Neuroradiology: Nuts and Bolts, Do's and Don'ts. Part 2: SPINE

Michael A. Johnson, PA-C, MPAS
Assistant Professor of PA Studies and Neurologic Surgery

School of Medicine & Health Sciences
THE GEORGE WASHINGTON UNIVERSITY

Physician Assistant Studies

Disclosure

I have no relevant relationships with ineligible companies to disclose within the past 24 months.

Learning Objectives

At the end of this learning session, the participant should be able to:

1. Compare and contrast the risks, benefits, alternatives, indications, contraindications, advantages and costs of different imaging modalities used to evaluate patients with neurologic complaints involving the spine
2. Select the most appropriate imaging modality to evaluate a patient with neurologic complaint
3. Apply fundamentals of image interpretation in reviewing Magnetic Resonance Imaging and Computed Tomography

Overview of Imaging Modalities

Radiograph (X-ray)

Computed Tomography (CT, CAT scan)

Magnetic Resonance Imaging (MRI)

Case #1

47-year-old fell 8 feet from a ladder hanging Christmas Lights

Arrives to ER on backboard with a rigid cervical collar

- Obvious Left wrist fracture
- Reports neck stiffness

Exam:

No noted Neurologic Deficits, GCS 15

Clinical Decision Tools

- No tool is 100% sensitive, application of any tool results in a non-zero missed injury rate.

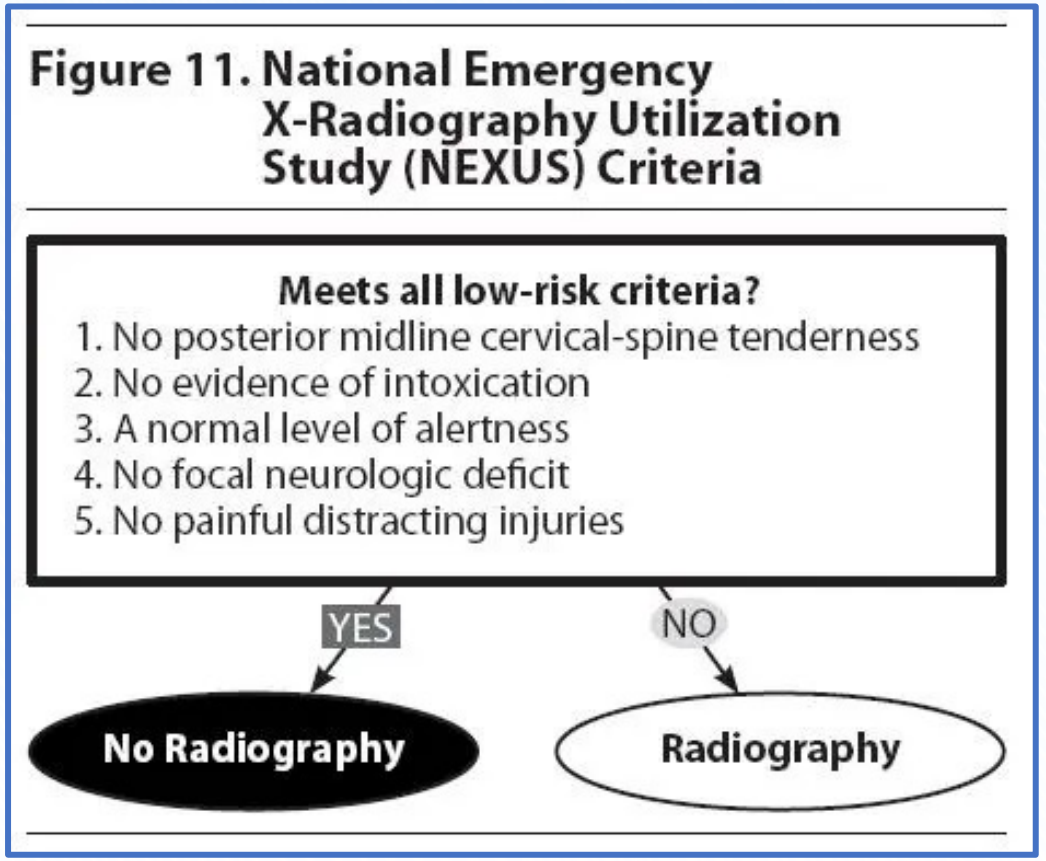
- **NEXUS Criteria** and **Canadian C-Spine Rule** are the most common

Cervical Imaging – NEXUS Criteria

34,069 patients in 21 centers

Greater than 99% sensitive

Cervical spine imaging required given distracting injury



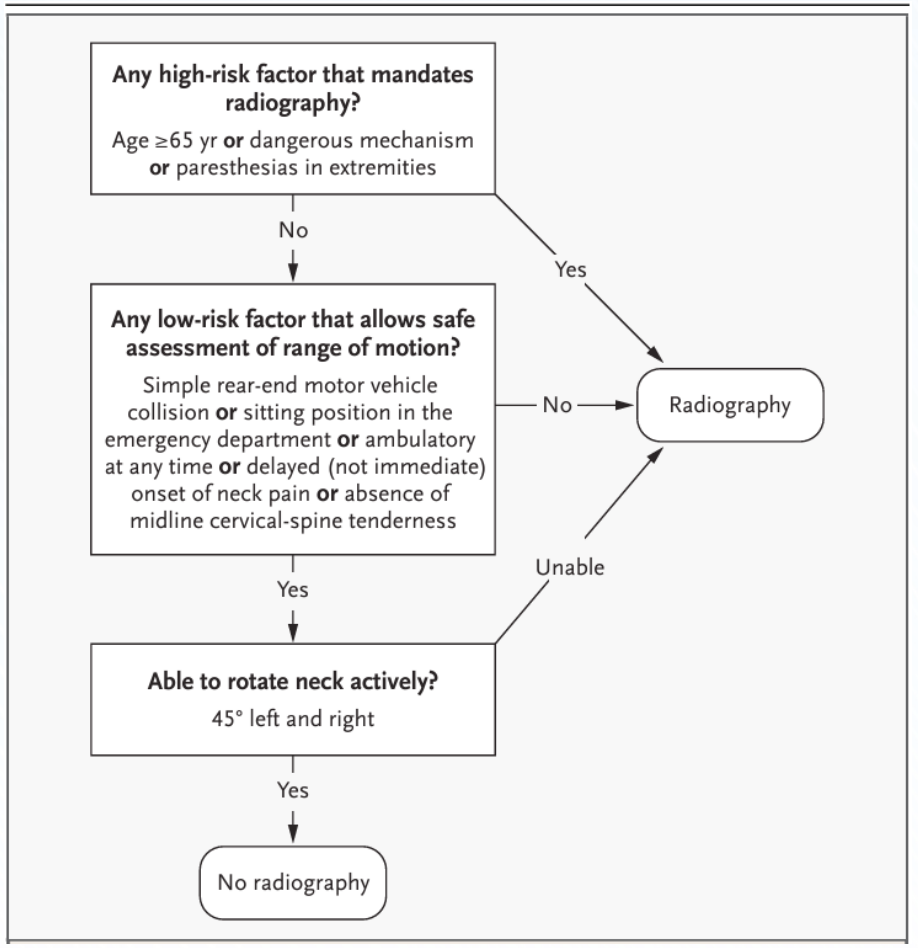
National Emergency X-Radiography Utilization Study (NEXUS), Hoffman, et al. 2000

Canadian C-Spine Rules

8924 patients in 10 EDs

100% sensitive for ‘clinically significant’ spine injuries

Cervical spine imaging required given fall from height



Stiell IG, Wells GA, Vandemheen KL, et al. The Canadian C-Spine Rule for Radiography in Alert and Stable Trauma Patients. *JAMA : the journal of the American Medical Association*. 2001;286(15):1841-1848. doi:10.1001/jama.286.15.1841

Canadian C-Spine Rules

8924 patients in 10 EDs

100% sensitive for ‘clinically significant’ spine injuries

Cervical spine imaging required given fall from height

*Dangerous Mechanism:
- Fall From ≥1 Meter/5 Stairs
- Axial Load to Head, eg, Diving
- MVC High Speed (>100 km/hr), Rollover, Ejection
- Motorized Recreational Vehicles
- Bicycle Collision

†Simple Rear-end MVC Excludes:
- Pushed Into Oncoming Traffic
- Hit by Bus/Large Truck
- Rollover
- Hit by High-Speed Vehicle

‡Delayed:
- Not Immediate Onset of Neck Pain

Stiell IG, Wells GA, Vandemheen KL, et al. The Canadian C-Spine Rule for Radiography in Alert and Stable Trauma Patients. *JAMA : the journal of the American Medical Association*. 2001;286(15):1841-1848. doi:10.1001/jama.286.15.1841

The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

The Canadian C-Spine Rule versus the NEXUS Low-Risk Criteria in Patients with Trauma

Ian G. Stiell, M.D., M.Sc., Catherine M. Clement, R.N., R. Douglas McKnight, M.D., Robert Brison, M.D., M.P.H., Michael J. Schull, M.D., M.Sc., Brian H. Rowe, M.D., M.Sc., James R. Worthington, M.B., B.S., Mary A. Eisenhauer, M.D., Daniel Cass, M.D., Gary Greenberg, M.D., Iain MacPhail, M.D., M.H.Sc., Jonathan Dreyer, M.D., Jacques S. Lee, M.D., Glen Bandiera, M.D., Mark Reardon, M.D., Brian Holroyd, M.D., Howard Lesiuk, M.D., and George A. Wells, Ph.D.

ABSTRACT

BACKGROUND

The Canadian C-Spine (cervical-spine) Rule (CCR) and the National Emergency X-Radiography Utilization Study (NEXUS) Low-Risk Criteria (NLC) are decision rules to guide the use of cervical-spine radiography in patients with trauma. It is unclear how the two decision rules compare in terms of clinical performance.

METHODS

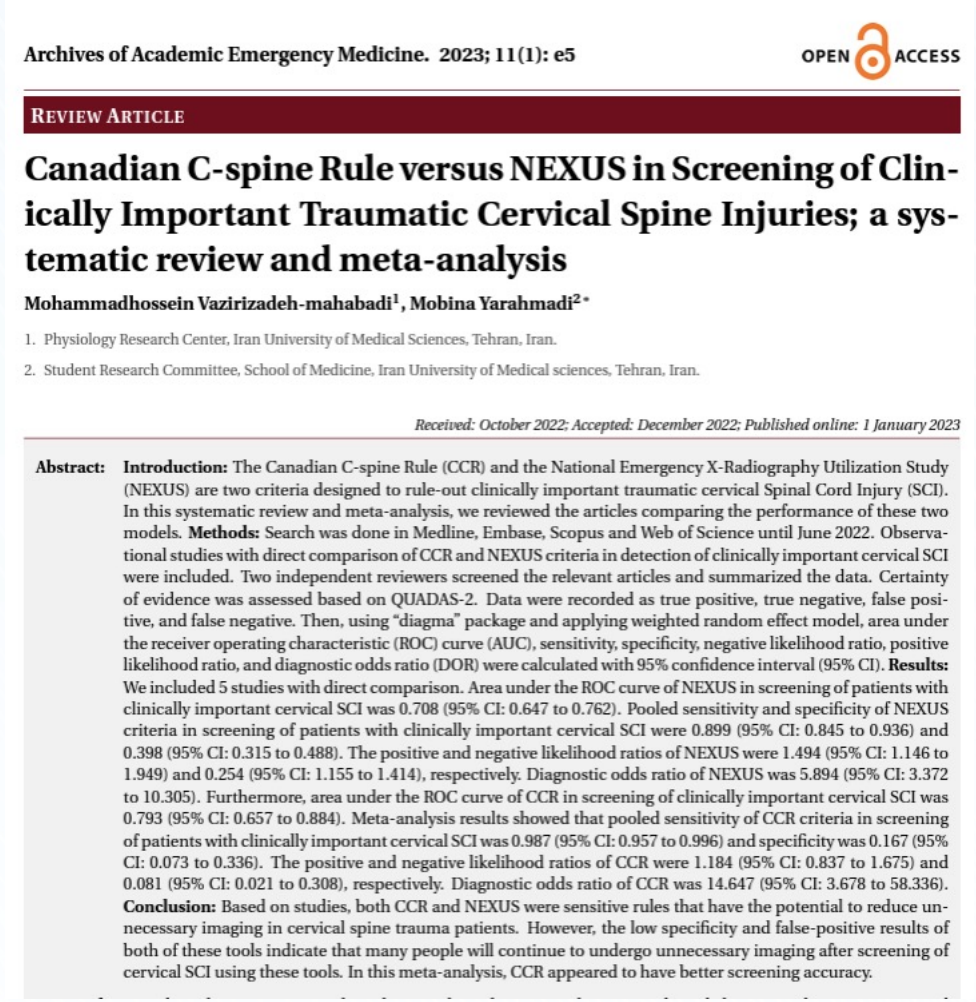
We conducted a prospective cohort study in nine Canadian emergency departments comparing the CCR and NLC as applied to alert patients with trauma who were in stable condition. The CCR and NLC were interpreted by 394 physicians for patients before radiography.

Soooo.....

Both tools have similar high sensitivity

Both tools have low specificity

Stiell IG, Clement CM, McKnight RD, et al. The Canadian C-Spine Rule versus the NEXUS Low-Risk Criteria in Patients with Trauma. *The New England journal of medicine*. 2003;349(26):2510-2518. doi:10.1056/NEJMoa031375



Archives of Academic Emergency Medicine. 2023; 11(1): e5

OPEN ACCESS

REVIEW ARTICLE

Canadian C-spine Rule versus NEXUS in Screening of Clinically Important Traumatic Cervical Spine Injuries; a systematic review and meta-analysis

Mohammadhossein Vazirizadeh-mahabadi[1], Mobina Yarahmadi[2]*

1. Physiology Research Center, Iran University of Medical Sciences, Tehran, Iran.
2. Student Research Committee, School of Medicine, Iran University of Medical sciences, Tehran, Iran.

Received: October 2022; Accepted: December 2022; Published online: 1 January 2023

Abstract: **Introduction:** The Canadian C-spine Rule (CCR) and the National Emergency X-Radiography Utilization Study (NEXUS) are two criteria designed to rule-out clinically important traumatic cervical Spinal Cord Injury (SCI). In this systematic review and meta-analysis, we reviewed the articles comparing the performance of these two models. **Methods:** Search was done in Medline, Embase, Scopus and Web of Science until June 2022. Observational studies with direct comparison of CCR and NEXUS criteria in detection of clinically important cervical SCI were included. Two independent reviewers screened the relevant articles and summarized the data. Certainty of evidence was assessed based on QUADAS-2. Data were recorded as true positive, true negative, false positive, and false negative. Then, using "diagma" package and applying weighted random effect model, area under the receiver operating characteristic (ROC) curve (AUC), sensitivity, specificity, negative likelihood ratio, positive likelihood ratio, and diagnostic odds ratio (DOR) were calculated with 95% confidence interval (95% CI). **Results:** We included 5 studies with direct comparison. Area under the ROC curve of NEXUS in screening of patients with clinically important cervical SCI was 0.708 (95% CI: 0.647 to 0.762). Pooled sensitivity and specificity of NEXUS criteria in screening of patients with clinically important cervical SCI were 0.899 (95% CI: 0.845 to 0.936) and 0.398 (95% CI: 0.315 to 0.488). The positive and negative likelihood ratios of NEXUS were 1.494 (95% CI: 1.146 to 1.949) and 0.254 (95% CI: 1.155 to 1.414), respectively. Diagnostic odds ratio of NEXUS was 5.894 (95% CI: 3.372 to 10.305). Furthermore, area under the ROC curve of CCR in screening of clinically important cervical SCI was 0.793 (95% CI: 0.657 to 0.884). Meta-analysis results showed that pooled sensitivity of CCR criteria in screening of patients with clinically important cervical SCI was 0.987 (95% CI: 0.957 to 0.996) and specificity was 0.167 (95% CI: 0.073 to 0.336). The positive and negative likelihood ratios of CCR were 1.184 (95% CI: 0.837 to 1.675) and 0.081 (95% CI: 0.021 to 0.308), respectively. Diagnostic odds ratio of CCR was 14.647 (95% CI: 3.678 to 58.336). **Conclusion:** Based on studies, both CCR and NEXUS were sensitive rules that have the potential to reduce unnecessary imaging in cervical spine trauma patients. However, the low specificity and false-positive results of both of these tools indicate that many people will continue to undergo unnecessary imaging after screening of cervical SCI using these tools. In this meta-analysis, CCR appeared to have better screening accuracy.

Sooooo.....

Both tools have similar high sensitivity

Both tools have low specificity

CCR appeared to have better screening accuracy

CCR has high false positive for geriatrics

Vazirizadeh-Mahabadi M, Yarahmadi M. Canadian C-spine Rule versus NEXUS in Screening of Clinically Important Traumatic Cervical Spine Injuries; a systematic review and meta-analysis. Archives of academic emergency medicine. 2023;11(1):e5-e5. doi:10.22037/aaem.v11i1.1833

What to Order??

American College of Surgeons:

- Radiographs **NOT** recommended

- **CT cervical spine is the initial study of choice**

- MRI to be considered with Spine Surgery consultation

What was the Mechanism?

Help the radiologist!

Describe mechanism in the order

Think about mechanism when you review

Hyper-flexion	• Ant Wedge • Tear drop • Flexion/ Distraction
Axial Load	• Compression fracture • Jefferson Fracture
Hyper-extension	• Lateral Mass/ Posterior elements • Anterior Avulsion Fracture • Posterior Dislocation

CT Cervical Spine

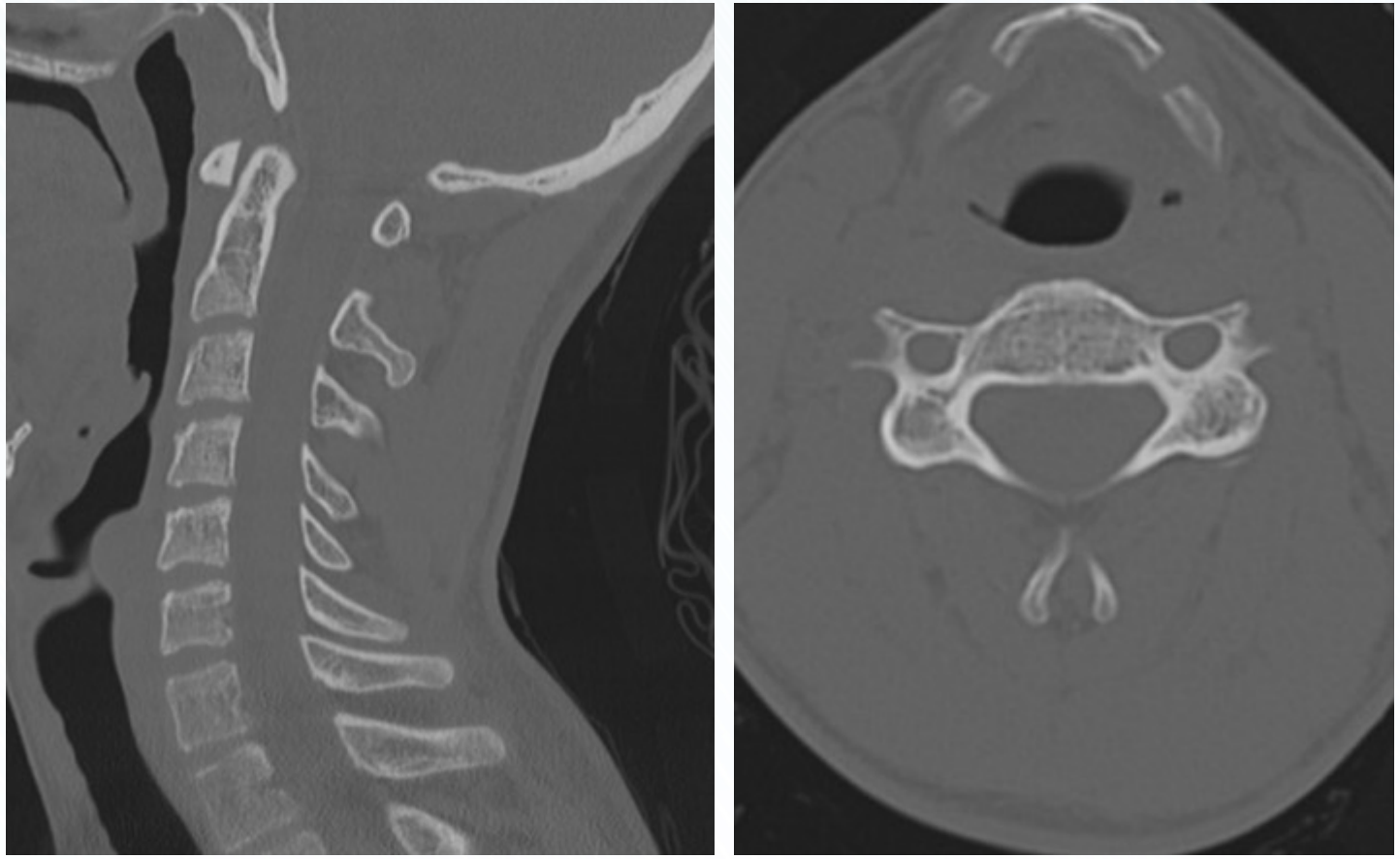
No fracture

Normal alignment

No bony canal stenosis

No information about

- Cord / Nerves
- Ligaments
- Discs
- Vessels

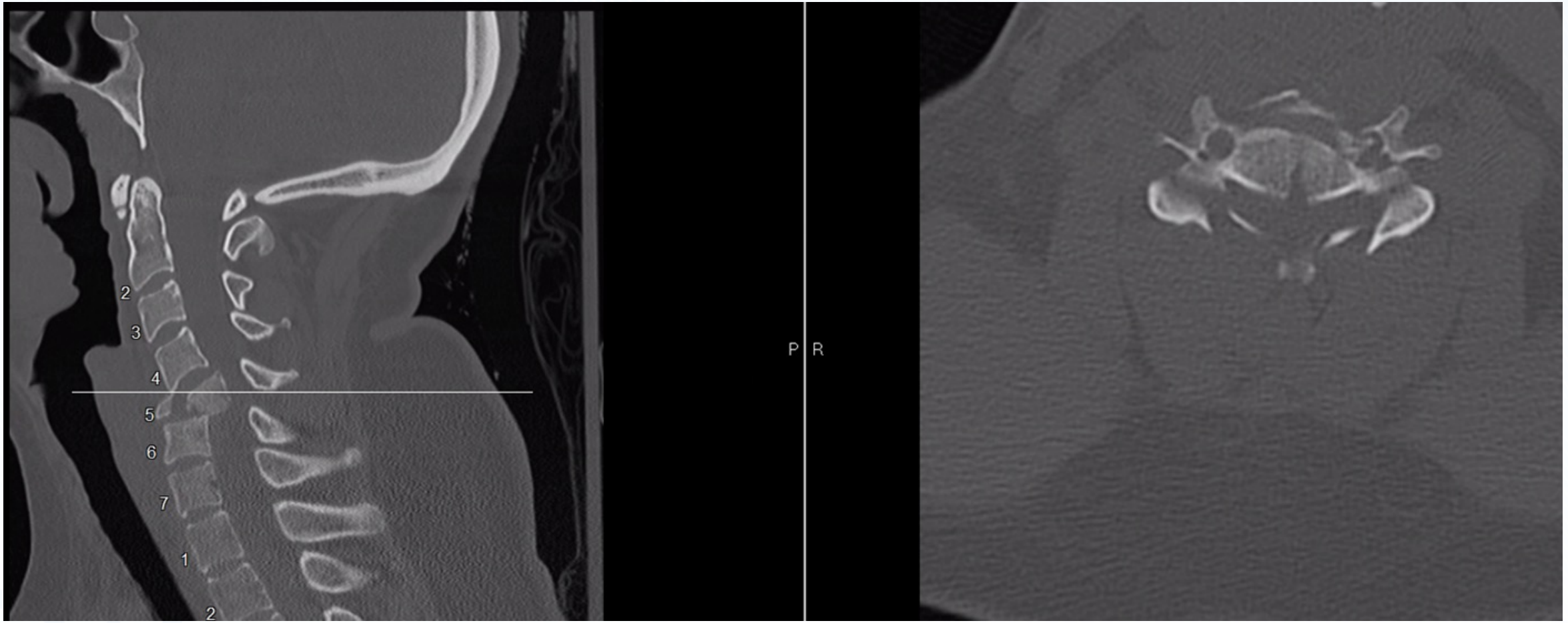


Gaillard F, Normal cervical spine CT. Case study, Radiopaedia.org (Accessed on 05 Nov 2023) https://doi.org/10.53347/rID-29401

Hyperflexion

Ebouda F, Cervical spine fracture - hyperflexion injury. Case study, Radiopaedia.org (Accessed on 24 Feb 2024) https://doi.org/10.53347/rID-66184

Axial Loading



CT Cervical Spine- Don’t Miss

Atlanto-Occipital Dislocation / Rotation

Occipital Condyle Fracture

Subdural / Epidural Hematoma

Anterior Neck Injuries

Wong C, Atlanto-occipital dislocation. Case study, Radiopaedia.org (Accessed on 29 Feb 2024) https://doi.org/10.53347/rID-44648

Thoracic and Lumbar Spine Trauma

No clinical guidelines on ordering imaging

Most recommend against radiographs (EAST, ACR, ACS)

CT Thoracic and Lumbar are preferred

- CT CAP for trauma can be reformatted to CT T+L

Consider imaging the entire spine

MRI for Thoracolumbar Trauma

Not useful for *screening* in trauma

Evaluation of patients with neurologic deficits

Evaluation of cord compression, hematoma, disc herniation

Planning for surgical decompression

Assessing chronicity of compression fractures

What was the Mechanism

Help the radiologist!

Describe mechanism in the order

Think about mechanism when you review

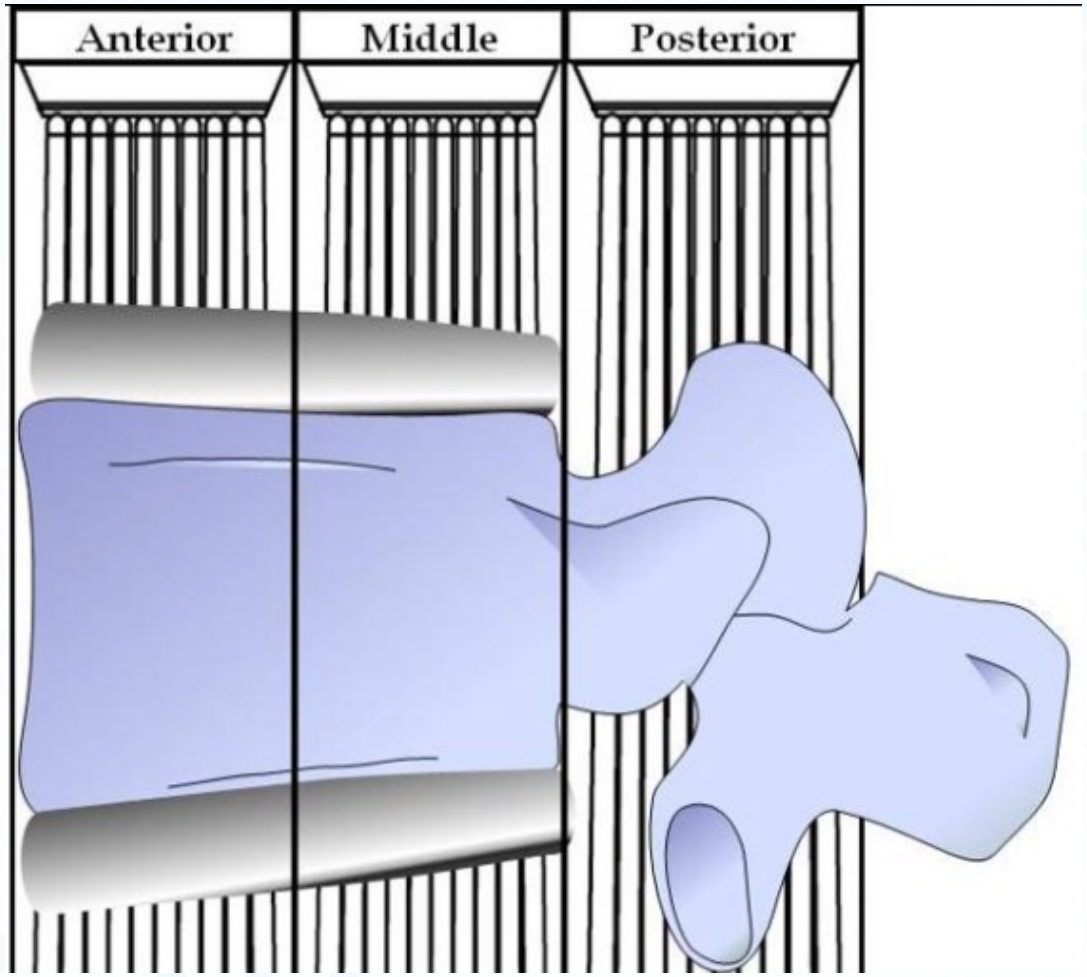
Hyper-flexion

- Ant Wedge
- Flexion/ Distraction
  - Seatbelt, “Chance Fracture”
- Fracture Dislocation

Axial Load

- Compression fracture
- Burst Fracture

Spinal Stability



3 Column Model of Denis:

- A fracture involving 2 contiguous columns is ‘unstable’

- TLICS score accounts for morphology, neurologic status and stability

Schubert R, Three column concept of the spine. Case study, Radiopaedia.org (Accessed on 29 Feb 2024) https://doi.org/10.53347/rID-15490

Compression Fracture

Robertson P, Lumbar spine compression fracture. Case study, Radiopaedia.org (Accessed on 29 Feb 2024) https://doi.org/10.53347/rID-30048

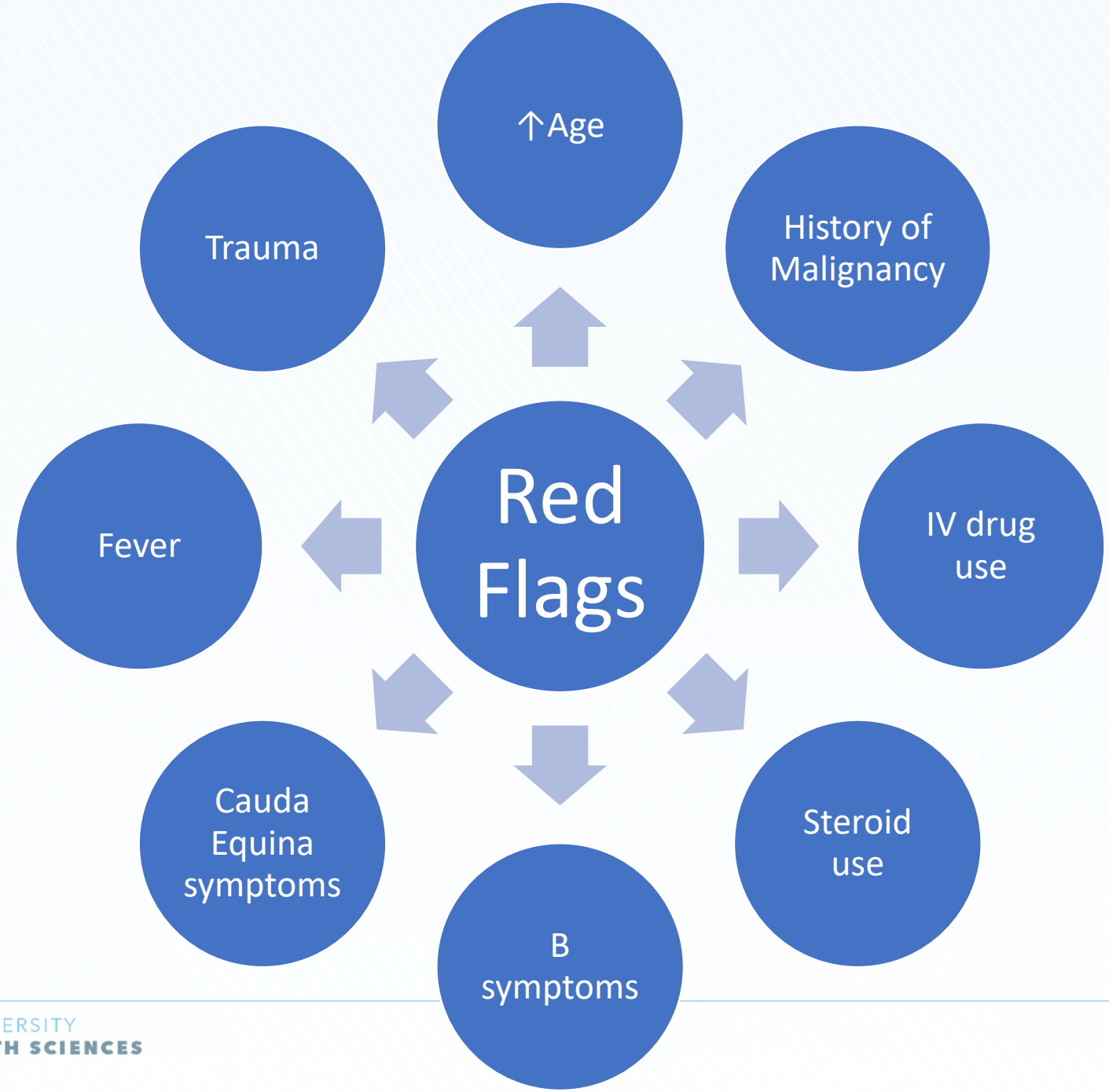
Flexion Distraction

Cuete D, Chance fracture. Case study, Radiopaedia.org (Accessed on 29 Feb 2024) https://doi.org/10.53347/rxID-36521

Case Study# 2

55 year old male presents to Internal Medicine Clinic with 3 weeks of atraumatic low back pain

- No neurologic symptoms


↑Age
History of Malignancy
IV drug use
Steroid use
B symptoms
Cauda Equina symptoms
Fever
Trauma
Red Flags

Back Pain – TUNA FISH

T - Trauma

U - Unexplained Weight Loss

N - Neuro Symptoms

A - *Age over 65*

F - Fever

I - IV drug use

S - Steroid Use

H - History (Cancer, bacteremia, immunosuppression, osteoporosis)

Case Study# 2

American College of Radiology
ACR Appropriateness Criteria®
Low Back Pain

Variant 1: **Acute low back pain with or without radiculopathy. No red flags. No prior management. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography lumbar spine	Usually Not Appropriate	☢☢☢
MRI lumbar spine with IV contrast	Usually Not Appropriate	O
MRI lumbar spine without and with IV contrast	Usually Not Appropriate	O
MRI lumbar spine without IV contrast	Usually Not Appropriate	O
Bone scan whole body with SPECT or SPECT/CT complete spine	Usually Not Appropriate	☢☢☢
CT lumbar spine with IV contrast	Usually Not Appropriate	☢☢☢
CT lumbar spine without IV contrast	Usually Not Appropriate	☢☢☢

Hutchens, TA. ACR. American College of Radiology ACR Appropriateness Criteria® Low Back Pain . 2021. Accessed February 26, 2024. https://acsearch.acr.org/docs/69483/narrative/.

Case Study# 2.5

55 year old male *RETURNS* to Internal Medicine Clinic after 6 weeks of structured PT for back pain

- Ongoing back pain
- Radiates to Left foot
- Associated tingling

The Case Against Radiographs

Radiographs are generally not indicated for evaluation low back pain (ACR, Choosing Wisely®, AAFP)

Relatively high radiation dosing

- 1.6mSV for L-spine XR
- 0.1mSv for Chest XR (radiologyinfo.org)

Not helpful in planning interventions

Indications for Radiographs

Upright to assess for axial loading

Flexion and extension to assess for dynamic instability

Evaluation and planning for spinal deformity

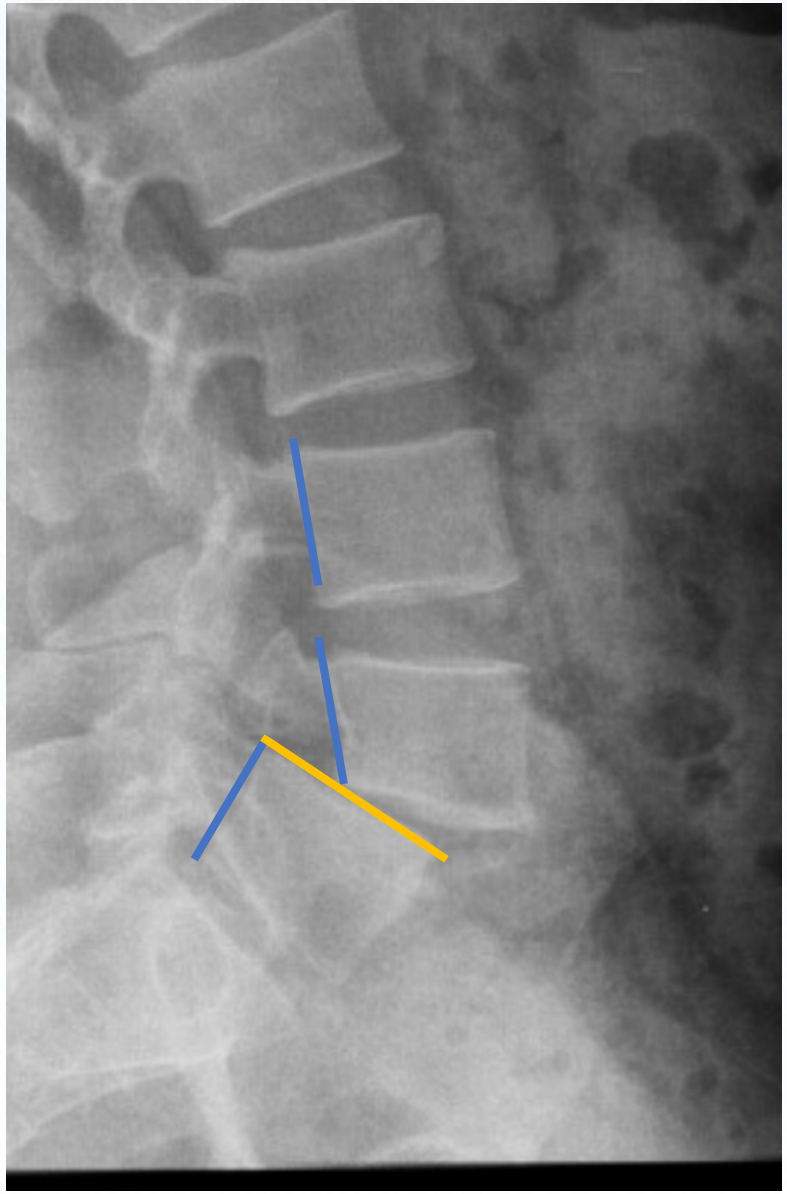
Post operative evaluation of back pain

Insurance requirement (cervical)

Spondylolisthesis

- Anterolistheisis
- Retrolisthesis

**new to PANCE in 2025*

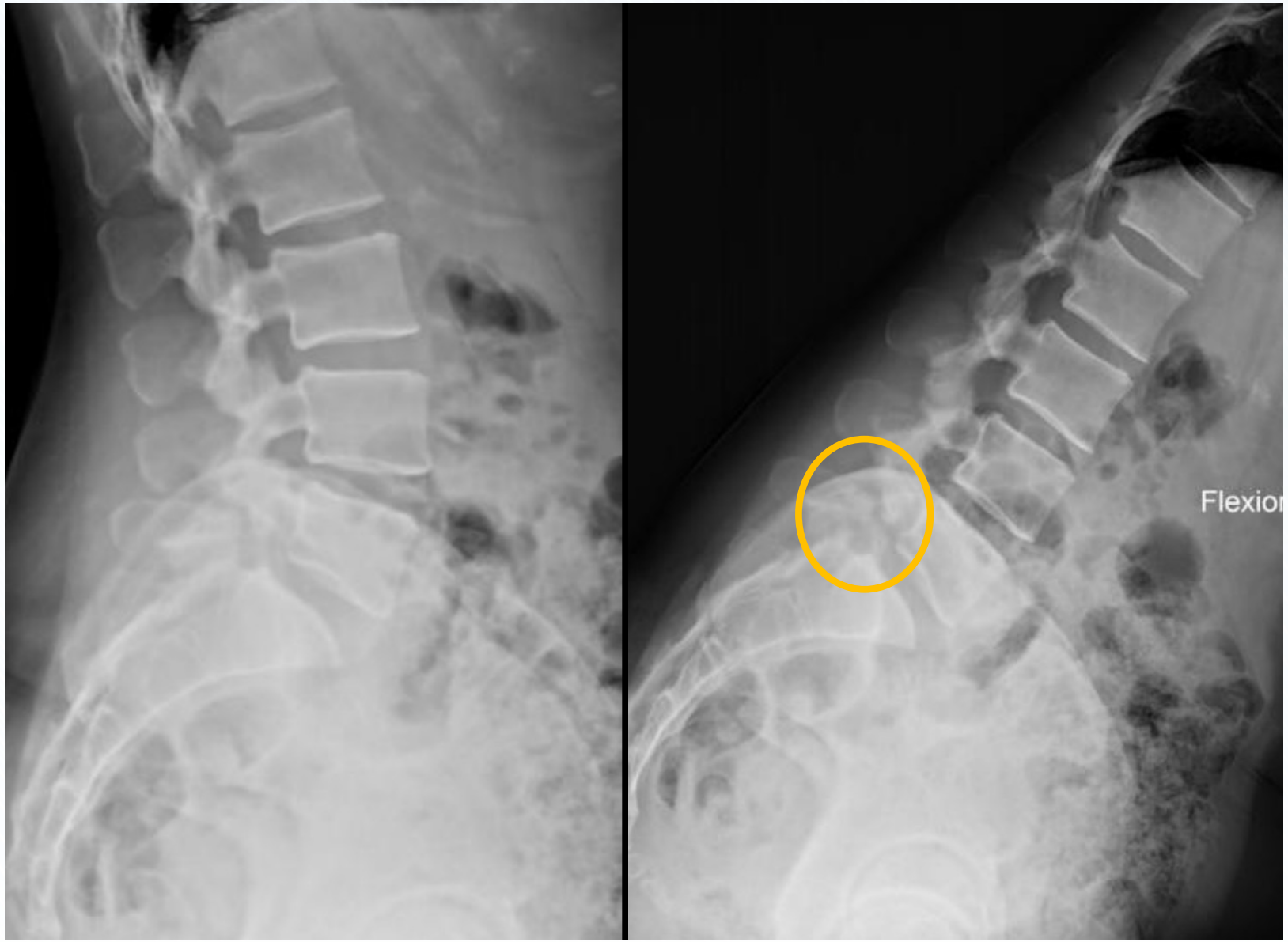


Aragon J, L4-5 anterolisthesis - grade II. Case study, Radiopaedia.org (Accessed on 26 Feb 2024) https://doi.org/10.53347/rID-44132

Spondylolysis

- Pars Defect

**new to PANCE in 2025*



Niknejad M, Spondylolisthesis. Case study, Radiopaedia.org (Accessed on 26 Feb 2024) https://doi.org/10.53347/rID-91145

Variant 7: **Low back pain with or without radiculopathy. One or more of the following: suspicion of cancer, infection, or immunosuppression. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI lumbar spine without and with IV contrast	Usually Appropriate	O
MRI lumbar spine without IV contrast	Usually Appropriate	O
Radiography lumbar spine	May Be Appropriate (Disagreement)	☢☢☢
CT lumbar spine with IV contrast	May Be Appropriate	☢☢☢
CT lumbar spine without IV contrast	May Be Appropriate	☢☢☢
CT myelography lumbar spine	May Be Appropriate	☢☢☢☢

Hutchens, TA. ACR. American College of Radiology ACR Appropriateness Criteria® Low Back Pain . 2021. Accessed February 26, 2024. https://acsearch.acr.org/docs/69483/narrative/.

Case #2.5 – Ordering the MRI

Expectations for Documentation (check with your insurance carriers)

- Failure of 6 weeks of conservative management
- New or worsening neurological deficit
- Abnormal reflexes
- Dermatomal sensory loss
- Non-diagnostic radiograph? (cervical)

MRI Lumbar Spine

MC pays about $240, patient pays about $59 (medicare.gov)

Cost for private insurance varies widely (deductibles, co-insurance, out of pocket maximum, hospital facility fees)

Case Study #3

55 year old patient presents to ER with increasingly severe atraumatic low back pain.

- Now radiating into both buttocks
- Tingling in thighs

Exam:

- Uncomfortable, bilateral plantar flexion weakness
- Decreased rectal tone

Cauda Equina Syndrome

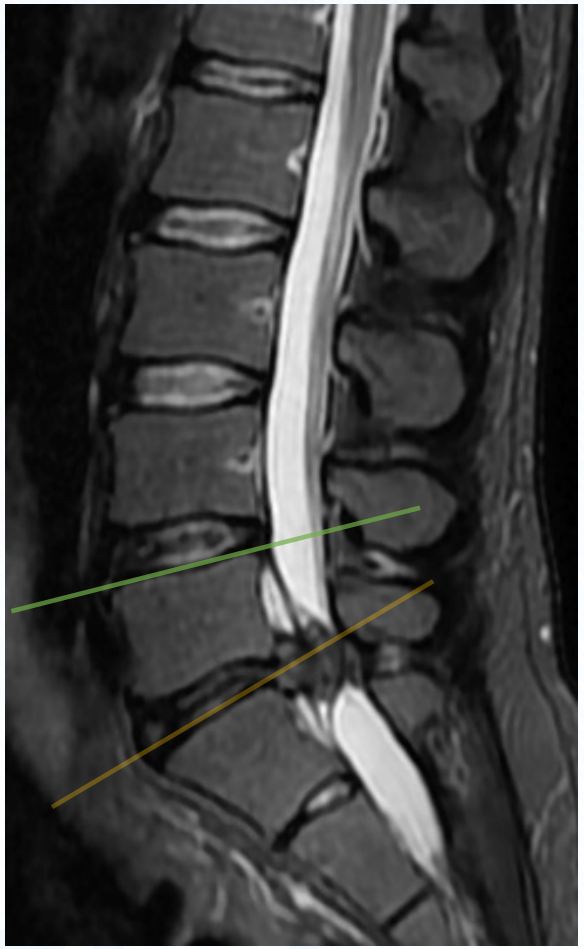
Clinical syndrome from disruption of multiple nerve roots

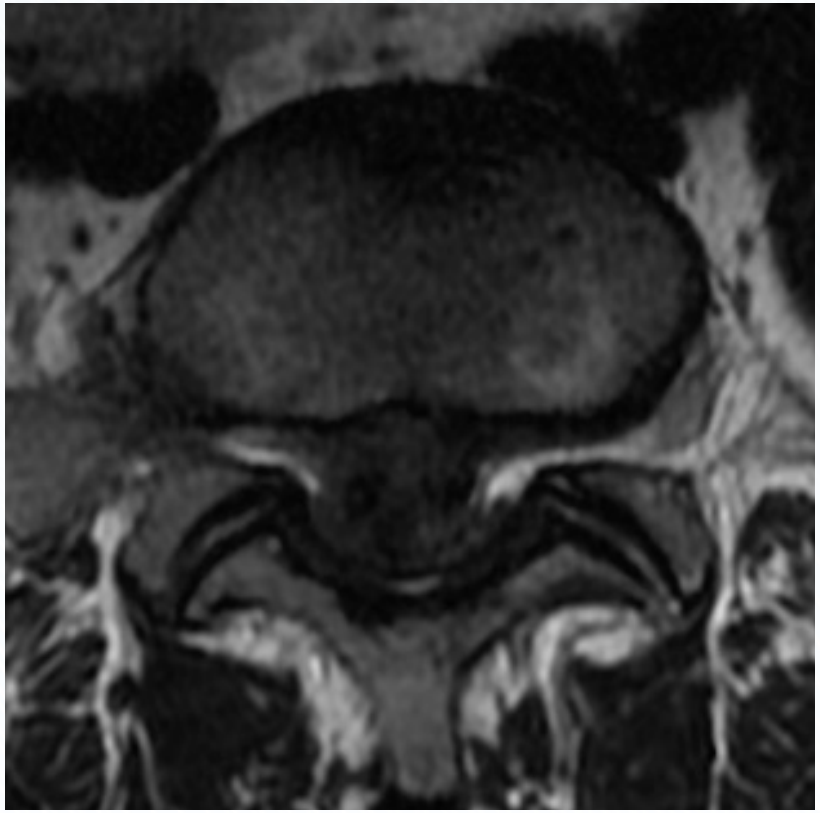
A diagnostic and surgical emergency

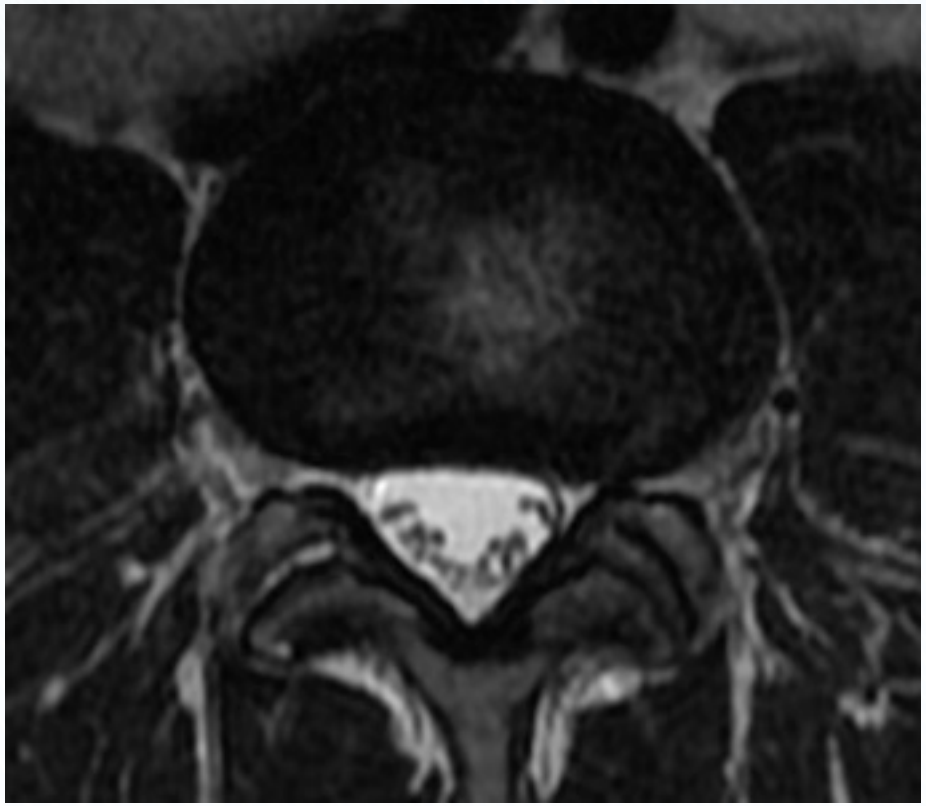
“No sign, symptom or combination that reliably diagnoses or excludes Cauda Equina Syndrome”(Todd, 2016)

An MRI is urgently needed

Cauda Equina Syndrome







Alghamdi K, Cauda equina syndrome. Case study, Radiopaedia.org (Accessed on 29 Feb 2024) https://doi.org/10.53347/rID-79069

Case Study #3

“I forgot to tell you, I have an ICD, and I cant get an MRI”

- CT may have value in excluding high-grade narrowing (Peacock, 2017)

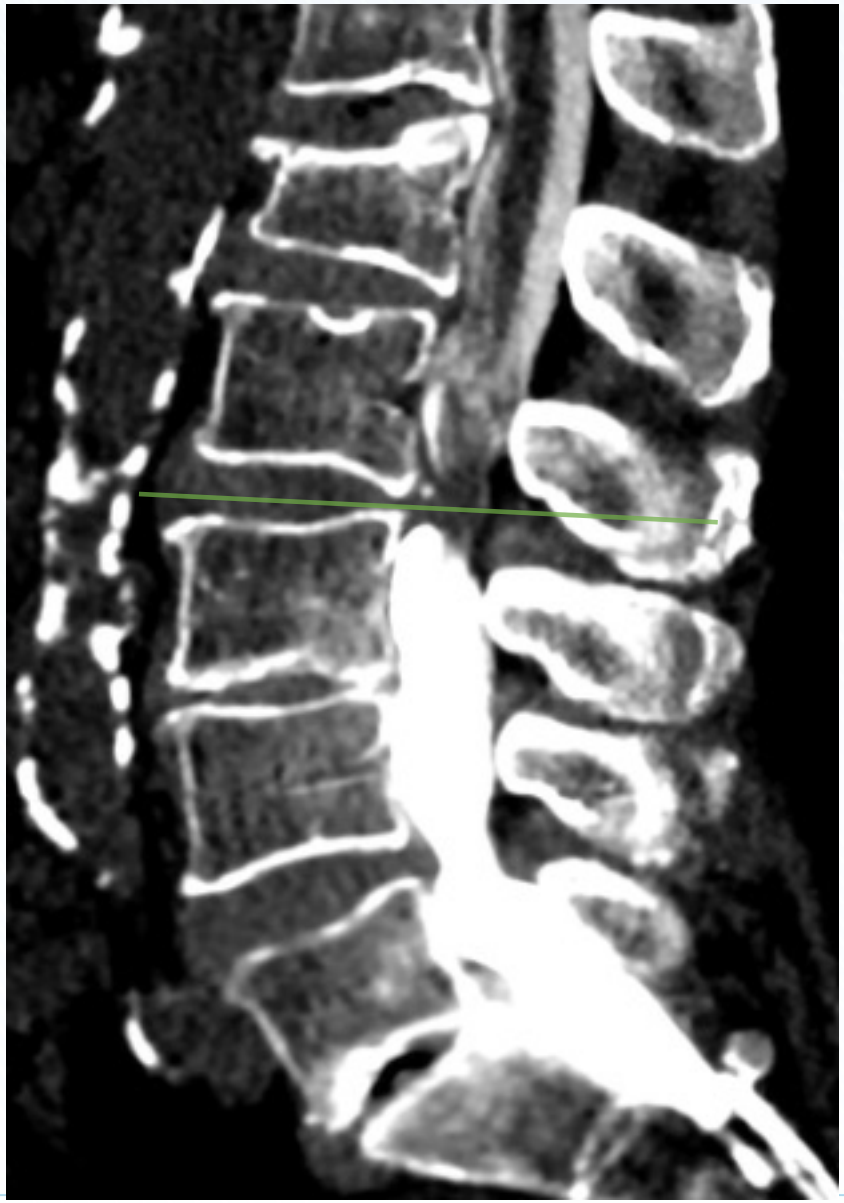
- CT may fail to diagnosis causes of CES (abscess, tumor, hematoma)

- Spine service will likely ask for a CT Myelogram

Case Study #3

CT done after instillation of intrathecal iodinated contrast

- Filling defect at L3-4



Knipe H, Lumbar canal stenosis (CT myelogram). Case study, Radiopaedia.org (Accessed on 29 Feb 2024) https://doi.org/10.53347/rID-163321

Take Home Points

- Application of Clinical Decision Making Tools can be helpful in deciding when to order imaging
- Providers must understand indications and limitations of different radiologic modalities
- Communication is key
- Look at all of your imaging, ask questions, use resources

References

Aran S. *Emergency Radiology*. (Abujudeh HH, ed.). Oxford University Press; 2016.

Berman D, Holtzman A, Sharfman Z, Tindel N. Comparison of Clinical Guidelines for Authorization of MRI in the Evaluation of Neck Pain and Cervical Radiculopathy in the United States. *Journal of the American Academy of Orthopaedic Surgeons*. 2023;31(2):64-70. doi:10.5435/JAAOS-D-22-00517

Best practices guidelines spine injury. March 2022. Accessed February 24, 2024. https://www.facs.org/media/k45gikqv/spine_injury_guidelines.pdf.

Hutchins TA, Peckham M, Shah LM, et al. ACR Appropriateness Criteria® Low Back Pain: 2021 Update. Journal of the American College of Radiology. 2021;18(11):S361-S379. doi:10.1016/j.jacr.2021.08.002

Peacock JG, Timpone VM. Doing more with less: Diagnostic accuracy of CT in suspected cauda equina syndrome. *American journal of neuroradiology : AJNR*. 2017;38(2):391-397. doi:10.3174/ajnr.A4974

Todd NV, Dickson RA. Standards of care in cauda equina syndrome. British journal of neurosurgery. 2016;30(5):518-522. doi:10.1080/02688697.2016.1187254

Questions?

ffmike@gwu.edu

Thank you

- Images courtesy of Michael Johnson unless otherwise noted.

Case study questions

Case Study #1 Other than a wrist radiograph, would you like to order any other imaging?

B- CT Cervical Spine.

This patient meets criteria for C-spine imaging using both NEXUS and Canadian –Spine Rule

Case study questions

Case Study 2.5 - What is the plan for this patient with ongoing back pain, and NEW leg pain?

B- MRI Lumbar Spine without contrast is the most appropriate study to evaluate this back pain with radicular symptoms. He meets ACR criteria for MRI imaging.

Case study questions

Case Study #3: Which of the following is the most appropriate initial study for this patient?

C- MRI lumbar spine without contrast

MRI is the study of choice to evaluate complaints of Cuada Equina Syndrome. There may be a role for contrast depending on the presentation and if the differential includes tumor or abscess.