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Diagnostic and therapeutic spinal interventions: Facet joint interventions

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Diagnostic and therapeutic spinal interventions

Facet joint interventions

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Summary

Axial spine pain is a common condition that is due to facet joint disease in some patients. Local anesthetic blocks of the medial branches of the dorsal rami of the spinal nerves that innervate facet joints are used to identify painful facet joints. Subsequent radiofrequency neurotomy of the medial branches serving symptomatic facet joints may provide prolonged albeit impermanent pain relief. The diagnostic blocks and radiofrequency treatments are better validated in the cervical than lumbar than thoracic spine. Neurologists should be aware that patients with axial spine pain who are referred to a pain clinic or pain management facility are likely to be considered for diagnostic and therapeutic interventions directed at facet joints and their sensory nerve supply.

Pain of spinal origin is common and can manifest as axial pain originating from the spinal articulations (facet joints or intervertebral disks) or radicular pain due to a compressed or irritated spinal nerve. Neurologists are frequently asked to diagnose and treat patients with such pain. With the development of advanced spinal imaging that can allow for precise needle placement, spine interventions for diagnostic or therapeutic purposes or both have become commonplace. This series of 3 articles addresses the most common minimally invasive spine interventions—medial branch blocks and radiofrequency (RF) facet neurotomy, selective spinal nerve blocks and epidural corticosteroid injections, and diskography. Medial branch blocks, selective spinal nerve blocks, and diskography are purely diagnostic procedures. RF neurotomy and



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Spine interventions have a higher risk when performed in the cervical or thoracic more than the lumbar spine.

epidural steroid injections have therapeutic intent. While some neurologists perform facet interventions and epidural injections, more often they refer patients to interventionalists (typically anesthesiologists, physiatrists, or radiologists) who work in specialized pain centers. This article covers indications for medial branch blocks and RF facet neurotomy, how the interventions are performed and interpreted, and risks and benefits.

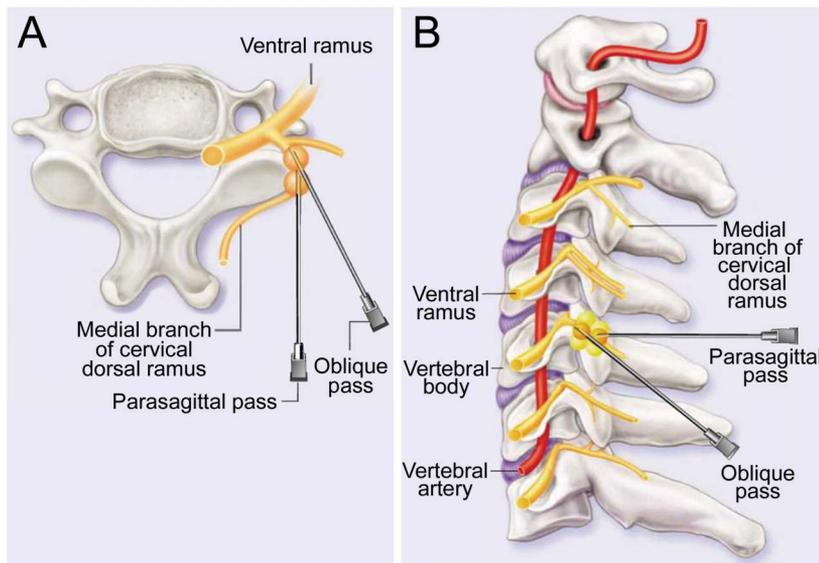
Indications, contraindications, and patient and segment selection for medial branch blocks and RF neurotomy

The facet or zygapophyseal joints are a considerable source of axial spine pain.^{1,2} Lumbar region facet-mediated pain is rare in young adults (about 15% of chronic back pain) but increases in prevalence up to age 70 and accounts overall for about 30% of patients with chronic low back pain.³ Cervical facet joints are responsible for 25%–65% of nontraumatic and 50%–60% of trauma-induced cases of chronic neck pain.⁴ The medial branches of the dorsal rami of the spinal nerves innervate the facet joints. Medial branch blocks are indicated in patients with chronic (>6 months) axial spine pain that is inadequately explained and poorly controlled. If diagnostic blocks of the nerves that supply specific facet joints relieve the patient's pain, RF lesioning of the same nerves can be offered to provide prolonged benefit. Contraindications to the performance of medial branch blocks or subsequent RF neurotomy include systemic infection, local infection at the procedure site, substantial bleeding diathesis, and pregnancy.

The facet joints targeted for medial branch blocks are chosen based on a combination of clinical and prevalence data. Physical and neurologic examination does not identify symptomatic facet joints. Structural findings of facet joint arthrosis on plain radiographs, CT, or MRI are not predictive of facet joint origin pain.⁵ MRI T2 hyperintensity or increased uptake on SPECT or SPECT/CT are purported to identify painful joints, but these findings have not been confirmed. Facet joint localization can be facilitated by comparing the patient's pain to facet joint pain referral maps.^{1,2,4} Prevalence data are also used.² Upper cervical pain with headache is most likely attributable to the C2-3 facet. Lower cervical pain is more likely to be C5-6 than C6-7 in origin. Lumbar pain is overwhelmingly due to the L4-5 or L5-S1 facet joints.

How the interventions are performed and interpreted

Medial branch blocks Each facet joint is innervated by 2 vertically adjacent spinal medial branches; the only exception is the C2-3 facet, innervated solely by the superficial medial branch of the C3 dorsal ramus known as the third occipital nerve.^{1,2} The medial branches can be targeted with image guidance because anatomic studies have shown consistent relationships between the medial branches and bony landmarks visible on fluoroscopy. Under fluoroscopic x-ray guidance, with sterile technique and without sedation, 25-gauge spinal needles are sequentially placed at the predicted position of medial branches of the dorsal rami of the spinal nerves, which innervate the targeted facet joints. Injection of a small amount of contrast material (0.3 mL) excludes vascular uptake. A small volume of local anesthetic (0.5 mL) is then instilled. Because of frequent false-positive responses, the diagnostic criterion best supported by the literature is that of dual, comparative medial branch blocks in which the targeted medial branches are blocked on separate occasions using local anesthetics with different durations of action (e.g., lidocaine and bupivacaine). For a positive medial branch block, the patient must have substantial (80%–100% pain relief for an appropriate duration with each anesthetic agent. Such a concordant response should provide a specificity of 88%.²

Figure The use of electrodes to coagulate a medial branch of a cervical dorsal ramus

(A) Cross-section through the C5 vertebra. An oblique pass is used to reach the nerve over the anterolateral aspect of the articular pillar. A parasagittal pass is used to reach the nerve over the lateral aspect of the pillar. With each pass, lesions are placed at, above, and below the cephalocaudal center of the pillar (B). From Lord SM, Barnsley L, Wallis BJ, et al. Percutaneous radiofrequency neurotomy for chronic cervical zygapophyseal joint pain. *N Engl J Med* 1996;335:1721-1726. Copyright © Massachusetts Medical Society. Reprinted with permission from Massachusetts Medical Society.

Many patients only receive a single local anesthetic injection directed at each suspect facet joint's medial branches. Because single injections have a false-positive rate of 27%–34%, the specificity of single blocks is much reduced.^{2,6}

RF neurotomy Properly performed dual comparative blocks can confirm or refute a diagnosis of facet-mediated pain. If the diagnosis of facet joint pain is confirmed, the medial branches innervating the implicated facet joints can be thermocoagulated using RF energy (RF neurotomy or rhizotomy). In this procedure, performed with minimal or no sedation, a RF electrode (16–22 gauge; larger electrodes produce larger thermal lesions) is directed under fluoroscopy via a posterolateral approach to the location of each targeted medial branch (figure). Meticulous electrode placement is essential to successful medial branch nerve lesioning. In the cervical spine, the medial branch is targeted as it passes over the lateral aspect of the articular pillar. In the lumbar region, the medial branch is targeted at the junction of the superior articular process and transverse process. The electrodes are heated to 80–85°C for 90 seconds. Because 1 facet joint is innervated by 2 medial branch nerves, RF neurotomy is appropriately performed at 2 levels on 1 side. The procedure may be performed on both sides for bilateral pain or more than 1 spinal level on the same side. Depending on the duration of benefit, RF neurotomy can be repeated. The authors stress the need to carefully select patients and identify symptomatic facet joints using dual comparative diagnostic medial branch blocks. There is no place for performing multisegment, bilateral procedures simply to “cover all possibilities.”^{1,2}

Intra-articular corticosteroid injections Separately, or coupled with a medial branch block, patients may receive intra-articular facet joint injections of a steroid in hopes of providing prolonged pain relief by an anti-inflammatory effect. There is, however, no high-quality literature support for therapeutic benefit from such injections.

Risks and benefits

Serious side effects are very rare and occur in a fraction of 1% of interventions. Patients undergoing RF neurotomy may experience local numbness, dysesthesias, or transient increase in

Outcomes are better, and the evidence is stronger, in the cervical spine than in the lumbar spine.

pain. Temporary neuritis may occur (2%).² Third occipital neurotomy patients often experience cutaneous numbness and mild ataxia due to this nerve's role in cervical proprioception.² Allergic reactions are extremely rare but can occur with local anesthetics, corticosteroids, or contrast media. If corticosteroids are injected, systemic side effects can occur. Pretreatment imaging and fluoroscopy during the procedure expose the patient to radiation. Complications common to any needle procedure can occur and include infection, dural puncture, spinal nerve or cord injury, and vascular injury. Spine interventions have a higher risk when performed in the cervical or thoracic more than the lumbar spine. The medial branches can regenerate with return of pain.

Benefits include discovery of the patient's pain mechanism, improvement in their chronic pain, improvement in physical functioning, return to work, and decreased use of other health care. In the cervical spine, RF neurotomy may be especially helpful for pain following whiplash-type injury.⁷ If obtained, pain relief may not be complete or permanent. Additional improvement often follows repeat intervention, but benefit may wane over time. In addition to the facet joints, the medial branches supply some paraspinal muscles (chiefly the multifidus), soft tissues, and at some spinal levels, paraspinal skin. As RF neurotomy is designed to interrupt sensory signals, not treat or modify a disease process, the ultimate pathologic cause of the patient's pain is not known or directly treated.

What is the evidence that medial branch interventions are beneficial? A Cochrane systematic review concluded that there is "limited evidence that RF denervation offers short-term relief for chronic neck pain of zygapophyseal joint origin and for chronic cervicobrachial pain" and "conflicting evidence on the short-term effect of RF lesioning on pain and disability in chronic low-back pain of zygapophyseal joint origin."⁸ Chou et al.⁹ in an evidence-based American Pain Society Clinical Practice Guideline found "insufficient evidence to adequately evaluate benefits of" therapeutic medial branch blocks and RF denervation for low back pain.

A challenge to such reviews is that they evaluate and include studies based on research methodology, not whether the procedures were performed with evidence-based patient selection and procedural technique. Studies performed without rigorous patient selection, or without procedural technique based on proven anatomic principles, will not achieve good outcomes and will obscure the benefit that can be achieved with proper technique. In contrast to these reviews, high-quality studies using meticulous technique report that the majority of patients experienced 80%–100% pain relief for months to a year or more following RF neurotomy for chronic neck pain.^{7,10,11} With optimal technique, 66% of cervical RF patients achieved complete pain relief, restoration of activities of daily living, return to work, and no need for other health care for neck pain for a median duration of 17–20 months.¹¹ Prolonged relief could be restored by repeat neurotomy.^{7,10,11} In a study of low back pain patients using dual comparative medial branch blocks and correct RF technique, 60% of patients achieved at least 90% pain relief at 1 year follow-up; 87% of patients obtained at least 60% pain relief after 1 year.¹² In another rigorous study of lumbar RF neurotomy, the majority of patients had complete relief of low back pain, restoration of function, return to work, and no other health care needed for back pain for a median duration of 15 months from the first procedure and 13 months for repeat treatment.¹³ Outcomes are better, and the evidence is stronger, in the cervical spine than in the lumbar spine. This in part reflects the lower prevalence of facet-mediated pain in the lumbar region and hence greater challenges in patient selection. There is

little evidence to support facet interventions in the thoracic spine. When appropriately evaluated, only a minority of patients with axial spine pain will be candidates for RF neurotomy.

The discrepancy between the less favorable results in metadata and guidelines analyses and the excellent results reported in series using optimal diagnostic and RF technique implies considerable provider variability. Skilled interventionalists who select patients using established criteria will have much better outcomes than less skilled providers who are willing to use these procedures on anyone with neck or low back pain. With proper technique, these interventions are beneficial. However, the paucity of data regarding provider skill levels and outcomes makes it difficult to select interventionalists for referral.

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Diagnostic and therapeutic spinal interventions: Epidural injections

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Diagnostic and therapeutic spinal interventions

Epidural injections

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Summary

Epidural injections of local anesthetic or a corticosteroid are frequently given to diagnose and treat patients with radicular pain originating from any spinal level. The best-quality evidence supports a transforaminal approach in the lumbar spine. Many patients experience substantial benefit from a single therapeutic injection. Depending upon the benefit obtained, additional injections may be administered. Selective nerve blocks with local anesthetic alone can identify the spinal nerve mediating the patient's pain. Serious short-term risks are rare but occur; long-term risks are infrequent and can be due to systemic effects of multiple corticosteroid injections. Patients who have failed conservative therapy or are not candidates for surgical intervention can be considered for epidural steroid injections to relieve their radicular pain temporarily.

Radicular pain, with or without radiculopathy, is a common clinical condition most frequently due to disk herniation or fixed lateral recess or foraminal stenosis. In the lumbar region, lifetime prevalence estimates range from 12% to 43% with annual prevalence estimates of 2%–34%.¹ Cervical radicular pain is less common, and more likely due to fixed stenosis than disk herniation.² Clinical and experimental studies of the pathophysiology of radicular pain suggest that both mechanical compression and an inflammatory response are needed for pain production.³ The inflammatory process supports the targeted injection of corticosteroids as a therapy for radicular pain. Local anesthetics alone may be used diagnostically to identify the spinal nerve mediating the patient's pain.



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Epidural steroid injections as a therapeutic procedure are much better supported in the lumbar spine than in the cervical or thoracic spine.

Corticosteroids can be delivered to the dorsal epidural space using an interlaminar approach, or via the sacral hiatus with a caudal approach. However, these midline techniques place the injected drug some distance from the site of inflammation. The transforaminal approach delivers the corticosteroid directly to a symptomatic spinal nerve in the intervertebral foramen where pharmaceuticals are much more likely to reach the site of inflammation in the ventral epidural space. While some neurologists perform epidural injections, more often they are done by interventionalists (usually anesthesiologists, physiatrists, or radiologists) who work in specialized pain center or hospital settings. This article covers 1) indications for epidural injections, 2) how epidural injections are performed and interpreted, and 3) risks and benefits.

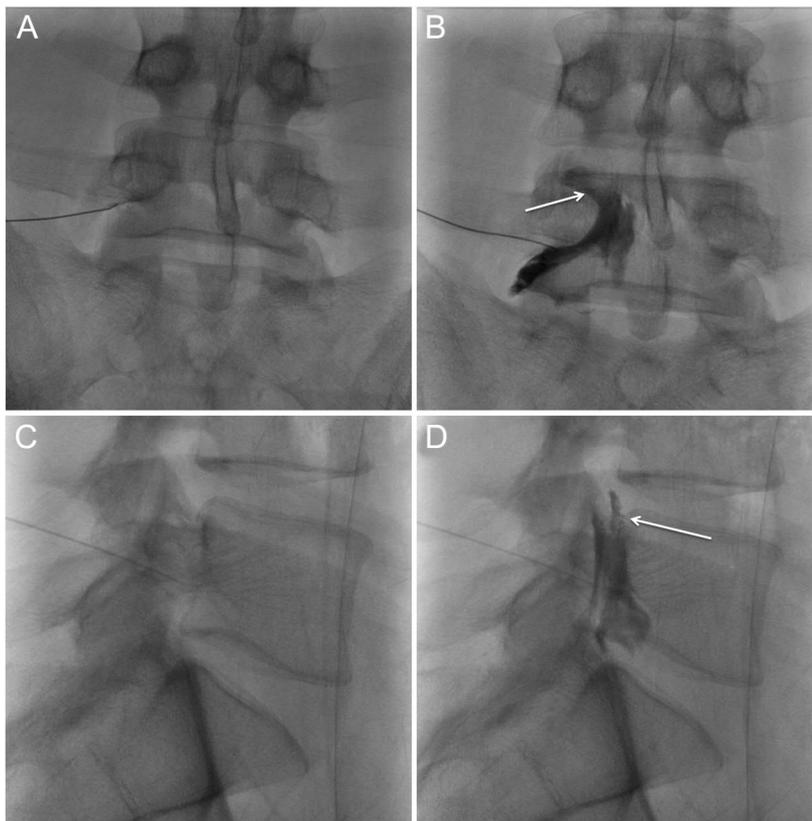
Indications and contraindications for epidural injections

These injections are indicated for the diagnosis and especially treatment of significant radicular pain with or without radiculopathy in patients who have failed a trial of conservative therapy.^{4,5} Epidural steroid injections as a therapeutic procedure are much better supported in the lumbar spine than in the cervical or thoracic spine. Although epidural injections are sometimes given to patients with axial spine pain and neurogenic claudication, there is no high-quality evidence supporting their use in these conditions. The spinal nerve to be targeted is selected based on a synthesis of imaging, clinical, and neurophysiologic findings. Advanced spinal imaging with MRI, plain CT, or CT myelography is considered a prerequisite for epidural injections by most interventionalists. Preprocedure imaging allows the injection route to be planned to optimize medication delivery to the epidural space and minimize risk to neural or vascular structures.⁶ Such imaging also excludes underlying tumor and infection. Local anesthetics alone are injected for diagnostic purposes; this is properly termed a selective spinal nerve block. The response to a selective spinal nerve block can aid in diagnosis and localization. Injections of a corticosteroid with or without a local anesthetic are given for therapeutic purposes. Contraindications include systemic or local infection at the injection site, allergies to the medications used, pregnancy, or significant coagulopathy. Anticoagulant use is currently being reevaluated; the risk of hemorrhagic complications must be weighted against the real risk of systemic thrombotic complications from withholding anticoagulants. Aspirin and nonsteroidal anti-inflammatories are not contraindications.⁷ Anticoagulants (warfarin, antiplatelet, and antithrombin agents) should be stopped for interlaminar injections; the issue is less clear for transforaminal injections and the reader is referred to published guidelines for specific recommendations.^{5,7}

How epidural injections are performed and interpreted

Interlaminar epidural steroid injections can be given in the lower cervical, thoracic, and lumbar spine; caudal epidural injections are administered via the sacral hiatus.^{4,5} There is less evidence of benefit from lumbar interlaminar and caudal epidural steroid injections, and they are being supplanted by transforaminal injections. Lumbar interlaminar and caudal injections may be used if the transforaminal route is not feasible (due to postoperative changes or anatomic limitations) or with multilevel, bilateral radicular symptoms and findings. Interlaminar injections are appropriate in the low cervical region, as the literature support for cervical transforaminal injections is much less robust than for lumbar transforaminal injections. Interlaminar procedures are performed on prone patients, without sedation, and with fluoroscopic guidance, using 18- to 22-gauge needles. The dorsal epidural space is entered by a loss of resistance technique, but exclusion of vascular or intrathecal flow via contrast injection

Figure Left L5 radicular pain due to an L4-5 disk extrusion with caudal migration into the lateral recess in a 32-year-old man



Left L5 transforaminal epidural steroid injection; final needle position (A, C) is immediately superior and lateral to the exiting L5 nerve. Contrast injection (B, D) confirms that medication will reach the interface of the disk and L5 nerve in the lateral recess (arrows).

is mandatory. Typically only corticosteroids are administered with interlaminar and caudal injections, which are not target-specific and have no immediate diagnostic value.

A transforaminal procedure is performed without sedation and with the patient supine or on his or her side (cervical) or prone (thoracic and lumbar). Under fluoroscopic guidance, a 22- to 25-gauge needle is advanced into the targeted epidural space. Contrast medium is injected to make certain that the injection is not intrathecal or intravascular, and to ensure that the injectate spreads appropriately along the targeted neural sleeve (figure). If the injection of contrast medium is intrathecal or intra-arterial, the procedure should be terminated and postponed until the dura or artery has healed. In transforaminal epidural steroid injections, patients are usually given both local anesthetic and a corticosteroid, administered sequentially. The patient's vital signs, neurologic status, and pain level are monitored. The patient may obtain immediate benefit if a local anesthetic was administered, or it may take several days for the injected corticosteroid to provide pain relief. Due to potential spread of the agents to adjacent spinal nerves, transforaminal epidural injections have limited diagnostic utility. Improvement 2 weeks after the injection when the corticosteroid anti-inflammatory effect is engaged predicts long-term benefit.

There is a historical practice of providing a series of epidural injections (e.g., weekly for 3 weeks), but this is unsupported by the literature and has no place in current practice.⁵ A decision to repeat an injection should be based on the response to previous injections. If benefit was substantial (e.g., >50% pain reduction) but incomplete, or has waned after a considerable period of relief (e.g., >1 month), then it is reasonable to perform additional

Benefits of epidural steroid injections include pain relief, functional recovery, avoidance of surgical intervention, and identification of the patient's pain generator.

injections in hopes of obtaining greater benefit, or recovery of prior benefit. Most patients do not require repeated injections. In a systematic literature review of lumbar transforaminal injections, 94% of patients achieving 50% or greater reduction in pain did so with a single injection.⁸ Although there is insufficient evidence to identify an absolute maximum number of injections in a year, a consensus statement by the North American Spine Society (NASS) suggests that a potential need for more than 4 injections in 1 year should prompt consideration of alternative treatment, including possible surgical intervention.⁹

Risks and benefits

Very rare catastrophic spinal cord and vertebralbasilar infarction can occur with transforaminal epidural injections, presumably due to injection into or damage to an artery supplying the spinal cord in the thoracolumbar region (artery of Adamkiewicz or another large radiculo-medullary artery) or the vertebral artery in the cervical spine.^{4,5} The risk of catastrophic spinal cord and vertebralbasilar infarction may be mitigated by meticulous technique including contrast injection, minimal or no patient sedation, use of a test dose of local anesthetic, and use of a nonparticulate steroid (e.g., dexamethasone). Interlaminar epidural injections risk injury to the cervical or thoracic spinal cord by direct needle trauma or epidural hematoma formation. Risks of all epidural injections are greater in the cervical spine. There are also risks inherent in any spine-related interventional procedure that include allergy to medications, radiation exposure, dural puncture, needle injury to neural or vascular structures, and infection (e.g., epidural abscess and recently reported iatrogenic fungal meningitis and spinal and paraspinal infections).^{4,5,10} Multiple corticosteroid injections can cause systemic side effects including suppression of the hypothalamic-pituitary-adrenal axis and worsening of osteoporosis.

Benefits of epidural steroid injections include pain relief, functional recovery, avoidance of surgical intervention, and identification of the patient's pain generator. There is more evidence of temporary symptomatic benefit than avoidance of surgery. While there is support for their use in the cervical spine,^{11,12} there is much stronger evidence of benefit in the lumbar spine.^{5,8,9} Epidural injections in the thoracic spine are poorly studied. In 2007, the American Academy of Neurology Therapeutics and Technology Assessment Subcommittee concluded that "epidural steroid injections may result in some improvement in radicular lumbosacral pain when assessed between 2 and 6 weeks following the injection, compared to control treatments (Level C, Class I–III evidence). The average magnitude of effect is small and ... in general ... does not impact average impairment of function, need for surgery, or provide long-term pain relief beyond 3 months."¹³ A 2009 review found "fair evidence that epidural steroid injection is moderately effective for short-term (but not long-term) symptom relief" for sciatica.¹⁴

Recent reviews provide stronger support for major benefit from lumbar transforaminal epidural steroid injections.^{8,9} The systematic analysis by MacVicar et al.⁸ suggests that for radicular pain from lumbar disk herniations, "60% of patients seem to achieve at least 50% relief of pain at between 1 and 2 months, but only about 40% maintain this outcome for 12 months." The NASS position statement reports that >50% of patients experience pain relief for >1 month, with half still benefitting after 1 year.⁹ A recent comparative effectiveness study in disk herniations demonstrated that 70% of patients achieved 50% pain relief and

50% functional restoration 6 months after lumbar transforaminal injections.¹⁵ In disk herniation patients, temporary pain relief from the anti-inflammatory effect of the injected corticosteroid may last until the disk herniation and its associated pain have improved or resolved. There is evidence that patients with more recent onset of pain,¹⁶ with lesser degrees of neural compression,¹⁷ and with optimal delivery of corticosteroid to the ventral epidural space¹⁸ have better outcomes. The pain relief provided by epidural injections should enable some patients to avoid discectomy. A surgical sparing effect has been demonstrated with lumbar transforaminal injections in some studies,¹⁹ but not in others; this issue is unresolved. For radicular pain with lumbar spinal stenosis, uncontrolled studies report benefit, but NASS states that there is insufficient evidence to make a recommendation regarding the use of epidural injections in this setting.⁹

Epidural steroid injections are popular and will continue to be recommended by providers to patients for relief of radicular pain. They should be used judiciously and in the context of proper indications.

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Diagnostic and therapeutic spinal interventions: Epidural injections

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Diagnostic and therapeutic spinal interventions: Diskography

Timothy P. Maus and J.D. Bartleson

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Diagnostic and therapeutic spinal interventions

Diskography

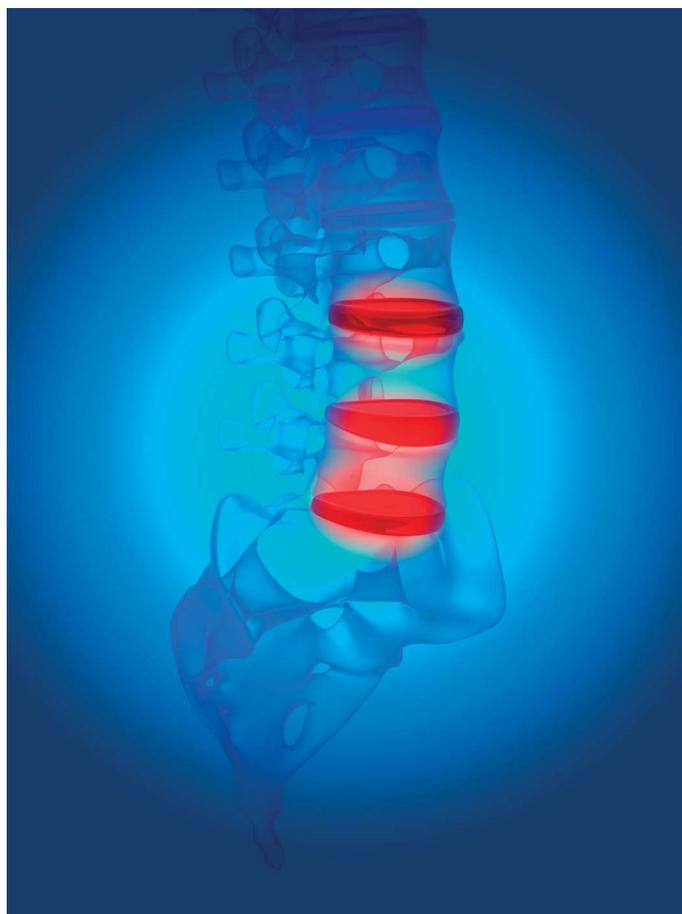
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Summary

Diskography (provocation diskography, disk stimulation) is an invasive diagnostic test performed to confirm or exclude internal disk disruption as the cause of axial spine pain. Diskography involves injecting fluid into the nucleus of the disk under manometric control; a positive response is reproduction of typical pain. Extensive but indirect literature validates diskography in the lumbar spine; it is less well-supported in the cervical or thoracic spine. Risks include rare instances of infection and neural injury; lumbar diskography may be associated with accelerated disk degeneration. Diskography has utility in establishing a diagnosis of diskogenic pain. When negative, it prevents inappropriate interventions directed at the disk; when positive, it prevents interventions directed at other axial pain generators. Its role in selecting patients for therapies directed at diskogenic pain is limited by the lack of available validated treatments.

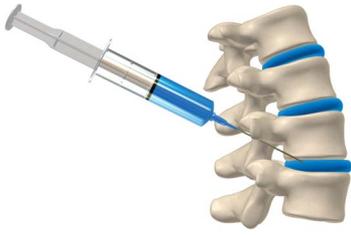
Axial spine pain is common; low back pain is estimated to affect 66%–80% and neck pain 67% of people during their life.^{1,2} The most common cause of chronic low back pain is internal disk disruption (IDD) or diskogenic pain. Distinct from radicular pain or radiculopathy, this describes pain originating from the disk itself. It accounts for approximately 40% of chronic low back pain; the differential diagnosis also includes facet joint pain (~30%), sacroiliac joint pain (~20%), pain from vertebral insufficiency fractures (~3%–5%), and myofascial pain.³ Diskogenic pain is more prevalent in young adults and declines with age while pain of facet and sacroiliac origin increases with age.³



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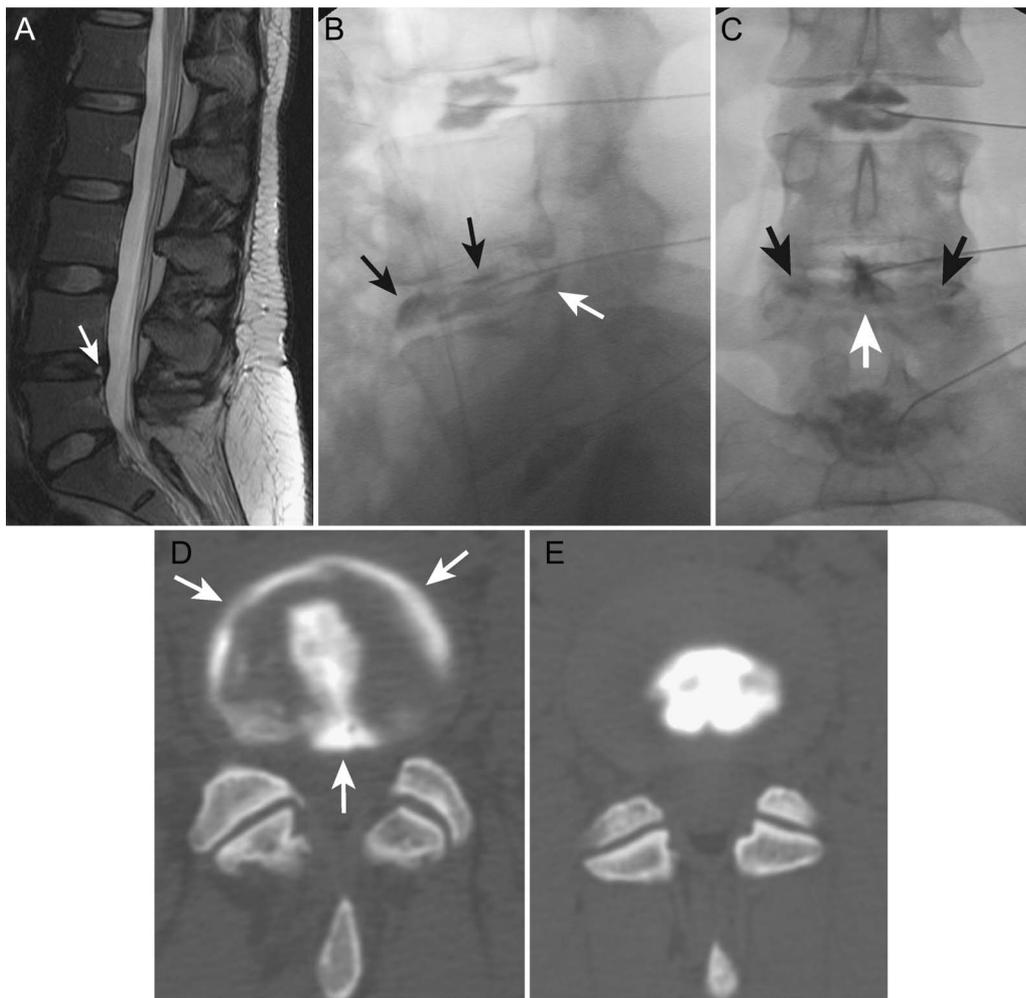
While diskography may be performed in any spine segment, supporting evidence is far stronger in the lumbar spine than in the cervical or thoracic levels.

The pathophysiology of diskogenic pain is complex, and supported by a synthesis of biomechanical, histologic, and physiologic studies.⁴ The process in the lumbar disk can be summarized as follows: degradation of the nuclear matrix of the disk, likely precipitated by endplate fractures, reduces the nucleus pulposus' ability to bear axial load. Load bearing is transferred to the posterior annulus. The posterior annulus may undergo structural failure, resulting in radially directed fissures extending from the nucleus to the outer annulus. This creates the anatomic substrate for diskogenic pain. The native nociceptive innervation of the disk is confined to the outer annulus; reparative granulation tissue in annular fissures results in neovascularization and ingrowth of additional nociceptive afferents that may extend deep into the disk. The native and acquired innervation is subject to mechanical stimulation by the increased load on the posterior annulus; inflammatory cytokines from nuclear degradation are present within radial fissures and may provoke chemical stimulation of nociceptors. By these mechanisms, a disk may become painful. The purpose of diskography (also termed provocation diskography or disk stimulation) is to make the diagnosis of IDD or diskogenic pain. Diskography is most commonly performed by interventional pain specialists, typically anesthesiologists, physiatrists, or radiologists. Neurologists will encounter patients with chronic axial pain, and should be familiar with the indications, contraindications, procedure, validity, utility, and risks of diskography.

Indications, contraindications, imaging, and performance

In general, diskography is only performed in patients with significant, persistent axial spine pain of at least 6 months' duration that is undiagnosed despite noninvasive testing and unresponsive to conservative therapy.^{5,6} Contraindications include any local or systemic infection, inability to assess patient response during the procedure, allergy to pharmaceutical agents used, bleeding diathesis/anticoagulation, and pregnancy. MRI, CT myelography, or plain CT of the affected spine segment is a prerequisite, primarily to exclude rare sinister causes of axial pain (e.g., tumor, infection, fracture, spondyloarthropathy). Imaging alone has major limitations in the diagnosis of diskogenic pain. Typical "degenerative" changes such as loss of disk space height, osteophyte formation, nuclear T2 signal loss on MRI, and disk herniations are usually simply age-related changes, and have no association with pain.⁷ Studies correlating MRI findings to diskography have, however, identified 2 useful findings: 1) T2 hyperintensity in the posterior disk annulus, the high intensity zone, as a marker of an inflammatory fissure; and 2) inflammatory endplate change of either type 1 or type 2, as a marker of endplate infraction or fracture. These MRI findings provide approximately 70% confidence that that disk will be positive on diskography.⁴ While diskography may be performed in any spine segment, supporting evidence is far stronger in the lumbar spine than in the cervical or thoracic levels.

Diskography is performed under fluoroscopic guidance, with minimal anxiolytic sedation, as the patient's pain responses are critical to the interpretation. Small-caliber (25-gauge) needles are placed into the target disk and 1 or 2 adjacent control disks from a posterolateral vector in the prone lumbar or thoracic pain patient or an anterolateral vector in a supine cervical patient. Under manometric control, contrast material is slowly instilled into the nuclear compartment of each disk while the patient's pain response is monitored. Injection into lumbar disks is continued until pressure reaches at least 50 psi, there is pain production, injected volume reaches 3 mL, or contrast extravasation from the disk is observed. Cervical

Figure Diskography

(A) Sagittal T2-weighted MRI shows desiccation (decreased T2 signal) in L4 disk and an annular fissure associated with bulging disk at L4-5 (arrow). (B) Lateral and (C) anteroposterior views of a 3-level diskogram. The L3 and L5 levels are normal, but at L4 there is a posterior radial fissure with a small disk protrusion (white arrow) and a greater than 180-degree circumferential fissure anteriorly, which tracks the annular laminae (black arrows). (D) Axial CT image after instillation of contrast material into the abnormal L4 intervertebral disk and (E) the normal L3 disk. The arrows in (D) show contrast material in the superficial layers of the annulus fibrosus well beyond the bounds of the nucleus pulposus, while the contrast in (E) is confined to the nucleus pulposus. From Bartleson JD, Deen HG. *Spine Disorders: Medical and Surgical Management*, 2009. Copyrighted by and used with permission of Mayo Foundation for Medical Education and Research.

and thoracic disks accept much lower volumes (0.5 mL) and injection is terminated with pain production, extravasation, or resistance to further injection. Local anesthetics may be injected into the disk after pain provocation to avoid confounding the results of testing additional disks or to alleviate provoked pain. However, diskography is not a therapeutic intervention. There is as yet no clearly defined role for purely analgesic diskography. The patient's response to the injection is monitored and documented. The patient is asked to compare any provoked pain with their typical spine pain in terms of its intensity, location, and character. In lumbar diskography, CT is performed after the procedure to better define the presence and grading of annular fissures (figure). Cervical and thoracic disks are structurally unique from lumbar disks and postdiskography imaging has no role in diagnosis. Provocation of the patient's characteristic spine pain is the key outcome measure and the lumbar target disk is positive if the pain is significant ($\geq 6/10$), concordant with the patient's baseline pain, caused by no more than moderate pressure (≤ 50 psi), not brought on by stimulation of at least 1 adjacent

Cervical and thoracic disks are structurally unique from lumbar disks and postdiskography imaging has no role in diagnosis.

control disk, and occurs in the presence of high-grade fissures on postdiskography CT.⁵ In the cervical or thoracic regions, the diagnosis is dependent on production of concordant pain.⁵

Validity and utility of diskography

Validation of any test for the diagnosis of diskogenic pain is hampered by the lack of a pathoanatomic reference standard; there is no histologic marker of a painful disk. Conventional sensitivity and specificity cannot be assessed. There is, however, a substantial body of evidence supporting the assertion that diskography can identify a painful disk, and that the false-positive rate for lumbar diskography, as assessed by studies of asymptomatic volunteers, is low.⁴ This has been challenged in several studies,^{8,9} but a systematic review of the original data for all studies of diskography in asymptomatic volunteers, with the meticulous application of manometric, patient response, and imaging criteria, found that the false-positive rate for diskography did not exceed 10%, and may be as low as 6%.¹⁰ Interpretation of diskography responses may be more challenging in patients with multiple positive disks and in the presence of somatization disorders.

Diskography can identify a painful disk, but what is its utility in clinical practice? Diskography might be used to identify patients who would benefit from a proven treatment, but there is no consensus on an appropriate interventional therapy. Surgical fusion as a treatment for diskogenic pain remains highly controversial. A recent meta-analysis of the randomized controlled trials of surgical arthrodesis vs conservative care did not show a significant difference in functional recovery in surgical vs conservative care patients.¹¹ Only one study has provided modest evidence that diskography improves surgical outcomes through better patient selection.¹² In the cervical spine, only observational trials are available, the evidence is more tenuous, and the role of diskography is less certain. Diskography is often utilized to define the extent of a proposed fusion, or qualify patients for disk arthroplasty, but there is no high-quality evidence to support these uses. A host of destructive techniques (lasers, conductive heating, plasma field or radiofrequency lesioning, ozone or methylene blue instillation) have been applied to diskogenic pain patients, with generally disappointing results. Regenerative disk therapies are on the horizon, but are not yet validated.

The lack of a proven therapy does not discount the value of reaching a diagnosis; neurologists pursue the diagnosis of amyotrophic lateral sclerosis or multiple sclerosis despite limited therapeutic options. A diagnosis via diskography will allow diskogenic pain patients to participate in trials of emerging treatments. There is also utility in that a diagnosis provides closure, identifying the patient as having a medical condition, and protecting the patient from being labeled as malingering or having a psychological disorder. Negative diskography protects the patient from inappropriate therapies directed at diskogenic pain. Positive diskography, by establishing a diagnosis, protects the patient from futile, invasive, and expensive diagnostic and therapeutic endeavors directed to other causes of axial spine pain.

Risks

The primary risk of disk stimulation is bacterial diskitis, which is very low. In a systematic review, the prevalence of diskitis without prophylactic antibiotics was 0.24%; the prevalence of diskitis with antibiotics was stated to be 0%, but with confidence intervals (CI) of 0%–2.9%.¹³ Antibiotic prophylaxis is typically delivered into the disk, mixed with the contrast media. Meticulous aseptic technique is mandatory. Infection risks are higher in the cervical spine. There are very rare risks of spinal nerve or spinal cord injury, dural puncture, pneumothorax

in the thoracic spine, or vascular injury in the cervical spine. Recent evidence based on MRI 7–10 years postdiskography has raised concern that diskography may accelerate degenerative changes and increase the incidence of disk herniation.¹⁴ Disks undergoing diskography had a greater proportion with progression of degenerative change (35%) vs controls (14%), although the CI overlap.^{14,4} There were also more new disk herniations in injected disks than in control disks. Although the CI for disk herniations also overlap in the small samples, the twofold to fivefold increase in foraminal disk herniations and extrusions over controls raises concern. Larger studies are needed to better define this apparent risk. Diskography should always be applied selectively and thoughtfully as a means of establishing the diagnosis of internal disk disruption or diskogenic pain.

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