Chapter 12
Interventional Procedures

Daniel A. Fung and Timothy T. Davis

Key Points

- Interventional procedures should be considered after conservative treatments (medications, therapy, activity modification) have failed and before surgical intervention.
- Physicians should be familiar with all medicare guidelines which have outlined specific criteria that must be accurately documented prior to proceeding with any interventional procedure.
- Trigger point injections are considered medically necessary when there is a regional muscular pain complaint with a palpable taut band in an accessible muscle and all conservative treatments have failed and been documented.
- Targeted medial branch blocks or intra-articular injections of the zygapophyseal joints (facet joints, z-joints) with local anesthetic are indicated when a diagnosis of cervical, thoracic, or lumbar spondylosis is established and correlated with regional pain in the respective area.
- Epidural injections are indicated in the cases of radicular pain that has failed all conservative treatments.
- SI joint injections will be considered medically necessary when an injection is given with imaging confirmation for diagnostic or therapeutic purposes after conservative management has failed.
- Discography is considered medically necessary for evaluation of disc pathology in persons with persistent, severe low back pain and abnormal interspaces on MRI, where other diagnostic tests have failed to reveal clear confirmation of a suspected disc as the source of pain and surgical intervention is being considered.

D.A. Fung, M.D. (✉) • T.T. Davis, M.D.
Orthopedic Pain Specialists, 2428 Santa Monica Blvd., Suite 208,
Santa Monica, CA 90404, USA
e-mail: dfung@orthopaindocs.com; tdavis@orthopaindocs.com

S.M. Falowski, J.E. Pope (eds.), *Integrating Pain Treatment into Your Spine Practice*, DOI 10.1007/978-3-319-27796-7_12

Introduction

Minimally invasive interventional procedures should be considered when conservative modalities have failed to provide adequate relief. Selection of the proper interventional treatment is predicated on the accurate identification of a pain generator. There is no substitute for a thorough history and physical exam. Imaging should be used as a supportive tool to confirm the suspected diagnosis. The future of interventional pain medicine depends on a mindful and conservative application of procedures, based on published outcome data. There is no place in the near or long term for the "shot-gun" approach to identifying and treating sources of pain.

Medicare guidelines have outlined diagnosis-specific criteria that must be accurately documented prior to proceeding with any interventional pain therapy. Each interventional procedure is diagnosis specific and certain criteria must be met in order to validate a diagnosis. These diagnosis criteria are separated into "major" and "minor" criteria which consist of subjective complaints and objective findings. The authors recommend a review and full comprehensive understanding of the Medicare Coverage Database as it applies to each interventional procedure that is planned in practice [1].

This chapter provides a comprehensive review of the most common interventional procedures and discusses "evidence-based indications" with an overview of the proper execution of each type of procedure.

Trigger Point Injections

Myofascial trigger points are "small, circumscribed, hyperirritable foci in muscles and fascia, often found with a firm or taut band of skeletal muscle" [1]. When pressure is applied over the trigger point, local tenderness and occasionally radiating pain are elicited. Pressure or needle entry into the trigger point injections can sometimes elicit a local "twitch response" when the tense muscle involuntarily contracts.

Indications and Rationale

Trigger point injections are indicated when a diagnosis of myofascial pain syndrome is established as the source of a patient's pain. Direct pressure over the trigger point should reproduce the patient's pain and commonly associated radiating pattern.

Trigger point injections are considered medically necessary when there is a regional muscular pain complaint with a palpable taut band in an accessible muscle. All failed conservative treatments including therapy, medications, and activity modification must be documented. There must be exquisite spot tenderness at one point along the length of the taut band with some degree of restricted range of

motion and pain or altered sensation in an expected distribution. The pain must be reproducible by pressure over the tender spot or a local twitch response or resolution of pain by stretching or injection [1].

Studies have shown a direct relationship between trigger point injections and improved pain, range of motion, and quality of life. In a randomized controlled trial Ay et al. showed that trigger point injections lead to statistically significant improvements in pain, range of motion, and depression scores with both local anesthetic injection and dry needling of trigger points [2].

Technique

Trigger points are identified by palpation over the painful muscle, a taut band of muscle is usually felt, and reproduction of the patient's pain is produced. Needle placement into the trigger point is typically performed in the office under the physician's knowledge of anatomy without specific equipment for guidance; however electromyography or nerve stimulation can be used to confirm placement and ultrasound can be used to visualize intramuscular placement [3]. When the needle is in place, medication (typically an anesthetic and a small amount of corticosteroid) is injected or dry needling can be performed. Directing and repositioning the needle in multiple planes within a trigger point area may help in further mechanical breakdown of the taut band. Some advocate the use of other injectates in trigger point injections such as botulinum toxin, prolotherapy, or platelet-rich plasma (PRP) which further treat the patient's pain through their individual healing mechanisms.

Paravertebral Facet Joint Block and Facet Joint Denervation

Targeted medial branch blocks or intra-articular injections of the zygapophyseal joints (facet joints, z-joints) with local anesthetic are indicated when a diagnosis of cervical, thoracic, or lumbar spondylosis is established and correlated with regional pain in the respective area. For coding purposes, "an injection may be placed in the facet joint itself or around the medial branch nerve innervating the joint" [1]. Diagnostic facet blocks must provide at least 80 % relief of an individual's usual and customary pain, in order to justify proceeding with a facet rhizotomy.

Indications and Rationale

Facet joint pain is most commonly related to degenerative spondylosis and arthropathy which presents as localized pain over the region of the degeneration [4]. A traumatic forced flexion or hyperextension can cause capsular stretch or joint

compression can also cause injury to the facet joints [5, 6]. Facet joint pain typically presents as localized pain over the facet joint with myofascial radiating patterns that is worse with extension and rotation.

Along with clinical findings, diagnostic "paravertebral nerve blocks" (medial branch blocks or intra-articular facet blocks) are used to assist with the diagnosis of facet joint pain [4]. Local anesthetic is used to anesthetize the facet joint or the medial branch nerves that innervate the facet joints. If the blocks achieve 80 % or greater pain relief temporarily, then a patient is considered to be a good candidate for radiofrequency denervation of the medial branch nerves [7]. There is moderate evidence to support benefits of medial branch blocks. Randomized, placebo-controlled, and double-blinded studies have shown significant pain relief with radiofrequency nerve ablation, indicating strong evidence for its benefits [8]. Available evidence from randomized, controlled trials and observational studies for benefits of intra-articular facet joint injections is mixed and rated moderate to limited [9].

Techniques

Paravertebral Facet Blocks and Radiofrequency Ablations (Facet Rhizotomy)

The medial branch nerves are terminal divisions of the dorsal rami of each spinal nerve. They provide sensory sensation from the facet joints and motor innervation to the multifidi muscles. Each facet joint is innervated by the medial branch nerves at that vertebral level and the level above; thus it is important to block two sets of medial branch nerves for each facet joint.

In the cervical spine, the medial branch courses around the waist of the articular pillars. The patient can be placed in the prone or lateral decubitus position. The fluoroscopic beam is oriented with a slight tilt to line up the plane of the joint and the needle is guided towards the lateral aspect of the waist of the articular pillar. The fluoroscopic beam is then reoriented to a lateral position and the needle is advanced to the midpoint of the articular pillar (Figs. 12.1 and 12.2).

In the thoracic spine, the medial branches course over the superior aspect of the transverse process. Patients are placed in the prone position and the fluoroscopic beam is oriented in an AP or slightly oblique view. The needles are directed towards the superior aspect of the transverse process [10].

In the lumbar spine, the medial branch is at the junction between the superior articular process and the transverse process [11]. Patients are placed in the prone position and the fluoroscopic beam is oriented to square off the vertebral end plates in an AP or slightly oblique view. The spinal needles are directed towards the superolateral aspect of the pedicle at the junction of the superior articular process and transverse processes (Figs. 12.3 and 12.4).

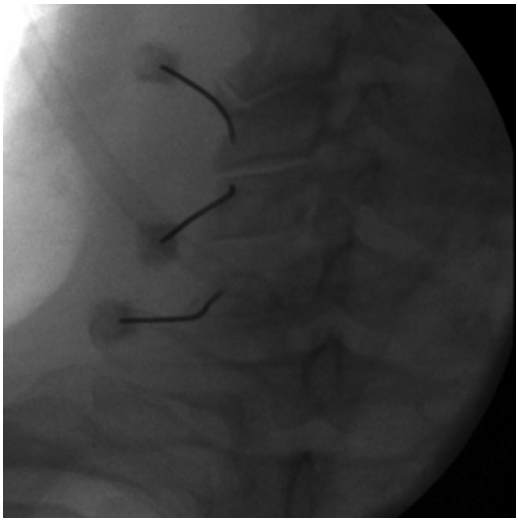

Fig. 12.1 AP fluoroscopic view of right cervical medial branch block

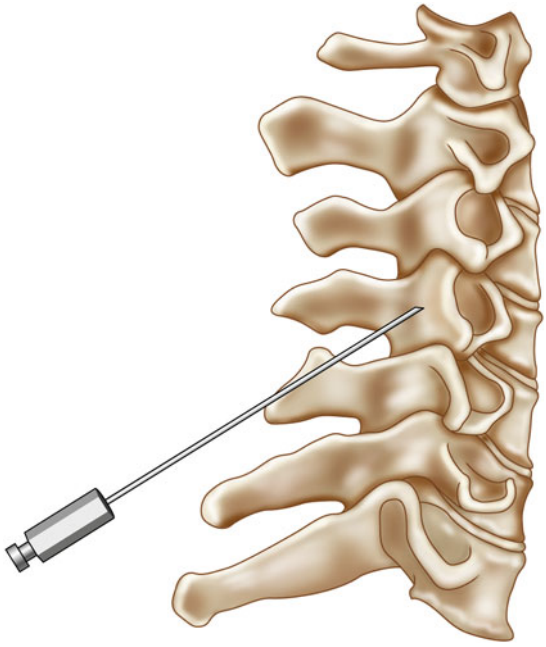

Fig. 12.2 Lateral illustration of cervical medial branch block. From Fung DA et al. Injections of the Cervical, Thoracic, and Lumbar Spine. In: Surgical Approaches to the Spine, Watkins RG III and Watkins RG, IV, eds. Springer New York;2015:389–409. Reprinted with permission from Springer

Radiofrequency ablation of the medial branches is performed at a similar location to the medial branch blocks. An insulated needle with an active tip is used to carry out the ablation. Sensory and/or motor stimulation are used to confirm placement of the needle near the medial branch nerves and away from the dorsal roots.

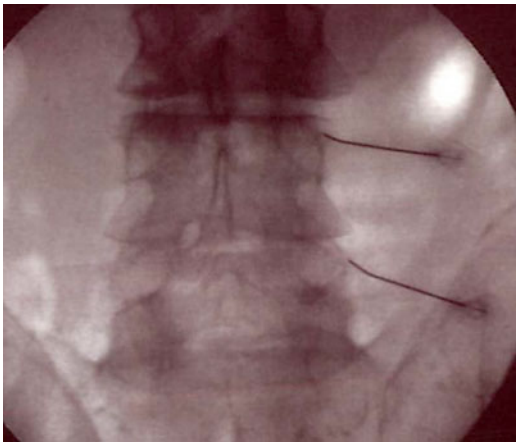

Fig. 12.3 AP fluoroscopic view of left lumbar medial branch block

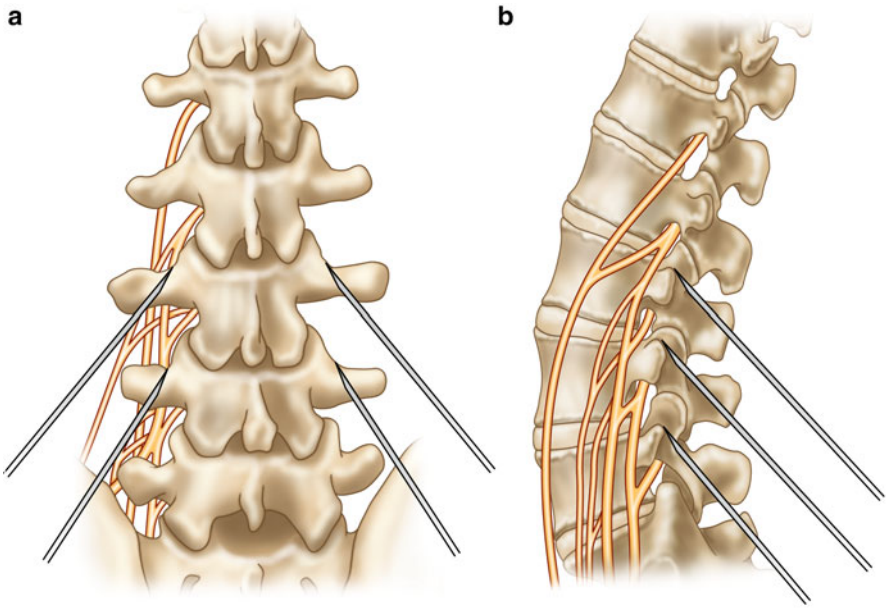

Fig. 12.4 AP and lateral medical illustration of bilateral lumbar medial branch block. From Fung DA et al. Injections of the Cervical, Thoracic, and Lumbar Spine. In: Surgical Approaches to the Spine, Watkins RG III and Watkins RG, IV, eds. Springer New York;2015:389–409. Reprinted with permission from Springer

Fig. 12.5 AP fluoroscopic view of bilateral lumbar medial branch radiofrequency ablation

Local anesthetic is administered prior to the ablation and the ablation is typically carried out at around 80 °C for a duration of 60–90 s [12] (Fig. 12.5).

Facet Joint Intra-Articular Injection

Cervical facet joint injections are performed with the patient lying prone and a 25–35 ° caudal tilt of the fluoroscopic beam to line up the facet joint space. The needle is advanced towards and into the joint space, and slight resistance is felt when the joint capsule is engaged. A lateral fluoroscopic view can be used to assess the depth of the needle. Contract is used to confirm location of the needle tip in the facet joint and 0.5–1 cc of medication is then typically injected to avoid distending the joint capsule.

Thoracic facet joint injections are performed with the patient lying prone and the fluoroscopic beam in a far (50–60 °) caudal tilt. Using fluoroscopic guidance the needle is directed towards the inferior articular process; once bone is contacted the needle type is walked superiorly into the facet joint. Once needle is in place, contrast is used to confirm the locations and approximately 1 cc of medication is typically injected.

Lumbar facet joint injections can be performed in two ways. Both require the patient to be in a prone position. The traditional way is with the fluoroscopic beam orientated obliquely approximately 20–30 ° to visualize the facet joint. The needle is directed towards the facet joint and once entered contrast is injected to confirm location and approximately 1–1.5 cc of medications is typically injected. The

author's preferred method is to keep the fluoroscopic beam in a direct AP position. The target is the posterior inferior aspect of the joint capsule. The needle is inserted in a medial to lateral, inferior to superior trajectory. The needle tip contacts the pars interarticularis of the inferior vertebrae, and then is marched up to the inferior aspect of the joint space. A step off can be appreciated when the joint is entered. This method is felt to be superior to the traditional intra-articular facet approach for safety and reproducibility. The tip is on bone throughout the procedure; therefore, the depth of the needle tip is known during the procedure, which makes it safe and easy to avoid spinal canal entry. The technique is reproducible from an anatomic perspective. The oblique fluoroscopic perspective of the lumbar facet joint can be deceiving. The joint line can often appear to be a flat line under fluoroscopy, but in reality, the joint is not a flat line, and can have scalloping traction osteophytes on the posterior lateral margin of the superior articular process blocking the access to the facet joint from the oblique approach.

Facet joint injections are relatively safe procedures in the right hands. Pain can temporarily worsen after injection due to muscle spasms, contact with the articular surface, or joint capsule expansion. Cervical injections can be risker due to the denser arrangement of nerves and arteries; nonparticulate steroids should be used to minimize the risk of arterial embolism. Another complication is injury to the spinal cord if the needle is placed too deeply and medially [8, 9].

Epidural Injections

The epidural space surrounds the dural sac and exiting spinal nerve roots within the spinal canal. The exiting spinal roots are typically the targets for epidural injections to treat radicular symptoms.

Indications and Rationale

A radicular referral pattern of pain caused by injury or irritation to a spinal nerve root is the primary indication for epidural injections. Radiculitis is often associated with dull aching centrally at the level of the exiting nerve root with sharp radiating pain along a dermatomal pattern that can be associated with numbness, paresthesia, and myotomal weakness. Proper history and physical exam should be correlated with imaging studies to visualize the pathology at the exiting nerve root. Electromyography (EMG) can also be used to confirm a diagnosis of radiculitis. Subjects with radiculitis and positive findings on EMG are reported to have improved functional outcomes from epidural steroid injections as compared to EMG-negative subjects [13]. Epidural steroid injections are accepted as a standard treatment for radiculitis and neurogenic claudication [14].

The American Society of Interventional Pain Physicians (ASIPP) guidelines advise that epidurals should be limited to a maximum of six per year and only

repeated as medical necessary. Numerous studies have validated the efficacy and outcomes of caudal, interlaminar, and transforaminal steroid injections [15–18]. There is strong-to-moderate evidence supporting caudal and transforaminal epidural steroid injections [8]. Evidence for interlaminar injections is considered moderate to limited. However, multiple observational studies have shown positive results with all forms of epidural injections [8].

In order to meet CMS documentation requirements, providers must document moderate-to-severe pain, greater than 3/10, and functional impairment in activities of daily living. At least 4 weeks of failed conservative management must be adequately documented.

Accurate documentation of medication dosing, symptom location, as well as pre- and post-procedure response to the injection, including pain level and ability to perform previously painful movements, is also required [1].

Technique

Caudal, transforaminal, and interlaminar approaches to the epidural space are described.

Caudal Epidural Injection

The patient is placed in the prone position. The sacrum and sacral hiatus are identified using a lateral fluoroscopic view. A spinal or Tuohy epidural needle is advanced at a shallow angle in a cephalad direction into the sacral hiatus. A loss of resistance technique with a glass syringe and saline can be used to identify entrance of the needle through the sacral hiatus and into the epidural space. An epidural catheter can be advanced up to the desired level of injection or injectate can be administered into the lower caudal space with enough volume such that it spreads in a cephalad direction. Contrast solution is injected to confirm ideal placement in the epidural space without intravascular uptake and then the medications are injected. The needle should not be advanced past the S2 level to avoid the risk of dural puncture [19]. The risk of cauda equina syndrome is low, at around 2.7 per 100,000 epidural blocks [7].

Interlaminar Epidural Injection

The patient is placed in the prone position with slight flexion of the spine to help open up the intralaminar space (Fig. 12.6). AP fluoroscopy is used to visualize the intralaminar space and the lamina above and below. The spinal needle is advanced to just contact the superior aspect of the inferior lamina adjacent to the spinous process to confirm appropriate depth of the needle. The needle is then slowly walked off the lamina and advanced with a loss of resistance technique into the epidural

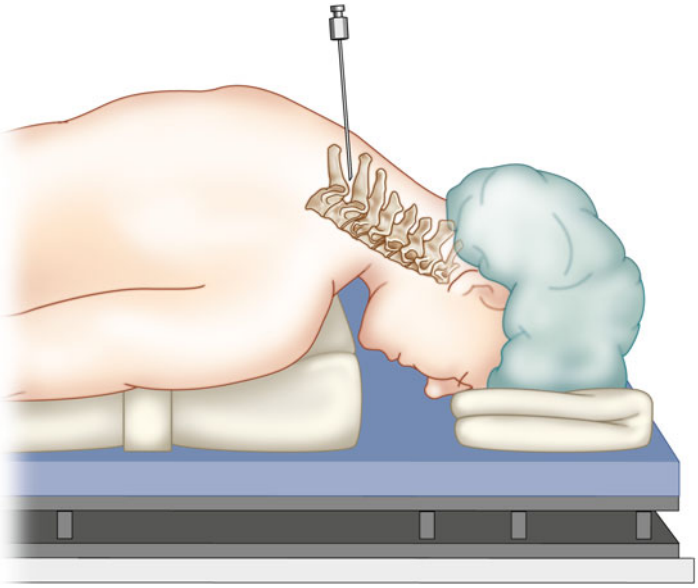

Fig. 12.6 Positioning for cervical interlaminal epidural injection. From Fung DA et al. Injections of the Cervical, Thoracic, and Lumbar Spine. In: Surgical Approaches to the Spine, Watkins RG III and Watkins RG, IV, eds. Springer New York;2015:389–409. Reprinted with permission from Springer

space (Fig. 12.7). Contrast is injection to confirm ideal placement of the needle and then medications are injected. The thoracic and cervical epidural space can be extremely narrow; thus entering at a more caudal interlaminar level and advancing an epidural catheter up to the desired level are often advised.

Aspiration is performed prior to injection of contrast to check for blood or CSF. The potential size of the dorsal epidural space is directly related to the volume of the spinal canal at the targeted level [20, 21] (Fig. 12.8).

Transforaminal Epidural Injection

The authors will present and prefer the retroneural method for transforaminal epidural steroid injections. The patient is placed in the prone position and an AP or oblique fluoroscopic view is used to direct the spinal needle from a lateral starting position medially towards the neural foramen. The needle is advanced obliquely toward the inferior lateral aspect of the pedicle at the junction of the transverse process and the pars. Lateral fluoroscopic imaging is then used to place the needle tip at the 10 o'clock position of the foramen, also known as the "safe triangle"

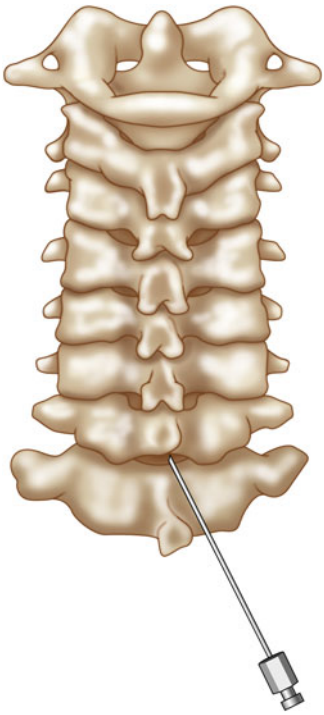

Fig. 12.7 Paramedian approach for cervical interlaminar epidural injection. From Fung DA et al. Injections of the Cervical, Thoracic, and Lumbar Spine. In: Surgical Approaches to the Spine, Watkins RG III and Watkins RG, IV, eds. Springer New York;2015:389–409. Reprinted with permission from Springer

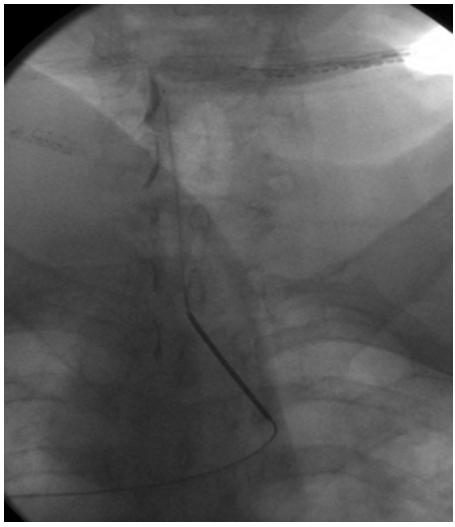

Fig. 12.8 AP fluoroscopic view of cervical interlaminar epidural steroid injection with entry point at the T1–T2 interlaminar space

Fig. 12.9 AP fluoroscopic view of lumbar transforaminal epidural steroid injection with needles in place

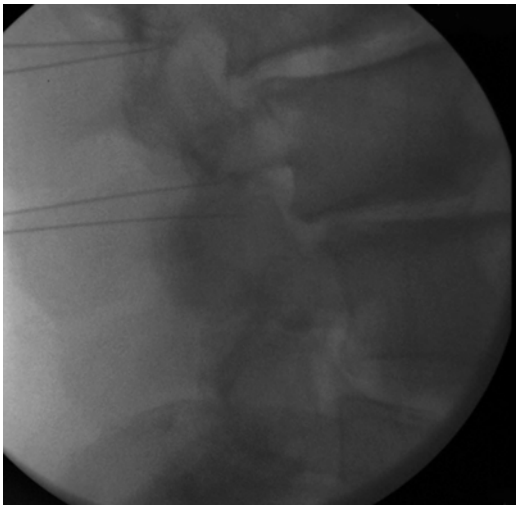

Fig. 12.10 Lateral fluoroscopic view of lumbar transforaminal epidural steroid injection with needles in place

(Figs. 12.9, 12.10, 12.11, and 12.12). Cervical transforaminal epidural injections are not advised for unexperienced physicians; serious adverse events have been reported including paralysis, stroke, and death [22, 23].

Fig. 12.11 AP fluoroscopic view of lumbar transforaminal epidural steroid injection after administering contrast and medications

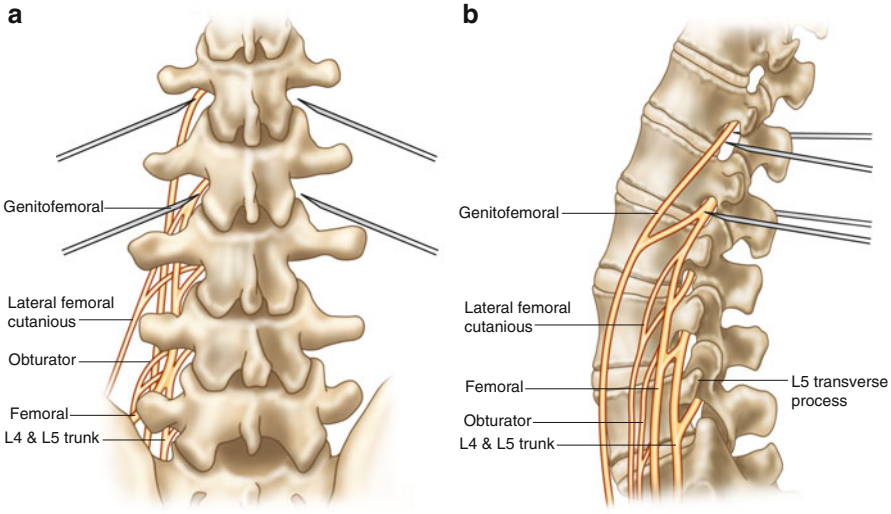

Fig. 12.12 AP and lateral medical illustration of lumbar transforaminal epidural steroid injection. From Fung DA et al. Injections of the Cervical, Thoracic, and Lumbar Spine. In: Surgical Approaches to the Spine, Watkins RG III and Watkins RG, IV, eds. Springer New York;2015:389–409. Reprinted with permission from Springer

Complications

Epidural injections are relatively safe procedures and complications are low. Previous studies have reported complications rates around 2.4 % with the most common complication being pain at the injection site [24]. Other studies have reported the incidence of a minor infection at 1–2 %, major infections 0.1–0.01 %, and the risk of epidural hematoma at less than 1 in 150,000 [25]. The risk of intravascular injection can be prevented by injecting contrast first to rule out intravascular placement but this is a possible complication and the use of nonparticulate steroid is recommended. A dural puncture can occur if the needle is advanced passing the epidural space; most patients will heal without intervention but if a dural leak persists it can be treated with staying supine, hydration, analgesics, and an autologous blood patch [26]. If the needle is advanced further into the dural space, contact with the spinal cord or nerve roots can occur. Epidural infections and epidural hematomas are rare occurrences that can lead to cauda equina syndrome. Extra care needs to be taken during left-sided injections between T8 and L1 because the artery of Adamkiewicz, the largest spinal segmental artery, lies at these levels in 60–80 % of patients [27, 28]. Certain steroid solutions now come with warning labels "not for epidural use." These are the same steroids that have been used in the epidural space for many years. The use of these products with this specific wording on the label in the epidural space is discouraged and very difficult to defend from a medical legal perspective.

Sacroiliac Joint Injections

The sacroiliac joint is a fibrocartilaginous joint formed by the connection between the sacrum and the ilium.

Indications

Sacroiliac (SI) joint pain typically presents as chronic axial low back pain that is localized to the lower back and buttock region. It is associated with leg length discrepancy, older age, inflammatory arthritis, scoliosis, previous spine surgery, pregnancy, and trauma. SI joint arthropathy is typically diagnosed on history and physical exam and with diagnostic SI joint injections.

In order to meet CMS documentation requirements, providers must document moderate-to-severe pain, greater than 3/10, and functional impairment in activities of daily living. At least 4 weeks of failed conservative management must be adequately documented. Accurate documentation of medication dosing, location, as well as pre- and post-procedure response to the injection, including pain level and ability to perform previously painful movement, is required. SI joint injections will be considered

medically necessary when an injection is given with imaging confirmation for diagnostic or therapeutic purposes after conservative management has failed [1].

Evidence-Based Rationale

Physical exam and imaging findings are often nonspecific for the diagnosis of SI joint pain [29]. Many patients with SI joint pain have radiographically normal-appearing SI joints [30]. SI joint injections can serve as diagnostic and therapeutic injections [29, 31]. Clinical studies have demonstrated intermediate-term benefit for both intra- and extra-articular injection of steroid at the SI region [29].

Technique

The patient is placed in a prone position with a contralateral oblique fluoroscopic angulation. The needle is advanced from an inferior and medial entry point cephalad into the joint space. Contrast can be injected to confirm intra-articular placement, and then followed by the injectate. ASIPP guidelines recommend that joint injections be repeated only as necessary and limited to a maximum of six local anesthetic and steroid blocks per year [7]. If adequate relief of symptoms is obtained, then sacral lateral branch rhizotomy or fusion procedures can be performed for longer lasting relief.

Discography

Intervertebral discs consist of a central nucleus pulposus and a surrounding annulus fibrosis. Only the outer third of the disc has neural innervations and vascular supply. Degenerative disc disease or traumatic fissures in the annulus fibrosis are thought to lead to discogenic pain [7, 32].

Indications

Discogenic pain typically presents as axial low back pain at the level of the suspect disc. Discography is a diagnostic procedure used to diagnose discogenic pain or for preoperative planning to evaluate for internal disc disruption, recurrent herniations, and pseudoarthrosis and to determine spinal fusion levels [7]. Stimulation of intervertebral discs and the reproduction of patient's usual axial pain indicate a positive physiologic test for discogenic pain. A normal disc should not produce the patient's usual

pain. Fluoroscopic evaluation of the contrast spread pattern or post-procedure CT or MRI can provide further radiologic evaluation of the internal anatomy of a disc [32].

Discography is considered medically necessary for evaluation of disc pathology in persons with persistent, severe low back pain and abnormal interspaces on MRI, where other diagnostic tests have failed to reveal clear confirmation of a suspected disc as the source of pain and surgical intervention is being considered. During the procedure, accurate documentation of volume of contrast injected, disc morphology, pressures, and concordant or discordant pain level is required [1].

Evidence-Based Rationale

Discography relies on the subjective provocation of patient's pain; due to this, clinical outcome data and peer-reviewed literature have published a wide range of results. Despite conflicting reports, discography does have applications in a number of clinical settings [7]. Cohen et al. published a comprehensive review of lumbar discography which reported discography to be the more accurate than other radiologic studies in detecting degenerative disc disease [32].

Technique

In lumbar discography the patient is placed in the prone position and a 25–35° oblique fluoroscopic angle is used to line up the superior articular process with the midline of the vertebral end plate. A two-needle technique is recommended using a 18-gauge needle followed by a 5–8 in. 22-gauge needle inserted through the 18-gauge needle to keep the needle tip as sterile as possible. The needle is advanced towards the superior articular process and walked just lateral off the superior articular process towards the midline of the disc. As the needle encounters the annulus there is increased resistance; at this point alternating AP and lateral fluoroscopy should be used to insure that the needle tip is advanced to the center of the disc. A mixture of radiographic contrast and antibiotics is then slowly injected to pressurize the disc and the patient is questioned regarding their symptoms. The morphologic features of the disc and contrast spread or leakage under fluoroscopy are also identified and recorded. Manometry can be used to monitor the opening pressure and the filling pressures. Discs that strongly reproduce the patients' typical pain at low-to-medium pressures are considered positive. Post-procedure CT or MRI imaging can be obtained within 2–3 h for further radiologic evaluation [33] (Figs. 12.13, 12.14, and 12.15).

Thoracic discography is similar in technique to lumbar discography but is only recommended for skilled proceduralists because of increased risk posed by the anatomy. In thoracic discography the needle is advanced into the disc through a hyperlucent region centered over the disc on oblique fluoroscopy. This hyperlucent region

Fig. 12.13 AP fluoroscopic view of lumbar discography

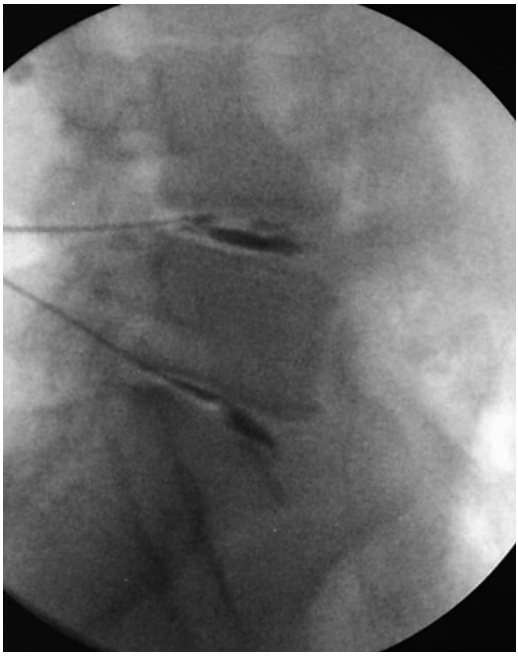

Fig. 12.14 Lateral fluoroscopic view of lumbar discography

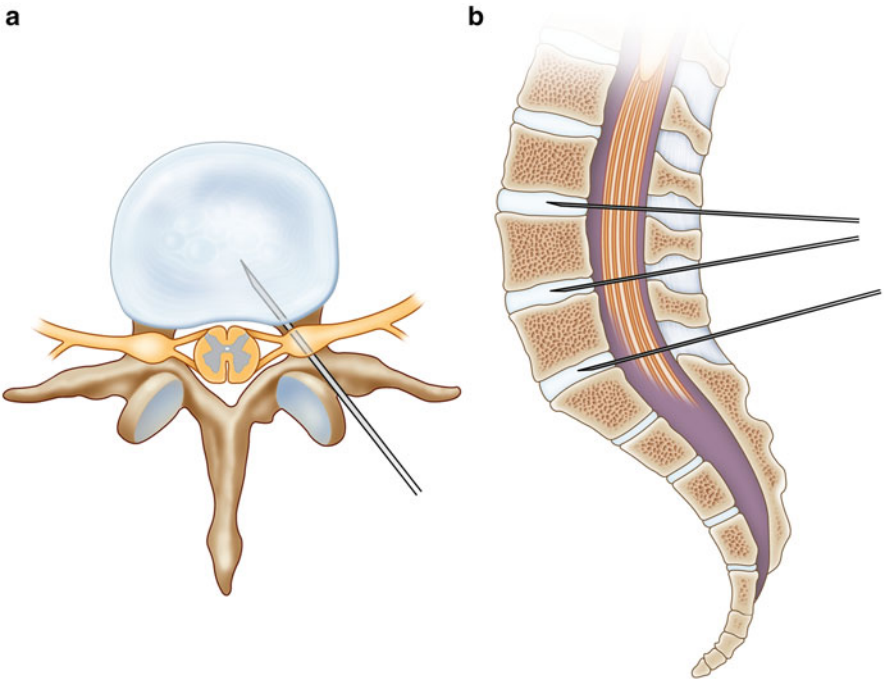

Fig. 12.15 Axial and lateral medical illustration of lumbar discography. From Fung DA et al. Injections of the Cervical, Thoracic, and Lumbar Spine. In: Surgical Approaches to the Spine, Watkins RG III and Watkins RG, IV, eds. Springer New York;2015:389–409. Reprinted with permission from Springer

is bordered by the superior and inferior vertebral endplates, laterally by the medial head of the rib and medially by the border of the pedicle.

Cervical discography is also only recommended for skilled proceduralists. The patient is placed in the supine position with the head slightly turned away from the needle entry point. A right-sided needle entry point is commonly used to avoid the esophagus. An oblique fluoroscopic view is used to visualize the uncinated process and neuroforamen. The needle should be directed towards the uncinated process. Once the uncinated process is contacted the needle is marched medially off the uncinated process into the disc. AP and lateral fluoroscopy should then be used to ensure proper placement into the midline of the disc (Figs. 12.16 and 12.17).

Complications

Although extremely rare, the most unique and serious complication of discography is discitis and it is difficult to treat with antibiotics due to the poor blood supply of the discs. Prophylactic IV antibiotics and antibiotics mixed in with contrast may

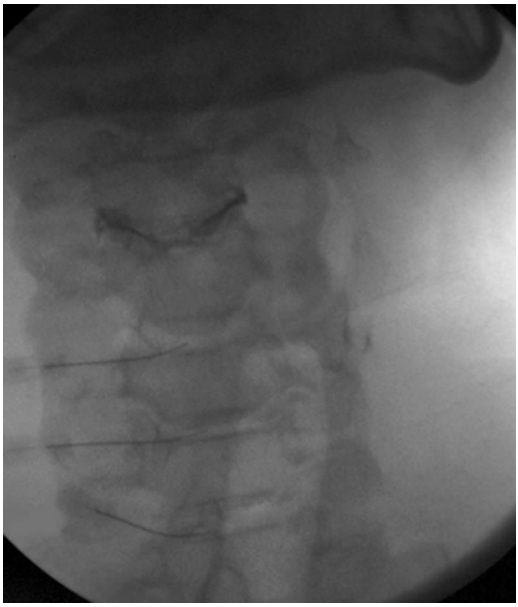

Fig. 12.16 AP fluoroscopic view of cervical discography

Fig. 12.17 Lateral fluoroscopic view of cervical discography

help decrease the risk of discitis [7, 34, 35]. Due to the subjective nature of discography, there can have a high false-positive rate [7, 34, 35]. "Control" or normal disc levels can be used to improve specificity of the study. However, Carragee et al. suggested that performing discography at a normal level may lead to accelerated progression of disc degeneration [36].

Minimally Invasive Interventional Procedures

Patients who have tried and failed conservative treatments and injections may be candidates for some of the more advanced minimally invasive interventional procedures. These procedures typically require small incisions and the implantation and administration of medical devices or biologic and synthetic materials. These procedures will be further discussed in future chapters but include and are not limited to spinal cord stimulation, peripheral nerve stimulation, intrathecal drug delivery, and vertebral augmentation for the treatment of advanced pain.

The Future of Interventional Procedures

The field of interventional pain management is constantly evolving with new minimally invasive procedures constantly being developed and adopted. The field of regenerative medicine is also emerging advocating biologic injections with stem cells and growth proteins. Further large-scale peer-reviewed studies on these subjects will be necessary to truly validate and confirm the safety and efficacy of such procedures.

References

1. CMS.gov Medicare Coverage Database. http://www.cms.gov/medicare-coverage-database/
2. Ay S, Evcik D, Tur BS. Comparison of injection methods in myofascial pain syndrome: a randomized controlled trial. Clin Rheumatol. 2010;29(1):19–23. Epub 2009 Oct 20.
3. Shankar H, Reddy S. Two- and three-dimensional ultrasound imaging to facilitate detection and targeting of taut bands in myofascial pain syndrome. Pain Med. 2012;13(7):971–5. doi:10.1111/j.1526-4637.2012.01411.x. Epub 2012 Jun 8.
4. Cohen SP, Raja SN. Pathogenesis, diagnosis, and treatment of lumbar zygapophysial (facet) joint pain. Anesthesiology. 2007;106(3):591–614.
5. Pearson AM, Ivancic PC, Ito S, Panjabi MM. Facet joint kinematics and injury mechanisms during simulated whiplash. Spine (Phila Pa 1976). 2004;29(4):390–7.
6. Cavanaugh JM, Ozaktay AC, Yamashita HT, King AI. Lumbar facet pain: biomechanics, neuroanatomy and neurophysiology. J Biomech. 1996;29(9):1117–29.
7. North RB, Han M, Zahurak M, et al. Radiofrequency lumbar facet denervation: analysis of prognostic factors. Pain. 1994;57:77–83.
8. Manchikanti L, Singh V, Kloth D, et al. Interventional techniques in the management of chronic pain: Part 2.0. Pain Physician. 2001;4(1):24–98.
9. Lynch MC, Taylor JF. Facet joint injection for low back pain. A clinical study. J Bone Joint Surg Br. 1986;68:138–41.
10. Bogduk N. International spinal injection society guidelines for the performance of spinal injection procedures. Part 1: Zygapophysial joint blocks. Clin J Pain. 1997;13(4):297–302.
11. Wallace MS, Moeller-Bertram T. Facet joint and epidural injections. Minimally invasive spine surgery. 2009: 99–104.

12. Niemistö L, Kalso E, Malmivaara A, Seitsalo S, Hurri H, Cochrane Collaboration Back Review Group. Radiofrequency denervation for neck and back pain: a systematic review within the framework of the Cochrane collaboration back review group. Spine (Phila Pa 1976). 2003;28(16):1877–88.
13. Annaswamy TM, Bierner SM, Chouteau W, Elliott AC. Needle electromyography predicts outcome after lumbar epidural steroid injection. Muscle Nerve. 2012;45(3):346–55.
14. Cohen SP, Bicket MC, Jamison D, Wilkinson I, Rathmell JP. Epidural steroids: a comprehensive, evidence-based review. Reg Anesth Pain Med. 2013;38(3):175–200. doi:10.1097/AAP.0b013e31828ea086.
15. Roberts ST, Willick SE, Rho ME, Rittenberg JD. Efficacy of lumbosacral transforaminal epidural steroid injections: a systematic review. PM R. 2009;1(7):657–68.
16. Abdi S, Datta S, Trescot AM, Schultz DM, Adlaka R, Atluri SL, Smith HS, Manchikanti L. Epidural steroids in the management of chronic spinal pain: a systematic review. Pain Physician. 2007;10:185–212.
17. Benny B, Azari P. The efficacy of lumbosacral transforaminal epidural steroid injections: a comprehensive literature review. J Back Musculoskelet Rehabil. 2011;24(2):67–76.
18. Macvicar J, King W, Landers MH, Bogduk N. The effectiveness of lumbar transforaminal injection of steroids: a comprehensive review with systematic analysis of the published data. Pain Med. 2013;14(1):14–28. doi:10.1111/j.1526-4637.2012.01508.x. Epub 2012 Oct 30.
19. Soleiman J, Demaerel P, Rocher S, Maes F, Marchal G. Magnetic resonance imaging study of the level of termination of the conus medullaris and the thecal sac: influence of age and gender. Spine (Phila Pa 1976). 2005;30(16):1875–80.
20. Cheng PA. The anatomical and clinical aspects of epidural anesthesia. Anesth Analg. 1963;42:398–406.
21. Husemeyer RP, White DC. Topography of the lumbar epidural space. A study in cadavers using injected polyester resin. Anaesthesia. 1980;35(1):7–11.
22. MacMahon PJ, Eustace SJ, Kavanagh EC. Injectable corticosteroid and local anesthetic preparations: a review for radiologists. Radiology. 2009;252(3):647–61. doi:10.1148/radiol.2523081929.
23. Scanlon GC, Moeller-Bertram T, Romanowsky SM, Wallace MS. Cervical transforaminal epidural steroid injections: more dangerous than we think? Spine (Phila Pa 1976). 2007;32(11):1249–56.
24. McGrath JM, Schaefer MP, Malkamaki DM. Incidence and characteristics of complications from epidural steroid injections. Pain Med. 2011;12(5):726–31. doi:10.1111/j.1526-4637.2011.01077.x. Epub 2011 Mar 10.
25. Goodman BS, Posecion LWF, Mallempati S, Bayazitoglu M. Complications and pitfalls of lumbar interlaminar and transforaminal epidural injections. Curr Rev Musculoskelet Med. 2008;1:212–22.
26. Turnbull DK, Shepherd DB. Post-dural puncture headache: pathogenesis, prevention and treatment. Br J Anaesth. 2003;91(5):718–29.
27. Bley TA, Duffek CC, François CJ, Schiebler ML, Acher CW, Mell M, Grist TM, Reeder SB. Presurgical localization of the artery of Adamkiewicz with time-resolved 3.0-T MR angiography. Radiology. 2010;255(3):873–81. doi:10.1148/radiol.10091304.
28. Glaser SE, Shah RV. Root cause analysis of paraplegia following transforaminal epidural steroid injections: the 'unsafe' triangle. Pain Physician. 2010;13(3):237–44.
29. Foley BS, Buschbacher RM. Sacroiliac joint pain: anatomy, biomechanics, diagnosis, and treatment. Am J Phys Med Rehabil. 2006;85(12):997–1006.
30. Dreyfuss P, Dreyer SJ, Cole A, Mayo K. Sacroiliac joint pain. J Am Acad Orthop Surg. 2004;12(4):255–65.
31. Forst SL, Wheeler MT, Fortin JD, Vilensky JA. The sacroiliac joint: anatomy, physiology and clinical significance. Pain Physician. 2006;9(1):61–7.
32. Cohen SP, Larkin TM, Barna SA, Palmer WE, Hecht AC, Stojanovic MP. Lumbar discography; a comprehensive review of outcome studies, diagnostic accuracy and principles. Reg Anesth Pain Med. 2005;30(2):163–83.

33. Wolfer LR, Derby R, Lee JE, Lee SH. Systematic review of lumbar provocation discography in asymptomatic subjects with a meta-analysis of false-positive rates. Pain Physician. 2008;11:513–38.
34. Bogduk N, editor. International spine intervention society practice guidelines for spinal diagnostic and treatment procedures. 1st ed. San Francisco: International Spine Intervention Society; 2004. p. 20–46. ISBN 0-9744402-0-5.
35. Mathis JM, Golovac S. Image-guided spine interventions. 2nd ed. New York: Springer; 2010. p. 107–46. ISBN 9781441903525.
36. Carragee EJ, Don AS, Hurwitz EL, Cuellar JM, Carrino JA, Herzog R. Does discography cause accelerated progression of degeneration changes in the lumbar disc: a ten-year matched cohort study. Spine. 2009;34(21):2238–45.