UPDATE IN RADIOLOGY

Evaluation of the postoperative lumbar spine

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Abstract Given the prevalence of low back pain, surgical interventions on the lumbar spine are becoming more common. Among the many surgical procedures available for these interventions, the most common are laminectomy and discectomy. In 10–40% of patients who undergo surgical interventions on the lumbar spine, low back pain is not completely alleviated or it recurs, and these cases fall into the category of “failed back surgery syndrome”. This syndrome can have many different causes and multiple factors are often involved. It is important not to confuse the normal postoperative findings with those specific to failed back surgery syndrome. Deciding which imaging technique to use will depend on the type of surgical intervention, whether metallic orthopedic material was used, and the clinical suspicion. It is essential to know the advantages and limitations of the available imaging techniques to ensure the optimal evaluation of these patients, especially after interventions carried out with instrumentation to minimize the artifacts due to these materials.

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PALABRAS CLAVE
Imagen por resonancia magnética;
Columna lumbar;
Columna lumbar postoperatorada;
Síndrome de cirugía fallida de columna

Evaluación de la columna lumbar posquirúrgica

Resumen Dada la gran prevalencia del dolor lumbar, la cirugía de columna es una intervención cada vez más frecuente. Existen múltiples procedimientos quirúrgicos disponibles, siendo la laminectomía y discectomía las intervenciones más frecuentes. En un 10-40% de los pacientes intervenidos, el dolor lumbar que ocasionó la intervención puede revertir o no solucionarse completamente, incluyéndose dentro del síndrome de cirugía fallida de columna. Hay múltiples causas que pueden ocasionar este síndrome, siendo frecuentemente de etiología multifactorial y no deben confundirse con los hallazgos normales en columnas postoperatoradas. La decisión de la técnica de imagen a realizar dependerá del tipo de cirugía, la utilización de material ortopédico metálico y la sospecha clínica. El conocimiento de las ventajas y limitaciones de las distintas técnicas de imagen disponibles es esencial para la óptima valoración de estos pacientes,

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Introduction

Surgery of the lumbar spine is becoming increasingly more common with a wide range of surgical procedures available. Radiological assessment following surgery requires knowledge of both the normal changes in the postoperative spine and the possible complications. Postoperative complications have been reported in up to 15–30% of patients. Complications can be acute or occur later after surgery, causing worsening or no resolution of the symptoms that led to surgery. These complications fall into the category of failed back surgery.

Prior to the postoperative radiological evaluation, we must be aware of the cause of surgery, the surgical technique used, current symptoms, and time elapsed since surgery. These factors will determine the imaging modality to be used and the protocol to be followed for radiological assessment.

In case of spinal fusion or instrumentation, certain technical aspects should be considered in order to reduce to the minimum the artifacts caused by these instruments.

This paper reviews the approach and radiological findings of postoperative lumbar spine.

Imaging techniques

Deciding the type of radiological study for postoperative spine assessment is determined by the surgical technique used. The increasing use of metal orthopedic hardware in spine surgery makes it necessary to adjust some technical parameters to reduce artifacts from this hardware.

Conventional radiography

Conventional radiography is the most commonly used imaging modality. In patients who undergo laminectomy and/or discectomy, radiography during surgery to confirm the level may be the only imaging technique used in the absence of suspicion of complications. Conventional radiography (X-ray) is particularly useful in surgery involving metal hardware because it is not biased by the artifact produced by the hardware in other techniques such as computed tomography (CT) and magnetic resonance imaging (MRI).

Computed tomography

CT is the modality of choice for bone and abnormal calcification assessment. CT requires intravenous iodine contrast in case of suspected infection.

The severity of the artifact produced by metal orthopedic hardware on CT depends on multiple factors such as the image reconstruction algorithm, kilovoltage (kVp), milliamperage, and pitch, as well as hardware composition. A number of technical aspects should be therefore taken into account for artifact reduction on CT Images:

- Multichannel CT shortens examination time, and minimizes motion artifacts.
- Acquisition with the thinnest slice thickness possible using isotropic voxels allows for more accurate z-axis resolution and for multiplanar and volumetric reconstructions with high spatial resolution.
- An increase in kVp results in a higher beam penetration. This measure should be taken carefully in young patients and patients undergoing multiple examinations.
- Lowest pitch possible and CT with the highest number of channels.
- Data should be acquired with a soft tissue reconstruction kernel to reduce artifacts. Using a bone kernel in the postprocessing allows for better assessment of bone structures.

The recommended protocols for 16- and 64-channel CT are shown in Table 1.

Orthopedic hardware with lower attenuation coefficient results in less distortion. Titanium produces less distortion than stainless steel, which in turn produces less distortion than cobalt-chrome.

Magnetic resonance

MRI is the modality of choice, especially in cases where postoperative complications are suspected. The high spatial and contrast resolution of MRI allows for better evaluation of soft tissues, bone marrow, and intraspinal content.

Metal orthopedic hardware produces magnetic susceptibility artifacts. The technical aspects to be considered for artifact reduction are the following:

- Fast spin echo (FSE) sequences are better than conventional spin echo (SE) sequences, and these latter are...
better than gradient echo (GE) sequences. The echo time (TE) and repetition time (TR) used in these sequences vary with the MRI equipment, and their values can be modified within a range. The shortest TE possible is recommended for metal artifact reduction in spin echo sequences. FSE sequences require longer TR than conventional sequences.
- T2-weighted sequences.\textsuperscript{10}
- A relatively short (<10) echo train should be used.
- The field of view and the voxel volume should be increased and reduced, respectively.
- Magnetic field with low intensity.
- Short time inversion recovery (STIR) sequences should be used for fat suppression, since sequences based on selective fat saturation pulses are associated with poor homogeneity\textsuperscript{11} (Fig. 1).
- In addition, the phase encoding direction in both the axial and sagittal planes should be parallel to the long axis of the orthopedic material, since the artifact produced will be linear and parallel to the metal material, therefore with less interference with image assessment (Fig. 2).

At MRI, titanium and vitallium hardware produce fewer artifacts than stainless steel.\textsuperscript{6}
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There is no established protocol for the study of the postoperative spine with MRI. A routine protocol including axial and sagittal T1-weighted SE sequences and axial and sagittal T2-weighted FSE sequences would suffice in most cases. While contrast administration is particularly useful in patients with previous discectomy and suspicious of infection, it is not necessary in the rest of cases.

A limitation of multi-echo sequences that may be useful in nerve root and spinal canal assessment is their acquisition time, which extends the examination.

Evaluation of postoperative spine

After spine surgery, patients may have full resolution of lumbar pain. If this is not the case, failed back surgery syndrome occurs. This is a general term that refers to patients with recurrent symptoms or in whom surgery failed to fully correct the problem. Although there are a large number of potential causes, in most cases this syndrome has a multifactorial etiology (Table 2).

The failed back surgery syndrome is observed in 10–40% of postoperative patients; therefore, we should be able to differentiate normal radiological findings from abnormal findings in a postoperative spine.

Depending on the type of initial surgery and symptoms, most patients undergo one or more imaging examinations (X-ray, flexion-extension x-ray, CT, myelography, and MRI).

Table 2 Causes of failed surgery.

<table>
<thead>
<tr>
<th>Early causes</th>
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<td>Malpositioning of orthopedic hardware</td>
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<td>Hemorrhage</td>
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<td>Infection</td>
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<td>Pseudomeningocele</td>
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<td>Surgery at a wrong level</td>
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<td>Canal or foraminal stenosis</td>
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<td>Textiloma</td>
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<table>
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<tr>
<th>Late causes</th>
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<tr>
<td>Fracture of orthopedic hardware</td>
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<td>Failed fusion and pseudoarthrosis</td>
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<td>Spondylysis and spondylolisthesis</td>
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<tr>
<td>Osteophytosis</td>
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<td>Sterile arachnoiditis</td>
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<tr>
<td>Recurrent disc herniation</td>
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<td>Fibrosis</td>
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Normal radiological findings in postoperative spine

The most common lumbar spine surgical procedures are laminectomy, discectomy (with removal of herniated material and/or native disc), fusion, and orthopedic hardware placement.

A mid-line approach is the most common approach for lumbar spine surgery, and asymmetry of muscles and fat as well as small seromas and edema of the subcutaneous cell tissue are usually observed. During the first 30–60 days, this may determine a certain posterior mass effect on the thecal sac that will decrease over time.

MRI is the modality of choice for assessment of discectomies. Determination of time elapsed after surgery is particularly important, since findings in the early postoperative period (six months) require cautious evaluation. However, MRI is indicated during this period if the patient presents with failed back surgery syndrome. For non-contrast MRI images, early postoperative changes following discectomy may simulate the previously removed herniated material as a result of the disruption in the fibrous annulus and the presence of epidural edema. Following contrast administration, the homogeneous enhancement of this fibrosis and granulation tissue explains the observed mass effect that will progressively decrease (Fig. 3).

The edema and enhancement of the vertebral endplates are observed in 19% of patients between 6 and 18 months following surgery. In 20–62% of patients, enhancement of the nerve roots is observed between 3 and 6 weeks following surgery. This enhancement progressively decreases, and therefore any enhancement observed after six is considered pathological.

The findings described, which are considered normal during the postoperative period, should be distinguished from those associated with early discitis. In these cases, symptoms, laboratory data, and if necessary, biopsy of the suspicious area should be correlated. Enhancement associated with bacterial discitis is typically more intense than that reported during the normal postoperative period in asymptomatic patients. A fluid collection with a paraspinal or anterior epidural location or located adjacent to the disc involved and enhancement of the psoas are usually indicative of infection.

In the area of laminectomy, the dural sac may slightly bulge through the bone defect, which should not be confused with a pseudomeningocele (Fig. 4).

Figure 4 Normal findings following lumbar spine surgery. 40-Year-old male who underwent right L5-S1 laminectomy. Postoperative axial T2-weighted MRI shows herniation of the dural sac through the segment of laminectomy (arrows).

Figure 5 Misplacement of the orthopedic hardware. Axial CT (A) and parasagittal reconstruction (B) in the immediate postoperative period of a female patient who underwent laminectomy and L3, L4, and L5 transpedicular screw placement. The patient had a very poor postoperative outcome with severe pain at right L3 and L4 level. Misplacement of the right L3 screw that invades the canal (arrow in A) and intervertebral foramina (asterisk in B).
Abnormal radiological findings in postoperative lumbar spine

Complications associated with instrumentation

The integrity and proper placement of the surgical instrumentation should be evaluated to rule out displacements, which are usually associated with other abnormalities such as pseudoarthrosis, spinal instability, fractures, dural lacerations, and nerve injuries.\textsuperscript{15} The rate of nerve root irritation following transpedicular screw placement is 1%, typically caused by inappropriately low and medial positioning of the screws\textsuperscript{16} (Fig. 5). The cage devices used in intersomatic arthrodesis can be metallic or radio-transparent. In the latter case, most devices contain two radiopaque markers in their anterior and posterior margins for localization purposes.

Conventional radiography is the first imaging technique to be performed. However, CT is more helpful when a definitive diagnosis cannot be established and if there is suspicion of rupture or misplacement. Loosening of the orthopedic hardware is suspected when an area of hypodensity >2 mm in thickness is observed around the hardware (Fig. 6).

MRI is used to assess soft tissue and nerve structures in relation to the implanted material.

Textiloma

The textile surgical material accidentally left behind in a surgical bed may become a textiloma\textsuperscript{17} (Fig. 7). This material usually contains a radiopaque marker that is readily visible on X-ray and CT. This marker cannot be assessed in MRI studies because it is a barium sulfate filament that is not paramagnetic.\textsuperscript{2} T2-weighted sequences demonstrate hypointense lesions with peripheral foreign body reaction, and show enhancement of the peripheral inflammatory tissue after contrast agent administration.\textsuperscript{9}
Accelerated degenerative changes
Degenerative disc changes and arthrosis of interapophyseal joints in the segments adjacent to the postoperative segments are observed. These changes are more common after spinal fusion than decompression (Fig. 8), and they are caused by stress and altered biomechanics following fusion.18

Radiography is the first imaging modality used for the evaluation of these changes. MRI is more accurate in assessing changes in soft tissue and disc contour.

The findings are similar to those seen in degenerative changes secondary to other reasons, including intervertebral space narrowing, ex vacuo phenomena, osteophytes, facet arthrosis associated with foraminal stenosis, misalignment, Modic changes in the adjacent vertebral endplates, disc contour abnormalities, and spinal canal stenosis.

Spondylolisthesis
Patients who undergo laminectomy present with more instability and deformity, with displacement of the vertebral body onto the bone below. This condition increases with motion and worsens over time. It is more commonly associated with multilevel laminectomy with over 50% resection. A prophylactic fusion is usually performed in these patients.

In these cases, dynamic examinations performed with conventional radiography are particularly helpful (Fig. 9).

Multiplanar reconstructions with MRI and CT can show anterolisthesis, retrolisthesis, or lateral displacement (Fig. 10). These findings should be correlated with previous examinations, preferably including both the latest and earliest ones. This would improve the detection of subtle changes in alignment of vertebral bodies.

Figure 8 Accelerated degenerative changes. 78-Year-old female who underwent laminectomy and multilevel arthrodesis. Parasagittal T1-weighted MRI sequence demonstrates marked degenerative changes in the intervertebral endplates and discs (asterisks) and multilevel misalignment (arrows).

Figure 9 Spondylolisthesis. 67-Year-old male who underwent laminectomy and L3, L4, and L5 transpedicular fixation. Dynamic radiographs of the lumbar spine in extension (A) and flexion (B) demonstrate grade I anterolisthesis of L3 onto L4 (arrow) and L4 onto L5 (dashed arrow). Spondylolisthesis does not increase with flexion, which means absence of instability signs.
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Epidural fibrosis
This complication is caused by scarring tissue formation in the epidural space after spine surgery. Since epidural scarring is part of the normal reparative mechanism of tissue after surgery (Fig. 3), most patients with epidural fibrosis are asymptomatic.19 There is controversy regarding the involvement of epidural fibrosis in the failed back surgery syndrome. Multicenter studies have demonstrated that extensive epidural fibrosis patients are 3.2 times more likely to experience recurrent radicular pain.20

Fibrosis-induced pain may be due to irritation, compression, and traction of the fibrotic tissue on adjacent nerve structures. Outcomes after reintervention in patients who only presented with fibrosis are worse than in patients with associated recurrent disc herniation (DH). Consequently, the presence of associated conditions associated in patients with postoperative lumbar pain and fibrosis should be ruled out.

The main differential diagnosis of epidural fibrosis is recurrent DH. On CT images, recurrent DH shows higher attenuation, 90–120 Hounsfield units (HU), whereas fibrosis shows 50–75 HU. However, these values tend to overlap. Intravenous contrast-enhanced MRI is the modality of choice to differentiate fibrosis from DH with a sensitivity of 96%, which increases in T1-weighted fat-saturation sequences.21 At MRI, fibrosis is isointense on T1-weighted

Figure 10  Spondylolisthesis. 59-Year-old male who underwent laminectomy and L4 and L5 transpedicular screw placement, and presented with recurrent pain. CT sequences with reconstructions on the sagittal plane performed two (A) and three (B) years after surgery. The follow-up demonstrates increased anterolisthesis of L3 onto L4 (arrows).

Figure 11  Symptomatic epidural and perineural fibrosis. 37-Year-old female who underwent follow-up MRI for persistent lumbar pain one year and a half after surgery involving right hemilaminectomy and L5-S1 discectomy. Unenhanced and contrast-enhanced axial T1-weighted sequences (A and B) demonstrate diffuse enhancement of the epidural and perineural fibrosis tissue around the right S1 nerve root (arrows).
Persistent/recurrent disc herniation. 48-Year-old female who underwent laminectomy and L5-S1 discectomy. Follow-up MRI was performed 20 days after surgery due to persistent lumbar pain radiating to the left lower extremity. The axial T2-weighted image (A) shows persistent-recurrent left parasagittal DH connected to the left S1 nerve root at the lateral recess level (arrow). Unenhanced and contrast-enhanced axial T1-weighted image (B and C) shows peripheral enhancement of the herniated material.

and variable on T2-weighted sequences, with immediate homogeneous enhancement, and may be associated with adjacent nerve root thickening (Fig. 11). Recurrent DH may show early peripheral and late central enhancement (30 min after contrast agent administration) by diffusion of the contrast material into the center of the disc (Fig. 12).

Recurrent disc herniation
Recurrent DH is involved in 7–12% of cases of recurrent lumbar pain following spine surgery. MRI is the modality of choice for assessment of recurrent DH and the protocol should include T1-weighted and T2-weighted sequences on the axial and sagittal planes, as well as contrast-enhanced T1-weighted sequences. The herniated disc tissues are isointense with reference to the parent disc, but they may appear hypointense on T1-weighted sequences if calcified or associated with an ex vacuo phenomenon. After contrast administration, the disc material is not immediately enhanced, and peripheral enhancement is observed because of the granulation or dilated tissue of the adjacent epidural plexus (Fig. 12).

Pseudomeningocele
This postoperative complication involves a pseudocyst, which has no true meningeal lining, secondary to a postoperative dural dehiscence. Pseudomeningocele affects 0.19–2% of patients after lumbar laminectomy.

The size of a pseudomeningocele may vary from 1 to 10 cm. Small pseudomeningoceles may heal spontaneously, whereas large ones typically require surgery for the closure of the defect, and may be associated with headache induced by intracranial hypotension. Although most patients are asymptomatic, some may have symptoms related to compression and entrapment of adjacent nerve roots. MRI is the modality of choice and shows on all sequences an isointense cystic lesion filled with cerebrospinal fluid (CSF). Communication of the cyst with the thecal sac can be observed on T2-weighted sequences (Fig. 13) as an area of lower signal intensity due to the flow of CSF along this communication. After contrast administration, a fine peripheral enhancement can visible. If a more intense enhancement is visualized, superinfection of the pseudomeningocele should be ruled out (Fig. 14). In cases of large lesions with subcutaneous extension, enlargement of the window may be necessary to avoid artifacts and poor homogeneity produced by the surface coil.

Postoperative infection
Symptoms of postoperative infection are usually nonspecific; therefore, it should be suspected in patients with increased lumbar pain after surgery and in patients with

Figure 13 Pseudomeningocele. 36-Year-old female who underwent surgery for L5-S1 disc herniation. Postoperative MRI image with axial T2-weighted sequence, which demonstrates a postoperative pseudomeningocele on the bed of the left S1 laminectomy (arrow). MRI sensitivity is higher than sensitivity of any other imaging techniques, and allows for visualization of the communication between lesion and thecal sac (asterisk).
Figure 14 Superinfected pseudomeningocele. 53-Year-old male who underwent L4-L5-S1 laminectomy with transpedicular arthrodesis. In the days following surgery, T2-weighted sequences (A) showed a superinfected pseudomeningocele with decreased focal signal intensity (arrow) due to flow of CSF in the region of the dural tear and marked wall enhancement on pre-contrast and post-contrast T1-weighted sequences (asterisks on B and C).

abnormal laboratory tests such as increased C-reactive protein.24

Initially, postoperative infection originates as discitis, and less commonly, as facet joint infection, and it may extend into adjacent structures. The etiologic agents most commonly involved are Staphylococcus aureus and Staphylococcus epidermidis.25

At early stages, no changes are observed on X-ray. At later stages, however, lysis and erosion of the endplates adjacent to the affected disc can be observed21 (Fig. 5). The modality of choice is contrast-enhanced MRI with fat saturation,13 which allows for the evaluation of the bone edema and discitis earlier than other imaging techniques. Diffusion-weighted MRI images show hyperintensity of the central necrotic region of the abscess and hypointensity on the apparent diffusion coefficient (ADC) map. CT allows for assessment of the associated bone involvement, phlegmonous collections (seen as hyperenhancing soft-tissue lesions), and abscesses (hypodense collections with peripheral enhancement). CT and ultrasonography are usually used as guides for biopsy.18

Figure 15 Postoperative arachnoiditis. 57-Year-old male who underwent L5 hemilaminectomy. Sagittal and axial T2-weighted sequences (A and B) that demonstrate hypointense tracts within the thecal sac that divide the arachnoid space with CSF loculation (arrows). Post-contrast T1-weighted sequences (C) demonstrate meningeal and root enhancement with peripheral distribution (dashed arrow).
Arachnoiditis
The incidence of this complication is 3%, excluding lesions caused by a previous myelography.16

Although not a common finding, calcifications (calcified arachnoiditis) can be observed on CT images. The modality of choice for arachnoiditis evaluation is MRI, and axial T2-weighted FSE sequences the optimal sequences for characterization. There are three patterns of presentation. Type 1 designates a conglomerate of nerve roots and is suggestive of mild involvement. Type 2 refers to peripheral adhesions of the nerve roots to the thecal sac, giving rise to an "empty-sac" appearance. This pattern is associated with moderate involvement. Type 3 refers to an intermediate attenuation mass obliterating the subarachnoid space below the conus medullaris, being the most severe presentation27 (Fig. 15).

Conclusion
Radiological assessment of postoperative lumbar spine is a common procedure in everyday practice of the radiologist. Knowledge about the different types of surgical procedures and instrumentation, normal postoperative changes, and potential complications is essential for proper evaluation and choice of the radiological technique to use.

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6. Statistical analysis: N/A.
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Conflicts of interest
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References

