Image-guided spine intervention is used primarily for its precise diagnostic capabilities. This article reviews basic principles of the more common image-guided diagnostic techniques specifically as they relate to patients with low back pain. It also includes discussion of advanced modes of therapy, including spinal cord stimulation and intrathecal therapy, providing primary care physicians with an understanding of the primary indications for these therapeutic modalities. Two illustrative case presentations have been added to “refresh” this article, which was originally published in a supplement to the September 2005 issue of the JAOA and to further enhance primary care physicians’ understanding of spinal intervention.

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Although the variety of specialists caring for patients with chronic pain is broad, anesthesiology is the specialty that represents the majority of physicians who use interventional approaches in the treatment of these patients. Anesthesiologists who consider themselves as interventional pain management specialists agree that the spectrum varies widely from those who use only epidural steroid injections in a recovery room setting to those who are fellowship-trained and exclusively provide image-guided spine intervention.

Training and skill level among such anesthesiologists vary widely, mainly because until recently, no common comprehensive standards or guidelines existed for interventional pain management physicians. This situation changed in 2001 as the result of the establishment of guidelines set forth by the American Society of Interventional Pain Physicians\(^1\) and more comprehensive practice guidelines recently published by the International Spine Intervention Society (ISIS).\(^2\) As these standards become more commonplace in this specialty, the gap of varied skill levels and training will narrow with the expectation of improved outcomes based on randomized control trials that are ongoing to further delineate more accurate guidelines for each specific procedure.

Low Back Pain
Low back pain (LBP) is a common problem that has an enormous clinical, social, and economic impact on our society. One estimate is that this condition affects 15% of the US population.\(^3\) The impact on overall cost of healthcare is staggering when considering the disabling influence of LBP on the working population. According to Manchikanti’s epidemiologic review,\(^4\) probable risk factors for LBP include genetic factors as well as age and smoking; however, none was convincingly causal. Possible risk factors include a history of back pain, job dissatisfaction, heavy physical work, obesity, static work posture, and psychosocial factors. Because LBP is the most common symptom seen by interventional pain management physicians and is a common symptom seen by primary care physicians, this review article focuses considerably on diagnosis of LBP and treatment of patients with this condition.

The symptomatology of LBP is nonspecific with many possible etiologies. The lumbar spine is a complex structure, and for many years, treatment of patients with LBP\(^5\) was based on speculation. Limited understanding of lumbar spine anatomy, specifically neuroanatomy, and a lack of knowledge of functional anatomy contributed to this approach to treatment.

Fortunately, the dedicated, diligent, and unparalleled work of Nikolai Bogduk did much to change treatment. His text Clinical Anatomy of the Lumbar Spine and Sacrum\(^6\) contains knowledge and science essential to more complete comprehension of pathology, diagnosis, and treatment. This greater awareness of anatomy and function resulted in considerable research data generated by many quality double-blind controlled trials. These data were translated into precise diagnostics that further enhanced appreciation of complex issues in LBP and dramatically changed the specialty of interventional pain management. Scientific advances coupled with the ever-developing art of medicine will undoubtedly translate into less suffering with greater function and productivity for those who have chronic pain.
Given these fortuitous advances, there is no longer a place for the routine “series of three” injections. Spinal injection procedures are primarily diagnostic and, to a lesser degree, potentially therapeutic. Repeated injections should be considered only in regard to response of previous ones. A poor response precludes repeating the same spinal injection procedure. Furthermore, precise needle placement, an absolute requirement for diagnostic injections, cannot be accomplished unless fluoroscopy and contrast are used. Even for a potentially therapeutic injection such as a conventional (interlaminar) epidural steroid injection, the needle tip (and the desired delivery of corticosteroid) may not consistently reach its target when fluoroscopy is omitted.6,7

The concept of precisely diagnosing a potential anatomic structure responsible for generating LBP rests on the idea that for a structure to be a source of pain, it must have a nerve supply. Hence, a diagnostic nerve block can be administered to test this hypothesis.8

Based on several studies by Schwarzer et al,9-14 Bogduk15 postulated that precision diagnostic injections can assist in formulating a specific diagnosis in 70% to 80% of those who suffer from LBP.

With respect to the relative contributions of various structures in chronic LBP, Manchikanti et al16 evaluated 120 patients with a chief complaint of LBP by administering precision diagnostic injections. These injections targeted facet joints via medial branch blocks, intervertebral disks via provocation diskography, and sacroiliac joints (SIs) via intra-articular injections. They concluded that the facet joint contributed to chronic LBP in 40% of the population, the intervertebral disk in 26%, and the SIJ in 27%. Anecdotal experience among physicians at Advanced Pain Consultants, PA, in Voorhees, NJ, indicates that the intervertebral disk is the more frequent clinically significant source of chronic LBP than are lumbar facet joints.

Facet Joint Pain
Facet joints (zygapophyseal joints) are paired synovial joints formed by articulation of the inferior articular process of one vertebra with the superior articular process of the subjacent one. These joints allow the spine to move in flexion, extension, and rotation.

Innervated by the medial branch originating from the dorsal rami of the spinal nerve, facet joints can be identified as a source of pain either by placing a needle tip within the joint or by blocking the medial branch nerve that lies outside the joint. Osteoarthritis and trauma are among the most common conditions leading to pain emanating from facet joints. The primary symptom of pain emanating from this site is that of LBP. By injecting a solution of 10% hypertonic saline solution in the region of the facet joints, Hirsch and colleagues17 demonstrated that pain can be created in the upper back and thigh regions. Pain frequently is also referred into the groin, buttocks, hip, or lateral and posterior thigh regions (or a combination of these sites). Pain is often described as a “deep, dull ache” and may be either unilateral or bilateral.

On physical examination, there may frequently be increased pain with extension, tenderness to palpation over the affected joints, and normal findings on neurologic examination. Electrical stimulation of the medial branch nerves has also assisted in identifying referral pain patterns.18

Facet joint injections or medial branch nerve blocks are primarily diagnostic tools. An intra-articular facet injection usually includes use of a steroid such as methylprednisolone, which theoretically reduces inflammation within the joint, thereby potentially reducing pain. However, injecting steroid into the facet joint does not usually provide lasting relief.

The interventional pain management specialists at Advanced Pain Consultants, PA, routinely administer controlled diagnostic blocks of the lumbar medial branches to determine if a given patient may be a candidate for radiofrequency neurotomy. Dreyfuss et al19 have demonstrated that clinically significant and prolonged relief from back pain can be achieved with radiofrequency neurotomy of the lumbar medial branches. Patients’ pain must be carefully diagnosed with controlled diagnostic blocks of the lumbar medial branches.

Sacroiliac Joint Pain
Like the facet joint, the SIJ is also a diarthrodial synovial joint with a capsule. Unlike the facet joint, which has a clearly defined innervation, the SIJ has a nerve supply that is not clearly defined and is probably complex. The lack of a clearly defined innervation precludes use of a nerve block as a diagnostic tool for identifying pain emanating from this site.

The SIJ can be the source of LBP in a substantial percentage of cases. Schwarzer et al14 suggest that this causality may be true in 13% of cases. Using controlled diagnostic injections, Maige et al20 suggest the incidence of SIJ dysfunction causing LBP may be as high as 19%.

Because there is no scientific evidence that history or physical examination can accurately identify the SIJ as a source of pain, controlled intra-articular injections are the only available means of identifying this site as causing such discomfort.21,22 Because innervation of the SIJ is poorly defined and most likely complex, pain emanating from here cannot be diagnosed using nerve blocks. Intra-articular injection of a local anesthetic (eg, lidocaine or bupivacaine hydrochloride) into the SIJ is the technique of choice used to prove or disprove that it is the etiologic factor.

Based on the experience of Advanced Pain Consultants, patients in whom emanation of pain is suspected—and subsequently confirmed by intra-articular injection—to be from the SIJ, usually present with pain in the lower back, groin, or buttocks (or a combination of these sites). Referred lower extremity pain may also be present.

Fortin et al23 using asymptomatic volunteers, created a map suggesting that the characteristic location from which SIJ pain may be referred is an area of approximately 3 cm × 10 cm just inferior to the posterior inferior iliac spine. Unfortunately, this same referral pattern is not unique to the SIJ joint; it is also common to the facet joint and lumbar intervertebral disk. Therefore, intra-articular injections of a local anesthetic are necessary for diagnosis.
Diskogenic Pain

Because different structures in the lumbar spine share similar innervation, pain patterns do not assist in distinguishing the exact pain generator. Without use of precision diagnostic injection techniques, pain originating from the intervertebral disk, facet, or SIJs is indistinguishable.

Provocation diskography involves injection of contrast medium into the disk nucleus to define its morphology; this increase in intradiskal pressure allows simultaneous evaluation of the patient’s response to pain reproduction. Therefore, provocation diskography can determine if this anatomic location is a pain source. It is based on the concept that if a particular disk is the source of pain, stressing it should result in reproduction of that pain. Furthermore, if the disk is not the source of pain, then when stressed, it should either not cause pain or it may produce pain that is atypical (disconcordant) of the underlying pain.

Immediately following provocation diskography, computed tomography (CT) scanning is done to obtain a static axial view of the intervertebral disk to evaluate the degree of annular disruption. Sachs et al24 developed the Dallas diskogram scale, which grades disruption of the annulus on a four-point scale. A normal nucleogram, one in which contrast is entirely contained within the nucleus, is considered a grade 0 disk. Grades 1 to 3 describe extension of the contrast medium to the inner third, middle third, and outer third of the annulus fibrosis, respectively. Examples include a posterior radial fissure at L4-5 with contrast extravasating into the anterior epidural space (Figure 1) and a grade 3 posterolateral annular disruption on the postdiskography CT scan (Figure 2).

Provocation diskography with postdiskography CT imaging can be used to assist patients in making decisions regarding surgical intervention with either conventional spinal fusion techniques or disk replacement surgery. This diagnostic study can also serve to identify patients who may want to consider the less-invasive options such as intradiskal electrothermal annuloplasty (IDET) or other percutaneous disk interventions.

Epidural Steroid Injections

Undoubtedly, the epidural steroid injection (ESI) is the precursor of the more specific spinal injection procedures done today and the most familiar to primary care physicians. Historically, the ESI has been administered primarily as a therapeutic procedure. With widespread use of fluoroscopy and contrast medium, epidural injections into the anterior epidural space (transforaminal approach) also now have substantial diagnostic value.

Anatomically, the epidural space is divided into an anterior and posterior compartment. The posterior aspect of the vertebral body, intervertebral disk, and posterior longitudinal ligament anteriorly border the anterior epidural space. The posterior confine of the anterior epidural space is the thecal sac. The posterior epidural space is bordered by the thecal sac anteriorly and the ligamentum flavum posteriorly.

Three approaches to the epidural space are, historically, the more conventional interlaminar and caudal procedures and the more target-specific transforaminal method.

Despite ESI’s widespread use since first described in 1953,25 most early studies on its efficacy have been criticized because of the use of the blind (ie, without fluoroscopy) technique and hence, the lack of target specificity. Even in the hands of experienced clinicians, an epidural needle placed without using fluoroscopy will result in approximately 25% incorrect placements.7,26 Therefore, the fluoroscopically guided approach has become standard of care among interventional pain management physicians, not only for all spinal diagnostic injections, but also for the more conventional caudal and interlaminar epidural steroid injections.

When an intervertebral disk is herniated, a host of inflammatory mediators may affect lumbar nerve roots and result in clinical symptoms of radiculopathy or radicular pain. Inflammatory mediators identified in disk material which may irritate the dorsal root ganglion or dural sleeve include nitric oxide, phospholipase A2, phospholipase E2, tumor necrosis factor, interleukins, metalloproteinases, and immunoglobulins.27 Corticosteroids such as methylprednisolone or betamethasone decrease inflammation by inhibiting phospholipase A2 activity.28,29 Other mediators of inflammation are also most likely inhibited by corticosteroid therapy.

Precisely placing a corticosteroid at the site of the pathologic process and inflammatory cascade should provide improved clinical outcomes. Unlike the more conventional interlaminar and caudal techniques, the transforaminal approach to the epidural space delivers drug very close, if not directly, to the site of the pathologic process. Under fluoroscopic guidance, a transforaminal needle is positioned within the intervertebral foramen just below the pedicle (Figures 3-5). Contrast traverses the regional epidural space and outlines the dorsal root ganglion (Figure 6). This more
target-specific method is used for diagnostic as well as therapeutic purposes.

Additionally, Derby and colleagues demonstrated prognostic value by reporting that patients not responding to relief of radicular pain following transforaminal injections were less likely to benefit from surgical intervention. Riew et al demonstrated that transforaminal steroids, as opposed to local anesthetics alone, may decrease the need for surgery, i.e., 67% of patients treated with transforaminal local anesthetics alone required an operation, but this rate was reduced to 29% when steroids were given.

Advanced Therapies

Spinal cord stimulation and intrathecal therapy are advanced therapeutic modalities used for treating patients with chronic intractable pain. They are essentially reserved for patients in whom continuing pain is not the symptom, but rather the disease. Together, these modalities consist of technology that is considered “neuromodulatory.”

Neuromodulation is electric or chemical alteration of the central nervous system to significantly reduce chronic pain or improve neurologic function by precise delivery of small doses of electricity or drugs directly to targeted nerve sites.

Electricity to treat pain dates back hundreds of years and was usually met with considerable skepticism. However, in 1967, Shealy and associates reintroduced the use of electricity in treatment of patients in pain based on the Melzack and Walls publication of the gate control theory.

In the early 1970s, spinal cord stimulation technology lost enthusiasm as technical failures and poor patient selection resulted in limited success in treating patients with chronic pain. During the past 30 years, however, many well-controlled studies have provided a substantial level of clinical experience. Subsequently, more specific patient selection criteria (Figure 7) and technologic changes have resulted in successful utilization of electricity in management of chronic pain. Many common chronic pain conditions such as chronic radiculopathy, neuralgia, peripheral ischemia pain, and phantom limb pain respond to electrical neuromodulation (Figure 8).

Currently, the drugs approved by the US Food and Drug Administration for intrathecal use include morphine sulfate, baclofen, and, most recently, ziconotide. Other drugs commonly administered by physicians experienced with this technology include other opioids such as hydromorphone, as well as agents such as bupivacaine and clonidine hydrochloride. Intrathecal therapy is used for malignant and nonmalignant pain as well as for spasticity not relieved with oral agents.

Systemic analgesics administered either orally or transdermally, as well as other conservative modes of therapy, are usually effective in reducing symptoms in most patients with malignant and in those with nonmalignant pain. However, for patients with chronic pain not responding to more conventional treatment modalities, intrathecal therapy may be an option. It is reserved for those who failed all of the more conservative approaches, including systemic delivery of analgesic medications such as the many sustained-release opioids that are now available. Intrathecal therapy is considered a last-resort therapy. When delivered intrathecally, opioids exert a potent analgesic effect via spinal and supraspinal receptors, without significantly affecting motor, sensory, and sympathetic reflexes.

The most recent advance in intrathecal therapy is the now marketed ziconotide, a synthetic equivalent of a conotoxin derived from a marine snail.
Ziconotide selectively and reversibly blocks N-type voltage-sensitive calcium channels, thereby inhibiting the release of neurotransmitters from primary afferent nociceptors located in the dorsal horn of the spinal cord. Although slow titration is required to minimize the occurrence of adverse effects, tolerance to ziconotide does not appear to develop. Early clinical experience suggests that individual response can differ markedly. \(^3^4\) Ziconotide is currently not being used as a first-line intrathecal medication.

**Checklist**

- All more conservative modes of therapy have failed
- Psychological evaluation and clearance
- Further surgical intervention not indicated
- Successful trial screening
- No history of drug seeking, habitation, or addiction
- No contraindication to implant exists
- Pain complaint is consistent with an observable pathologic process

**Checklist**

- Failed back surgery syndrome
- Arachnoiditis
- Chronic radiculopathies
- Neuralgias
- Complex regional pain syndrome
- Peripheral neuropathy
- Peripheral neuropathies
- Postherpetic neuralgia
- Phantom limb pain

**Figure 7. Patient selection criteria for advanced pain therapies.**

**Figure 8. Most common chronic pain conditions that respond to spinal cord stimulation.**

Percutaneous Disk Decompression

A wide variety of new percutaneous procedures directed to the intervertebral disk (eg, percutaneous endoscopic laser discectomy and percutaneous discectomy) has been developed to provide patients with a minimally invasive procedure that may serve to avoid conventional open surgical techniques. These percutaneous techniques hold several theoretical advantages over their more aggressive surgical counterparts. However, widespread acceptance of these newer modalities remains limited primarily because of the lack of randomized controlled trials.

**Case Presentations**

Spinal injection procedures for LBP have evolved from potentially therapeutic blind epidural steroid injections to the more current and precise image-guided injections. Unlike blind injections, image-guided spine injections are used for diagnostic as well as therapeutic purposes. As a result of these more advanced treatment and diagnostic interventions, there has been a trend to initially refer patients to an interventional pain management specialist before consideration for surgery.

The following anecdotal case vignettes demonstrate how two of the more common interventions are used in the diagnosis and treatment of LBP.

**Case Presentation 1**

Jason, aged 34 years, sought treatment because of a 4-week history of right-sided LBP associated with pain and numbness into the right lower extremity and foot. He said that his symptoms began gradually with back pain progressing to involve the right lower extremity. He did not improve with 4 weeks of rehabilitation. Jason had no history of trauma or injury precipitating the onset of symptoms. However, a similar episode of back pain 3 years earlier occurred following an alteration during his employment as an inner-city police officer. He had no leg pain associated with this prior episode, and the back pain resolved completely after 3 weeks of rehabilitation. Jason gave her minimal relief. She was referred to physical therapy including aquatic rehabilitation. Two months of physical therapy failed to provide her with benefit. Lisa had undergone spinal surgical procedures before evaluation via diskography; however, these procedures failed to provide her with any sustained benefit. Ibuprofen gave her minimal relief.

**Case Presentation 2**

Lisa, aged 40 years, was referred by a spine surgeon for a spinal diagnostics evaluation to determine if she may benefit from spinal fusion. She has a long history of LBP and referred pain involving the lower extremities. The back pain is much more clinically significant than the lower extremity symptoms.

Lisa had been employed as an executive secretary, but due to an inability to sit for longer than 10 minutes without severe back pain, she stopped working 10 months before evaluation via diskography. Two months of physical therapy including aquatic rehabilitation failed to provide her with benefit. Lisa had undergone spinal surgical procedures before evaluation via diskography; however, these procedures failed to provide her with any sustained benefit. Ibuprofen gave her minimal relief.

Physical examination revealed moderately decreased flexion and extension due to pain. Lisa had moderate tenderness over the L4 spinous process. Neurosensory testing failed to reveal any focal deficits.

Magnetic resonance imaging demonstrated decreased signal on the T2-weighted sagittal images at L4-L5 and L5-S1, as well as high-intensity zones at both levels. Axial images demonstrated a right posterolateral annular tear at L5-S1 and a midline posterior annular tear at L4-5. Both levels also demon-
strated small central disk herniations.

Lumbar disk stimulation (diskography) was carried out using manometry to measure intradiscal pressures at L3-4, L4-5, and L5-S1. The anteroposterior view showed contrast extending to the far right lateral annular margin of the L4-5 disk. The lateral view showed a normal L3-4 nucleogram. The L4-5 nucleogram demonstrated a posterior annular tear. No contrast was seen in the L5-S1 disk. Postdiskography CT scanning demonstrated a normal nucleogram at L3-4, a right posterior lateral radial fissure at L4-5 which reproduced clinically significant back and leg pain at low pressures, and diffuse annular disruption at L5-S1 which also reproduced back and leg pain at moderately high pressures.

Following diskography, Lisa was sent back to her referring surgeon to discuss her surgical options. Apart from any corrective spine surgery, other options for treatment would include a pharmacologic approach to control the symptoms of pain with further attempts at rehabilitation. Should these nonsurgical or surgical approaches fail, a trial of spinal cord stimulation would be indicated.

Discussion

Divergent in the precise etiology of pain, these two case studies demonstrate that patterns of pain can be identical in their clinical presentation yet originate from entirely different and distinct sources. When evaluating spine-related pain, it is crucial to differentiate between somatic versus radicular pain. This delineation is critical in the application of appropriate management and treatment modalities.

Stimulation of nerve endings in muscle, bone, ligaments, or joints will result in pain. Noxious stimulation of one of these musculoskeletal structures can result in somatic pain, which is typically described as deep, aching pain that usually is diffuse and difficult to localize. Often, pain originating in one of the somatic sites can be referred or perceived in regions relatively remote from its origin. This is a common phenomenon in patients presenting with low back pain from stimulation of small nerve endings that innervate intervertebral disks. These patients frequently present with referred pain into the lower extremity which is clearly not radicular pain. Referred pain can be explained on the neurophysiologic basis of convergences. Nerves from different sites converge in the dorsal horn cells of the spinal cord, therefore rendering the higher centers unable to differentiate pain arising from anatomically different locations.

Radicular pain arises from a chemical or mechanical irritation of a spinal nerve or root. While somatic pain is characteristically difficult to localize, radicular pain is typically shooting and may follow a dermatomal distribution; herniation of an intervertebral disk is the most common cause.

The two cases presented here represent the more classic clinical presentation for radicular pain and for diskogenic pain, respectively. Typically, the clinical presentation may not be accompanied with positive neurologic findings or imaging techniques that demonstrate an obvious disk herniation compressing an exiting nerve root or a high-intensity zone on the T2-weighted sagittal MRI images that is diagnostic of painful internal disk disruption.35 The important role of image-guided spine intervention for diagnostic and therapeutic purposes is further emphasized by the interventional pain medicine specialty designation by Medicare.

Comment

Low back pain usually is self-limiting, but when it persists and is unresponsive to rehabilitation and analgesics, precise determination of the source of pain becomes key to planning proper treatment. Patients with LBP may demonstrate varied clinical scenarios, none of which, unfortunately, helps in determining the exact source of the pain. A precise spinal diagnostic evaluation can identify the correct anatomic site of such discomfort in most patients. An epidural steroid injection is one of many tools used by interventional pain management physicians. Use of image-guided procedures and contrast medium affords pain management physicians a methodology for precision diagnostics.

When patients visit their primary care physician with a complaint of LBP and they have no response to conservative treatment such as analgesics and physical therapy, it would be appropriate to obtain MRI scans and refer these patients to a pain management physician. The interventional pain specialist will be able to precisely diagnose the etiology of the pain and determine whether further rehabilitation, therapeutic injections, or a surgical evaluation would be prudent.

References


