
Challenges and pitfalls in postoperative spine imaging

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Image interpretation of the postoperative spine presents significant difficulty because of the various types of surgery performed, new surgical devices employed, different imaging techniques used, and limited clinical information available at the time of image interpretation. The radiologist must understand the many different postoperative spine imaging presentations in order to accurately convey clinically important but often subtle findings.

In this article, we will discuss and illustrate some of the common and uncommon imaging findings in the postoperative spine, with a particular emphasis on the uncommon cases—specifically, retained surgical material with associated clinical sequelae, including gel foam, dural autograft, and catheters. The article will also address magnetic susceptibility artifacts and dislodged surgical hardware, as well as how to distinguish between inflammation and infection and between scar and recurrent disc herniation. Another topic covered is the common dilemma of delineation between postoperative fluid collections (including seroma, abscess, and pseudomeningocele). This article reviews several manifestations of post-procedure and postoperative spine

imaging with a focus on the challenges and pitfalls that are often encountered.

Historical background

Spine surgery was first contemplated by the ancient Egyptians and was later advanced by the Greeks and Romans.¹ Many of their works were preserved during the Dark Ages by Arabic and Byzantine translators and were rediscovered during the Renaissance.¹ Major impediments to progress from Hippocrates' era until the 19th century included the lack of antiseptics, inadequate anesthetics, and the absence of medical imaging. With the development of radiography, it was possible to visualize the effects of surgery and the consequences of intervention, and to document the presence of disease. The first successful spinal fusion was performed in 1911 to reduce pseudoarthrosis. This was followed by autologous interbody bone grafting in 1933; transfacet fusions in the 1940s; distraction Knodt rods in the 1950s; Harrington rods, methylmethacrylate, and transverse process plate fusion in the 1960s; Luque rods and sublaminar wire in the 1970s; and intrapedicle screws with rod fixation in the 1980s.² A medical industrial complex surrounding spinal surgery has arisen as a direct result of the introduction of computed tomography (CT) and spinal magnetic resonance imaging (MRI).³ This growth in surgical intervention has in turn created an increase in the demand for advanced imaging for preoperative planning, intraoperative evaluations, immediate postsurgical assessment, and postoperative care. Postoperative evaluation of potential complications (such

as retained surgical material, infection, pseudomeningocele, seroma, hemorrhage, loose hardware, compromised hardware, fracture, and pseudoarthrosis) plays an increasingly important role in the radiologist's daily interpretation of the postoperative spine. Multiple artifacts may complicate the interpretation of spine imaging, and these artifacts can arise from chemical shift, motion, magnetic field nonuniformity, magnetic susceptibility and incomplete fat saturation.⁴ A textbook would be required to provide a complete compendium of postoperative imaging findings; therefore, this article includes several of the more interesting and challenging presentations.

Clinical considerations and imaging *Retained foreign material*

Gel foam—Placement of surgical hardware to obtain spinal stability typically leads to a successful postoperative outcome; however, surgical material may be unintentionally malpositioned or inadvertently retained, which may have significant patient care implications (Figure 1). Gel foam, which is used for hemostasis and postoperative scar reduction in spinal surgery, has been associated with significant pain.⁵

Pantopaque retention

The myelographic agent that was used prior to the availability of water-soluble agents (Pantopaque, Lafayette Pharmaceutical, Inc., Lafayette, IN) could be retained within the spinal canal for years or even decades, depending on the volume used.⁶ Adhesive arachnoiditis may result as a complication of

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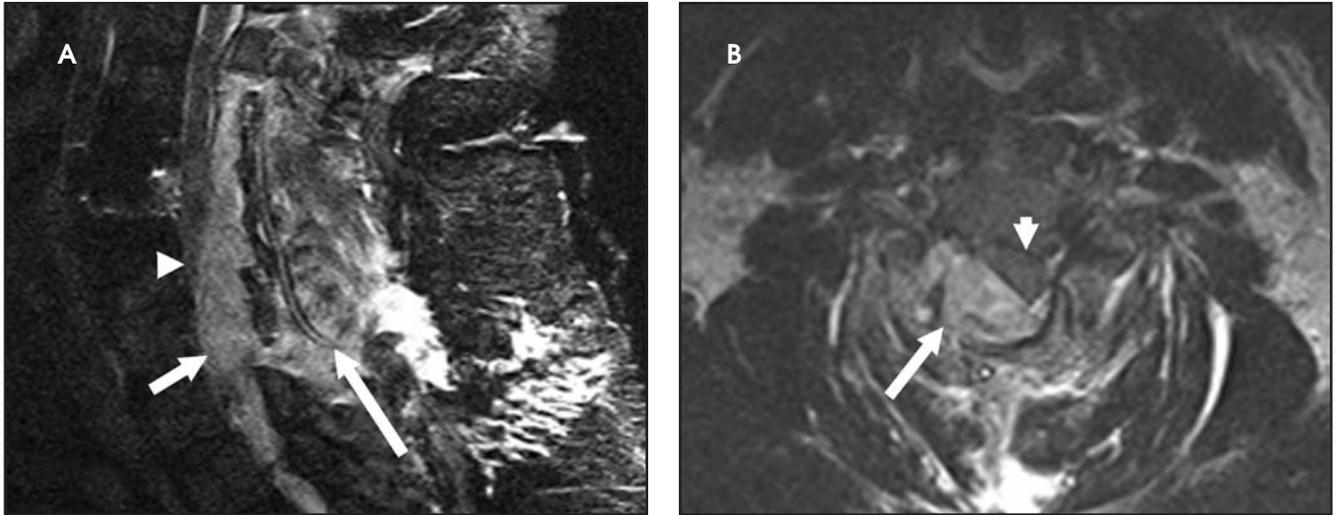


FIGURE 1. This 54-year-old man experienced progressive weakness in the right hand, then right leg, and then left leg several hours postoperatively, which required emergent follow-up with magnetic resonance imaging of the cervical spine. These short tau inversion recovery images show a drain and reveal gel foam compressing the spinal cord. (A) High short tau inversion recovery signal from the fluid-imbibed gel foam (short arrow) can be seen within the spinal canal compressing the cervical cord (arrowhead). A drain posterior to the spinal canal was also placed after laminoplasty of the cervical spine (long arrow). (B) The gel foam in the posterolateral portion of the spinal canal on the right (long arrow) compresses and displaces the cervical cord into the left lateral recess (arrowhead). Excess gel foam (which may imbibe fluid and swell) in combination with overall spinal canal narrowing may have contributed to the compression of the cervical spinal cord and exiting roots, which can lead to subsequent neurological deficits. The postoperative imaging evaluation was critical to correctly denote the compressive etiology, which led to emergent surgical decompression and removal of the excess gel foam. The patient experienced rapid clinical improvement following surgery.



FIGURE 2. Pantopaque (Lafayette Pharmaceutical, Inc., Lafayette, IN) plaques and arachnoiditis. This sagittal gradient-recalled echo image of the thoracic spine shows patches of low signal adjacent to the posterior dural margin. These findings are consistent with calcific Pantopaque plaques (white arrows). Associated high signal within the cord is attributed to the arachnoiditis (black arrows). These collections typically form at the posterior dural margin, presumably as a result of the supine recumbent position during rest.

persistent Pantopaque (Figure 2), which can cause meningeal thickening and hyalinization of the arachnoid.⁷ The nerve roots may adhere to themselves and/or the dural margins.⁸ Arachnoiditis may occur in the postmyelographic state, particularly if bloody cerebrospinal fluid (CSF) is present.

Catheters and stents

Suboccipital decompression (with or without dural grafting), cyst shunting, and lysis of intradural adhesions is the most commonly performed surgical treatment in the Chiari malformations and associated syringohydromyelia. Suboccipital decompression relieves stenosis at the foramen magnum, which corrects associated flow-related abnormalities and thus prevents syrinx development or enlargement of an existing syrinx. Some researchers advocate intradural exploration to lyse commonly associated intradural adhesions.⁹ Stents and shunts diverting CSF from the syrinx to the adjacent CSF or into the peritoneal or pleural cavity are favored in cases of isolated syrinx rather than cases associated with Chiari I malformations¹⁰ (Figure 3).



FIGURE 3. Syringa and enhancing drain. These images show a syringa placed in a syringa 7 years earlier in a 51-year-old woman. She presented with new myelopathy, bilateral visual disturbance, and recurrent limb weakness. (A) Axial T1-weighted pre- and (B) postgadolinium images reveal enhancement around the syringa (arrows). (C) This sagittal T2-weighted image shows an edematous and enlarged cord (long arrow). Note the multilevel laminectomy and the abnormal signal within the pons (arrowhead). (D) This sagittal T1-weighted gadolinium-enhanced study performed 2 days after treatment with Solu-Medrol (Pfizer Inc., New York, NY) shows improvement in cord size with persistent, though diminished, enhancement (sagittal prior comparison study not shown) around the syringa (long arrow), with reduction of cord swelling. Notice the abnormal signal within the pons (arrowhead), which was thought to represent an active demyelinating plaque. The enhancement pattern around the syringa can be seen in a setting of foreign body reaction, granulation tissue, or infection.

A multicenter study that evaluated the surgical preferences and outcomes reported that suboccipital decompression was a better treatment option for Chiari I malformations while stents and shunts were more efficacious in treating cases of isolated syringa.¹⁰ Several shunting procedures have been suggested for the correction of symptomatic syringomyelia. One multicenter study determined surgical preferences in the following order:

syringosubarachnoid shunt, syringopleural shunt, syringoperitoneal shunt, and syringocisternal shunt.¹¹⁻¹³

Magnetic susceptibility

Magnetic susceptibility artifacts are frequently encountered in the postinstrumented spine; particularly when GRE sequences are used. Gradient-recalled echo allows for a significantly decreased acquisition time; however, T2* field



FIGURE 4. Acquired with a 1.5T magnet, parasagittal (A) T1-weighted (T1W) and (B) T2-weighted (T2W) images show cervical laminoplasty with little evidence of orthopedic hardware (arrows). At 3T, parasagittal (C) T1W and (D) T2W images in the same patient show extensive signal morphologic abnormality, which is consistent with the expected exacerbation in magnetic susceptibility from spinal fixation hardware (arrows) at increased field strength.

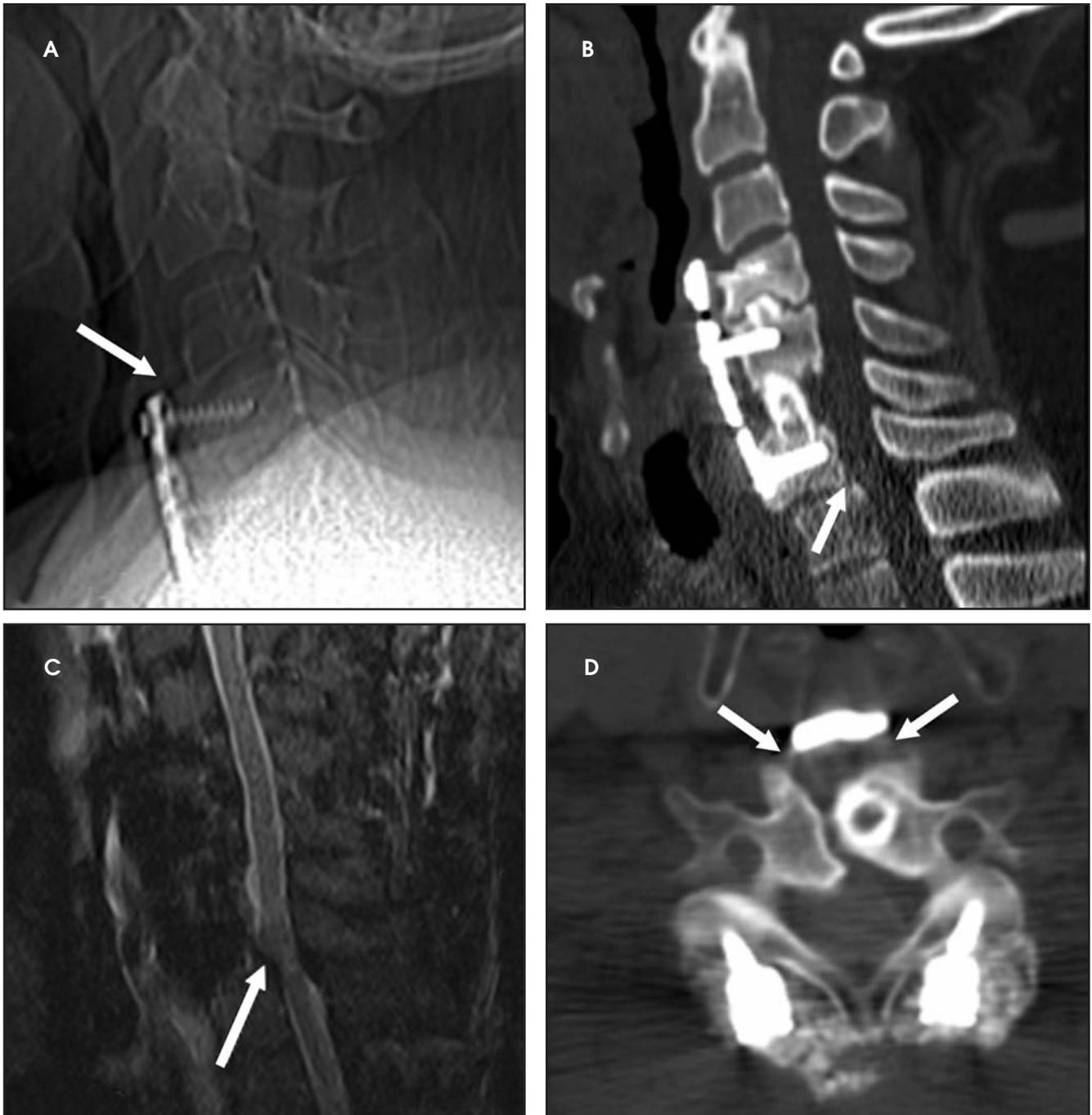


FIGURE 5. Traumatic listhesis caused by a motor-vehicle-collision (MVC) in a patient who had previously undergone spine surgery. (A) This scout CT scan of the cervical spine shows an anterior plate and screw fixation of the cervical spine with mild separation of the plate superiorly (arrow). (B) This sagittal CT reformatted image shows anterolisthesis of C7 on T1 (arrow) at the normally hypermobile segment—the result of a second MVC; the anterolisthesis was not present on the prior postfixation study (not shown). (C) A sagittal T2-weighted image reveals a loss of the surrounding cerebrospinal fluid secondary to spondylolisthesis, which resulted in cord compression (arrow). (D) This axial CT scan of the cervical spine shows the subsequent posterior transfacet fusion used to secure the cervical spine and separation of the plate from the anterior margin of the vertebral column at the C4–C5 level (arrows). The fibular autograft that was placed after the first MVC is incompletely fused to the right side of the vertebral body.

inhomogeneities are worsened with GRE because of lack of a refocusing RF pulse.¹⁴ Therefore, gradient-recalled echo imaging can be used in certain applications to

not only limit acquisition time but also to search for otherwise subtle foci of magnetic susceptibility such as paramagnetic blood products, air/water interfaces, or

calcium deposition.¹⁴ Magnetic susceptibility due to neurosurgical hardware is increased at higher field strengths and, therefore, the ferromagnetic properties

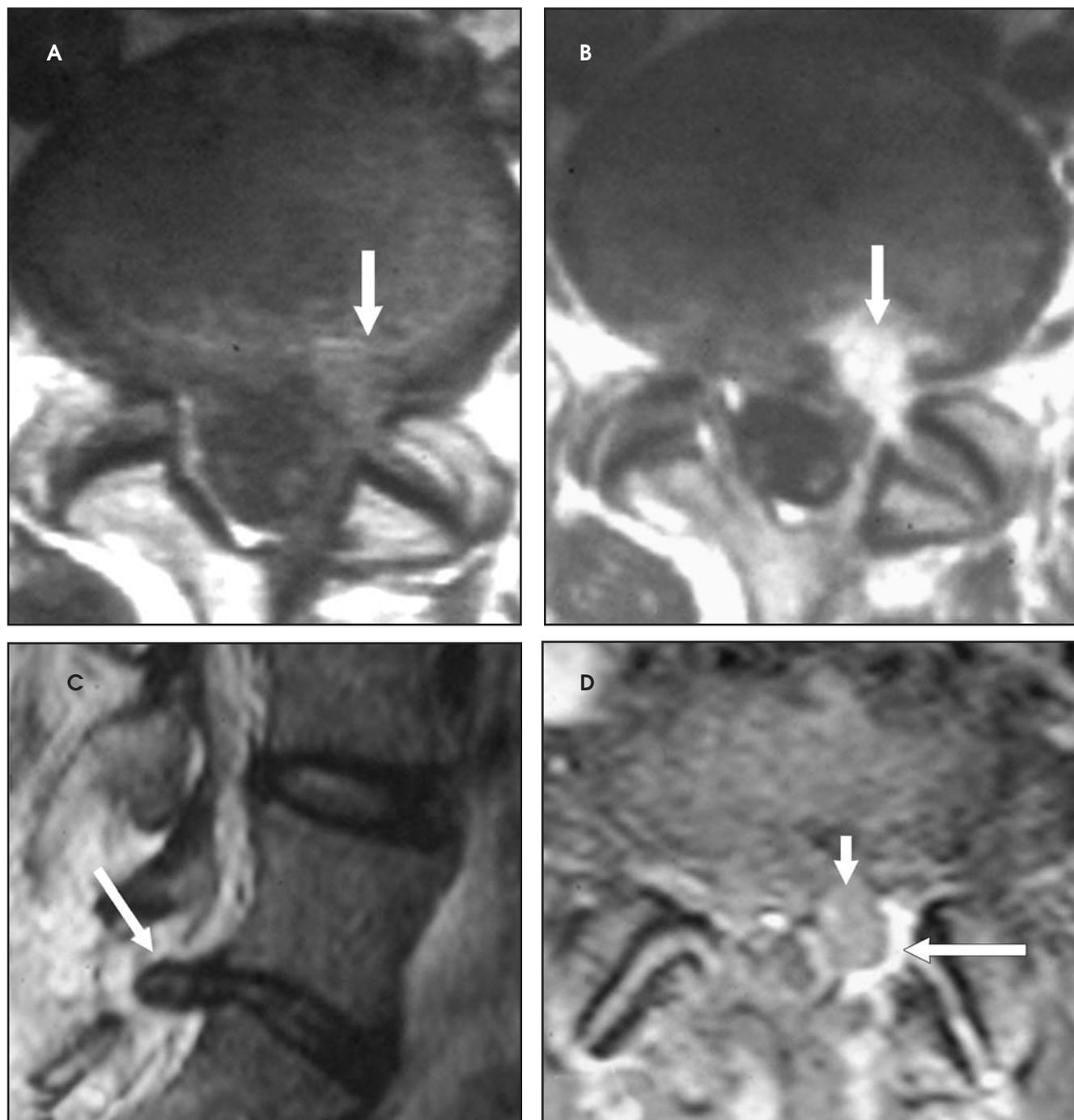


FIGURE 6. Recurrent herniated disc versus postoperative scar. (A) Axial T1-weighted (T1W) pre- and (B) postgadolinium lumbar spine images show diffuse enhancement in the left lateral recess of the lumbar spine, which is consistent with scar tissue (arrows). (C) A T2-weighted sagittal image in another patient shows low signal extending from the disc margin into the lateral recess of L5-S1 (arrow). (D) In the same patient as shown in C, an axial T1W fat-saturated gadolinium-enhanced image reveals peripheral enhancement (long arrow) around the isointense disc, which is consistent with recurrent herniation (short arrow).

of spinal hardware are amplified as the field strength is increased. The use of fast spin-echo (FSE) T2-weighted (T2W) imaging is preferred in these patients. Phased-array coils with parallel imaging,

high bandwidth, and relatively long echo train FSE sequences can be used to further reduce magnetic susceptibility.¹⁴ This fact should be taken into special consideration when comparing scans

from 1.5T and 3T magnets (Figure 4).¹⁵ Artifacts may be significant enough, even with the use of FSE techniques, to limit the evaluation of the spinal canal and the surrounding structures.

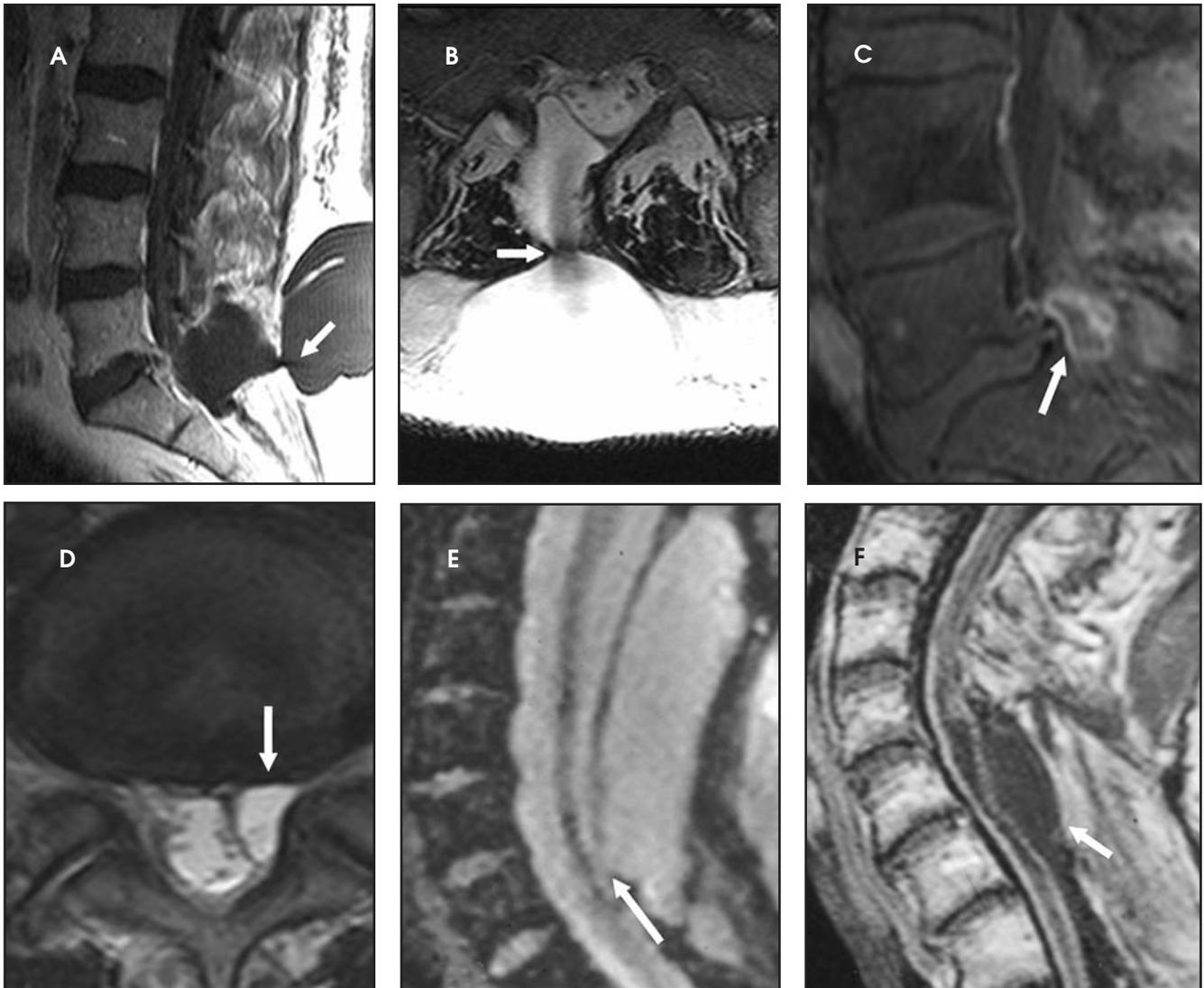


FIGURE 7. Fluid collections. (A) Sagittal T1-weighted (T1W) and (B) axial T2-weighted (T2W) images show a pseudomeningocele posterior to the lumbar spinal canal with flow characteristics depicting a jet of cerebrospinal fluid communicating with a large subcutaneous collection (arrows). In another patient, (C) sagittal T1W fat-saturated gadolinium-enhanced and (D) axial T2W images of the lumbar spine delineate a cystic collection in the left lateral recess with a thin rim of peripheral enhancement. The lesion was an infected pseudomeningocele, as had been clinically suspected (arrows). (E) A sagittal T2W image in a third patient reveals a cervical pseudomeningocele posterior to a myelomalacic cord with a focal dural rent showing communication with the thecal sac (arrow). (F) A sagittal T1W gadolinium-enhanced image of a fourth patient depicts a peripherally enhancing epidural lesion compressing the cervical cord (arrow). The culture positively confirmed an abscess.

Failure of surgical hardware

Postoperative spine fracture may occur from osteoporotic insufficiency, neoplasia, subsequent trauma, osteomyelitis, pseudoarthrosis, Charcot joint formation, repetitive stress reaction, hardware failure, or a combination of these entities. Spinal hardware may fracture or migrate from malpositioning, misconstruction, excessive stress, acute trauma, or metal fatigue.^{16,17} This potential for hardware compromise requires the radiologist to

precisely identify and report the configuration of hardware placement (Figure 5). Transfacet, lateral mass, or transpedicular screws may fracture from metal fatigue, may cause fractures in vertebral body margins, or may enter neural foramen, the spinal canal, adjacent vertebral body levels, or approximate soft tissues.¹⁸

Disc versus scar

The removal of herniated discs is one of the most common indications for spinal

surgery. Knowledge of the patient's detailed surgical history is essential, as there may be little evidence of postprocedure changes to indicate any prior operations or interventions. Various terms have been used to describe disc disease in an attempt to improve understanding of the configuration, degree, and location of disc pathology.^{19,24} Postsurgical findings may include recurrent disc herniation, residual disc material, scar formation, infection, hemorrhage, or a combination of these

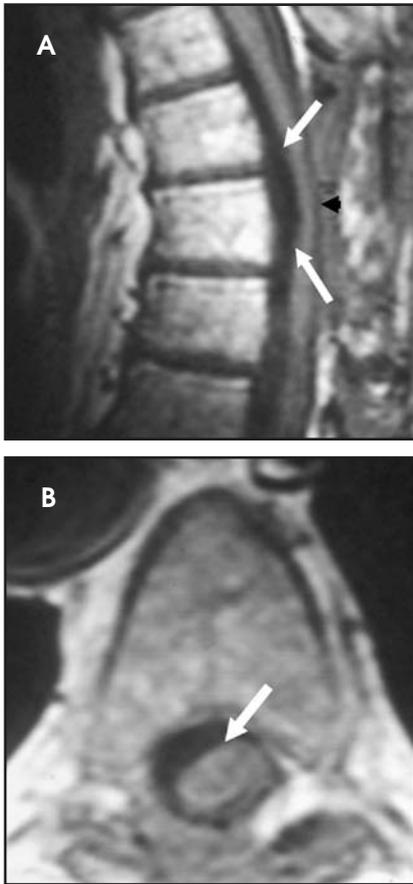


FIGURE 8. Tethered cord. (A) Sagittal and (B) axial T1-weighted (T1W) images show widening of the right anterior subarachnoid space caused by subarachnoid cyst formation, occurring at the levels of the laminectomy, and mild ventral cord compression (arrows). Dorsal tethering can be seen on the sagittal T1W image (arrowhead in A).

entities. The hallmark sign distinguishing postoperative scar from recurrent or residual disc herniation is the pattern of enhancement. Scar tissue tends to enhance homogeneously, while disc herniation tends to enhance peripherally (Figure 6). In the early postoperative period (less than 3 to 6 months), it may be impossible to distinguish peripherally enhancing scar type changes from recurrent/residual disc herniation.

Postoperative fluid collections

Postoperative fluid collections are frequent and must be differentiated from seroma, hemorrhage, abscess, and/or pseudomeningocele. Identification is critical because of adjacent vulnerable

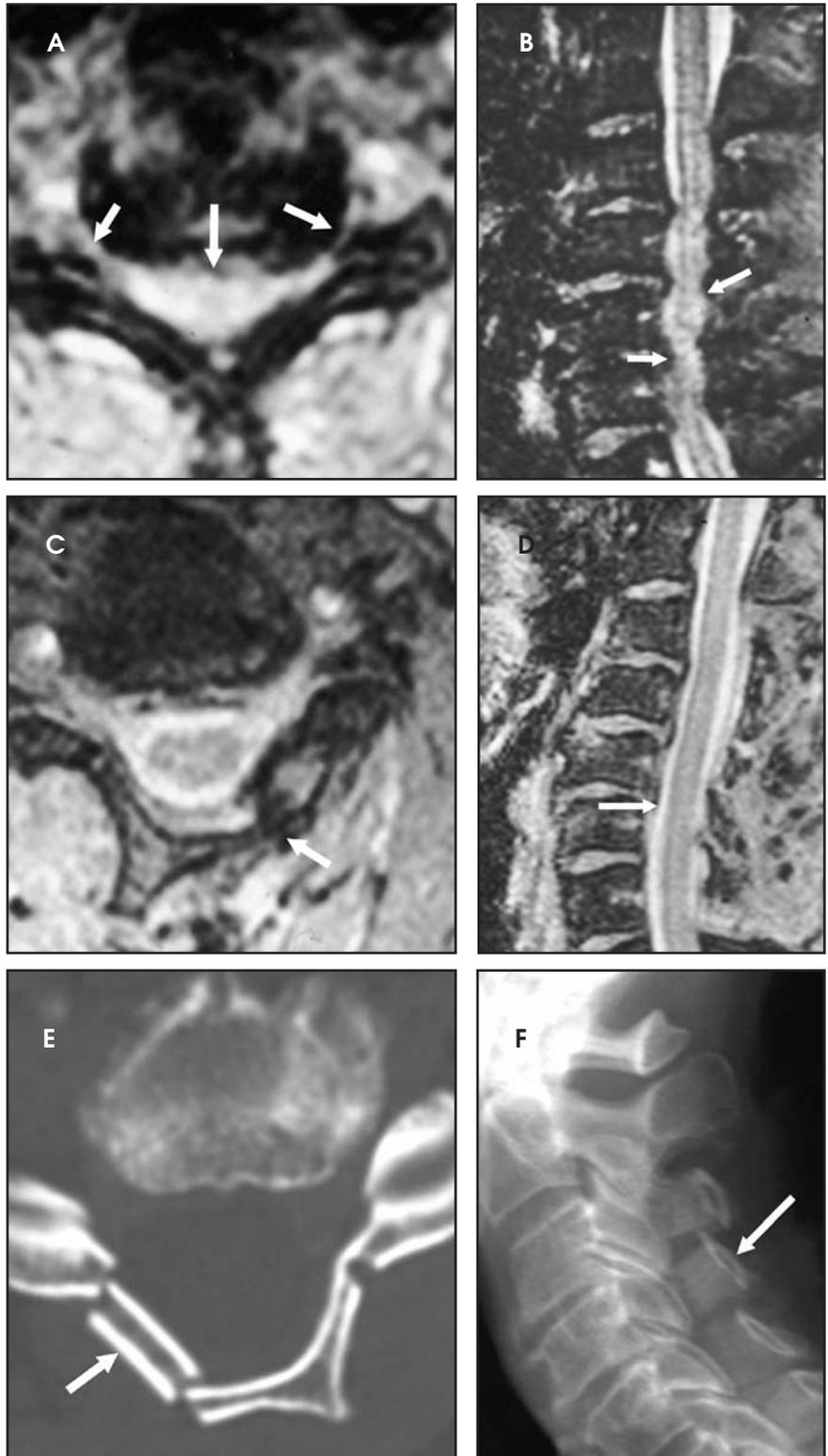


FIGURE 9. Laminoplasty. (A) Preoperative axial and (B) sagittal gradient-recalled echo (GRE) and (C) postoperative axial and (D) sagittal GRE imaging in a patient who underwent a multilevel laminoplasty procedure (arrows). Postoperative (E) CT and (F) sagittal plain-film radiographic results of laminoplasty in another patient. There is a significant increase in spinal canal capacity as the spinous processes are rotated laterally. (E) The CT shows osseous graft in the resulting defect (arrow). (F) The radiograph shows rotation of the lamina seen on end (arrow).



FIGURE 10. Dural allograft after posterior cord untethering. (A) Sagittal T1-weighted (T1W), (B) sagittal T2-weighted (T2W), (C) axial T1W, and (D) axial T2W images after multilevel laminectomy show with residual cystic and noncystic signal in the cord. Posterior to the cord, there is enlargement of the subarachnoid space (compared with that seen on the preoperative scan [not shown]) bounded posteriorly by dural allograft material that is isointense to cerebrospinal fluid on T1W imaging and hypointense on T2W imaging (arrows in A and B). Dural suture lines are seen posterolaterally on both axial views (arrows in C and D).

neural structures and potentially serious sequelae of delayed or inappropriate treatment.²⁵⁻²⁷ Hemorrhage may be identified by observing a blood/serum level on cross-sectional imaging, measuring HU on CT, and/or evaluating the MRI

sequence signal characteristics that are indicative of blood products.²⁸ A hemorrhage may be complicated by a superimposed infection, which may be difficult to distinguish from inflammatory scar formation.

Pseudomeningoceles

Pseudomeningoceles may enhance peripherally in a manner that may simulate an inflammatory or infectious process (Figure 7). It may be possible to differentiate abscess from pseudomeningocele by observing T1W pre- and postgadolinium and T2W sequences to determine the enhancement characteristics and whether the internal signal exactly follows the signal of CSF.^{29,30} Pseudomeningoceles do not regularly show the degree of adjacent inflammation and enhancement characteristics that are associated with most abscesses. Pseudomeningoceles exhibit signal that should virtually match CSF intensity. Abscesses, conversely, are expected to display lower signal intensity on T2W sequences and higher signal on T1W sequences because of intermixed proteinaceous products. Infrequently, pseudomeningoceles reveal the site of a leak through the dura and are seen as low signal that represents dephasing of fluid due to flow.

Abscess or phlegmon

A focal region of infectious inflammation, also known as a *phlegmon*, often precedes frank abscess formation and may enhance with characteristics that are difficult to differentiate from recently formed scar tissue or tumor. An abscess typically presents in an epidural location; however, it may also present in a subcutaneous or intramuscular position or in the intradural space or disc space, and/or it may involve the ligamentum flavum or lie within the cord. An abscess often appears with a thick rind or capsule of inflammatory tissue that enhances avidly.³¹⁻³³ Spinal epidural abscesses have been shown to occur more commonly in the lumbar spine. In these abscesses, 72% of cultures reveal gram-positive organisms with *Staphylococcus aureus* as the most common culprit (45%).³³ Figure 7F depicts a peripherally enhancing epidural lesion compressing the cord that was culture-positive, consistent with abscess.

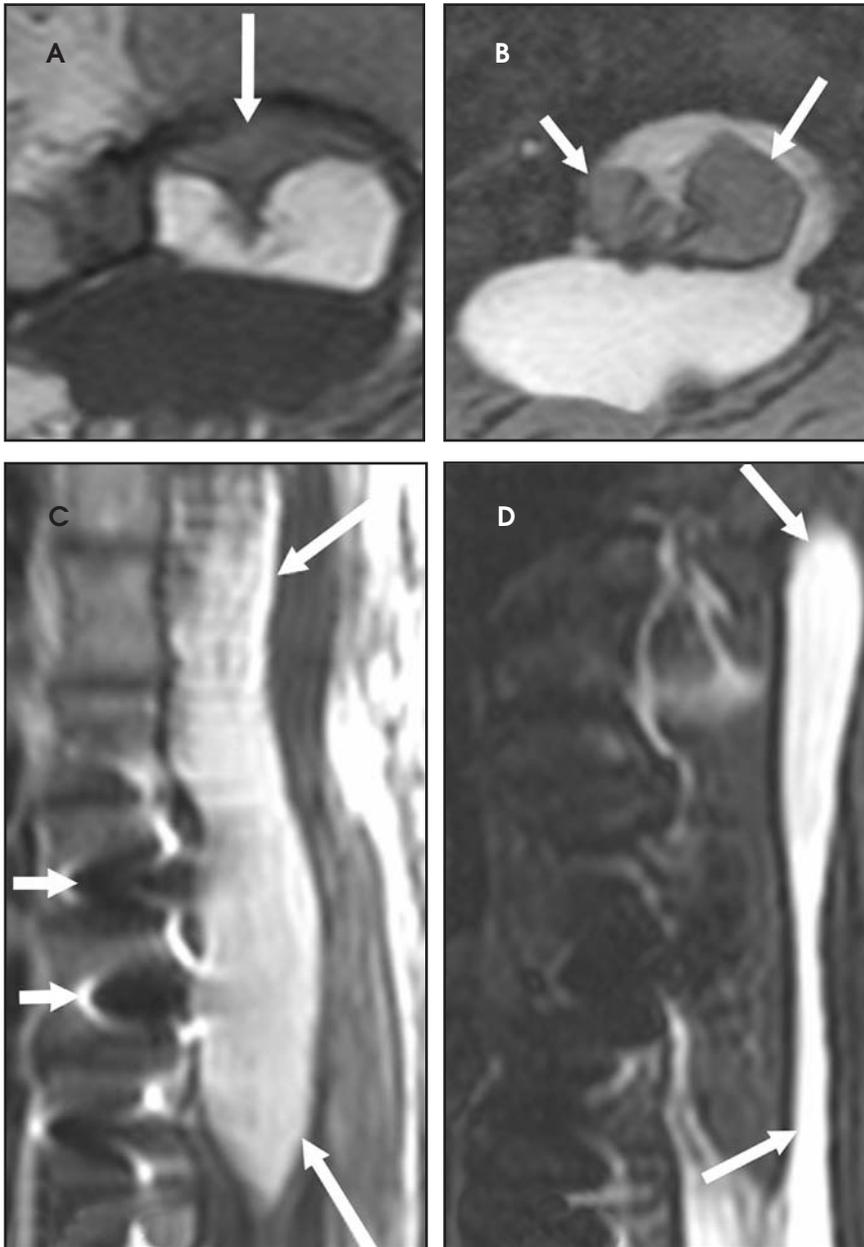


FIGURE 11. Intradural lipoma and pseudomeningocele in a 35-year-old severely scoliotic paraplegic man who has multilevel lateral support screw and rod fixation. (A) A T1-weighted (T1W) axial image shows an atrophied cord centrally (arrow). (B) An axial proton-density with fat suppression image shows intermediate signal lipoma (arrows) around the heterogeneous high signal intensity cord. (C) A sagittal T1W image shows magnetic susceptibility from laterally placed hardware (short arrows) in patient with scoliosis and intradural lipoma (long arrows). (D) A T2-weighted sagittal image shows posterior extradural fluid signal, which is consistent with a known pseudomeningocele (arrows).

Inflammation

Inflammatory processes such as arachnoiditis, fibrosis, inflammatory pseudotumor, and tethered cord may complicate the postoperative state (Figure 8). MRI evaluation of the lumbar spine following myelomeningocele

repair shows findings that are consistent with tethered cord in virtually all patients.³⁴

Spinal canal decompression

Stenosis of the spinal canal may be congenital or the result of spondylosis,

including facet hypertrophy, ligamentum flavum hypertrophy, ossification of the posterior longitudinal ligament, and posterior endplate spurring, which may be exacerbated by intervertebral disc herniation and congenital spinal canal stenosis. Scoliotic deformities, spondylolisthesis, and compressive fractures may also complicate spondylotic stenosis. Spinal stenosis is most common in the cervical and lumbar areas, and the pain associated with neural compression may be ameliorated by decompressive surgical procedures such as partial disc resection, laminectomy, unilateral laminotomy, bilateral laminotomy, laminoplasty, and other surgical variations.^{35,36} Laminoplasty of the cervical spine has become an accepted procedure for alleviating focal or multilevel spinal canal stenosis (Figure 9). Hydroxyapatite, ceramics, and other material have been used to promote structural stability. Osseous autografts, allografts, and xenografts (including the fibula, iliac crest, vertebral bodies, and other sources) have been used extensively for spinal reconstruction.³⁷⁻³⁹

Dural autografts

Dural grafts are used for the repair of some congenital malformations, following dural resection, or in cases requiring enlargement of the dural sac. It is important to recognize the expected presentation of a dural graft (Figure 10) and to differentiate it from other potentially associated complications, such as scar tissue, complicated pseudomeningocele, infection, or CSF leak.⁴⁰ It is essential that the radiologist is familiar with the patient's surgical history, since this presentation may be inadvertently interpreted as an inflammatory or infectious process.

Complicated postoperative spine

A complicated postoperative spine may include multiple surgical hardware revisions, hardware compromise, complicated fluid collections, tumor recurrence, subsequent osteoporotic insufficiency fractures, a mixture of the above, or other complications. Figure 11 displays one example of the

plethora of potential complicated postoperative spine presentations.

Conclusion

Interpreting postoperative spine imaging requires a systematic approach and knowledge of the patients' surgical history. This approach will allow the radiologist to separate the many possible confounding findings. Obtaining surgical reports and detailed clinical history can be invaluable in understanding and properly reporting on the postoperative spine.

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