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Selective Nerve Root Blocks for Low Back Pain and Radiculopathy

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In the management of patients with low back pain and radiculopathy, selective nerve root blocks (SNRBs) are now a common procedure for both diagnostic and therapeutic purposes. This article reviews the available studies as well as the relevant anatomy, pathology, technical considerations, and complications. *Reg Anesth Pain Med 2004;29:243-256.*

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Since the original report by Macnab[1] describing the technique of selective nerve root injection, numerous investigators have reported on its value in the management of patients with radicular pain.[2-8] Although there is a lack of prospective, randomized, double-blind, controlled studies, selective nerve root blocks (SNRBs) are now a common procedure for both diagnostic and therapeutic purposes (Table 1).[9] Therapeutic SNRBs are performed via the intervertebral foramen. Diagnostic SNRBs are performed extraforaminally distal to division of the ventral and dorsal rami; they are used to identify nerve roots responsible for pain when clinical or radiographic studies are equivocal and for planning surgical treatment. Application of this procedure requires not only a knowledge of the technique but also an understanding of its utility, efficacy, safety, and validity.

Anatomy

The spine may be divided anatomically into anterior, neuroaxial, and posterior compartments.[10] The vertebral body and intervertebral disc form the anterior compartment, whereas the intrinsic back muscles and facet joints, together with associated bony vertebral arch structures, form the posterior compartment. From experiments in normal volunteers and neuroanatomical dissections, 5 main areas have been identified as potential sources of back pain: intervertebral discs, the facet joints, spinal nerves, posterior longitudinal ligaments, and paraspinal muscles.[11-15]

The neural foramen is bounded superiorly by the pedicle, anteriorly by the vertebral body and intervertebral disc, inferiorly by the pedicle of the vertebrae below, and posteriorly by the superior articular facet of the inferior vertebra (Fig 1). The lumbar neural foramen averages 18 to 22 mm in height and 7 to 12 mm in width. Membranous structures, an epidural membrane, and an epiradicular sheath can be found around nerve roots.[16] The space around the nervous tissue, both in the spinal canal and in the intervertebral foramen, is narrower in the male than in the female.[17] At each segmental level, the sinuvertebral nerve (recurrent meningeal nerve) is formed by the union of a somatic root from the ventral ramus and an autonomic root from the adjacent sympathetic chain (gray ramus communicans) (Fig 2).[18] The sinuvertebral nerve supplies the posterior longitudinal ligament, posterior annulus of the disc, and dura. The nerve may ascend or descend 1 or more segments. The lateral and anterior aspects of the intervertebral disc are innervated by nerves associated with the sympathetic trunk and the gray ramus communicans.[19] There is more extensive innervation of the severely degenerated disc compared with normal discs.[20]

The blood supply of the spinal cord is from the abdominal and thoracic aorta via its cervical, intercostal, and lumbar branches, which form segmental

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Table 1. Indications for Selective Nerve Root Block

Atypical extremity pain
Patients with equivocal imaging studies
Patients with equivocal neurologic examinations
For anomalous innervations, such as conjoint nerve roots or furcal nerves (Kikuchi, 1986)
Failed back surgery syndrome with atypical extremity pain
Patients with transitional vertebrae
To provide temporary pain relief from a known cause of pain (e.g., disc herniation)

spinal arteries. These enter the intervertebral foramen at each spinal level. The segmental arteries split into 3 arteries before entering the spinal canal. These are the anterior and posterior longitudinal spinal canal arteries and the radicular artery. The radicular artery continues along the nerve root and divides into an anterior and posterior radicular artery, which join with the anterior spinal artery and the 2 posterior spinal arteries. The largest of the radicular arteries is the artery of Adamkiewicz (arteria radicularis magna).[21] This artery, which is the main vascular supply to the lower two thirds of the spinal cord, arises from the aorta and enters the spinal cord anywhere from T7 to L4.[22] The typical location of the artery of Adamkiewicz is on the left (approximately 80%) from T9-L1. The artery usually enters in the superior or middle portion of the neural foramen, slightly ventral and superolateral to the dorsal root ganglion. Injury to the artery of Adamkiewicz can result in devastating ischemia of the lower spinal cord causing the anterior spinal artery syndrome.

To be selective, a nerve root block should be performed extraforaminally, distal to division of the ventral and dorsal rami; otherwise, the dorsal rami and all its innervated structures will also be anesthetized. Also, epidural spread to other levels is possible even with low volumes of injectate.[23] It has therefore been suggested that the therapeutic procedure be referred to as a "transforminal epidural steroid injection" and that the diagnostic procedure be referred to as a "selective spinal nerve block" or "selective ventral ramus block."[23]

Spinal Nerve Pathology

SNRBs are performed to identify or treat spinal nerve pathology. The pathophysiology of spinal nerve root pain is not fully understood.[24] Nerve root pain may result from inflammation or compression secondary to foraminal stenosis, postsurgical scar tissue formation, leakage of substances such as phospholipase A_2 from the intervertebral disc, direct compression by an intervertebral disc, or from a combination of factors.[12,16,17,25-34] Compression alters nerve root conduction and compromises the nutritional support of spinal nerve roots. Mechanical forces can lead to intraneural damage and functional changes in nerve roots. However, compression alone does not independently cause pain.[35] Patients who have radicular symptoms associated with the "failed back surgery syndrome" may have pain because of nerve injury and/or ongoing traction on the nerve root. These patients are less likely to respond to steroid injections compared with those having an acute inflammatory condition.[36]

Olmarker et al.[37] observed that epidural placement of autologous nucleus pulposus in pigs, without mechanical nerve root compression, induced a pronounced reduction in nerve conduction velocity in the nerve roots of the cauda equina. This observation suggested a mechanism that is based on direct biochemical effects of nucleus pulposus on nerve fiber structures and function. Also, in an experimental pig model, it was found that the nucleus pulposus–induced effects on nerve function may be reduced dramatically by high-dose methylprednisolone administration within 24 to 48 hours after epidural application of autologous nucleus pulposus.[38] Otani et al.[39] observed that the inflammatory effect of nucleus pulposus is only temporary. The inflammatory effect is most pronounced after 7 days and diminishes within 2 months. Moreover, it has been shown that most disc herniations gradually resorb on their own.[40] This could explain the relatively benign and self-limiting course of sciatica in the majority of cases.

Disc herniation refers to localized displacement of nuclear, annular, or end plate material beyond the normal limits of the disc space.[41] A bulging disc may be defined as a disc in which the contour of the outer annulus extends beyond the edges of the disc space, usually greater than 50% (180°) of the disc circumference. Extrusion refers to focal, obvious disc extension beyond the interspace, the base against the parent disc narrower than any diameter

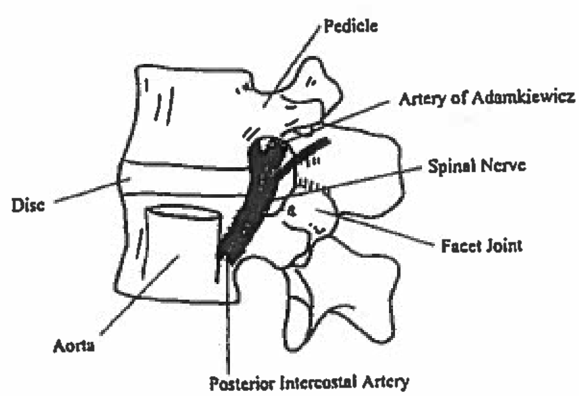

Fig 1. Anatomy of the neural foramen.

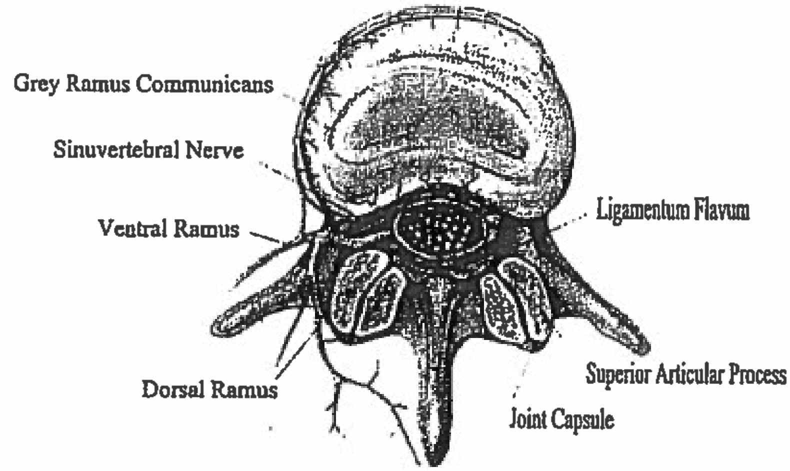

Fig 2. Anatomy of the spine.

of the extruded material itself, or no connection between displaced disc material and parent disc. On magnetic resonance imaging examination of the lumbar spine, many people without back pain have disc bulges or protrusions but not extrusions.[42]

The failed back surgery syndrome is seen in 10% to 30% of patients who undergo back surgery.[43,44] The reason for failure is often poorly understood, but the most common lesions accounting for surgical failure include recurrent or persistent disc herniation, arachnoiditis, epidural fibrosis, forminal stenosis, myofascial pain syndromes, and psychosocial factors. The lumbosacral nerve roots pass through the intervertebral foramina after originating from the thecal sac. Forminal stenosis is a common cause of radicular symptoms[45-47] and may be a significant cause of persistent postoperative symptoms.[48]

SNRB as a Diagnostic Test

Selective nerve root block (SNRB), when combined with a careful history, physical examination, and quality radiographic studies, is an important tool in the diagnostic evaluation of patients with predominantly radicular symptoms.[49-52] They may be used to define the source of pain and are especially useful when clinical examination, electrodiagnostic studies, and imaging studies are equivacol.[2,8,53,54] However, although SNRB is used to determine whether pain is originating from a specific nerve root or spinal nerve, it does not determine what has caused the spinal nerve pain. It should also be noted that many persons without low back pain or radicular syndromes have abnormal computed tomographic or magnetic resonance imaging scans.[55,56] Conversely, radicular pain secondary to local trauma[57] or chemical radiculitis[58] may be present in the absence of imaging abnormalities. Diagnostic blocks may be particularly useful in patients with multilevel pathology, to identify the symptomatic level.[2,6] Electromyography has limitations in localizing a patient's radicular pain to a single level.[59] Radiographic tests may be difficult to interpret after spinal surgery because of scar tissue in the epidural space and other anatomic changes.[60,61] In addition, radicular symptoms may not correspond to classic dermatomal patterns.[62]

Reproduction and temporary relief of a patient's leg pain provides useful diagnostic and prognostic information, confirming clinical and radiographic findings. A test is considered positive for a given spinal nerve if needle contact produces pain similar to the patient's usual pain and if relief follows local anesthetic injection, including a lack of pain during maneuvers that produced pain before the block, such as straight leg raising or walking.[63] The pain provocation portion of the spinal nerve injection test examines pain quality and distribution. Reproduction of the typical quality of the pain as a criterion is supported by the demonstration that inflamed nerves are more sensitive to manipulation than normal nerves.[26,64] A negative SNRB also gives strong and valuable negative prognostic information.[2,7,65] Patients who experience no relief after SNRB either do not have pain consistent with the clinical examination and imaging studies or have severe pathology that prevents medication from reaching the root. A false-negative test may also result from incorrect needle placement.

The essential features the clinician seeks in a diagnostic test are accuracy, safety, and reproducibility. The general parameters of accuracy are described as the specificity and sensitivity of the diagnostic test. Sensitivity is the ability of a test to predict positive results based on a gold standard. The most sensitive test will be positive for all cases in which the disease is present. The specificity is the ability to predict negative results. The ideal diagnostic test would have a sensitivity of 100% and a specificity of 100%. It has been questioned whether SNRBs are sensitive enough to differentiate between radicular pain and other potential sources of pain.[65,66] When the presence or absence of pain is the endpoint, there is no completely reliable gold standard with which to compare a diagnostic test.

To be valid, diagnostic blocks must be target specific and controlled.[67] Use of fluoroscopy and contrast confirms that anesthetic agent flow is limited to its intended target. Even with volumes as low as 1 to 2 mL, the injected medication may cover more than one level and therefore more than one nerve root, resulting in a false-positive result.[23] The results of nerve root stimulation are not as reliable as confirmation with a contrast agent, because needle stimulation of an annulus, facet joint capsule, or periosteum, may result in referral to the extremity.[68] For cervical medial branch blocks, to minimize the effect of the placebo effect comparative anesthetic blocks have been recommended. These involve administering a particular local anesthetic during the first block and then a different agent on a second occasion. The agents recommended are lidocaine and bupivacaine. The essential criterion for a positive response to comparative blocks is that the effect of bupivacaine is longer than that of lidocaine.[69,70] However, for lumbar and sacral selective nerve root injections, comparative blocks are not routinely performed.

Studies

Schutz et al.[53] retrospectively reported on SNRBs performed on 23 patients. In 15 patients, an operation was performed at the level indicated by the results of the SNRB. The operative findings were in agreement with the test findings in 13 (87%) of these patients. Pathology found at surgery included scarring and fibrous adhesions around the nerve root, bony entrapment at the intervertebral canal, sequestered disc fragments, intradural adhesions, recurrent disc prolapse, and in 1 case a foreign body (metallic screw). In this study, 18% of tests failed because of intolerable pain during the procedure or failure to stimulate the desired root, most often at S1.

Krempen et al.[6] reported retrospective data on 22 patients who underwent SNRB. Criteria for performing the procedure included the presence of sciatica of unclear etiology. Of the 22 patients tested, 21 had previous laminectomies or laminectomies and fusions. The level of injection was determined on the basis of clinical examination and diagnostic studies including myelograms, discograms, and electromyograms. Two patients had excellent relief of pain during the immediate postinjection period but decided against surgery. Four had a negative result. The remaining 16 patients had a positive response and underwent surgery with relief of pain to varying degrees in all cases (100% sensitivity). At operation, 2 patients showed retained disc material, 13 showed scar tissue, and 1 showed impingement of the articular process on the nerve root. Follow-up ranged from 8 to 20 months after surgery.

Haueisen et al.[3] reported on 105 patients with sciatica of unclear etiology who underwent selective nerve root block; 55 subsequently had surgical exploration of the suspected lesion. The operative findings consisted of a herniated disc in 30, bony compression of a spinal nerve in 13, extensive scarring of a spinal nerve in 15, and segmental spinal stenosis in 1. In patients with a diagnostic or highly suggestive selective nerve injection study, an accurate diagnosis was made in 43 of 46 (93%). Myelograms in the same group had an accuracy of 24%. At follow-up evaluations ranging from 12 to 60 months (average 20 months), 40 (73%) of the patients were improved by further surgical treatment. Satisfactory needle placement could not be achieved in 10% of patients at L4, 15% at L5, and 30% at S1.

Dooley et al.[2] retrospectively reviewed 62 patients with radiculopathy who had undergone nerve root infiltration. Indications for the procedure included normal investigations (myelograms and computed tomography scans), multilevel pathology (spinal stenosis, spondylolisthesis), previous spine surgery, and the hip-spine syndrome. The follow-up period was an average of 28 months (range 24-36 months). Surgical exploration of 44 patients with typical pain reproduced by needle placement and then relieved by nerve root infiltration, confirmed local pathology in all.

Herron et al.[71] retrospectively reported on 215 patients who underwent selective nerve root blocks over an 8-year period. Contrast agent was not used during the procedure, and a total of 2 mL of local anesthetic was injected. Of this group, 78 patients underwent surgery. After surgery, 71 patients were available for follow-up. Preoperative diagnoses included lumbar disc herniation, spinal stenosis, and previous lumbar spine surgery. The average follow-up was 34 months (range, 12-96 months). Overall, there were 38 (53%) good, 16 (23%) fair, and 17 (24%) poor surgical results, as assessed by the surgeon. Nine patients had imaging studies that showed possible 2-level lumbar disc herniations. In these patients, selective nerve root block was used to identify the symptomatic level. Laminectomy and discectomy were performed only at the symptomatic level. The results for those patients who had had prior surgery were disappointing (52% poor). The authors recommended that patients with previous surgery should be recommended for surgical intervention only if diagnostic tests are unequivocal.

Stanley et al.[7] prospectively evaluated 50 nerve root infiltration studies in patients referred to a back clinic with complicated problems. Sixteen (32%) had undergone previous surgery. All patients were reviewed after a minimum follow-up period of 18 months. In 20 patients (40%), infiltration reproduced the symptomatic pain, which was then abolished by injection of local anesthetic. These patients were considered suitable for surgery. One patient in this group had spontaneous resolution of his pain and therefore did not undergo surgical treatment. In those patients undergoing surgical decompression, nerve root infiltration correctly identified the symptomatic level in 18 of the 19 (95% sensitivity). The major pathologic finding at operation was bony entrapment, with lateral canal stenosis being the predominant abnormality.

North et al.[65] examined the specificity and sensitivity of local anesthetic blocks in a series of 33 patients with a chief complaint of sciatica, attributable in all cases to spinal disease (radiculopathy, with some clinical features of arthropathy). Three different nerve blocks were found to be significantly more effective than control lumbar subcutaneous injection of an identical volume of 3 mL of 0.5% bupivacaine. Not only paraspinal lumbosacral root blocks and posterior medial branch blocks (at or proximal to the pathology) but also sciatic nerve blocks (distal or collateral to the pathology) produced temporary relief in a majority of patients. This confirmed the hypothesis that false-positive results are common, and specificity is low. For sciatic nerve blocks, specificity was between 24% and 36%. Patterns of responses specific to the established diagnosis of radiculopathy (i.e., root block most effective) had sensitivities between 9% and 42%. The findings of this study indicated a limited role for uncontrolled local anesthetic blocks in the diagnostic evaluation of sciatica and referred pain syndromes in general. Negative blocks or a pattern of responses may have predictive value, but isolated, positive blocks are nonspecific. This lack of specificity may, however, be advantageous in therapeutic applications because spread to multiple structures may be beneficial. Indeed such injections may obviate the need for surgery.[72]

In another prospective study, Van Akkerveeken et al.[68] reported on use of diagnostic nerve root infiltration in patients with nerve root entrapment resulting from disc disease or malignant disease. The procedures were performed by 2 radiologists on 37 patients with disc protrusions and 9 patients with metastases. In all the cases, the test was positive and the clinical and radiologic diagnosis was confirmed at surgery. The test would seem to be particularly helpful when there are radiologic signs of entrapment of 2 or more nerve roots.

Dorsal root ganglionectomy and dorsal rhizotomy are performed in an attempt to cause direct nociceptive deafferentation and have been suggested as methods for the treatment of chronic intractable radicular pain.[73] However, the efficacy and safety of these procedures is questionable.[74,75] Studies have repeatedly shown that pain relief by nerve root blocks does not predict success by neuroablative surgery, either by dorsal rhizotomy[76,77] or dorsal root ganglionectomy.[75]

In summary, in a patient who otherwise meets standard criteria for surgery, a SNRB may be a useful confirming step, particularly for its negative value (Table 2): Clearly, patients with reversible pathology will respond better that those with permanent nerve damage.

Confounding Variables

Injection of local anesthetic may spread beyond the intended spinal nerve target to structures such as adjacent dorsal rami, spinal nerves, or the sinuvertebral nerves, thereby causing a false-positive result. Anatomical variation is another potential problem. In a cadaver study, nerve root abnormalities were found in 14% of individuals.[78] Magnetic resonance imaging studies may provide information regarding these abnormalities.[79] The furcal nerve usually arises from the L4 root level and contributes to both the lumbar and sacral plexuses of nerves.[80] Neurologic symptoms, suggestive of 2 roots being involved, frequently result from furcal nerve compression.

Pain relief resulting from blockade of a spinal nerve cannot distinguish between pathology of the proximal nerve or pain transmitted from distal sites by that nerve. It has been reported before, in a small series of cases, that ongoing, spontaneous sciatic pain can be relieved by sciatic nerve block, distal or collateral to any pathology.[81,82] And in experimental settings, distal referred pain in response to paraspinal noxious stimuli (hypertonic saline) can be prevented by peripheral somatic blockade in the area of referral.[83]

Table 2. Studies on Diagnostic Selective Nerve Root Blocks

Author /Study Design	Patient Population	Results
Schutz et al.[63] Retrospective	23 patients with sciatica	15 patients had positive test results and underwent surgery Surgical findings agreed in 13 (87%)
Krempen et al.[6] Retrospective	22 patients with sciatica	18 patients had a positive result 16 patients underwent surgery All patients had relief of pain to a varying degree 100% sensitivity
Haueisen et al.[3] Retrospective	105 patients with sciatica	55 patients had a positive result 55 patients underwent surgery; 93% sensitivity
Dooley et al.[2] Retrospective	62 patients with radicular symptoms	44 patients had a positive result Surgery confirmed local pathology in all cases
Heron et al.[71] Retrospective	215 patients with leg pain	78 patients underwent surgery 7 patients lost to follow-up 38 patients (53%) had a good surgical result 16 patients (23%) had a fair result 17 patients (24%) had a poor result 76% sensitivity
Stanley et al.[7] Prospective series	50 patients with leg pain	20 patients had a positive result 19 patients underwent surgery Surgery confirmed pathology in 18 (95%)
North et al.[65] Prospective randomized	33 patients with radiculopthy	Nerve root blocks had sensitivities between 9% and 42%
Van Akkerveeken et al.[68]	137 patients with nerve root entrapment	Test positive in all cases 100% sensitivity

Pain is purely subjective, often with uncertain pathophysiology. It may be influenced by psychological, social, financial, and legal factors, as well as by the efficacy of concurrent therapies such as medications and physical therapy. Additionally, spinal injections may be associated with a significant placebo effect. It has been reported that the placebo effect increases in direct correlation to the invasiveness of a procedure.[84,85] Performing injections on 2 or more occasions may minimize the influence of the placebo response.

SNRB as a Therapeutic Procedure

Most authorities agree that the initial treatment of acute low back with radicular symptoms should include short-term bed rest, anti-inflammatory medication, and physical therapy.[86,87] Patients who fail to respond to conservative therapy may then benefit from an interventional procedure. Epidural steroid injections are a common treatment method, although still controversial particularly with respect to long-term efficacy.[86,88,89] Although there are few randomized, double-blind, placebo-controlled studies, interlaminar epidural steroids appear to provide short-term benefits, especially for disc herniation and radicular symptoms.[90-104] Of 6 clinical trials, 3 have shown benefit[93,101,105] and 3 have not.[88,99,103] Even though epidural steroids may provide short-term pain relief, the procedure is nonspecific, offering the clinician little diagnostic information. The aim of an epidural injection is to place corticosteroids on or near an area of inflammation, either an inflamed nerve root(s) or the cauda equina. However, as a result of epidural scarring or a midline raphe, the injectate may flow away from an area of resistance and fail to reach the site of pathology.[106,107] For diagnostic purposes, it may therefore be more rational to target a specific nerve root rather than the epidural space.

An alternative method for delivering steroids to inflamed nerve tissue is the use of selective nerve root injection, which is the term given to the procedure developed by Krempen and Smith.[6] Epidural injections are relatively high-volume injections (8-12 mL) intended to permeate a large area of the epidural space and thereby deliver a small amount of diluted agent to each of multiple vertebral levels.[108] In contrast, SNRB delivers a low volume (1-2 mL) of concentrated medication directly onto the nerve root in question. Under fluoroscopic guidance, the needle is placed next to the presumed affected nerve root, resulting in a precise and concentrated delivery of the drug to the nerve. Because the tissue surrounding the spinal nerve is considered to be an extension of the epidural space, the therapeutic SNRB may be considered to be a selective epidural steroid injection,[63] providing the same mechanism of pain relief with a much smaller amount of therapeutic agent.

Transforaminal injections result in medication flow into the epidural space. This route allows delivery of medication to the pathologic site and may be more efficacious than delivery by the caudal or interlaminal route.[109] The anti-inflammatory properties of corticosteroids are well known.[38] Their local application is considered to relieve reversible inflammatory changes or processes, such as vascular congestion related to mechanical obstruction. In a rat model, topical administration of methylprednisolone was found to selectively inhibit C-fiber transmission.[110] In an experimental animal study, it was reported that the effect of an epidural steroid injection was related to inhibition of phospholipase A_2 activity.[111] Steroid formulations used for selective nerve root blocks can be found in tissues in measurable quantities for 2 to 3 weeks, although the therapeutic effects may far outlast the presence of measurable steroid.[112] Although most study findings indicate a markedly declining effect after 3 months,[93] there is also evidence of a potential long-term effect.[100]

Studies

A retrospective report by Derby et al.[86] attempted to predict surgical outcome by evaluating pain relief in response to steroid injections. Most patients were tested with selective spinal nerve blocks, but 20% received an epidural injection. All patients had surgery regardless of test outcome, so complete outcome data are available. For postoperative relief of radicular pain, the results showed that patients with pain lasting less than 1 year had a positive surgical result (89%), regardless of response to steroid. Patients with pain lasting more than 1 year and who have had a positive response to steroid injected into the symptomatic nerve root (roots) had a positive surgical outcome of 85%. Patients who did not respond to the steroid and had pain for more than 1 year generally had a poor surgical outcome. Although poor outcome may be explained in some cases by an inadequate structural correction, inadequate stabilization, or functional reasons, the majority of these failures were thought to represent irreversible changes in the neural structures.

Kraemer et al.[108] reported 2 controlled studies involving 182 patients. One study compared the responses of patients with lumbar radicular syndromes who received epidural perineural injections, conventional posterior epidural injections, or paravertebral local anesthetic. A second study compared the effect of epidural perineural injections with triamcinolone and pure saline. All patients had disc protrusions with signs of nerve root compression, such as paresthesias and a positive straight leg–raising test. Epidural perineural injections were more effective than conventional posterior epidural injections; 68% had excellent or good responses versus 53.8%. A good response was defined as leg pain less than 10%, back pain less than 20%, return to work, and sports as before. A fair response was defined as leg and back pain less than 50%, return to reduced work, return to reduced sports, and a positive straight leg–raising test. Patients were assessed before treatment, at 3 weeks, and at 3 months.

Weiner et al.[113] studied 30 patients with severe lumbar radiculopathy secondary to foraminal and extraforaminal disc herniation that had not resolved with rest and use of nonsteroidal anti-inflammatory agents. Patients were treated with foraminal injection of local anesthetic and reviewed at an average of 3.4 years (range, 1-10 years) after injection. Relief of symptoms was obtained in 27 (90%) patients immediately after injection. Three subsequently relapsed, requiring operation, and 2 were lost to long-term follow-up. Thus, 22 of the 28 patients available for long-term follow-up had considerable and sustained relief from their symptoms. Before the onset of symptoms, 17 were in employment and, after injection, 13 (76%) resumed work.

Lutz et al.[114] reported a prospective case series that investigated the outcome of patients with lumbar herniated nucleus pulposus and radiculopathy who received fluoroscopic transforaminal epidural steroid injections. Sixty-nine patients were followed for an average period of 80 weeks (range, 28-144 weeks); 75.4% of patients had a successful long-term outcome, reporting at least greater than 50% reduction between preinjection and postinjection pain scores, as well as an ability to return to, or near to, their previous levels of functioning after only a mean of 1.8 injections per patient (range, 1-4 injections).

In an open, nonblinded, randomized study, Devulder et al.[115] evaluated outcome in patients with failed back surgery syndrome treated with nerve root sleeve injections. Sixty patients with documented fibrosis in less than 3 nerve roots were randomly allocated to receive injections of either bupivacaine 0.5% combined with 1,500 units hyaluronidase and saline (group A), bupivacaine 0.5% combined with 40 mg methylprednisolone solution (Depo Medrol) (group B), or bupivacaine 0.5% combined with 1,500 units hyaluronidase and 40 mg methylprednisolone solution (group C). The volume of each injection was 2 mL. The injections were given twice at an interval of 1 week apart. The patients were evaluated 1, 3, and 6 months after the second injection. Although injections induced analgesia at 1 month, these effects were reduced at 3- and 6-month follow-ups. No statistical differences were found between the 3 treatment groups.

Karppinen et al.[116] conducted a randomized, double-blind trial to test the efficacy of periradicular corticosteroid injection for sciatica. In this study, 160 consecutive patients with sciatica who had unilateral symptoms of 1 to 6 months' duration, and who had never undergone surgery, were randomized to receive injection of either methylprednisolone with bupivacaine or saline alone. Recovery was greater in the steroid group at 2 weeks as assessed by leg pain, straight leg raising, lumbar flexion, and patient satisfaction. Back pain was significantly lower in the saline group at 3 and 6 months and leg pain at 6 months. Sick leaves and medical costs were similar for both treatments, except for cost of therapy visits and drugs at 4 weeks, which were more favorable in the steroid injection group. The combination of methylprednisolone and bupivacaine appeared to have a short-term effect, but at 3 and 6 months, the steroid group seemed to experience a "rebound" phenomenon. A subgroup analysis of this study was subsequently performed.[117] In the case of contained herniations, the steroid injection produced significant short-term efficacy for treatment of leg pain. For symptomatic lesions at L3 to L5, steroid was superior to saline in the short term as assessed by leg pain, disability, and straight leg raising. By 1 year, steroid seemed to have prevented operations for contained herniations. In addition to short-term effectiveness for contained herniations and lesions at L3 to L5, steroid treatment also prevented surgery for contained herniations. However, steroid was not effective for extrusions.

Riew et al.[72] studied the effectiveness of selective nerve root injections in reducing the need for surgery in patients with lumbar radicular pain. Fifty-five patients who were referred to 4 spine surgeons because of lumbar radicular pain and who had radiographic confirmation of nerve root compression were studied. They were randomized to receive a selective nerve root injection with either bupivacaine alone or bupivacaine with betamethasone in a double-blind fashion. The patients were allowed to choose to receive up to 4 injections. Twenty-nine of the 55 patients (53%), all of whom had initially requested operative treatment, decided not to have the operation during the follow-up period (range, 13-28 months) after the nerve root injections. Of the 27 patients who had received bupivacaine alone, 9 (33%) elected not to have the operation. Of the 28 patients who had received bupivacaine and betamethasone, 20 (71%) decided not to have the operation.

Pfirrmann et al.[118] studied the efficacy of SNRBs in 36 patients as well as contrast material distributions in both patients and cadavers. Eighty-six percent of patients had at least some pain relief 2 weeks after the injections, which consisted of 2 mL of local anesthetic and 1 mL of corticosteroid. The early response to the procedure did not predict the effect at 2 weeks. Patterns of contrast distribution were assessed by radiologists as indicating intraepineural, extraepineural, or paraneural injection. Results indicated that there was no need to inject corticosteroids and local anesthetics into the nerve root sleeve. In addition to possible damage to neural structure resulting from puncture with a sharp needle tip, an injection into the nerve root produces substantial pain, which can be avoided at least in part by peri- and paraneural injections.

Vad et al.[96] reported a prospective study of patients with disc herniations According to patient choice, patients received either a transforaminal epidural steroid injection or a saline trigger point injection. Randomization by patient choice is likely to have caused bias error. A successful outcome required a patient satisfaction score of 2 (good) or 3 (very good), improvement on the Roland-Morris score of 5 or more, and pain reduction greater than 50% at least 1 year after treatment. The final analysis included 48 patients with an average follow-up period of 16 months (range, 12-21 months). After an average follow-up period of 1.4 years, the group receiving transforaminal epidural steroid injections had a success rate of 84%, as compared with 48% for the group receiving trigger point injections. Factors associated with decreased success in the steroid group included preexisting spondylolisthesis in addition to disc herniation and duration of symptoms exceeding 1 year.

In summary, transforaminal epidural steroid injections appear to be efficacious in the treatment of radicular pain particularly when caused by an acute inflammatory process without irreversible changes in neural structure and with duration of symptoms less than 1 year (Table 3).

Technique

Contraindications to the procedure include coagulopathy, local or systemic infection, allergy to injectate, and lack of patient cooperation. Use of fluoroscopy during spinal injections allows accurate needle placement with the minimum of attempts and may therefore minimize complications.[119-126] For the L1 to L4 lumbar nerve roots, the C arm is rotated to a 20° to 30° oblique angle, toward the

Table 3. Studies on Therapeutic Selective Nerve Root Blocks

Author	Patient Population	Groups	Results
A. Retrospective			
Derby et al.[86] Retrospective	71 patients with radicular pain	Epidural injections Selective nerve blocks (1–2 mL lidocaine 2%, 6 mg betamethasone, 2–3 mL total)	Patients with pain <1 year and a positive response had a positive surgical response in 89%
B. Prospective Outcome Studies			
Weiner et al.[113] Prospective	30 patients with lumbar disc herniation and radiculopathy	All received transforaminal injections (2 mL 1% lidocaine (with 11.4 mg betamethasone, 4 mL total)	Immediate relief in 27 patients 22/28 (79%) had benefit Average of 3.4 years follow-up
Lutz et al.[114] Prospective	69 patients with lumbar disc herniations and radiculopathy	All received transforaminal injections (1.5 mL 2% lidocaine with 9 mg betamethasone, 3 mL total)	75.4% had successful long-term outcome Average of 80 weeks follow-up
Pfirrmann et al.[118] Prospective	36 patients with acute sciatica	Selective nerve root blocks with local anesthetic and steroid (2 mL 0.2% ropivacaine, 40 mg triamcinolone, 3 mL total)	86% reported relief at 2 weeks 15-28 months follow-up
Devulder et al.[115] Randomized Open	60 patients with nerve root fibrosis	All patients received nerve root sleeve injections (2 mL) A: bupivacaine 0.5%, 1,500 U hyaluronidase B: bupivacaine 0.5%, 40 mg methylprednisolone C: bupivacaine 0.5%, 1,500 U hyaluronidase, 40 mg methylprednisolone	No difference in analgesic effects between groups 6 months follow-up
C. Prospective, controlled studies			
Kraemer et al.[109] Injections Randomized Controlled	182 patients with lumbar radicular syndromes	Epidural perineural injections (triamcinolone 10 mg) Posterior epidural injections Paravertebral local anesthetic	Epidural perineural injections more effective than epidural injections (68% vs. 53. 3 months follow-up 3 months follow-up
Karppinen et al.[116] Randomized Double-blind	160 patients with sciatica	Transforaminal methylprednisolone with bupivacaine (2-3 mL methylprednisolone 40 mg/mL-bupivacaine 5 mg/mL) Transforaminal saline alone	Improvement found in both groups 1 year follow-up
Riew et al.[72] Randomized Double-blind	55 patients with lumbar radicular pain	Transforaminal bupivacaine (1 mL 0.25% bupivacaine) Transforaminal bupivacaine and betamethasone (6 mg)	9 of 27 (33%) who had bupivacaine alone elected to have surgery 20 of 28 (71%) who had bupivacaine and betamethasone elected to have surgery 1 year follow-up
Vad et al.[96] Randomized* Prospective	48 patients with radicular pain	Transforaminal ESI (1.5 mL 2% lidocaine, 9 mg metamethasone, 3 mL total) Saline trigger point injections	Transfominal ESI 84% success Saline trigger point injections 48% Average of 16 months follow-up

*Randomized by patient choice.

side being injected, which will bring the facet joint and "Scotty dog" appearance into view. Then the C arm is rotated 15° in the caudocephalad direction to give a clear picture of the superior par articularis. In the lumbar spine, the nerve roots travel inferiorly and exit in a lateral plane, exiting under the pedicle with a downward course of 40° to 50° from the horizontal, thus occupying the superior portion of each foramen.[127] A safe triangle has been described with the sides corresponding to the horizontal base of the pedicle, the outer vertical border of the intervertebral foramen, and the connecting diagonal nerve root (Fig 3).[118] A needle placed into the safe triangle will lie above and lateral to the nerve root. The nerve root normally passes a few millimeters inferior to the pedicle and 1 to 2 mm superficial to the vertebral body. The nerve can be approached by placing a needle inferior to the pedicle of the vertebra at the level of the nerve to be blocked or at the

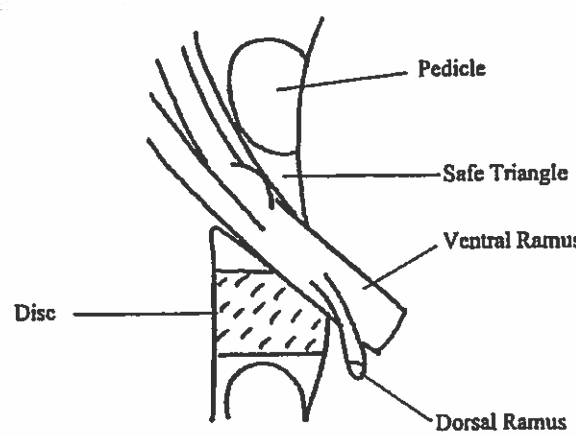

Fig 3. The safe triangle.

Fig 4. L4 SNRB.

Fig 5. S1 SNRB.

superior articular process of the vertebra below. If the latter approach is chosen, the needle is inserted until it strikes the superior articular process. The needle is then adjusted to pass lateral until it lies within the intervertebral foramen. On a posteroanterior fluoroscopic view, the target point lies at the "6 o'clock" position. Avoiding placing the needle medial to this position reduces the risk of dural puncture. For a L5 block, the needle is inserted toward the triangular window formed by the inferior margin of the transverse process of L5, the superior articular process of S1, and the iliac crest. The S1 foramen appears as a small radiolucent circle just below the oval S1 pedicle. It may be necessary to direct the fluoroscopic beam in a cephalocaudad direction for the alignment of the anterior and posterior foramina. First contacting the posterior sacral bone before entering the S1 foramen provides the depth and direction of the needle, thus avoiding placing the needle through the anterior foramen and into the pelvis. Injection of 0.5 to 1.0 mL of nonionic contrast material is used to outline the spinal nerve and to ensure that there is no vascular uptake or subarachnoid spread (Figs 4 and 5). Injection of the contrast under "real-time" or "live" fluoroscopy may be used to detect partial intravascular injection that may be otherwise missed. During a diagnostic injection, 1 mL of local anesthetic is then injected. If the radicular artery has been injected, it may be safer to perform the procedure on another occasion, thereby allowing the arterial puncture to heal, although there are no data to support this approach.

Complications

Complications during SNRB include direct trauma to the nerve root from the needle or damage to the neural vasculature, resulting in a hematoma or neural infarction (Table 4).[128-133] Houten and Errico[129] reported 3 cases of paraplegia after lumbosacral nerve root block. All patients had a history of prior surgery, and in 2 procedures the needle was placed transforaminally. It was postulated that there was damage to the artery of Adamkiewicz either by direct injury resulting in thrombosis or by embolization of particulate steroid preparations. Strategies to avoid this complication include the use of nonparticulate solutions for injection, aspiration before injection, use of blunt-tipped needles, and needle placement in the safe area of the foramen, so as to avoid contact with the nerve root (the radiculomedullary artery travels with the nerve root).

Conclusion

SNRB is a valuable tool in the evaluation and treatment of patients with radicular pain. The procedure will have variable success depending on the underlying cause of nerve root pathology. Chronic irritation can lead to irreversible changes. Intraneural and extraneural fibrosis is not always reversed with surgical decompression; this disorder can

Table 4. Potential Complications

Exacerbation of pain
Allergic reactions
Bleeding
Infection
Dural puncture and headache
Vasovagal responses
Paraplegia caused by damage to the artery of Adamkiewicz

cause persistent neural ischemia and fixation of the nerve root complex by scar tissue. Practitioners should be experienced in the procedure to avoid technical difficulties, particularly at the L5 and S1 levels. During diagnostic blocks, the local anesthetic must only be placed on the spinal nerve in question and interpreted with consideration of possible confounding variables. Many of the published studies to date have significant limitations, with variation in patient population, entry and outcome criteria, pain etiology, follow-up period, and injection technique. Further prospective randomized controlled trials with subgroup analyses are required.

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