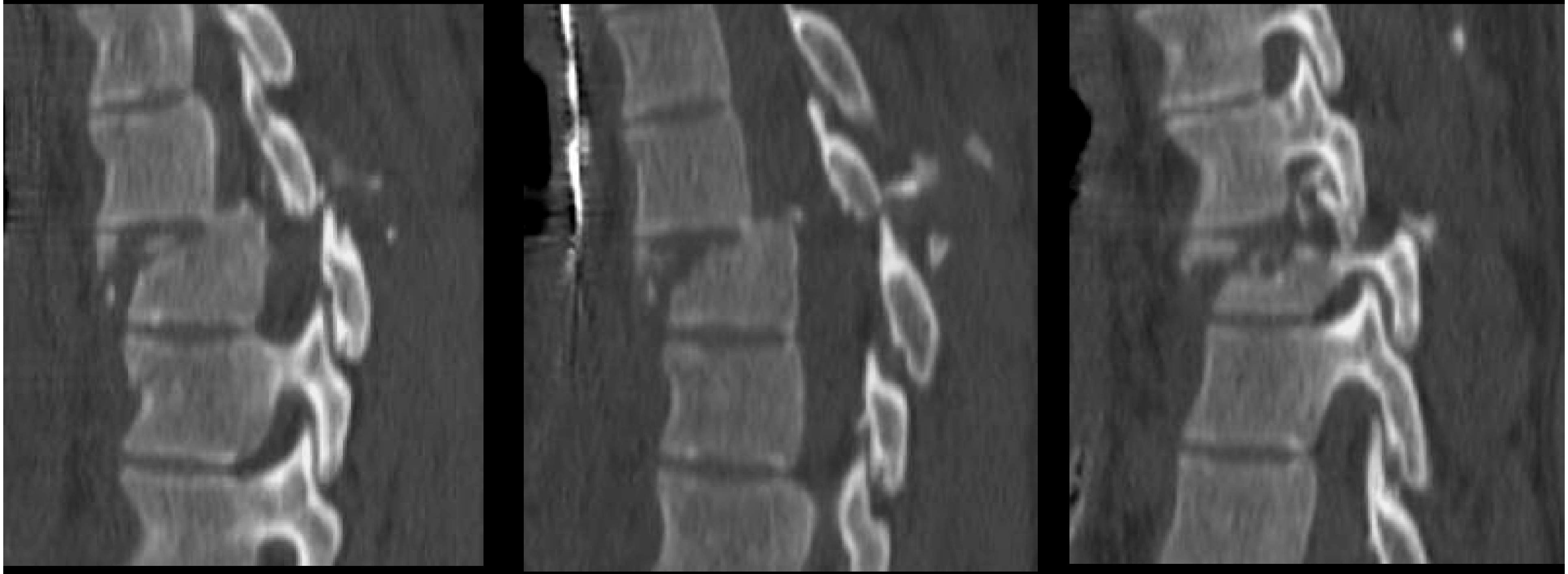
Anterior Wedge Fracture



Anterior Wedge Fracture

STIR sequence: PPL, ligamentum flavum and intraspinous ligaments are disrupted: Unstable

Flexion Teardrop Fracture



All three columns involved: Unstable

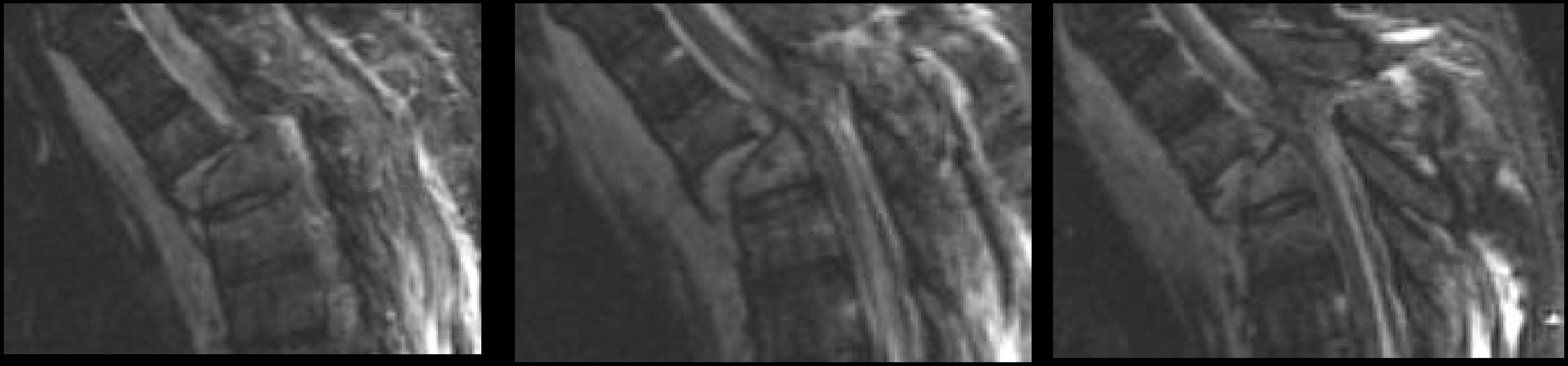
Flexion Teardrop Fracture

All three columns involved: Unstable

Fracture-Dislocation

All three columns involved: Unstable

Fracture-Dislocation

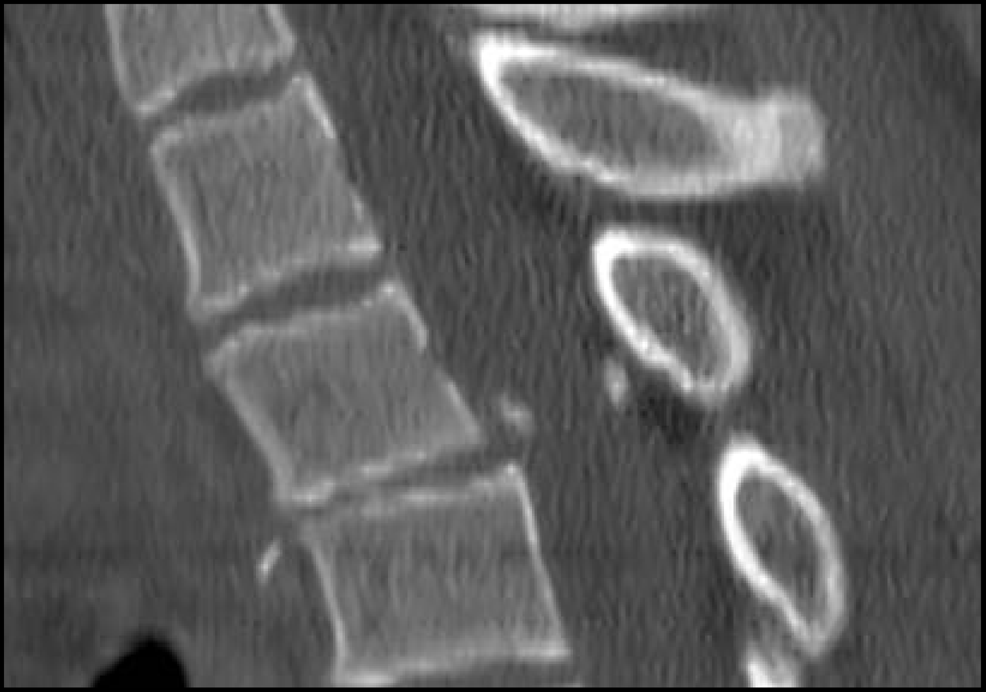


All three columns involved: Unstable

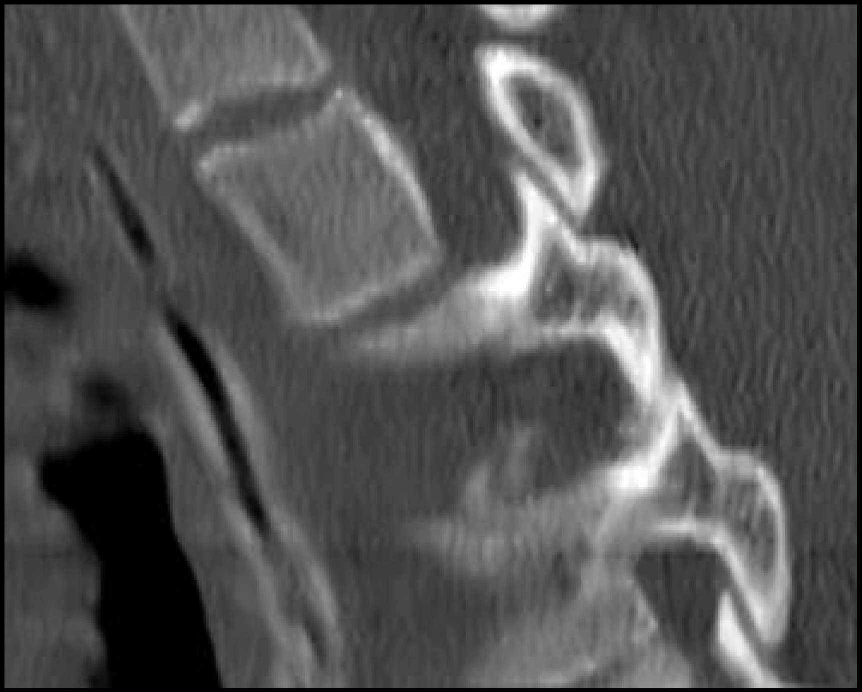
Flexion/Rotation Injuries

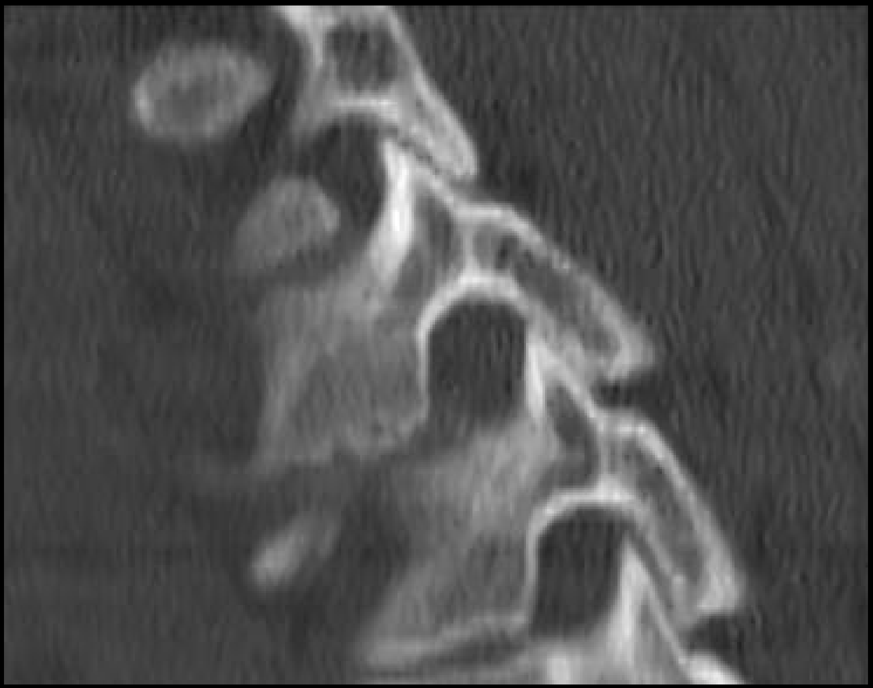
- Flexion component
  - Anterior wedge or burst injury
- Rotation component
  - Facet dislocation or fracture
- Stable vs. unstable
- Unilateral facet lock
  - majority neurologically intact
- Bilateral facet lock
  - majority paraplegic

Flexion/Rotation Injury



Unilateral Facet Dislocation

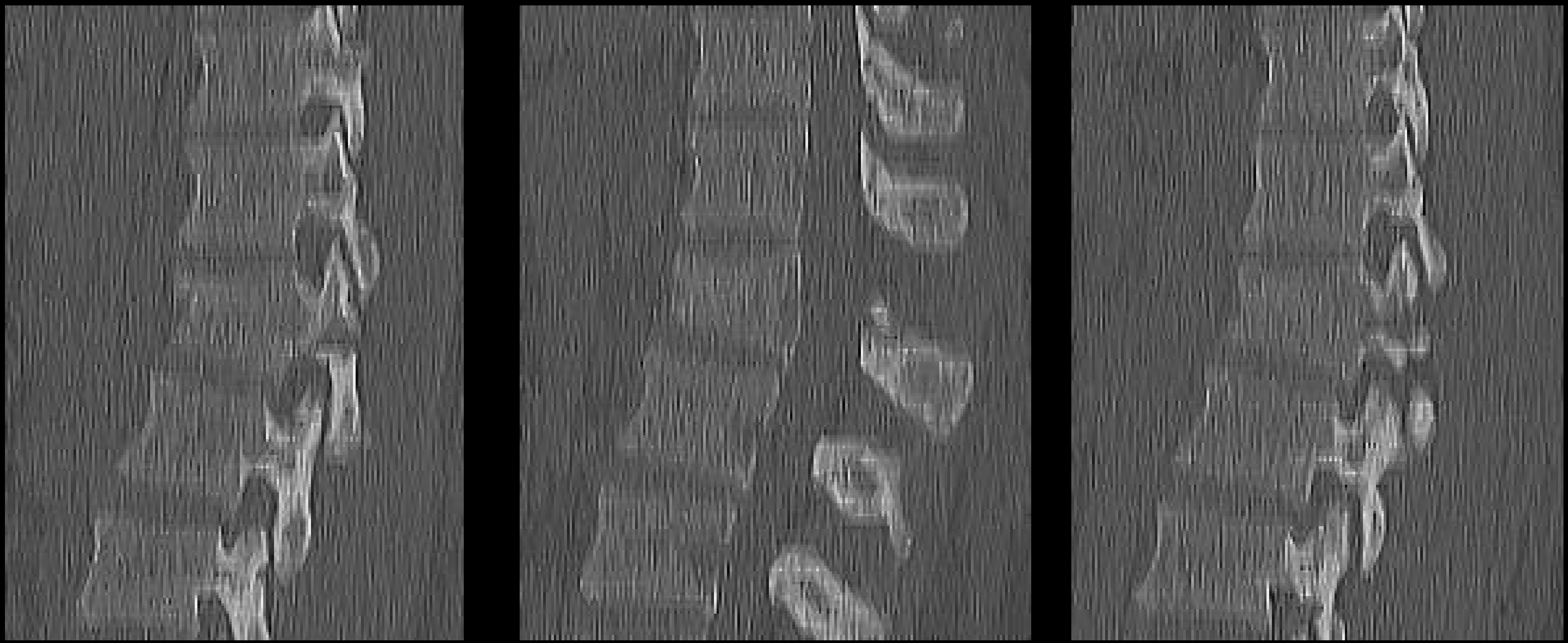




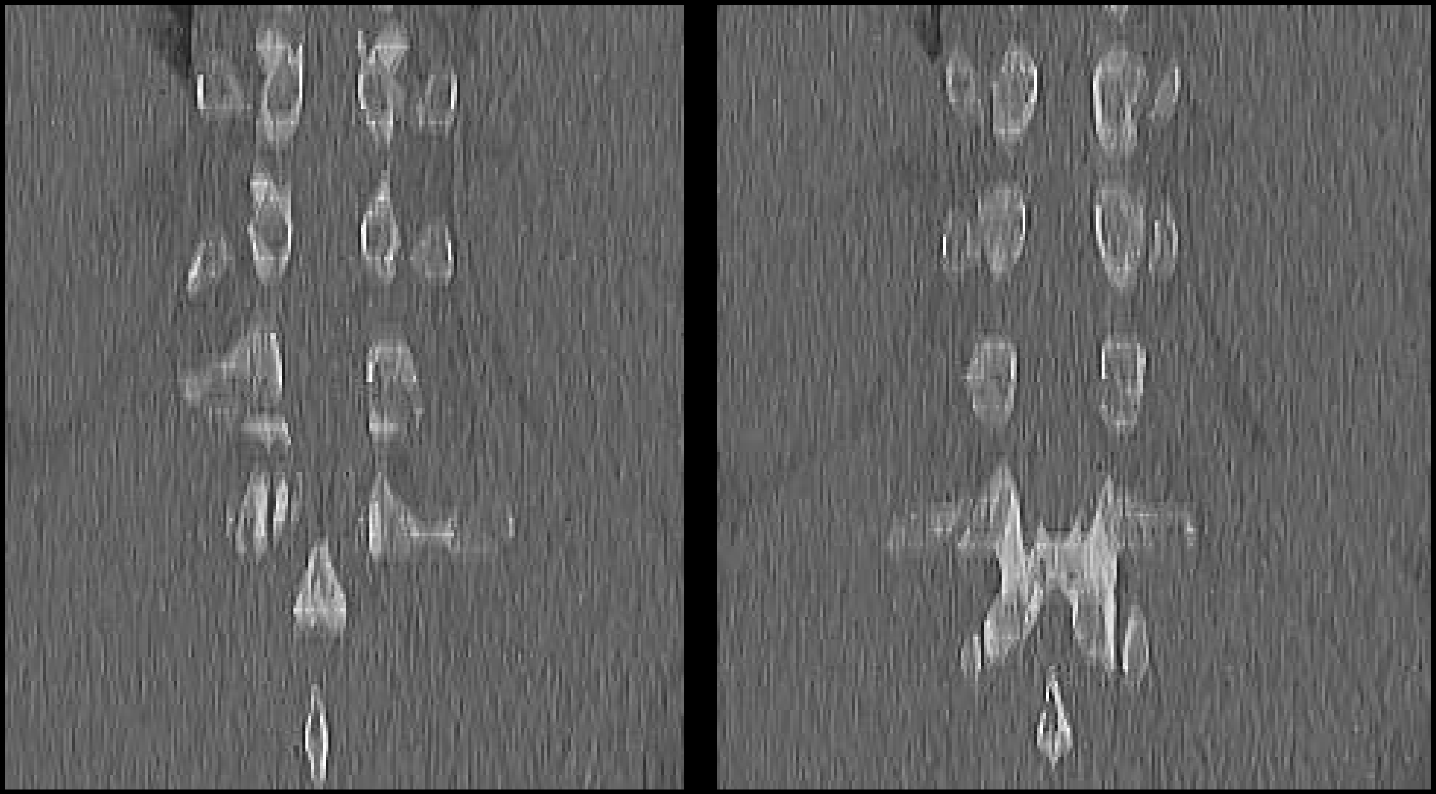
Flexion Distraction Injury

- Hyperflexion around an anterior fulcrum
  - Two point restraint
- Horizontal split of the vertebral body and pedicles, Chance fracture
- Posterior ligamentous complex disruption
- Considered unstable
- Associated abdominal injuries

Chance Fracture

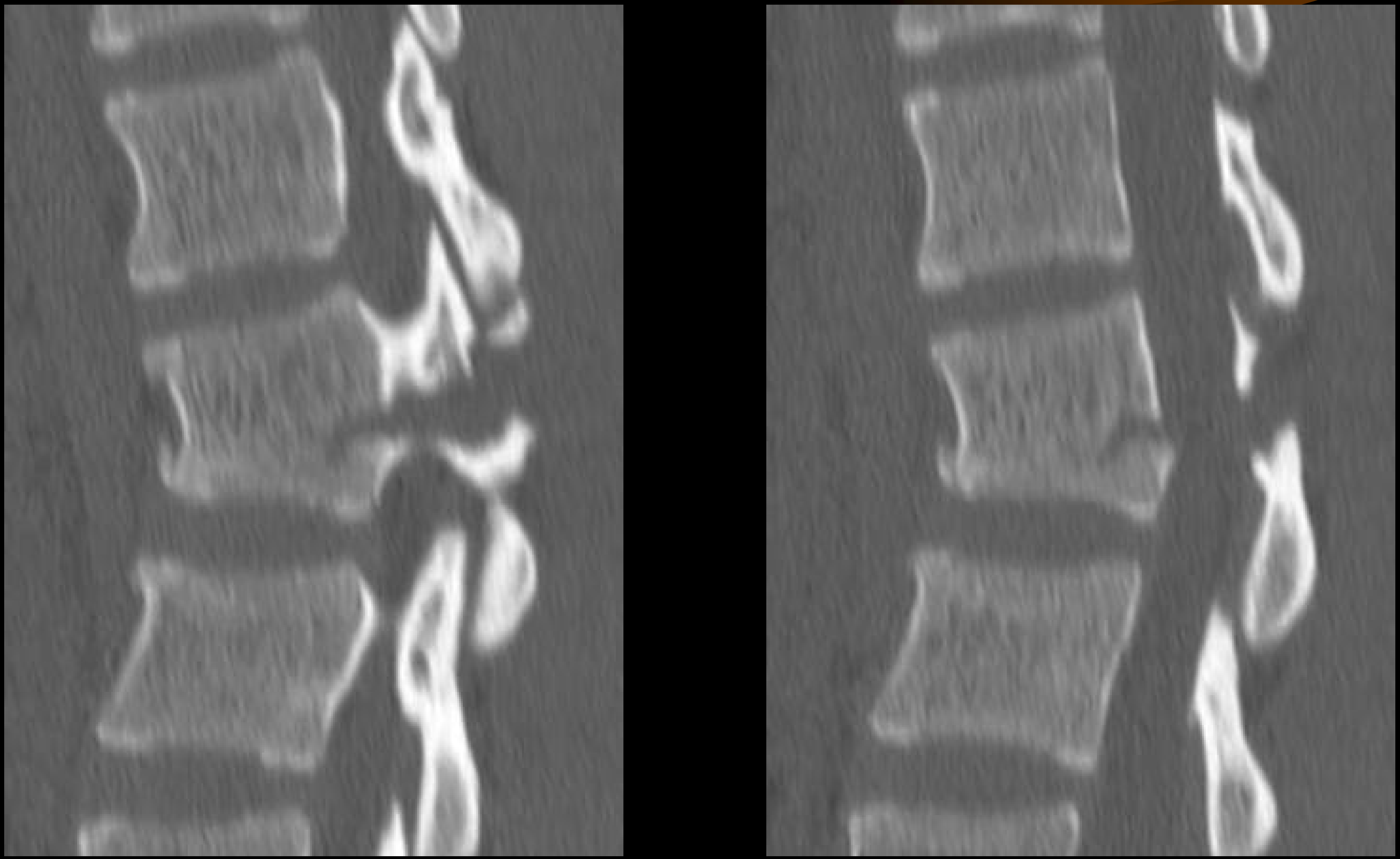


Chance Fracture



Chance Fracture

Chance Fracture

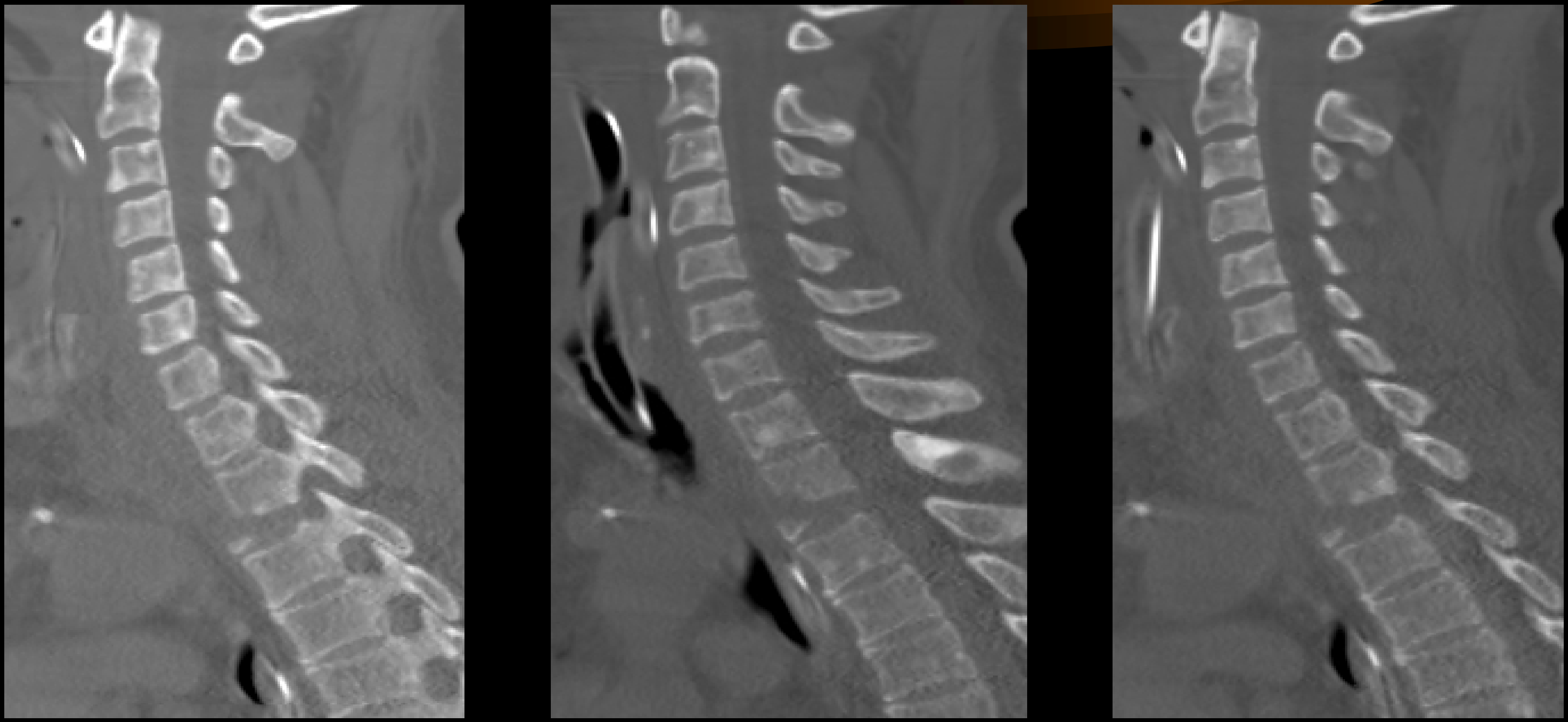


Chance Fracture

Extension Injuries

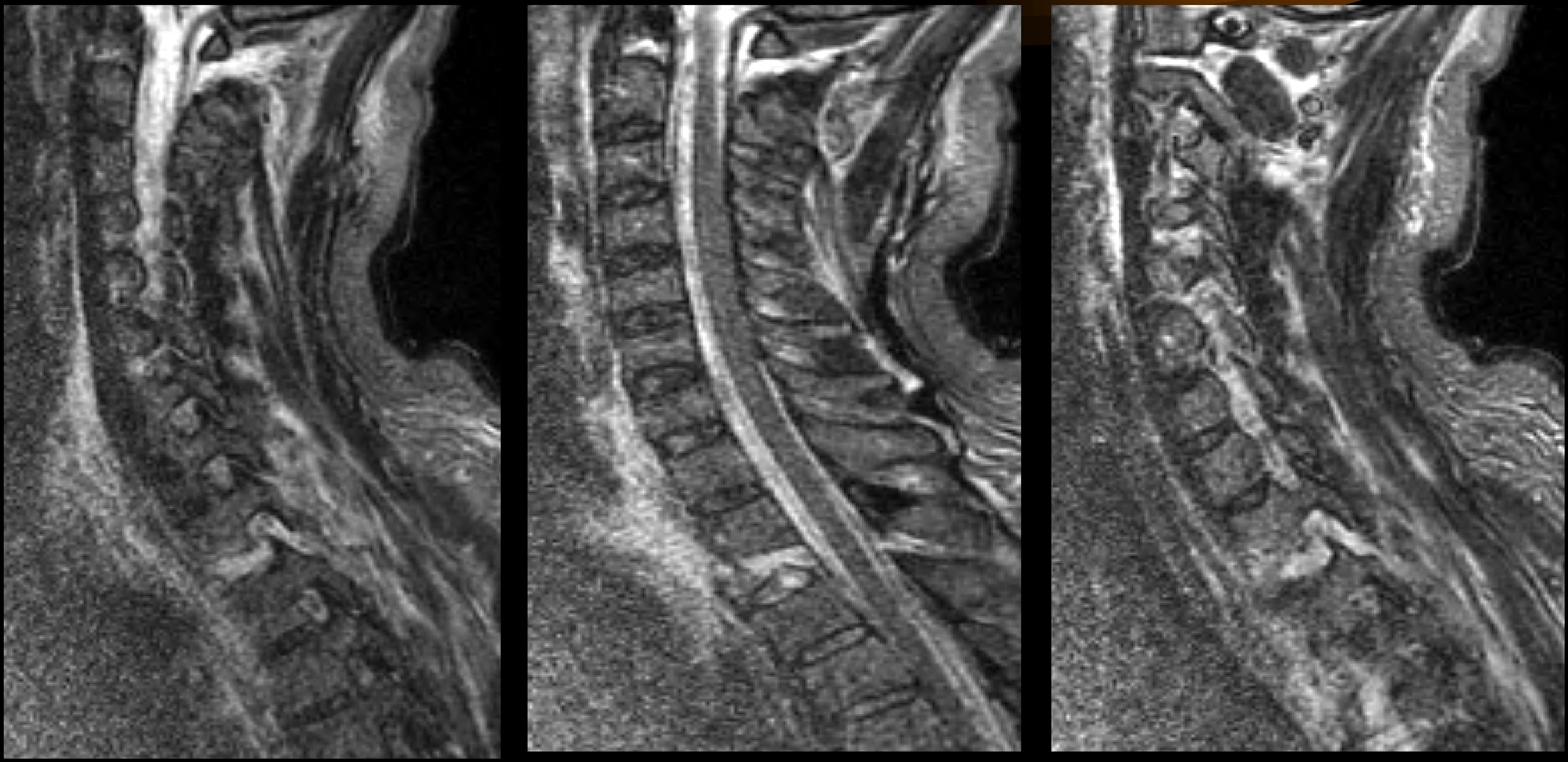
- Force pushes the upper trunk backward or a direct blow to the back
- Unstable, if the anterior and middle column ligaments are disrupted
- Anterior intervertebral space widening
- Possible avulsion fracture from anterior endplate
  - Extension teardrop

Extension Injury



Extension teardrop, 3 column disruption: Unstable

Extension Injury



Extension Injury

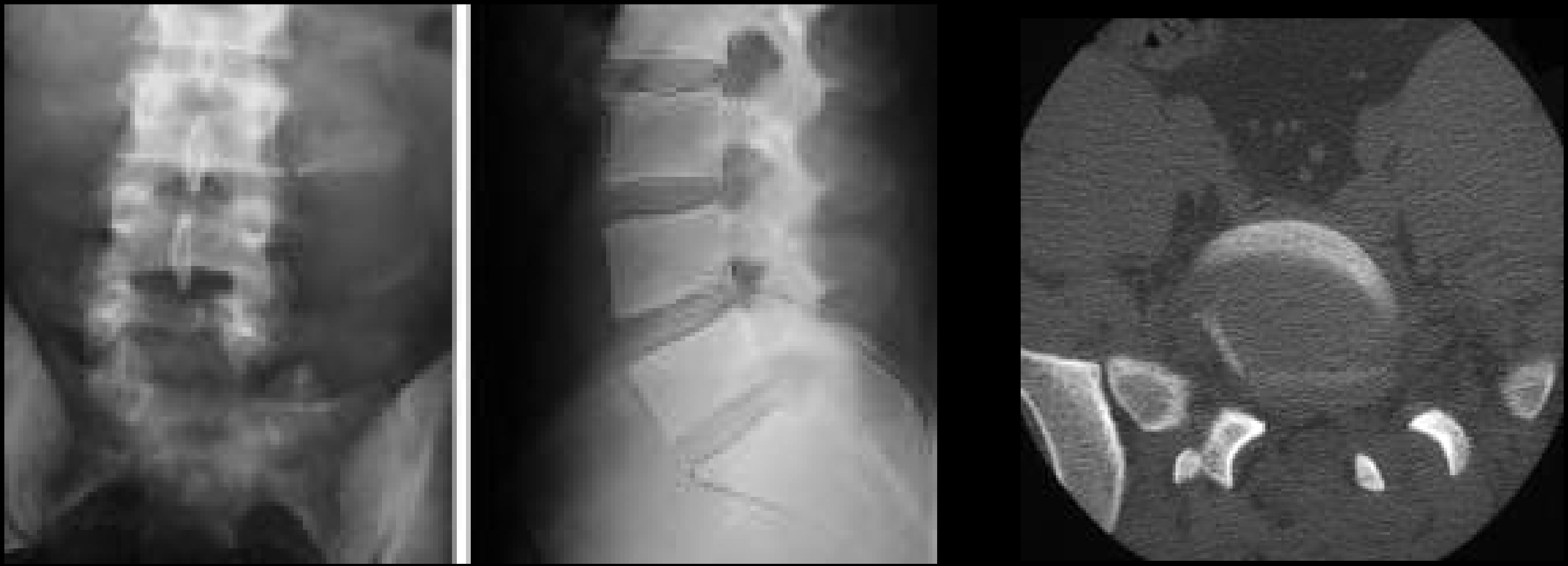
Extension Injury

PLL and posterior column appear intact: Stable

Shear Injuries

- Application of a lateral, horizontal force
- Unstable, three column injury
- Neurologic impairment is common

Shear Injuries



Vialle & Court, J of Spinal Disorders 2005

Summary

- Recognize, analyze, and classify the TL fracture
- "Stability" is a tricky concept
  - Mechanical / neurological
  - Immediate / delayed
- Stability as assessed on MR usually relates to ligamentous integrity
  - May not coincide with the three column model

Summary

- Burst fractures may not be “stable”
  - Load sharing classification
  - Assess stature, kyphosis, canal compromise
  - Assess PLL and posterior column with MR
- Flexion/compression injuries
  - Stable anterior wedge fracture
  - Anterior wedge with middle column disruption
  - Anterior wedge with three column disruption
  - Flexion teardrop fracture

Summary

- Flexion/rotation injuries
- Flexion/distraction
  - Chance fracture
- Extension injuries
- Shear injuries

Summary

- Thanks and Good Luck!

- http://www.uth.tmc.edu/radiology/RSNA/2009/mann_west_cervical_spine.htm
  - Posted next week
  - URL address in RSNA program