Imaging of Posterior Element Axial Pain Generators
Facet Joints, Pedicles, Spinous Processes, Sacroiliac Joints, and Transitional Segments

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KEYWORDS
• Baastrup disease • Bertolotti syndrome • Facet synovitis • Fat-suppressed MR imaging
• 18F-FDG PET/CT • Interspinous bursitis • Posterior elements • SPECT

KEY POINTS
• The role of the posterior elements in generating axial back and neck pain is well established.
• Morphologic imaging findings are nonspecific and are frequently present in asymptomatic patients.
• Edema, inflammation, and hypervascularity are more specific for sites of pain generation.
• Physiologic imaging techniques such as fat-suppressed magnetic resonance imaging, single-photon emission computed tomography (CT), or 18F-fluorodeoxyglucose positron emission tomography combined with CT are more sensitive for edema, inflammation, and hypervascularity than morphologic imaging alone.

INTRODUCTION
Radiologists and referring clinicians evaluating patients with low back pain (LBP) or radicular symptoms tend to focus on the anterior spinal column, specifically on disc pathology, often overlooking the role of the posterior elements in pain generation. Facet joints, pedicles, spinal ligaments, spinous processes, transitional lumbosacral segments, and sacroiliac (SI) joints have all been implicated as sources of axial back and neck pain, and may be causal of radicular symptoms. Imaging of the posterior elements in LBP remains controversial, primarily because of the specificity fault seen in all spine imaging. Morphologic changes on radiography, computed tomography (CT), and magnetic resonance (MR) imaging are common in asymptomatic individuals. Conversely, posterior element causes of LBP and neck pain may remain underrecognized secondary to use of MR imaging techniques which fail to demonstrate the bone marrow edema, soft-tissue inflammation, and hypervascularity often associated with posterior element pain generators. Inclusion of fat-suppressed T2-weighted or fat-suppressed contrast-enhanced (CE) T1-weighted images into a standard spinal MR imaging protocol increases the conspicuity of these findings. Nuclear medicine bone scanning with single-photon emission computed tomography (SPECT), SPECT/CT, and/or 18F-fluorodeoxyglucose positron emission tomography combined with CT (FDG-PET/CT) are additional physiologic imaging techniques that may identify sites of posterior element pain. This article focuses on the use of appropriate imaging techniques to diagnose posterior element–associated spine pain and discusses imaging findings associated with posterior element pain generators (Box 1).
ANATOMY OF THE POSTERIOR SPINAL COLUMN

The 3-column spine model was originally described by Denis in 1983 to explain injury and instability patterns, and remains useful today. It consists of anterior (anterior half of the vertebral body, intervertebral disc and annulus fibrosus, and anterior longitudinal ligament), middle (posterior half of the vertebral body, intervertebral disc and annulus fibrosus, and posterior longitudinal ligament), and posterior columns (pedicles, facet joints, laminae, spinous processes, ligamentum flavum, and interspinous ligaments). This article focuses on the elements of the posterior column.

The functional unit of the spine consists of the 2 adjacent vertebral bodies, the intervening intervertebral disc, and the bilateral paired facet joints. The superior articular process of the lumbar facet joint has a concave surface and faces dorsomedially to meet the inferior articular process of the level above. The inferior articular process has a convex surface and faces anterolaterally, typically resulting in a parasagittal oblique orientation to the lumbar facet joint articulation. The obliquity of the facet joints varies greatly from patient to patient, but is generally greatest at the L4-L5 and L5-S1 levels, accounting in part for greater susceptibility of these 2 levels to disc protrusions and degenerative spondylolisthesis. The superior and inferior articular processes are joined by the pars interarticularis (Fig. 1).

The paired facet joints at each level are true synovial joints lined by hyaline cartilage surfaces, surrounded by a synovial membrane and fibrous capsule. The cervical and lumbar facet joints are primarily innervated by medial branches of the primary dorsal rami that arise from the spinal nerve just peripheral to the dorsal root ganglion. These nerves carry both sensory and motor information. Each dorsal ramus supplies two adjacent facet joints, one at the level of its emergence from the spinal canal and the other one vertebral segment inferiorly. Therefore, each facet joint is supplied by branches from 2 adjacent spinal segments (Fig. 2). The medial branch also supplies the periosteum of the lamina and continues along the

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**Box 1**

**Posterior element pain generators**

- Facet joints
- Ligamentum flavum
- Pedicles and pars interarticularis
- Spinous processes and interspinous ligaments
- Transitional lumbosacral segments and pseudoarticulations
- Sacroiliac joints

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**Fig. 1.** Bony and ligamentous anatomy of the posterior spinal elements. (Courtesy of Mayo Clinic, Rochester, MN; with permission.)
inferior border of the spinous process to innervate the interspinous soft tissues; it also supplies motor innervation to the multifidus muscle. The posterior ligamentous complex consists of the paired ligamentum flavum, the interspinous ligaments, the supraspinous ligament, and the facet joint capsules. These ligaments normally provide stability. The paired ligamenta flava connect adjacent laminae at each level from C2 to the lumbosacral junction. The ligamenta flava are loosely attached to the facet joint capsule at their lateral margin and extend medially to the base of the spinous process in the midline, at which point they may be discontinuous. These ligaments are thin and broad in the cervical region and become thicker in the lumbar region. The interspinous ligaments connect adjacent spinous processes, extending from the ligamentum flavum anteriorly to the supraspinous ligament posteriorly. The supraspinous ligament merges with the ligamentum nuchae at its cranial end at C7, then extends inferiortly along the tips of the spinous processes, becoming progressively thicker, to the lumbosacral junction. The supraspinous ligament is fused with the posterior margin of the interspinous ligaments at each level. Alteration in biomechanics (excessive lordosis, loss of disc-space height, vertebral articulations) can result in ligamentous degeneration: calcification, ossification, bone proliferation at sites of attachment, granulomatous reaction, and perivascular cellular infiltration.

A retrodural and retroligamentous potential space providing communication between bilateral cervical facet joints at a single level was first described by Okada in 1981. Subsequent reports have described similar communication between facet joints and the interlaminar region, interspinous region, contralateral facet joints, and pars interarticularis defects in both the cervical and lumbar regions via a retrodural space lying posterior to the ligamentum flavum. This potential space can serve as a conduit of inflammatory reaction.

Fig. 2. Innervation of the posterior elements. The posterior elements are primarily innervated by the medial branches of the primary dorsal ramus. Each facet joint is innervated by branches from 2 adjacent spinal levels. (Courtesy of Mayo Clinic, Rochester, MN; with permission.)
and, rarely, infection, between posterior element structures usually considered distinct entities. The SI joints are large, C-shaped, true diarthrodial synovial joints demonstrating great variability in size and shape. The SI joints are lined by a synovial membrane surrounded by a fibrous articular capsule, and contain a small synovial fluid-filled space in their anterior and inferior portion. Anteriorly, the articular capsule is a well-defined fibrous capsule with thin ligamentous connections between the sacrum and ileum. Posteriorly there is an extensive network of ligamentous connections between the sacrum and ileum with ligamentous fusion to a less well-defined posterior joint capsule. Unlike most synovial joints, the SI joints are not lined by hyaline cartilage on both articulating surfaces. Only the sacral surface is lined with hyaline cartilage. The ileal surface is lined by a thin layer of fibrocartilage, which may account for greater susceptibility of the iliac side of the joint to degenerative change.\textsuperscript{10} Innervation of the SI joints has been a source of controversy; current consensus suggests the dominant innervation arises from the dorsal rami of L5 through S4.\textsuperscript{11,12} Transitional spinal segments can occur in as many as 30\% of patients, typically involving the last lumbar or first sacral segment.\textsuperscript{13} The transitional segment demonstrates anatomic features of both lumbar-type and sacral-type vertebral bodies with frequent asymmetry from left to right side, particularly in the configuration of the facet joints. Sacralization of the lowest lumbar segment can range from an enlarged transverse process articulating with the ileum to complete incorporation of the lowest segment into the sacrum. Lumbarization of the sacrum results in elevation of S\textsubscript{1} above the sacral fusion mass and assumption of a lumbar anatomic configuration. Lumbarization and sacralization, therefore, can have a very similar imaging appearance, and accurate counting of spinal segments from C\textsubscript{2} inferiorly is required to precisely define anatomy.\textsuperscript{7}

**PHYSIOLOGIC AND FUNCTIONAL IMAGING TECHNIQUES**

It is often difficult to identify the source of a patient’s LBP or neck pain because history and physical examination findings are nonspecific; degenerative or age-related changes in the spine are highly prevalent even in asymptomatic patients, and pain patterns may overlap secondary to rich anastomoses of pain-sensing neural structures.\textsuperscript{14} Both conventional CT and MR imaging techniques can demonstrate the structural and anatomic changes of spondylosis such as sclerosis, joint-space narrowing, and osteophytosis. However, these findings are common in both asymptomatic and symptomatic patients and often fail to correspond to the site of the patient’s pain. Physiologic imaging with fat-suppressed T2-weighted and/or CE T1-weighted MR imaging, radionuclide bone scanning, or FDG-PET/CT and functional imaging with weight bearing or axial loading may demonstrate findings more specific to the subset of degenerative age-related changes that are actually responsible for the patient’s pain (Box 2).

**Fat-Suppressed MR Imaging Techniques**

MR imaging and CT are very sensitive to morphologic degenerative changes that may cause LBP. However, these findings are very common, and marked degenerative changes may be identified even in asymptomatic patients. Inflammatory changes and hyperemia may be more specific findings for the source of a patient’s back pain, but these changes are difficult to detect on the standard T1-weighted and fast spin-echo (FSE) T2-weighted sequences most commonly used for spine imaging, because of the relatively increased signal intensity of both marrow fat and edema or enhancement on these sequences.\textsuperscript{15} Bone marrow edema and soft-tissue inflammation are much more conspicuous on fat-suppressed T2-weighted images; the hypervascularity associated with soft tissue inflammation can best be seen on fat-suppressed CE T1-weighted images. Fat-suppressed T2-weighted and CE T1-weighted sequences therefore enable the clear visualization of facet joint effusions, subchondral bone marrow edema, and paraspinal soft-tissue inflammation that may be overlooked with conventional non–fat-suppressed MR imaging techniques (Fig. 3).\textsuperscript{15–17}

To increase the conspicuity of edema and inflammation on MR imaging, several distinct

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<td>○ Short T1 inversion recovery (STIR)</td>
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<td>• Nuclear medicine bone scintigraphy</td>
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<td>• (^{18})F-fluorodeoxyglucose positron emission tomography combined with CT (FDG-PET/CT)</td>
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Fig. 3. Fat-suppression MR techniques. A 45-year-old woman presents with LBP worse with sitting. L5 pedicle edema (white arrow) and posterior L4-L5 facet synovial cyst (white arrowhead) are poorly visualized on standard fast spin-echo (FSE) T2-weighted sagittal sequence (A), and are much better demonstrated on fat-saturated FSE T2-weighted (B) and fat-saturated contrast-enhanced (CE) T1-weighted sagittal images (C). The fat-saturated CE T1-weighted sagittal sequence (C) best demonstrates facet edema and extensive periarticular soft tissue inflammation (black arrows).
Fat-suppression techniques can be used: the short T1 inversion recovery (STIR) sequence, \(^16,^{19}\) fat-saturated \(^20\) or water-excitation \(^21\) T2-weighted or CE T1-weighted sequences, or Dixon-based fat separation methods. \(^22,^{23}\) Each of these techniques relies on either the difference between fat and water in relaxation time (T1 or T2) or in the resonant frequency (chemical shift).

Fat has a very short T1 relaxation rate, and therefore has a high signal on most T1-weighted sequences as well as on FSE T2-weighted techniques. The difference in T1 relaxation between water and lipid can be used to selectively suppress or null the signal from short T1 tissues, such as fat, using the STIR sequence. A short inversion time is chosen close to the T1 value of fat, approximately 100 milliseconds, so that the signal intensity of fat is close to zero when the 90°/C14 inversion pulse is applied. \(^19\) STIR sequences with long spin-echo times resemble fat-saturated T2-weighted images. However, unless the inversion time chosen exactly matches the T1 of fat tissue, some fat signal will remain and the T1 signal from other non-fat-containing short T1 tissues may also be suppressed; this results in a lower signal-to-noise ratio with this technique than with other fat-suppression techniques. The advantages of STIR are that it is relatively insensitive to magnetic field inhomogeneity such as with the presence of implanted metallic hardware, and can also be used at lower scanner field strengths. \(^24\) However, because the T1 signal is suppressed, STIR cannot be used for CE imaging.

The chemical shift, or small difference in resonance frequency between fat and water related to differences in the local magnetic environment around their respective protons, allows for fat saturation or water excitation. \(^20,^{21}\) Both use a frequency-selective spectral pulse before the spin-echo pulse sequence to either saturate signal from fat or excite signal from water. These techniques are reliable in areas with large amounts of fat such as bone marrow or paraspinal soft tissue, do not affect signal from non-fat-containing tissues, and can be applied to either T1-weighted or FSE T2-weighted sequences. However, in the presence of local magnetic field inhomogeneities, such as with shorter bore scanners and in patients with implanted metallic hardware, incomplete or nonuniform fat saturation can result (\textbf{Fig. 4A}). The chemical shift decreases with the strength of the magnetic field, so fat saturation is also of lower quality at lower field strengths. \(^24\)

\textbf{Fig. 4.} Fat-suppression MR techniques. A 61-year-old woman, status post laminectomy and instrumented fusion, presents with LBP. Conventional fat-saturated CE T1-weighted sequence (\textit{A}) is limited by the presence of susceptibility artifact related to the presence of metallic hardware. Fat suppression is incomplete and inhomogeneous, and signal from intraspinal structures is lost. CE T1-weighted IDEAL sequence (\textit{B}) clearly demonstrates a peripherally enhancing synovial cyst above the L4 pedicle screw (\textit{white arrow}).
Dixon techniques were originally developed for fat and water separation by using information from both the phase and frequency of water and fat obtained from 2 separate acquisitions and then applying a subtraction technique. Three-point Dixon techniques use phase and frequency information from 3 acquisitions to estimate field inhomogeneity and to separate fat and water. The iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL) technique is a recently introduced 3-point Dixon technique that is less susceptible to artifact from implanted metallic hardware. This sequence can be used for both FSE T2-weighted and CE T1-weighted images (Fig. 4B).

**Nuclear Medicine Bone Scintigraphy and FDG-PET/CT**

Nuclear medicine bone scintigraphy with $^{99m}$Tc-methylene diphosphonate ($^{99m}$Tc-MDP) has long been used to identify occult destructive neoplastic and infectious processes in patients with LBP, but is increasingly recognized for its ability to also identify benign pathology associated with LBP. Nuclear medicine bone scintigraphy provides a whole-body anatomic survey while also allowing for evaluation of tissue function. Uptake of $^{99m}$Tc-MDP is primarily related to osteoblastic activity, but is also related to the degree of blood flow, so this radiotracer will accumulate in areas of hypervascul arity. Anatomic localization is imprecise with routine bone-scan technique secondary to poor spatial resolution. SPECT is a tomographic technique that increases sensitivity for spine pathology and improves spatial resolution, allowing more precise localization of abnormal uptake to specific posterior element structures in the spine. A recent study suggests that combining nuclear medicine SPECT with standard CT will further improve diagnostic accuracy and anatomic localization. Foci of increased radiotracer uptake may be seen in the posterior elements associated with facet arthropathy/synovitis, acute or subacute pars interarticularis defects/fractures, and Baasstrup phenomenon of the spinous processes. It can identify facet arthropathy with active findings related to inflammation and hypervascul arity, which therefore is more likely to benefit from treatment (Fig. 5).

FDG-PET combined with CT provides both metabolic and anatomic information. The improved specificity for benign versus malignant disease over that of nuclear medicine bone scintigraphy with MDP may be in part related to better localization with the CT component. Increased uptake associated with degenerative change in the spine was found in 22% of 150 patients in one study of whole-body FDG-PET/CT. This finding is likely secondary to the inflammatory component that accompanies these degenerative changes. Increased uptake is most severe in patients with milder changes on CT and decreases in intensity as the CT changes progress, suggesting that CT changes represent the end-stage result of the inflammatory process.

**Functional Imaging**

Many patients with LBP complain of pain only in the upright position or with standing and/or walking. With CT or MR imaging performed in a recumbent position, abnormalities are frequently absent or minimal in this patient population. Imaging such patients in the upright position, or with axial loading that mimics an upright position, is known to show increased abnormality of disc and posterior element. This basic sensitivity fault of spine imaging is discussed more fully in an article elsewhere in this issue by Nassr. Recently, 3-dimensional rotational myelography using flat-panel detectors has been described. Rotational time is increased compared with CT, which may introduce motion artifacts. However, this technique allows reconstruction in any plane and can also be performed with the patient in the upright position.

**FACET JOINTS**

Facet, or zygapophyseal, joints are true synovium-lined diarthrodial joints. Facet degeneration, or age-related changes, are common, beginning in the first 2 decades of life, with increasing prevalence with age, and becoming nearly universal in patients older than 60 years. There is no gender predilection. Clinical examination findings such as morning stiffness and mechanical pain exacerbated with bending, rotation, or extension, and relieved with gentle flexion, and pain with palpation over the suspected joint can suggest facet-mediated pain, but ultimately are nonspecific. Schwarzer and colleagues reported a 45% false-positive diagnostic rate for facetogenic pain when physical examination findings alone were correlated with diagnostic medial branch blocks.

Further complicating diagnosis is the fact that facet degeneration is often an asymptomatic finding at imaging. It could be argued that in a more select population of patients with LBP, structural evidence of facet degeneration might predict a painful joint.
Fig. 5. Nuclear medicine bone scintigraphy with SPECT for the same patient as in Fig. 3. Increased radionuclide uptake posteroanterior (PA) planar bone scan (A) in the lower lumbar spine on the right (arrow) more clearly localizes to the facet joint on axial (B), sagittal (C), and coronal (D) SPECT and corresponds to advanced osteoarthritis on axial (E), sagittal (F), and coronal (G) CT.
This aspect has been studied, and no consistent evidence has emerged to support such a relationship. Schwarzer and colleagues\(^{39}\) semiquantitatively scored the degree of facet degeneration on CT in patients with axial LBP; there was no correlation between the degree of degeneration and response to placebo-controlled intra-articular anesthetic blocks. In a more recent study, Cohen and colleagues\(^{40}\) showed no relationship between MR-imaging structural evidence of facet hypertrophy or degeneration and the response to radiofrequency facet denervation. In a systematic review, the investigators noted no credible evidence that structural imaging can predict a painful facet joint. Physiologic imaging parameters are discussed later.

It is well established that facet abnormality may account for 15% to 30% of mechanical axial LBP.\(^{37,38,40–42}\) Facet joint abnormality encompasses osteoarthrosis, joint effusions, ligamentous laxity, inflammatory facet synovitis, and synovial cysts. Facet-mediated pain can be radicular, and may result from mass effect and central or lateral recess stenosis related to hypertrophic degeneration and osteophytes, ligamentum flavum redundancy, or synovial cysts. Alternatively, an intrinsic inflammatory process of the facet, facet synovitis, can result in axial neck and back pain (Box 3).

**Osteoarthrosis**

Age-related disc changes may result in loss of disc height and load-bearing capacity, shifting a greater burden to the posterior column. The alteration in spatial relationships caused by the loss of disc height leads to malalignment of facet joints, increased biomechanical stress, and subsequent facet joint osteoarthrosis. Both disc degeneration and facet osteoarthrosis lead to increased stress on the posterior ligaments, with subsequent ligamentous laxity and buckling. Facet joint degeneration leads to further disc degeneration, facet osteoarthrosis, ligamentous buckling, and a continued positive feedback cycle.\(^2\) As a result the facet joints are rarely the only, and often not the primary, source of LBP.

Anatomic changes of facet osteoarthrosis include erosion of the articular cartilage associated with joint-space narrowing, periarticular hyperostosis with marginal osteophyte formation, subchondral eburnation/sclerosis, subchondral erosions and cysts, intra-articular bony fragments ("joint mice"), intra-articular gas (vacuum phenomenon), joint subluxation, and joint effusions (Fig. 6). Hypertrophy, redundancy, thickening or buckling, and calcification of the ligamentum flavum may also be seen.\(^{16,43}\) Facet osteoarthrosis alone, or in combination with buckling of the ligamentum flavum, can result in spinal stenosis (Fig. 7).

Osteophytes develop at the site of greatest stress on the joint, more frequently involving the superior facet of the lower vertebral body as the inferior facet is covered by the ligamentum flavum.\(^{43}\) This hypertrophy can result in spinal stenosis, narrowing of the lateral recess, or narrowing of neural foramina, with a resultant mass effect on adjacent spinal nerve roots and radicular symptoms (Fig. 8). Subluxation of the facet joint can also result in compression of the nerve root in the lateral recess between the superior facet of the vertebral body below and pars interarticularis of the vertebral body above.

**Synovial Cysts**

Synovial cysts form from degenerated facet joints when synovium herniates through the facet joint capsule, which may result from facet joint effusion and and/or associated capsular inflammation. These cysts may be true synovium-lined cysts or fibrous tissue-lined pseudocysts. Ninety percent of synovial cysts occur in the lumbar region with 65% to 80% occurring at L4-L5.\(^{44,45}\) Synovial cysts may narrow the neural foramen or central spinal canal and impinge on adjacent nerve roots. As a result, patients with synovial cysts most frequently present with radicular symptoms.\(^{45,46}\) When symptomatic, these are seen as a cyst in the lateral or posterolateral extradural space or neural foramen arising from the facet joint (Fig. 9). Synovial cysts are difficult to detect on CT because the fluid density in the cyst is similar to that of cerebrospinal fluid (CSF) in the adjacent thecal sac. The presence of hemorrhage in the cyst increases conspicuity on CT secondary to the increased density associated with the hemorrhage. If present, facet joint gas may communicate with the synovial cyst. On MR imaging, synovial cysts are also similar in signal to CSF, being hypointense on T1-weighted and hyperintense on

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**Box 3**

Facet joint–related back and limb pain

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<td>Axial pain: intrinsic pathology</td>
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Fig. 6. Facet joint osteoarthrosis. A 77-year-old man imaged for thoracic spine trauma. Axial (A) and sagittal (B) CT images demonstrate joint space narrowing, marginal osteophyte formation (arrows), subchondral sclerosis, and subchondral cysts (arrowheads).

Fig. 7. Facet joint osteoarthrosis and spinal stenosis. A 67-year-old man with low back pain and weakness in both legs exacerbated with walking. Sagittal (A) and axial (B) FSE T2-weighted MR images demonstrate multilevel loss of disc space height with resultant redundancy of the ligamentum flavum (arrows), causing severe spinal stenosis at each level.
Fig. 8. Superior articular facet osteophytes. A 47-year-old man imaged for right-sided radiculopathy. Sagittal CT (A) and sagittal FSE T2-weighted MR (B) images demonstrate osteophytes from the right superior articular facets at L5 and S1 (arrows) with impingement of the exiting L4 nerve root (arrowhead).

Fig. 9. Synovial cyst in the neural foramen. A 50-year-old woman presents with LBP radiating down the left leg to the foot. Axial FSE T2-weighted sequence (A) shows a cystic structure in the left L5 neural foramen (white arrow) compressing the exiting nerve root (black arrow). Sagittal STIR sequence (B) more clearly demonstrates that the cyst (white arrow) arises from a degenerated facet joint with associated synovial effusion, pedicle and periarticular soft-tissue edema.
T2-weighted imaging. Acute hemorrhage into a synovial cyst may result in rapid enlargement of the cyst with impingement of neural structures and acute radicular symptoms. In these cases, the cyst may then be isointense or hyperintense on T1-weighted imaging, and hypointense on T2-weighted imaging, with occasional identification of blood/fluid levels (Fig. 10). A low-intensity rim related to the fibrotic reaction and enhancement related to the associated inflammatory process may also be seen. With chronic inflammation, synovial cysts may calcify.

**Ligamentum Flavum Laxity**

The ligamentum flavum normally contributes to spinal stability. Alteration in biomechanics with excessive lumbar lordosis, loss of disc-space height, or facet osteoarthrosis can result in degeneration of the ligamentum flavum. Intrinsic degeneration of the ligamentum flavum may manifest as edema, inflammation, calcification, and/or bone proliferation at attachment points on anatomic imaging (Fig. 11).

As the disc space narrows or facet subluxation progresses, the ligamentum flavum becomes redundant, buckling anteriorly into the spinal canal and resulting in narrowing of the canal from a posterior vector. This spinal stenosis may result in symptoms of neurogenic intermittent claudication or radiculopathy. Symptoms may be exacerbated with weight bearing. In these cases, functional imaging with weight bearing or axial loading may demonstrate increased spinal stenosis (Fig. 12).

**Facet Synovitis**

Active facet inflammatory arthropathy or facet synovitis is a noninfectious inflammatory osteoarthropathy. Nociceptors in the facet joint capsule may be sensitized by inflammatory mediators. Patients with facet synovitis may present with morning stiffness, pain to palpation over the affected facet joints, and aggravation with rotation or extension; in these cases an inflammatory cause should be sought on imaging studies. Inflammatory changes are difficult to detect on standard T1 and FSE T2 sequences because of increased intensity of both marrow fat and edema/enhancement. Edema is much more conspicuous on fat-suppressed FSE T2-weighted or fat-suppressed CET1-weighted images. Imaging findings in facet synovitis include T2 hyperintensity

![Fig. 10. Hemorrhagic synovial cyst. A 56-year-old man presents with acute left leg and back pain. Axial T1-weighted (A) MR image demonstrates bilateral L4-L5 facet osteoarthrosis, but the synovial cyst is difficult to identify because it is isointense to cerebrospinal fluid. Axial T2-weighted MR image (B) clearly shows bilateral joint effusions and a well-defined synovial cyst (white arrow), with a fluid-blood level (arrowhead) arising from the left-sided joint and low-intensity fibrotic rim.](image-url)
Facet synovitis is an underrecognized cause of back pain and radicular symptoms.\textsuperscript{15,48}

Injection of local anesthetic into the facet joint is an imperfect gold standard for diagnosing facet joints as the source of axial LBP or neck pain; the false-positive rate for single intra-articular injections exceeds 30%.\textsuperscript{14} Medial branch blocks under fluoroscopic guidance using a dual-block paradigm are considered the best available means of diagnosis of cervical or lumbar facet–mediated pain. Once the diagnosis is established, radiofrequency denervation of the painful facet joint is the only effective therapeutic intervention validated by high-quality literature.\textsuperscript{49} The monetary costs, time, and risks associated with a multistep invasive diagnostic procedure (dual medial branch blocks) are not insignificant, and a noninvasive method to diagnose facetogenic pain would be preferred. To date, no controlled study of response to diagnostic injection of local anesthetic has been performed to confirm facet synovitis as the cause of axial pain in patients with MR imaging findings consistent with facet edema, inflammation, or hyperemia.

Several studies have suggested an association with inflammatory facet abnormality identified on nuclear medicine bone scintigraphy with SPECT.\textsuperscript{27,29,50} Furthermore, nuclear medicine bone scintigraphy has a high negative predictive value, 93% with planar imaging and 100% with SPECT, excluding facet joints with degenerative changes on anatomic imaging as the source of pain (Fig. 13B).\textsuperscript{29}

Dolan and associates\textsuperscript{27} studied 58 patients with LBP clinically thought to be facetogenic, that is, their pain was exacerbated with extension and sitting and was relieved with rest. Twenty-two patients had increased radionuclide uptake localized to a facet joint on SPECT imaging, and 36 did not demonstrate focal radionuclide uptake. All patients were treated with intra-articular facet injection, those with positive scans at the level of the imaging abnormality and those without at the level suggested by clinical examination. The SPECT-positive patients had significantly greater response to injection at 1 and 3 months. There was no difference between the two groups at 6 months. SPECT-positive patients had more anatomic findings of degenerative facet osteoarthritis than did SPECT-negative patients, but there was no correlation between the level of most severe morphologic degenerative osteoarthritis and SPECT-positive level. Furthermore, the level of tenderness to palpation did not correlate with the level of SPECT positivity. The investigators concluded that SPECT could identify the facet joints most likely to

or enhancement of the facet joint articular surfaces, joint capsule, and periarticular tissue on fat-suppressed images. Inflammatory soft-tissue changes are common and may appear aggressive, mimicking infection or neoplasm.\textsuperscript{16}

Facet synovitis is a relatively common finding on MR imaging when appropriate fat-suppression techniques are used. In a retrospective review of 209 lumbar MR imaging examinations performed in 1 month at the Mayo Clinic, 41% of all lumbar spine studies demonstrated changes of synovitis as hyperintensity on fat-suppressed T2-weighted or CE T1-weighted images.\textsuperscript{15} In this study, Czerwionke and Fenton\textsuperscript{15} proposed a grading system for facet synovitis using fat-suppressed MR imaging techniques (Box 4). In this same study, unilateral grade 3 or grade 4 imaging findings in a subset of 30 patients correlated with the side of pain in 100% (Fig. 13A).\textsuperscript{15} In a subset of 9 patients with facet edema identified on STIR imaging, Friedrich and colleagues\textsuperscript{48} found a correlation between increasing, stable or decreasing facet edema and a concurrent worsening, stability, or improvement in pain, respectively. Both groups concluded that facet synovitis is an underrecognized cause of back pain and radicular symptoms.\textsuperscript{15,48}

![Fig. 11. Ligamentum flavum degenerative inflammation. A 84-year-old man presents with axial LBP. Axial fat-suppressed CE T1-weighted sequence demonstrates enhancement of bilateral ligamentum flavum (white arrows). Note bilateral facet osteoarthritis and grade 2 facet synovitis.](image)
have short-term benefit from facet injection therapy.  

Facet joints with increased activity on SPECT are often not those with the greatest degree of degenerative change on anatomic imaging studies such as CT and conventional MR imaging. However, whereas SPECT imaging findings have been correlated with MR imaging, fat-suppressed MR imaging techniques have not been routinely used and inflammatory changes and edema have been likely overlooked.

Pneumaticos and colleagues prospectively studied 47 patients divided into 3 groups: SPECT-positive patients treated at the level of increased radionuclide uptake, SPECT-negative patients treated at levels ordered by the referring clinician, and patients that did not have SPECT imaging who received injections at levels requested by the ordering clinician. Improvement in the pain score was significantly higher in the patients treated at facet levels of positive SPECT radionuclide uptake than in either the SPECT-negative patients or those not evaluated with SPECT. Furthermore, it was found that SPECT imaging decreased the number of levels treated in the SPECT-positive patients from 60, as requested by the ordering clinician, to 27. The use of SPECT imaging to select patients for level of injection therapy resulted in Medicare Fig. 12. Ligamentum flavum redundancy on upright myelography. A 66-year-old man imaged for LBP and burning sensation extending down both legs, worse with standing or walking. Conventional lateral myelogram in the lateral plane with the patient in the prone position (A) and postmyelogram sagittal (B) and axial (C) CT with the patient in the supine position show minimal redundancy of the ligamentum flavum (black arrows) and spinal stenosis at the L4-L5 level. Three-dimensional rotational myelography with the patient in the upright position demonstrates a marked increase in ligamentous redundancy (white arrow) on the sagittal reconstruction (D), and complete effacement of the thecal sac on the axial reconstruction (E). (Courtesy of Kent Thielen, MD, Mayo Clinic, Rochester, MN; with permission.)
cost reduction from $2191 in the patients not imaged with SPECT to $1865 in the patients selected for injection based on positive SPECT imaging. The investigators concluded that “bone scintigraphy with SPECT can help identify patients with LBP who would benefit from facet joint injections.”

Case reports and small series have shown that the FDG-PET component of FDG-PET/CT examinations may also show foci of increased FDG uptake corresponding to facet osteoarthritis, most commonly in the lumbar spine. The degree of uptake correlates with the degree of inflammation and not necessarily with the severity of osteoarthritic change seen on the CT component (Fig. 14). As with SPECT, this seems to indicate that the inflammatory component represents an early phase of disease, with changes on CT representing the end result of the degenerative process. No reports of controlled response to injection or ablation therapy have been reported in FDG-PET/CT–positive patients.

**PEDICLES AND PARS INTERARTICULARIS**

Signal abnormality in the pedicles on T2 and STIR sequences are not uncommon, occurring in 1.7% to 5% of patients imaged for LBP. These changes are generally associated with either a fracture of the ipsilateral pars interarticularis or pedicle, or with ipsilateral facet degeneration, all potential pain generators in their own right.

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**Box 4**

**Grading facet synovitis**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Signal Abnormality/Enhancement Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>1</td>
<td>Confined to joint capsule</td>
</tr>
<tr>
<td>2</td>
<td>Periarticular &lt;50% of joint perimeter</td>
</tr>
<tr>
<td>3</td>
<td>Periarticular &gt;50% of joint perimeter</td>
</tr>
<tr>
<td>4</td>
<td>Extension to foramen, ligamentum flavum, pedicle, transverse process, or vertebral body</td>
</tr>
</tbody>
</table>


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**Fig. 13.** Facet synovitis, grade 4. A 74-year-old man with a history of prostate carcinoma and right lower lumbar mechanical pain. Axial fat-suppressed CE T1-weighted MR image (A) shows bilateral facet osteoarthritis, and grade 4 synovitis on the right at the L4-L5 level, with extensive periarticular inflammatory enhancement extending into the right neural foramen. Grade 3 synovitis is present on the left. Radionuclide bone scan (B) in the PA projection demonstrates increased radionuclide uptake at the level of the L4-L5 facet joints, greater on the right. (Courtesy of Timothy Maus, MD, Mayo Clinic, Rochester, MN; with permission.)
Fig. 14. FDG-PET/CT facet synovitis. A 68-year-old man with a history of small cell lung carcinoma presents with right neck pain. Axial FDG-PET/CT image (A) shows increased radiotracer uptake on the right at C4-C5. Sagittal CT (B) demonstrates facet osteoarthrosis with subchondral sclerosis and cysts. Fat-suppressed CE T1-weighted MR image (C) demonstrates facet synovitis with bone marrow edema and periarticular soft-tissue inflammation (white arrows).
these cases the increase in T2 signal is likely the manifestation of a stress reaction related to altered biomechanics. The intensity of the signal has been correlated with perceived patient pain and measures of function.\(^5\) In the case of associated pedicle or pars interarticularis fracture, the changes in signal intensity may precede identification of a frank fracture line. These patients may also demonstrate increased T2 signal in adjacent structures such as facet joints, ligamentum flavum, and perispinal soft tissues (Fig. 15).

Continued repetitive microtrauma can progress to spondylolysis, or frank fracture through the pars interarticularis. Spondylolysis and edema of the pars and/or pedicle on T2-weighted MR imaging may be clues to the presence of spondylolysis but are nonspecific, as these findings are more commonly seen in cases of concurrent facet degeneration.\(^5\) It can be difficult to detect the bony defect on MR imaging. CT may be necessary to clearly identify a fracture line in suspected cases. The bony defect may be bridged by fibrocartilage or a pseudarthrosis may occasionally develop.\(^6\) Alternatively, T2 hyperintensity may resolve. It has been suggested that edema/inflammation on imaging may represent an acute phase to altered biomechanics and that their resolution suggests a stabilization phase.\(^5\) SPECT imaging may be helpful in distinguishing chronic asymptomatic defects of the pars interarticularis from those that are the cause of the patient’s pain.\(^2\)

This topic is more fully discussed elsewhere in this issue in the article by Murthy.

**SPINOUS PROCESSES AND INTERSPINOUS LIGAMENTS**

Baastrup disease, also termed kissing spines or interspinal bursitis, was first described in 1933, and results from close approximation of spinous processes and interspinal soft tissues.\(^5\) This condition is thought to be more common in patients with lumbar hyperlordosis resulting in mechanical pressure between the apposing spinous processes,\(^5\) but may also result from narrowing of the intervertebral disc space with resultant narrowing of the interspinous space, contact between apposing spinous processes and ligamentous tears, or fluid-filled pseudobursae or neoarthroses.\(^1\) Baastrup disease is not uncommon in young gymnasts who perform repetitive hyperflexion and hyperextension maneuvers.\(^5\) Baastrup disease maintains a controversial role as a spinal pain generator.\(^5\) When symptomatic, Baastrup disease can result in midline lumbar pain that may be reproduced with palpation and exacerbated with extension. This pain may be relieved with flexion, interspinous injection of local anesthetic or, in severe cases, surgical excision of the affected spinous process(es).\(^6\)

Imaging findings include contact between adjacent spinous processes, so-called kissing spines, with neoarthrosis formation. Radiographic findings of apposition, sclerosis, flattening, and enlargement of spinous processes are common and increase with increasing age, with 81% of patients older than 80 years affected in one study (Fig. 16).\(^6\) There is no gender predilection. These findings are not specific and are often found in asymptomatic patients. Kwong and colleagues\(^6\) found radiographic changes they termed “Baastrup phenomenon” in 41% of patients undergoing abdominopelvic CT for conditions unrelated to LBP. Of note, most patients in their series demonstrated imaging changes at only a single level.\(^6\)

MR imaging, with its ability to depict physiology, may provide more specific identification of interspinous bursitis in symptomatic patients than CT. MR imaging may demonstrate edema and/or inflammation in adjacent spinous processes and in the interspinous or supraspinous ligaments, and frank fluid accumulation in an interspinous adventitial bursa or neoarthrosis on fat-suppressed FSE T2-weighted or CE T1-weighted images (Fig. 17).\(^6\) Histologically these imaging changes are the result of disruption of the ligamentous fiber bundle, cellular proliferation, hypervascul arity, and bursa or neoarthrosis formation.\(^6\)

Findings of lumbar interspinous inflammation are not infrequent in patients undergoing MR imaging of the lumbar spine, most commonly occurring at the L4-L5 level.\(^6\) Maes and colleagues\(^6\) found lumbar interspinous fluid in 8.2% of symptomatic patients with back or leg pain undergoing lumbar MR imaging. In contrast to findings on CT, in this series almost half (47.7%) of the patients studied had involvement at more than 1 level. However, the prevalence of interspinous bursitis may be even higher, as not all of the patients in this study were evaluated with fat-suppressed T2-weighted imaging, which is likely more sensitive to hyperintense edema and fluid. In addition, they also excluded patients who had CE imaging, which may be even more sensitive to the edema and hyperemia associated with this condition. Associated disc pathology, degenerative end-plate changes, facet arthrosis, and spondylolysis were common.

In a small number of patients the interspinal bursal fluid may dissect centrally in a fashion analogous to that of synovial cyst formation, with a resultant midline posterior epidural fluid collection/cyst. This process may contribute to central canal stenosis and neurogenic claudication.
Fig. 15. Pedicle edema. A 74-year-old man (same patient as in Fig. 13) with a history of prostate carcinoma and right lower lumbar mechanical pain. Sagittal FSE T2-weighted image (A) demonstrates bone marrow edema in the right L4 and L5 pedicles (white arrows) without frank fracture line; facet synovitis is not appreciated. Sagittal fat-suppressed FSE T2-weighted (B) and CE T1-weighted (C) images also clearly demonstrate pedicle marrow edema (white arrows), but also clearly depict facet synovitis and extensive periarticular soft tissue inflammation and enhancement (black arrowheads).
Fluid may track into the retroligamentous space of Okada, and from there communicate with one or both facet joints at the involved level or into associated pars defects. Baastrup disease with interspinous bursitis may demonstrate increased uptake on radionuclide bone scan or FDG-PET/CT scans. These imaging findings are likely related to edema and inflammation associated with interspinous ligament degenerative inflammation and/or neoarthrosis formation, and should not be misinterpreted as neoplastic or infectious involvement of the spinous processes. These techniques may allow identification of degenerative changes of the spinous processes and interspinous ligaments more likely to account for the patient’s pain.

**TRANSITIONAL SEGMENTS AND PSEUDOARTICULATIONS**

Transitional spinal segments can occur in as many as 30% of patients, typically involving the last lumbar or first sacral segment. The transitional segment demonstrates anatomic features of both lumbar-type and sacral-type vertebral bodies with frequent asymmetry from the left to the right side, particularly of the facet joints. Accurate counting of segments from C2 inferiorly is required to precisely define transitional anatomy, to prevent intervention at the wrong spinal level. Baastrup phenomenon, called Bertolotti syndrome, is controversial. The incidence of symptoms in patients with transitional segments is similar to the incidence of LBP in the general population. When symptoms occur, they may arise from neoarthrosis formation between the transitional segment and upper sacrum or iliac wing, from nerve root impingement by an enlarged transverse process, from the contralateral facet joint, or from early degeneration at the suprajacent lumbar segment. As each of these processes may be treated differently, it is important to both recognize the presence of a transitional lumbosacral segment and to identify the specific source of the patient’s pain.

![Image of Baastrup phenomenon](image.png)
In a small group of patients with unilateral transitional segments, the side of pain correlated with the side of the anomaly, and in most patients was relieved with injection of local anesthetic and/or resection of the anomalous articulation. This pain was thought to be secondary to increased biomechanical stress at the pseudoarticulation or neoarthrosis. MR imaging with fat-suppressed sequences may demonstrate T2 hyperintensity related to marrow edema or enhancement related to hypervascularity at the neoarthrosis. Increased uptake on nuclear medicine bone scintigraphy may also be seen at the articulation of the anomalous spinal segment with the sacrum or ileum, and is best identified using SPECT (see Fig. 19B). In cases of unilateral anomaly, the extraforaminal nerve root may be also impinged between the enlarged transverse process and sacral wing. This characteristic is best detected using a coronal MR imaging sequence.

Butterfly or hemivertebrae are rare spinal anomalies that are typically asymptomatic, incidental findings on imaging studies. Occasionally anomalous articulations associated with these anomalies may be symptomatic and likely related to altered biomechanics and stress reactions, edema, or inflammation manifested as increased signal on fat-suppressed T2-weighted or CE T1-weighted images, or increased uptake on bone scintigraphy with SPECT (Fig. 20).

**SACROILIAC JOINTS**

SI joint pain accounts for 13% to 18% of patients with axial LBP. Historical information and findings on physical examination, as with other posterior element pain generators, are unreliable in identifying the SI joints as the source of a patient’s axial LBP. Factors that may predispose patients to SI joint–related back pain are pregnancy in women, spinal fusion to the sacrum, and leg-length discrepancies. Patients with seronegative spondyloarthopathies also have a high prevalence of SI joint–related inflammatory changes and associated SI joint pain.

The iliac surface of the SI joint is lined by fibrocartilage. This cartilage may account for greater susceptibility of the iliac side of the joint to degenerative or age-related change, which is present in most individuals by the age of 40 years. The posterior-superior one-third of the joint is a ligamentous connection. Inflammatory and structural changes of the SI joints may result in LBP. Structural changes include those seen in joints elsewhere: sclerosis, juxta-articular erosions and cysts, osteophytes, and ankylosis.

Radiography, CT, and MR imaging can identify successive stages of SI joint involvement from subchondral bone marrow edema and inflammation with bone erosions, evolving to postinflammatory fatty infiltration, subchondral sclerosis, and finally osteophytes and ankylosis. CT is more sensitive than either MR imaging or radiography in detecting later chronic structural changes of erosions, sclerosis, and ankylosis (Fig. 21). However, MR imaging best demonstrates both the structural changes and the early inflammatory component.
Fig. 18. Interspinal bursitis and midline epidural cyst. A 59-year-old woman with a history of breast cancer presents with back pain radiating to left buttock exacerbated in the upright position. Sagittal FSE T2-weighted image (A) shows fluid in the interspinous space (arrowheads) tracking to a poorly visualized midline posterior epidural cyst (white arrows). Axial fat-suppressed FSE T2-weighted image (B) better demonstrates the midline posterior epidural cyst (arrow), concurrent bilateral facet synovitis (thick white arrow), and right facet joint effusion (small white arrows). Enhancement in the interspinous space (arrowheads) and at the periphery of the midline epidural cyst (arrow) is well seen on the sagittal fat-suppressed CE T1-weighted image (C).
associated with SI joint pain. MR imaging is significantly more sensitive to subchondral bone marrow edema and synovial, capsular, and ligamentous enhancement using STIR, fat-suppressed T2-weighted, and/or CE fat-suppressed T1-weighted imaging, and may identify changes in the SI joints even in patients with structurally normal radiographs.\textsuperscript{74-76}

One consideration when imaging the SI region with CT or MR imaging is the parasagittal orientation of the joint surface and narrow anteroposterior dimension of the joint space, which may cause volume-averaging artifacts on sagittal or oblique coronal imaging. Therefore, transaxial imaging should always be used to better assess the articular surfaces and joint space.\textsuperscript{77}

Makki and colleagues\textsuperscript{78} found increased uptake localized to the SI joints on nuclear medicine bone scintigraphy with SPECT in 5.7\% of patients with LBP. Most of these patients were eventually diagnosed with inflammatory spondyloarthropathy. These investigators suggest that SPECT may be able to diagnose this condition at an early phase, allowing for more prompt treatment. The imaging findings of inflammatory spondyloarthropathies are described in detail elsewhere in this issue by Amrami.

**IMPORTANCE OF CLINICAL CONTEXT**

In patients with LBP it is common to encounter multiple degenerative or age-related changes (often at multiple vertebral levels) on conventional anatomic imaging. In such cases, it is impossible to determine from imaging alone which, if any, of the structural changes are possibly responsible for causing the patient’s symptoms. The literature is quite clear that the vast majority of structural age-related changes identified on imaging bear no relationship to axial or radicular pain syndromes. In this context, to perform an appropriate imaging examination and to provide useful information to the referring clinician, the imager must understand the nature of the patient’s pain syndrome. Only
a clear concordance of the pain syndrome and imaging findings can suggest causality (Box 5).

The intervertebral disc is the single most common source of LBP in adults, but taken as a group posterior element structures may be responsible for nearly half of all axial LBP. DePalma and colleagues\(^42\) studied 358 patients with chronic LBP and found facetogenic pain in 31%, SI joint pain in 18%, and interspinous bursitis in 2%. In their study population, discogenic pain was more

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**Box 5**

**Importance of clinical context**

- Axial, nonradicular pain → seek out a posterior element cause
- Additional suggestive findings:
  - Morning back stiffness
  - Decreased range of motion
  - Mechanical pain with extension, flexion, or rotation maneuvers
  - Pain to palpation over facet joints and spinous processes
- Patient age
  - Young → more likely discogenic
  - Older → more likely posterior elements

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**Fig. 20.** Transitional lumbosacral segment. A 50-year-old woman with long history of scoliosis presents with increasing right back, buttock, and hip pain, worse with sitting and forward flexion. Coronal FSE T2-weighted sequences (A) at the level of the left L4 hemivertebra (thick white arrow) and (B) at the level of the pseudoarticulation between the right L3 and L5 vertebral bodies and enlarged transverse processes demonstrate subtle bone marrow edema around the anomalous articulation (thin white arrows). (Courtesy of Naveen Murthy, MD, Mayo Clinic, Rochester, MN; with permission.)

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**Fig. 21.** Sacroiliac joint osteoarthrosis. An 85-year-old man presents with chronic LBP and right leg pain. Axial CT shows subchondral sclerosis (black arrowheads), marginal osteophytes (white arrows), and interarticular gas (vacuum phenomenon) (black arrow). Note the subchondral sclerosis is more severe on the iliac side of the joint.
prevalent in younger patients and posterior element pain more common in older adults.

In patients with axial, nonradicular pain, the imager should seek out a posterior element cause. While morning back stiffness, decreased range of motion, and pain with extension, flexion, or rotation maneuvers and pain to palpation over facet joints and spinous processes are nonspecific findings, they may also suggest a posterior element source of pain. To best identify posterior element pain generators, the imager must look beyond meaningless structural changes to the physiologic clues of edema, hypervascularity, and inflammation, to identify a possible cause of pain. This course of action implies guiding the referring physicians in choosing appropriate imaging tests, and conducting those studies so as to maximize conspicuity of inflammatory imaging findings.

SUMMARY
Facet joints, pedicles, ligaments, spinous processes, transitional lumbosacral segments, and SI joints have all been implicated as sources of nonradicular axial back pain. Imagers should be aware of these causes and tailor imaging examinations to identify these sources of back pain. Posterior element causes of back and neck pain may remain underrecognized secondary to use of MR imaging techniques which fail to demonstrate the bone marrow edema, soft-tissue inflammation, and hypervascularity often associated with posterior element pain generators. Fat-suppressed FSE T2-weighted and/or fat-suppressed CE T1-weighted sequence should be performed in at least one imaging plane in all MR examinations of the lumbar spine. Radionuclide bone scanning with SPECT, SPECT/CT, and FDG-PET/CT are additional imaging techniques that add specificity to the diagnosis of posterior element pain generators.

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