Anatomy of a Lumbar Spine MRI: Indications for Imaging and Interpretation of Imaging for Surgical Referral

ABSTRACT

Despite guidelines from multiple medical organizations including Choosing Wisely Canada, routine screening for low back pain symptoms with advanced imaging modalities such as Magnetic Resonance Imaging (MRI) persists. While sensitive, the high prevalence of asymptomatic or non-correlative degenerative findings limits their usefulness for routine screening. Given the constraints on Canadian healthcare resources this is a cause for significant concern. Lumbar MRI examinations should be ordered only with clear clinical indications and never for simple triage. Suitable indications include patients with symptoms of Cauda Equina Syndrome, suspected spinal malignancies, vertebral infections, or a progressive neurologic deficit correlating to a dermatomal and/or myotomal distribution.

KEYWORDS: Appropriateness in diagnostic imaging, lumbar MRI, low back pain, surgical indications

CME Pre-test Quiz

Usefulness of MRI as a screening tool

Magnetic resonance imaging (MRI) is a powerful tool in the diagnosis and management of spinal disease, providing high-definition, multi-planar images of spinal anatomy. These images are produced by magnetically aligning the nuclei of water molecules, disturbing this alignment using a radiofrequency pulse, and recording the resultant emitted signals. A lumbar spine MRI provides useful information for confirmation of a clinical diagnosis of radiculopathy or neurogenic claudication and is essen-

Samuel Yoon MD, MSc,
Division of Orthopaedic Surgery, University of Toronto, Toronto, Ontario, Canada

Tiffany Lung MD, BKin,
Division of Orthopaedic Surgery, University of Toronto, Toronto, Ontario, Canada

Albert Yee MD, MSc, FRCSC, FIOR
Professor of Surgery, Department of Surgery, University of Toronto, Marvin Tile Chair Division Chief of Orthopaedic Surgery, Division of Spine Surgery, Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada

tial for pre-operative planning for specific spinal interventions. However, the increasing availability of MRI has resulted in a concurrent overuse of this imaging modality for the perfunctory investigation of low back pain without appropriate symptoms or signs.

Routine MRI of the spine as a screening tool has been found to be ineffective due to the high prevalence of clinically irrelevant, normal, age-related degenerative changes to spinal anatomy. A seminal study in 1989 which collected lumbar spine MRIs of asymptomatic volunteers found one third of those MRI scans had abnormal findings, such as foraminal or central spinal stenosis.[1] Asymptomatic volunteers over 60 years old had a prevalence of positive but clinically insignificant MRI findings of 57%.[1] A follow-up study of the same cohort seven years later demonstrated that the severity of abnormal imaging findings in the original study did not predict the appearance, progression, intensity, or duration of low back pain.[2] Highlighting the high number of incidental degenerative findings, in a systematic review of 33 articles in 2015, the frequency of disc degeneration in asymptomatic individuals increased from 37% in 20-year-olds to 90% in asymptomatic 80-year-olds.[3] There are an abundance of investigations supporting this correlation.[4]

Advanced imaging to screen for back pain does not improve patient outcomes and can adversely affect patient outcomes through a nocebo effect. A meta-analysis of six randomized trials found that back pain management was equally successful for those who did not receive advanced imaging as for those who subjected to an MRI. Attempting to radiographically label nonspecific low back pain is has never been successful and the exercise has not improved patient outcomes.[4] On the contrary, incidental, age-related findings that are not clinically significant can alarm patients and may persuade health care providers that an intervention is required to normalize the spine.[5,6] The use of MRI to investigate low back pain was associated with threefold increased rates of spine surgery, with no difference in one-year outcomes.6 Another investigation reveals MRI utilization accounts for 22% of variability in spine surgery rates—more than twice that accounted for by patient characteristics.[7] Given the significant post-operative morbidity including up to 19% re-operation rate within 10 years, routine lumbar spine MRI can lead to patient harm through increased unnecessary intervention.[8] Due to the limited utility of routine imaging for low back pain, international guidelines, including Choosing Wisely Canada, recommend against imaging of the spine to investigate low back pain in the absence of sufficient clinical indications.[9]

In this article, we review the indications for MRI assessment of the lumbar spine, including the signs and symptoms that constitute Red Flags. We provide a step-by-step tutorial to interpret lumbar MRI scans and offer appropriate indications for referral to specialist care.

Indications for Obtaining an MRI of the Lumbar Spine

History and physical examination are essential in evaluating patients with low back pain. More than 85% of back pain patients do not have a disease or an unequivocal, identifiable mechanical abnormality causing their symptoms.[9] Only a minority of cases presenting to primary care with low back pain have pathology such as spinal tumours (approximately 0.7%), spinal infections (0.01%), compression fractures (4%), and Cauda Equina Syndrome (0.04%).[10]

A properly constructed history and physical examination can divide patients presenting with low back pain into mechanical back pain, with or without radicular symptoms, or back pain caused by specific non-mechanical pathology. Mechanical low back pain can be further classified into one of four patterns with two subdivisions (Table 1).[11] Implementation of appropriate, specific conservative management modalities according to the identified back pain syndrome can significantly improve patient outcomes without the risks associated with inappropriate advanced imaging.[12]

Back pain associated with other specific spinal pathologies or particular diseases can be triaged by urgency, recognizing that patients with severe or progressive neurological deficits must be investigated immediately.[4] Elicit appropriate risk factors in the history and physical examination to guide the clinical investigations (Table 2). Do not use imaging as a surrogate for thorough history and physical examination.

Acute neurological deficits, suspected spinal infections, spinal tumours, and Cauda Equina Syndrome require urgent investigation and early referral.[13-15] Key clinical features of acute Cauda Equina Syndrome include sudden urinary retention followed by insensible overflow incontinence, saddle paresthesia/anesthesia and fecal incontinence. In patients presenting with fever and risk factors for bacteremia such as immunosuppression, acute low back pain can be associated with vertebral infection. Severe or progressive neurologic deficits following a dermatomal or myotomal distribution, with or without the presence of low back pain, should be investigated with advanced imaging.

In the absence of sinister symptoms, patients with leg-dominant symptoms diagnosed as radiculopathy or neurogenic clau-

Table 1: Patterns of Pain[11]

Pattern number	Dominant site	History	Physical examination	Additional features	Sub-classification
1	Back	Pain in flexion Constant or intermittent	Pain in flexion Neurological normal	May have pain with extension May have unrelated neurological findings	**PEP** Decrease pain within 10 properly performed prone passive extensions
					PEN No change or increase pain within 10 properly performed prone passive extensions
2	Back	No pain in flexion intermittent	No pain in flexion Neurological normal	Pain with extension May have pain relief with flexion May have unrelated neurological findings	
3	Leg	Constant	Positive irritative and/or conduction findings	Pain with flexion and other movements or positions	
4	Leg	Intermittent	May have irritative and/or conduction findings		**FA** Flexion Aggravated
			Negative irritative findings May have conduction loss	Pain with activity in extension Conduction loss may be transient	**FR** Flexion Relieved

Table 2: Suspected diagnoses based on key features in the history and physical examination offer appropriate imaging indications[6]

Cause of Back Pain	Key Feature on History or Physical Exam	Appropriate Initial Imaging
Cauda Equina Syndrome	Urinary Retention Saddle anesthesia Fecal incontinence Motor deficits across multiple levels	MRI
Vertebral Infection	Fever History of recent infection IV drug use Chronic immunosuppression	MRI
Malignancy	History of cancer with new on set low back pain	
	Unexplained weight loss, fevers, chills, or malaise	Plain radiography (screening)
	Risk factors for cancer present	Plain radiography vs. MRI
Vertebral compression Fractures	Osteoporosis Chronic steroid use Older age Recent trauma	Plain radiography
Herniated Disc	Back pain accompanied by radiating leg pain along dermatomal distribution Positive straight leg test	None
	Symptoms >1 month or does not improve with conservative management	
Spinal Stenosis	Leg pain radiating to feet/toes Neurogenic claudication Older age	None
	Symptoms >1 month or does not improve with conservative management	MRI

dication that have not responded to appropriate conservative therapy should be referred electively to a spine specialist. In Canada, due to the high volume of referrals, many of which are inappropriate or are for patients who have not completed a trial of conservative management, it is not uncommon for patients to wait months for their consultation.[13] To make appropriate referrals, correlating history, examination, and subsequent advanced imaging results is crucial. Correct interpretation of the MRI examination is important to identify patients that may benefit from surgical management.

Interpretation of Lumbar MRI Examination

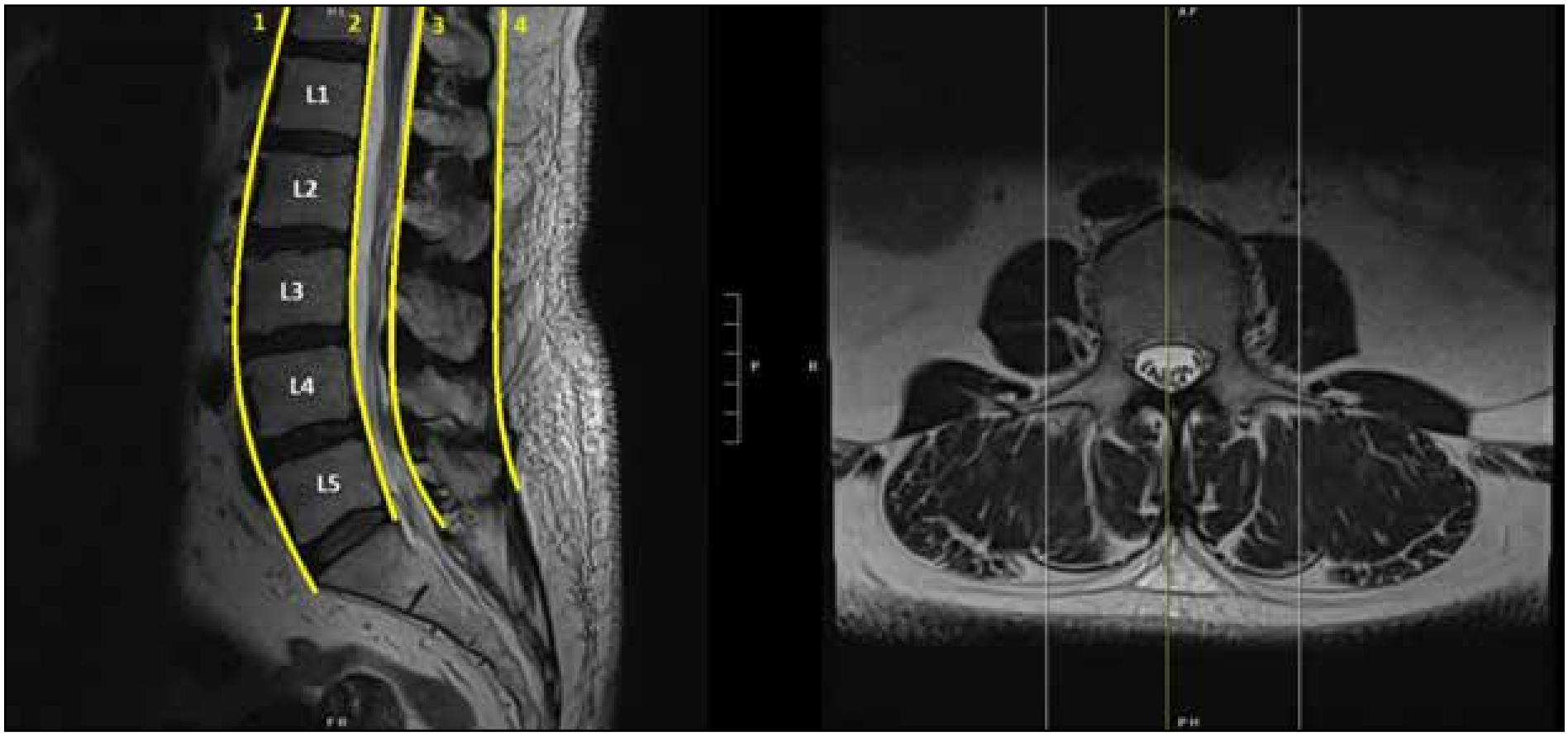
MRIs are obtained using a combination of two basic parameters: time to repetition (TR), referring to the time between radiofrequency pulses used to disturb the magnetically aligned atomic nuclei; and time to echo (TE), referring to time between the delivery of radiofrequency pulse to receipt of a signal. T1-weighted images are produced by using short TR and TE times, whereas T2-weighted images are produced using longer TE and TR times.

T1 weighted images are typically used for the evaluation of normal anatomy. Cerebrospinal fluid (CSF) that surrounds the nerve roots and spinal cord is shown as hypo-intense (i.e., dark).[14,15] In T2-weighted images, which are typically used to identify pathology in the lumbar spine, CSF is hyper-intense (i.e., bright). Pathological findings such as disc herniations, lumbar stenosis, and foraminal stenosis are more easily seen with T2 weighted images because deformation of the thecal sac can be interpreted by displacement or absence of the CSF. Fat, while hyper-intense in T2-weighted images, is comparatively less bright compared to CSF. The addition of gadolinium contrast is most useful when there is suspected infection or tumor.[14] With contrast, abscesses present as rim-enhancing lesions, while tumours are hyper-intense throughout. Gadolinium contrast is also useful in situations where patients have had prior surgery since it can differentiate a recurrent disc herniation (typically non-enhancing or rim-enhancing) from epidural fibrosis (uniformly enhancing).

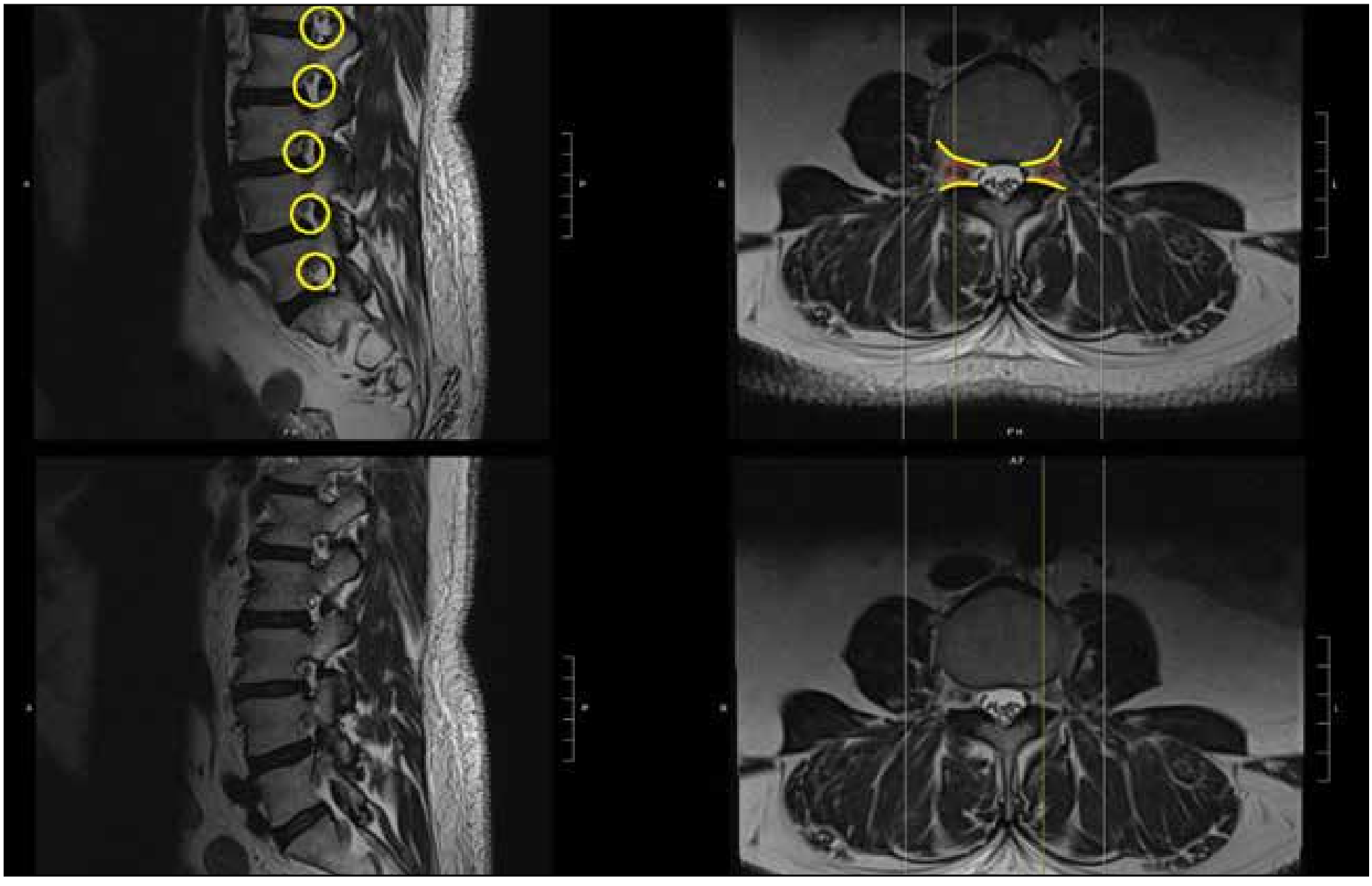
Short Tau Inversion Recovery (STIR) is a sequence of fat suppression that allows for easier differentiation between hyper-intense water, and hypo-intense fat. STIR sequencing can be useful for detecting bony edema facilitating the diagnosis of pathology, such as compression fractures, which may not be otherwise detected.[14]

Lumbar spine MRI images are typically acquired through the axial, sagittal, and coronal planes. Two viewing screens should be used to visualize the axial and sagittal planes (Figure 1). Set up

Figure 1: Review of Normal Spinal Anatomy



A) Paired imaging demonstrating reference lines set up to display the mid-sagittal plane of the lumbar spine. The 1) anterior and 2) posterior vertebral, 3) spino-laminar, and 4) posterior spinous lines can assess overall alignment.

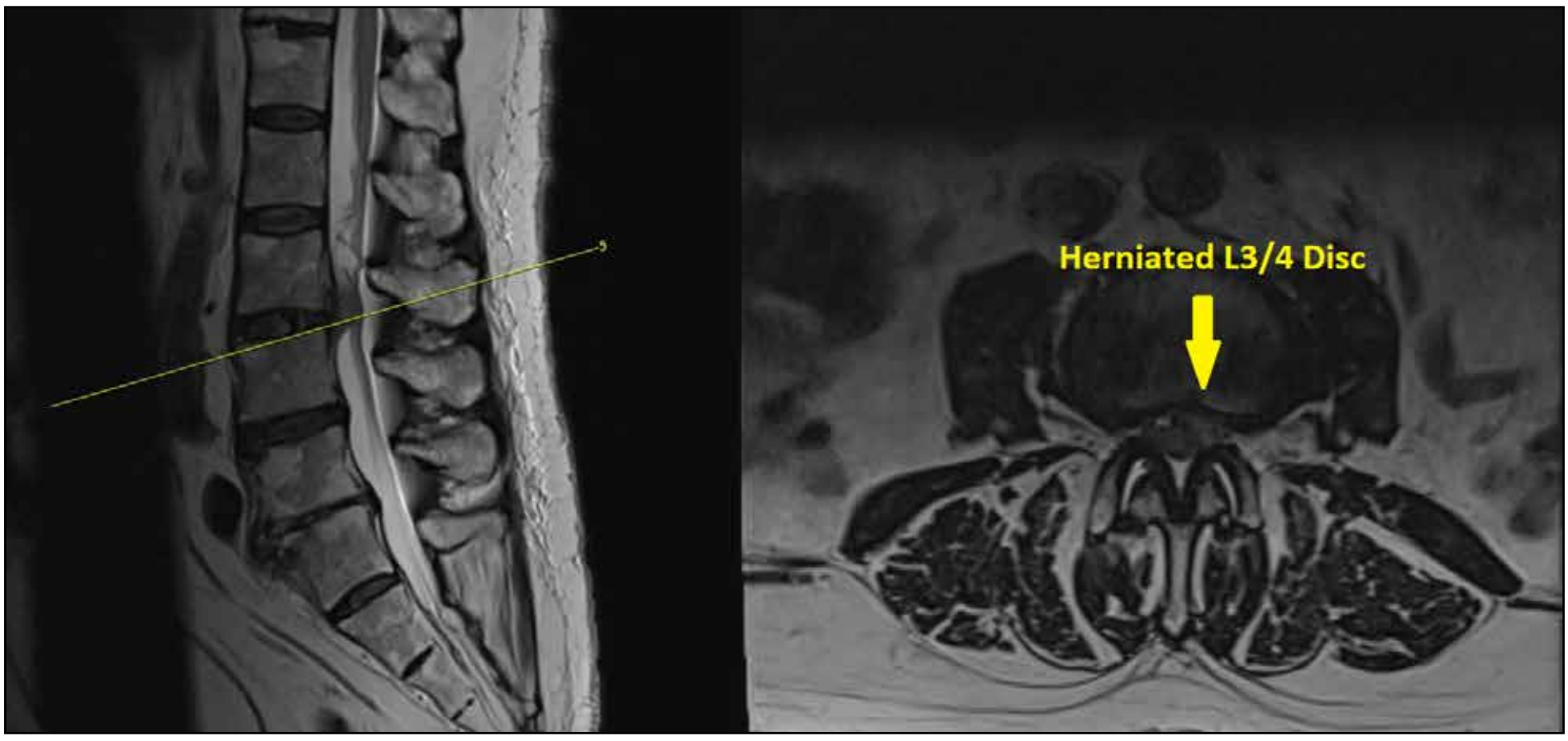


B) Paired imaging demonstrating views of right (top) and left (bottom) foramina of the lumbar spine on sagittal image; bony foramen highlighted in yellow, exiting nerve root highlighted in red.

reference lines using the imaging software to localize the image at hand to the corresponding orthogonal plane. These reference lines can be used to assess pathology at each disc level and visualize bilateral foramina on the axial and sagittal planes. Coronal plane images can be helpful in evaluating coronally based pathology, such as degenerative scoliosis.

Using both the axial and sagittal images, evaluate the overall alignment of the lumbar spine and the bony architecture. Most spines have five lumbar vertebrae with a lordotic curvature.[15] In the mid-sagittal plane (viewed from the side), four lines can evaluate overall alignment: 1&2: the anterior and posterior vertebral lines are drawn along the front and back of the vertebral bodies; 3: a spinolaminar line is drawn along the most posterior aspect of the spinal canal; 4: a posterior spinous line can be drawn down the back of the spinous processes. A step in any or all of these lines can indicate a fracture or spondylolisthesis.[14] Spondylolisthesis, a shift out of alignment of one vertebra relative to its neighbor, can be secondary to pars defects or degenerative changes to the facet joints; typically, the more proximal vertebral body moves anteriorly to the vertebra below. The vertebral bodies, pedicles, lamina, and spinous processes should be hypo-intense in T2 weighted images. The presence of hyper-intensity within the vertebral bodies can represent bony edema from trauma or malignancy.

Figure 2: Abnormal Degenerative Anatomy



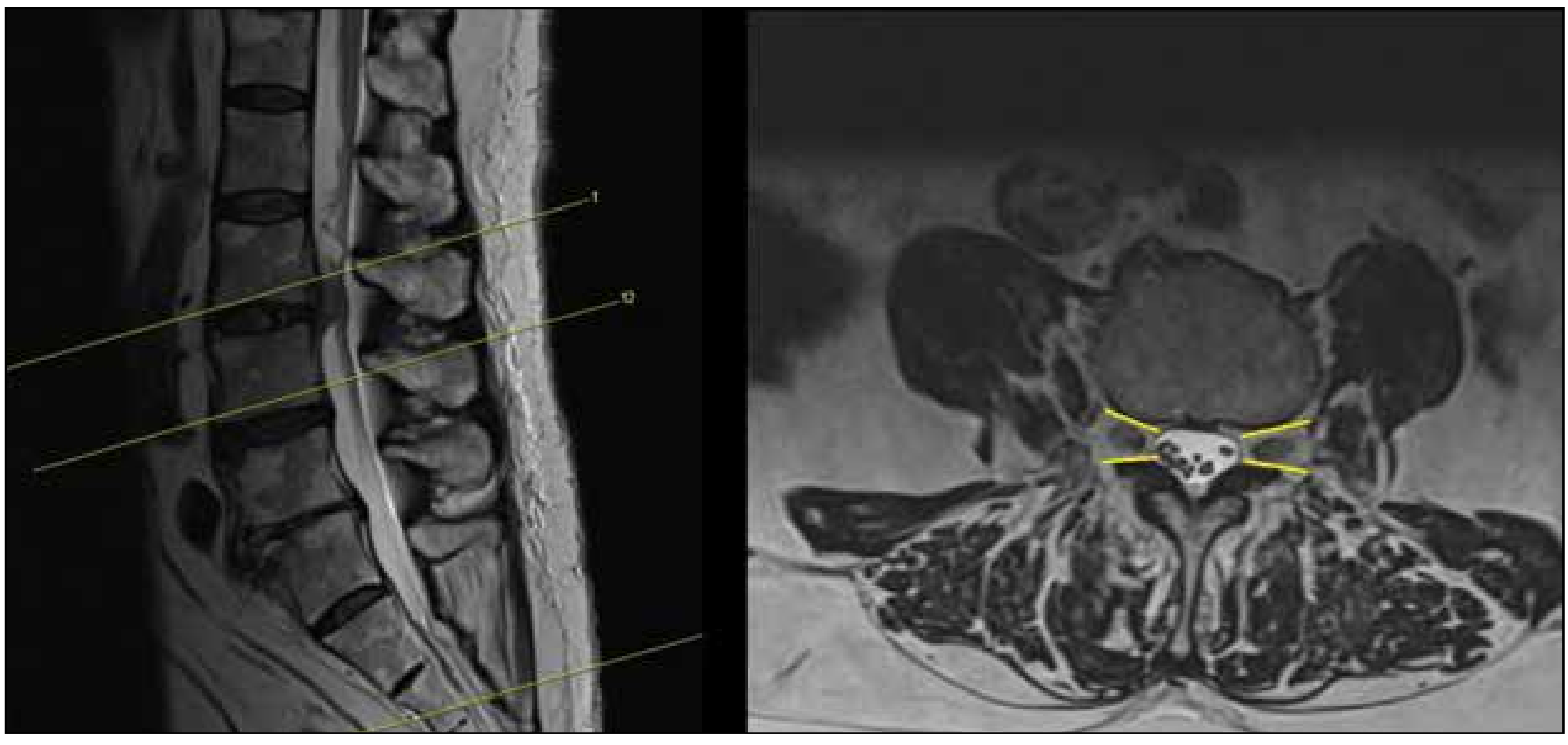
A) An example of severe central stenosis of L3/4 secondary to a central L3/4 disc herniation with resultant obliteration of CSF.

Next, examine the neural elements in closer detail. Both the spinal cord and nerve roots are hypo-intense, surrounded by and free-floating within hyper-intense CSF in T2-weighted images (Figure 1). At the T12-L2 levels, the most inferior aspect of the spinal cord transitions to the conus medullaris. Due to the higher water content in a healthy disc, intervertebral discs are hyper-intense compared to bone. On an axial image, the peripheral rim of each intervertebral disc is hypo-intense. This corresponds to the annulus fibrosus, which contains less water compared to the more central nucleus pulposus.

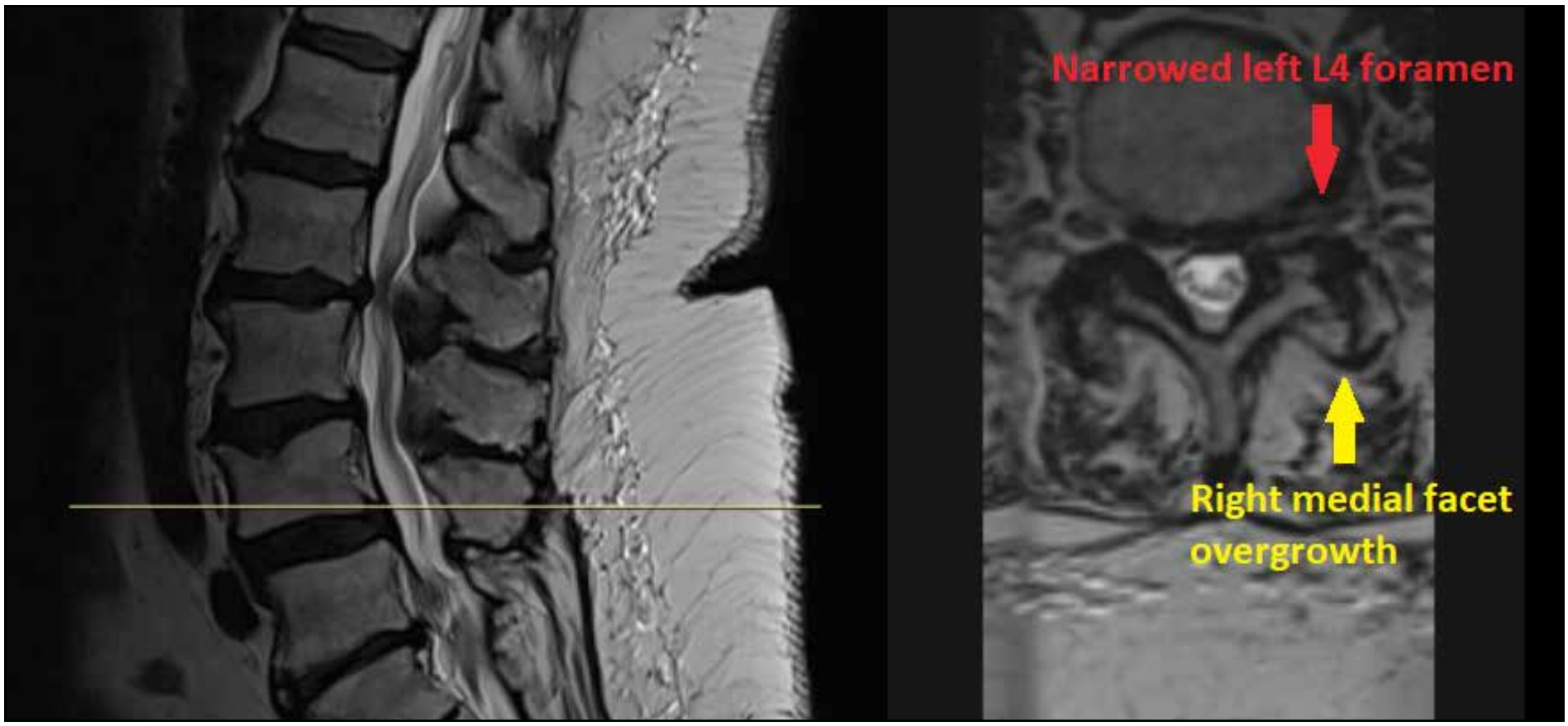
The absence of CSF surrounding a nerve root at a disc level is indicative of severe spinal stenosis, which can be due to a combination of degenerative changes including endplate osteophytes, herniated or degenerated discs, facet hypertrophy, and ligamentum flavum hypertrophy (Figure 2). In the sagittal plane, the nerve roots with surrounding CSF can be followed out of the spinal canal through the foramen. The absence of CSF in a foramen can be indicative of a foraminal stenosis secondary to pathology such as facet hypertrophy or disc herniation. Ensuring that the side and level of compression correspond to the patient's presenting complaints is crucial in identifying whether the imaged abnormality is relevant to the clinical picture.

MRI can identify specific pathologies such as ankylosing spondylitis or diffuse idiopathic skeletal hyperostosis (DISH). In ankylosing spondylitis, when the spine is fusing, the disc spaces

Bi

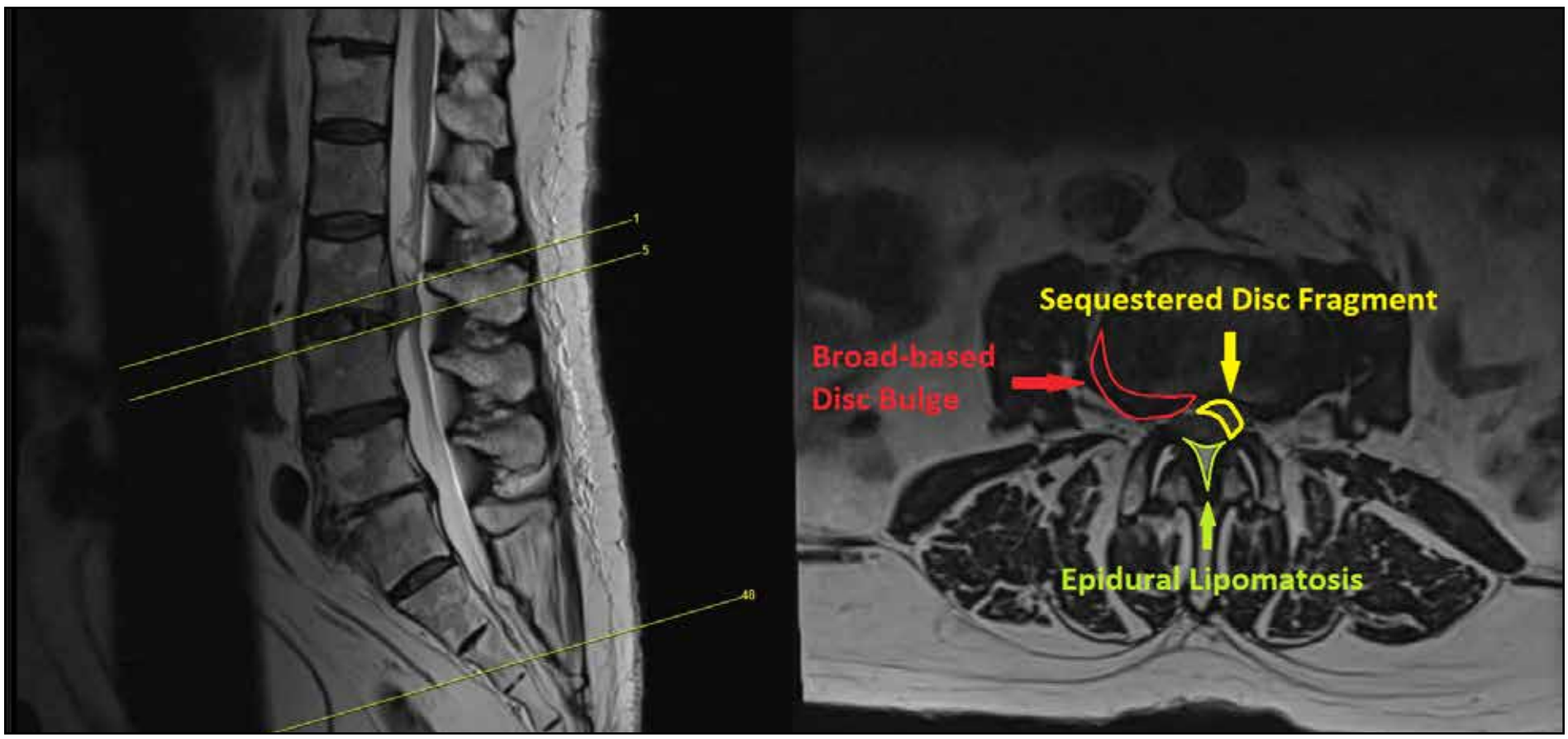


Bii



B) Paired imaging demonstrating i) normal L4 foramina on the axial plane (marked), with normal exiting nerve roots seen (oval-shaped in this cross-section) within the foramen; note the free-floating nerve roots centrally within the spinal canal surrounded by CSF. ii) Compressed left L4 foramen with compressed exiting nerve root.

narrow and look more hypo-intense, like bone. On a sagittal or coronal image , a spine with ankylosing spondylitis can look similar to a bamboo stem, where the marginal syndesmophytes (a bone growth that bridges the gap between two vertebral bodies) do



C) Severe degenerative changes including a broad-based disc herniation, facet joint overgrowth (hypertrophy) on the axial imaging with subtle L3/4 spondylolisthesis seen on sagittal imaging. No CSF can be seen surrounding the nerve roots within the spinal canal; the slight hypo-intense signal demonstrated on the dorsal canal reflects epidural lipomatosis (intensity similar to subcutaneous and intramuscular fat rather than CSF).

SUMMARY OF KEY POINTS

Lumbar spine MRI is not a useful screening tool as incidental degenerative findings are extremely common.

Routine lumbar MRI usage to investigate low back pain is inappropriate and can cause harm to patients through wasted time and resources, as well as possible nocebo effects.

Lumbar spine MRI is indicated if accompanying Red Flag symptoms, such as recent systemic illness, high suspicion for tumour, or progressive/severe neurological symptoms/signs are present with the back pain.

Elective referrals to spine surgical specialists should confirm that the patient's clinical spinal condition aligns with advanced imaging findings.

not extend beyond the anterior or lateral aspects of the vertebral bodies.[15] In contrast, with DISH, the syndesmophytes form excessive bone that extends well beyond the vertebral bodies.[15]

Conclusion

A thorough but focused history and physical examination is essential to determine whether the cause of low back pain warrants further investigation with advanced imaging. Clinicians should be familiar with risk factors associated with spinal tumours, infections, compression fractures, Cauda Equina Syndrome and other specific conditions that may require intervention. MRI findings must be correlated to the patient's clinical presentation to determine if they are relevant and whether they justify a referral for specialist care.

References

1. Boden SD, Davis DO, Dina TS, Patronas NJ WS. Abnormal Lumbar Magnetic-Resonance Spine Scans of the lumbar spine in asymptomatic subjects. J Bone Jt Surg. 1990;72-A(3):403-408.
2. Borenstein DG, O'Mara J, Boden SD, et al. The value of magnetic resonance imaging of the lumbar spine to predict low-back pain in asymptomatic subjects: A seven-year follow-up study. J Bone Jt Surg - Ser A. 2001;83(9):1306-1311. doi:10.2106/00004623-200109000-00002

CLINICAL PEARLS

The majority of patients with low back pain will improve with conservative management modalities.

Understanding clinical patterns of lumbar related axial pain and lower extremity referred neurologic symptoms is a more useful guide for determining whether or not patients are surgical candidates than obtaining images of structural change.

Patients suspected of having Cauda Equina Syndrome or exhibiting rapid progressive neurological decline in a dermatomal/myotomal distribution should be referred immediately for surgical evaluation.

3. Brinjikji W, Luetmer PH, Comstock B, et al. Systematic literature review of imaging features of spinal degeneration in asymptomatic populations. Am J Neuroradiol. 2015;36(4):811-816. doi:10.3174/ajnr.A4173
4. Chou R, Qaseem A, Snow V, et al. Diagnosis and treatment oflow back pain: a joint clinical practice guideline from the American College ofPhysicians and the American Pain Society. Ann Intern Med. 2007;147(July):478-491.
5. Rajasekaran S, Dilip Chand Raja S, Pushpa BT, Ananda KB, Ajoy Prasad S, Rishi MK. The catastrophization effects of an MRI report on the patient and surgeon and the benefits of 'clinical reporting': results from an RCT and blinded trials. Eur Spine J. 2021;30(7):2069-2081. doi:10.1007/s00586-021-06809-0
6. Verrilli D, Welch HG. The impact of diagnostic testing on therapeutic interventions. J Am Med Assoc. 1996;275(15):1189-1191. doi:10.1001/jama.275.15.1189
7. Chou R, Qaseem A, Owens DK, Shekelle P. Diagnostic imaging for low back pain: Advice for high-value health care from the American college of physicians. Ann Intern Med. 2011;154(3):181-189. doi:10.7326/0003-4819-154-3-201102010-00008
8. Martin BI, Mirza SK, Comstock BA, Gray DT, Kreuter W, Deyo RA. Reoperation rates following lumbar spine surgery and the influence of spinal fusion procedures. Spine (Phila Pa 1976). 2007;32(3):382-387. doi:10.1097/01.brs.0000254104.55716.46
9. van Tulder MW, Assendelft WJJ, Koes BW, Bouter LM. Spinal radiographic findings and nonspecific low back pain. Spine (Phila Pa 1976). 1997;22(4):427-434.
10. Jarvik JG, Deyo RA. Diagnostic Evaluation of Low Back Pain with Emphasis on Imaging. Ann Intern Med. 2002;137:586-597.
11. Hall H. Low Back Patterns of Pain: Classification Based on Clinical Presentation. In: Handbook of Spine Technology. ; 2021:3-25.
12. Hall H, McIntosh G, Boyle C. Effectiveness of a low back pain classification system. Spine J. 2009;9(8):648-657. doi:10.1016/j.spinee.2009.04.017
13. Huang J, Huang G, Teddy P. Low back pain in neurosurgical outpatients: an audit. J Clin Neurosci. 2008;15(11):1216-1221.
14. Shepard N, Samim M, Kim Y, Razi A. A practical approach to spine magnetic resonance imaging. JBJS Rev. 2020;8(3):1-10. doi:10.2106/JBJS.RVW.19.00099
15. Jeenes D. A practical approach to spine imaging. Contin Lifelong Learn Neurol. 2015;21(1):36-51. doi:10.1212/01.CON.0000461083.33500.ec