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Selective nerve root blocks as predictors of surgical outcome: Fact or fiction?

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The hypothesis that delivering local anesthetic to a single nerve root will selectively and specifically block only that nerve and will provide accurate information that could predict surgical success has been, to date, based mainly on clinical assumption without many adequately performed trials proving their validity. Many factors have been identified to be a source of bias in the response to these injections, including anatomical variations and technical/procedural differences. Review of the available data on selective nerve root blocks as predictors of surgical outcomes demonstrates that these blocks have high sensitivity, low specificity, and strong negative-predictive value and therefore should be considered as tools that dissuade (not persuade) surgical resolution.

Determining a single structure within the spine as the source of pain can prove to be a diagnostic challenge due to the complexity and interrelation of the structures involved in the spinal column. Additionally, distinct anatomical structures can clinically present with similar symptom patterns and no physical examination finding can be specifically attributed to any one structure. To further complicate this dilemma, multiple structural abnormalities noted on imaging studies are frequently found to be painless.[1] The inability of health care providers to accurately diagnose the exact etiology of chronic low back pain is an ongoing source of frustration for patients as well as physicians. Pain medicine's gravitation towards correctly identifying a specific structural source of pain is a result of the high rate of failure of symptomatic control when patients undergo decompressive surgery for back pain without neurologic deterioration. Most patients are willing to exhaust all measures necessary to avoid surgery, and pain clinicians assume that indisputably identifying a source may impact surgical outcomes. Therefore, the assumption that a selective nerve root block (SNRB) delivers medication to a specific target accurately identifies the source and provides information that could affect or predict their surgical outcome seems reasonable and somewhat logical.

Multiple factors pertaining to this injection have been under scrutiny in the current literature. Even the name of the procedure has been the topic of ongoing nomenclature debate by purists. Transforaminal, paraforaminal, nerve root block, SNRB, and periradicular injections are some of the terms used to describe what a number of practitioners consider to be the same procedure.[2] Some say that the basic difference between a transforaminal injection and a SNRB is probably just semantic and may be technically limited to only a few millimeters of the final needle tip position (in the medial to lateral plane). In a transforaminal injection, considered by some to be more of a therapeutic procedure, the injectate is delivered more medially and therefore more proximally to the anterior epidural space. It is spread on to adjacent nerves inside the spinal canal and is considered to limit the validity due to the lack of control of the spread of the injectate (Figure 1). By contrast, SNRBs could possibly permit greater specificity. The fact that this injection is extraforaminal and that the delivery of drugs would be distal

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Figure 1 Lumbar transforaminal.

to the convergence of the ventral and dorsal rami, a more confined spread could be achieved and therefore have improved legitimacy as a diagnostic tool (Figure 2). Despite the fact that Current Procedural Terminology coding recognizes these injections as "transforaminal", for the purpose of this review, SNRB will be used as the chosen nomenclature.

The principle behind diagnostic nerve root injections forms the premise that the local anesthetic used in these injections will act only at the desired site and therefore provides the practitioner an indisputable etiology of the pain-generating source. The lack of clinical-radiological correlation, the presence of multilevel spine disease, the conflicting correspondence between electromyography and clinical findings, as well as the presence of atypical pain patterns have prompted pain clinicians to collaborate in searching for a definite etiology of pain to limit spine interventions, and possibly, improve surgical outcomes.

This article attempts to explore the role of SNRBs in identifying the cause of pain and clarify their diagnostic validity when they are used as tools to predict surgical outcomes.

History

It is widely accepted that if a particular structure is specifically numbed and there is pain relief after the administration of a local anesthetic, then that structure is the generator of pain. Steindler and Luck[3] were the first clinicians to introduce this concept when they stated that no definitive diagnosis could be made based solely on clinical presentation. In 1938, they suggested that a valid causal relationship between a specific structure and painful symptoms could only be made if contact with a needle aggravated pain and elicited radiation, if infiltration of local anesthetic eliminated pain and suppressed radiation, and if positive leg signs disappeared after local anesthetic infiltration. It was MacNab in 1971 who granted value to SNRBs as an evaluation tool for patients with inconclusive clinical presentations and nonconcordant imaging studies.[4] Since then, these blocks have been used ubiquitously as a diagnostic tool for radicular pain despite the paucity of evidence.

A patient's subjective report of 50% pain relief or greater after local anesthetic infiltration is what currently exclusively defines a technically successful diagnostic or therapeutic nerve root injection.[5] This exact percentage of relief is not necessarily shared by all studies on pharmacologic management of acute or chronic pain.[6] The criterion of success is not particularly rigorous since it is based on a patient's subjective interpretation; hence, the predictability of the information provided by the diagnostic injection has to be modest at best.[7] The lack of an indisputable measurable objective finding leads to an unacceptable number of false-positive results. In view of the incidence of intra- and postoperative complications associated with spine surgery, especially failed back surgery syndrome, low specificity of a preoperative diagnostic test should be regarded as inadmissible.[8] Pain relief cannot be either proven or refuted, and therefore, it should not be used as the exclusive tool to measure the effectiveness of the block given the uncertainty and unreliability of the response. Some authors suggest, though, that instead of considering the information obtained after a nerve block as imprecise, the result should be viewed in light of all other diagnostic tests in medicine, few of which are medically considered as "absolute."[9] The combination of clinical findings (history and physical examination), radiological evidence, and interventional diagnostic procedural information is what should be weighed together

Figure 2 Cervical selective nerve root block.

to reach the final assessment of the causative source. The lack of response to blocks suggests either lack of delivery of the medication to the desired target, severe at-level pathology that prohibits the injectate from reaching the desired target, or inadequately blocking pain signals possibly generated more centrally. A technically successful selective nerve root block that does not provide post procedural pain relief gives strong and truly valuable negative prognostic information (negative-predictive value). Thus, since the lack of pain relief post block correlates with poor surgical outcome, the information obtained should be used to explore other forms of minimally invasive treatment modalities (ie, spinal cord stimulation) and defer surgery as a "permanent fix."[10]

When a SNRB is used as a part of a screening process to pursue additional minimally invasive treatments with low morbidity and mortality risks (ie, steroid injections, spinal cord stimulation), the relevance of exact discriminatory answers is low, probably justifying the performance of the "diagnostic" block. However, if a single positive response to a nerve root injection is to be used as the unique tool, with no other comparative controls, to determine the candidacy of a patient to have a decompressive surgery performed, the validity of the information obtained from an uncontrolled block and the inherent risks of the surgical procedure should be cautiously and prudently weighed. If SNRBs are performed in patients with focal back or neck pain without radicular symptoms, the diagnostic value of the injection is limited. Resolution of axial pain after these injections may be secondary to the effects of the local anesthetic on the sinuvertebral nerve, which provides innervation to various midline structures at multiple contiguous levels.

Several factors, including patient selection, inappropriate or insufficient interventional pain management training, technical differences (needle position), procedural technique (degrees of C-arm angulation), proper use of technology (with accurate interpretation of contrast dye spread), total volume of injectate, expected degree of pain relief (50%, 70%, 100%), correlation of pain relief with dermatomal sensory block, dermatomal overlap, and placebo responses, may all affect the outcome of SNRBs and therefore be sources for bias.

Dermatomal anatomy

Unlike the static diagram routinely taught, the dermatomal chart is a dynamic map and dermatomal overlap is frequent; therefore, a clear understanding may help improve the way to clinically identify a symptomatic spinal level.[11] Wolff et al determined that, after a low volume selective nerve root injection (0.5 mL), the resulting hypoesthesia could not be specifically confined to one exclusive dermatome. Therefore, confirmation of an adequately performed segmental nerve block by post block physical examination should not only be determined by the expected coexistence of hypoesthesia, elicited paresthesias, and pain relief in the examined dermatome, but instead the area surveyed should include or overlap with neighboring dermatomes. Bogduk has proposed that if an asymptomatic nerve is anesthetized, pain will not be reduced and resulting hypoesthesia will not overlap the typical area in which the patient experiences symptoms.[12] He additionally introduced the concept of time-dependent analgesia, meaning that pain relief must be consistent with the duration of the local anesthetic used (short- vs long-acting).[13] This probably introduces the first step to outcome control.

Volume of injection

The volume of injectate has been the subject of much controversy and is an important factor to weigh in as a source of bias. The precise volume required to exclusively anesthetize the desired structure (without contiguous spread) and the exact amount necessary to improve the specificity of these diagnostic blocks has not been well studied. It is acknowledged that one of the "benefits" of the SNRB technique is to "concentrate" the injectate over one individual nerve. However, the lack of standardization permits practitioners to individually choose the volume, small or large (0.5-3 mL having been reported), understanding that with the higher volumes injected, the greater probability of extravasation or "spillover." Theoretically, small volumes may confine the spread but be insufficient to block all pain-carrying fibers. High volumes, by contrast, may result in unintentional blockade of other adjacent nerve roots via contiguous spread of the injectate into the epidural space (spinal canal) similar to what occurs when an interlaminar technique is used, therefore, having equivocal and unreliable results. Castro et al randomized 94 patients to undergo a computed tomographic (CT)-guided L4 SNRB using 0.5, 1, or 2 mL of contrast dye. Epidural dye spread was noted in all the groups (48%, 67%, and 75%, respectively). Adjacent nerve root spread (24%, 27%, and 33%) and psoas muscle spread (12%, 33%, and 68%) were additionally seen as well.[14] These results question the validity and specificity of SNRBs even when low volumes are used.

Anderberg et al unveiled a study of 20 patients who presented with clinical and radiological (magnetic resonance imaging) single-level documented cervical radiculopathy and were secondarily confirmed by a diagnostic SNRB with 1 mL mepivacaine. Eighteen of these patients were ultimately treated with surgery, noting that arm pain was relieved in 86% of patients and neck pain was relieved in 65% of them after surgery. He concluded that the addition of diagnostic SNRBs to the combination of clinical findings and imaging studies was valuable in preparing for surgical resolution.[15] In a subsequent study, this same author used multislice CT to evaluate contrast dye spread patterns after cervical SNRBs. Volumes of 0.6, 1.1, and 1.7 mL were used. In this study, only the 0.6 mL volume was deemed to be appropriate for diagnostic investigations as the other 2 groups showed extensive flow to adjacent nerve roots via the intraspinal space.[16]

A further investigation by Furman et al determined that when volumes of 0.5 mL, 1.0 mL, 1.5 mL, and 2.5 mL of contrast are used for lumbar transforaminal injections, 30%, 67%, 87%, and 90%, respectively, are not "selective" for the specified root level, suggesting that only volumes less than 0.5 mL should be used when these blocks are performed for level identification purposes.[17] Injection volume and dye spread pattern were also studied by Vasilliev, who determined that the use of 1 mL of contrast under fluoroscopy does not guarantee selective spread around the intended lumbar nerve root but instead spreads to adjacent, more medially located nerve roots in 46% at L4 (L5 spread) and 57% at L5 (S1 spread).[18]

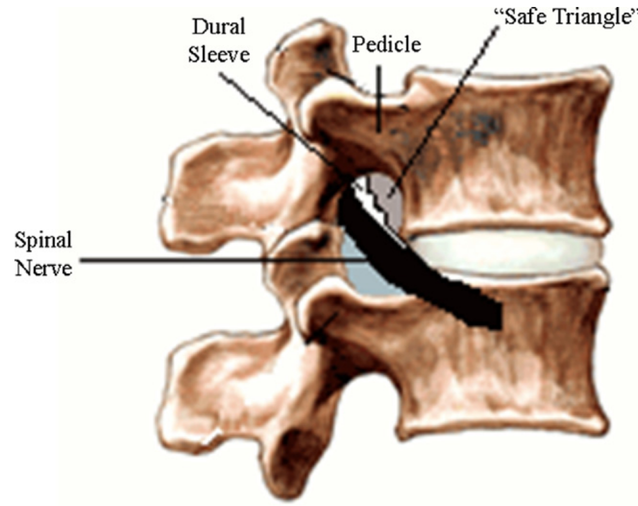

Figure 3 Bogduk's "safe triangle." This region allows needle placement without encountering neural elements or entering the dural sleeve.

Needle position and anatomical variations

Positioning of the needle with respect to the intervertebral foramen, which is usually achieved by directing the needle under CT or, more often, under fluoroscopy is also critical in obtaining a reliable diagnostic injection. Likely, the position of the needle in the foramen and the distance from the needle tip to the target nerve root has an important role on the spread of the injectate. Fluoroscopically, in the lumbar spine, the ideal place for the needle tip in a lumbar region has been at the 6 o'clock position of the pedicle on the anteroposterior and in the anterior aspect of the foramen on the lateral view. This positioning leads to the needle tip being placed in the "safe triangle" described by Bogduk; a space located in the anterior-superior aspect of the neural foramen that is bounded superiorly by the pedicle, inferomedially by the exiting nerve and laterally by the margin of the neural foramen. The relative safety of this region addresses the minimization of risk of neural and dural puncture but not of undesired accidental vascular puncture given the extreme anatomic variability of the position of blood vessels within the intervertebral foramen (Figure 3). A recent review of thoracolumbar spinal angiograms performed at the Mayo Clinic from 1998 to 2008 determined that the artery of Adamkewicz was overwhelmingly located in the superior half of the neural foramen in 97% of cases.[19] Based on this anatomical fact, some authors have proposed that the safest place for the needle tip to encounter, contrary to traditional idea, is in the inferior aspect of the foramen, remaining posterior to the exiting nerve root.[20-22]

In cervical nerve root blocks, correct needle placement, using an oblique entry, warrants the needle contacting the posterior wall of the foramen, which corresponds to the anterior aspect of the superior articular process of the desired level, followed by minimal subsequent advancement, directing the needle toward the middle third of the neural foramen. In the anteroposterior view, the needle should be positioned in the midpedicular line but never beyond the lateral border of the uncinate process.[12]

The technical ease of SNRBs coupled with the relative safety of these procedures lures many physicians into routinely performing these injections. However, a growing body of case reports with catastrophic complications attributed to this procedure warns of the lack of awareness by some practitioners of the structures that may be encountered during the execution of this technique.[23] Therefore, a brief review of the anatomy of the neural foramen seems appropriate when reviewing the topic of these injections.

The anatomy of the intervertebral foramen is unique in that its boundaries are set by joints, anteriorly by the "interbody" joint[24] and posteriorly by the zygapophysial joints. Therefore, the neural foramina can be considered osseous holes through which neurovascular structures pass. The lumbar neural foramen averages 18-22 mm in height by 7-12 mm in width.

The 3-dimensional or spatial understanding of the location and direction of blood vessels within the foramina is paramount for prevention of neurological and vascular spinal cord damage. The dorsal and ventral roots are encased in a dural sheath and are surrounded by cerebral spinal fluid as they leave the dural sac approximately one level above the intended foramina to be exited prior to expanding into the dorsal root ganglion.[25] The dura continues on as perineurium. The epineurium is then a continuation of the epidural connective tissue and surrounds the nerve, forming a sheath that retrogradely connects to the epidural space.[26] The nerve root exits the foramen from the posterior aspect of the neural foramen.

The spinal cord's vascular supply depends on a single anterior and a pair of posterior spinal medullary arteries that run vertically across its main axis (Figure 4). They stem from the abdominal and thoracic aorta via cervical, intercostal, and lumbar branches. The anterior spinal artery is responsible for the anterior two thirds of the vascular supply of the spinal cord. A large supplemental portion of the irrigation, however, comes from radicular arteries that anas-

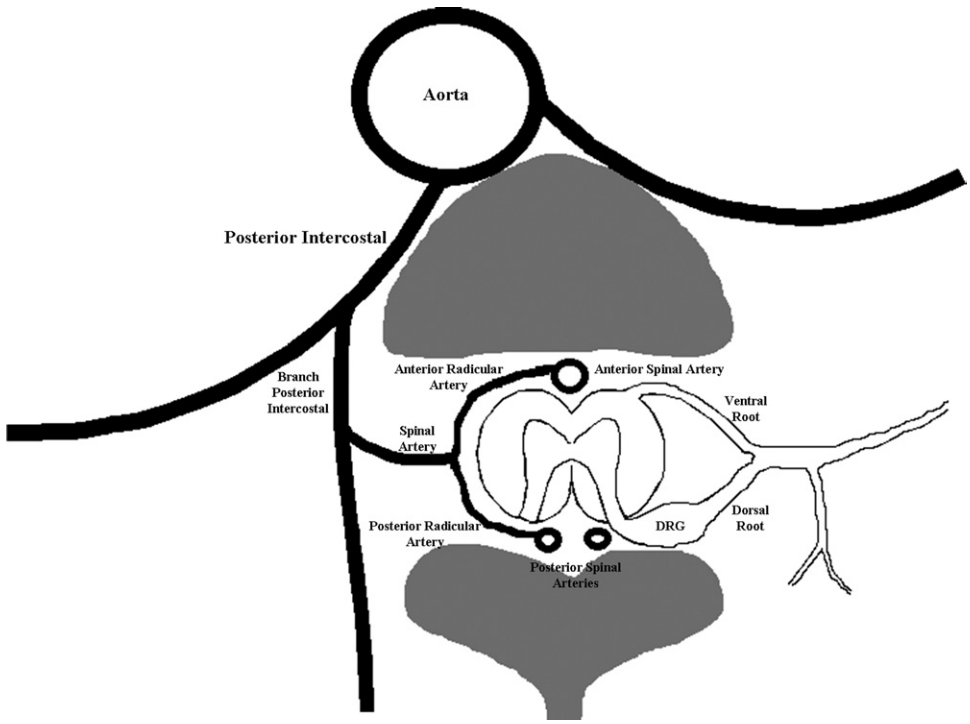

Figure 4 Spinal cord blood supply.

tomose with the medullary arteries. Most radicular arteries are small and supply only the nerve roots; however, some radicular arteries are large vessels that not only supply the nerve roots but also anastomose with the spinal arteries, thus providing the additional extrinsic blood supply to the spinal cord.

In the cervical region, blood supply to the spinal cord mainly stems from the vertebral arteries and radiculomedullary arteries. Radicular arteries result from the anastomosis of branches of the vertebral arteries, ascending cervical arteries, superior intercostal arteries, and the deep cervical arteries. Large cervical radicular arteries are more frequently seen at lower cervical levels.[27] The radicular arteries most likely enter the foramina inferior to the exiting nerve root and course a tortuous path along the anterior and inferior aspect of the nerve. They then go on to penetrate the dura to join the spinal arteries, typically traversing in the anterior aspect of the foramen. This is the rationale behind the recommendation of the preferred location for the needle tip: posterior to the exiting nerve root.[28] However, the posterior zone is not by any means avascular, noting the variable presence in this region of branches from the deep cervical and ascending cervical arteries. Huntoon demonstrated that in some cadavers the deep cervical artery usually gave branches only to the roots of the brachial plexus; however, in some, they formed large spinal branches that entered the posterior aspect of the external neural foraminal opening.[29] Due to the great anatomical variability seen in the positioning of vessels within the foramen, once negative aspiration of blood has been confirmed, injection of contrast dye should always take place under digital subtraction.[30]

In the lumbar region, the main vascular supply to the spinal cord arises from spinal branches of the aorta that give birth to the greatest radicular artery or artery of Adamkewicz. This large radicular artery typically enters the spinal canal on the left (80%) between the seventh thoracic and first lumbar level; however, in 1% of patients it has been reported as low as L2, and in even fewer cases at even lower levels.[31] The artery usually enters in the superior or middle portion of the foramen, slightly ventral and superolateral to the dorsal root ganglion.[32] Segmental radicular arteries can occasionally be substantially large and contribute significantly to the anterior spinal artery. Radicular arteries enter the spinal canal via the intervertebral foramen accompanying the dorsal and ventral roots.

Block technique

The growing number of catastrophic reports of complications after SNRBs may also play a role in the unfavorable results. Practitioners may want to "do" something for patients and are willing to take the risks of the procedure at the expense of obtaining negative results because of a sloppy technique. Kolsi et al pointed out that a portion of the success achieved by transforaminal steroid injections may well depend on the technical abilities or skill of the interventionalists.[33]

In a recent study, Wolff et al addressed the question of block technique as a factor that could increase the likelihood of epidural spread and therefore decrease the specificity of the procedure. In addition to fluoroscopic guidance for anatomic placement, he used electrostimulation as a technical adjuvant to correctly position the needle tip in close vicinity to the segmental dorsal root or dorsal root ganglion using a small volume (0.5 mL) of local anesthetic for the block. He determined that the risk of lumbar epidural spread is greater with more medial needle positioning within the intervertebral foramen. Due to the variability in anatomic positions of the dorsal root ganglion, electrostimulation is necessary to be added to fluoroscopy to correctly place the needle position in SNRB.[34]

Validity of selective nerve root blocks

In 1992, Nachemson, after a thorough review of the literature, concluded that diagnostic blocks provided important prognostic information about surgical outcomes.[35] Several authors in the forthcoming years continued to attach sensitivity, specificity, and validity to spinal nerve blocks, which popularized their frequent use for diagnostic purposes. However, it would seem that the acceptance of these blocks as diagnostic tools has been mainly based on face value, as very few studies have to date been conducted under controlled circumstances. Therefore the idea that pain relief obtained after selective nerve root injections under fluoroscopy using contrast dye with spread suggestive of nerve root outline somehow has been wrongfully assumed as to not have false positive effects.

The validity of SNRBs should be dependent on these injections being target specific as well as controlled. Sensitivity can be defined as the ability of a test to predict positive results based on a "gold standard." Specificity is the ability to predict negative results. When the endpoint of a test is pain relief, a completely subjective result, there cannot be a truly reliable gold standard as there is no comparator or objective measure possible but the same patient's report. Several reviews of the literature have assigned SNRBs sensitivity and specificity ranging between 45% and 100%.[36-38]

Dooley et al showed that patients who did not successfully respond to SNRBs were less likely to have a favorable surgical outcome and determined these injections to be good prognostic tools to determine the level where surgery should be performed. In their study, they found that the correlation of concordant pain reproduction and pain relief after local anesthetic selective nerve root infiltration has both strong positive- as well as negative-predictive values to determine the level of pathology and surgical outcome. The study was conducted in 46 patients with documented intramural adhesions (n = 7), bony entrapment (n = 17), or herniated disk (n = 8) as causes of radicular pain. All patients were found to have reproduction of pain during injection, followed by pain relief after the nerve block. At-level pathology was surgically confirmed in all but one and successful surgical outcomes (relief of radicular pain post decompression) were noted in 71%, 82%, and 100% of cases, respectively.[39]

A pivotal moment in diagnostic block validity came about in 1996 when North et al[40] published a study on 33 patients with clinical and radiological evidence of lumbosacral radiculopathy and performed a series of blocks in random order (L5 or S1 nerve root, L4-SA medial branch, sciatic nerve, and subcutaneous) using 3 mL 0.5% bupivacaine in each. Although significant statistical difference in pain relief was found among the patients who received the active blocks (medial branch block, sciatic nerve, and root block) compared to those patients in the control procedure group (subcutaneous injection), some relief was noted with the latter as well. According to the results of this study, the authors conclude that false positives are common and specificity of nerve root blocks is low. Isolated, uncontrolled "diagnostic" blocks are therefore nonspecific in localizing the putative source of pain. However, the failure of a properly performed diagnostic SNRB to eliminate pain could predict the failure of a surgical procedure, thus granting these blocks strong negative predictive value.

Haueisen et al was one of the first to report good surgical outcomes in 55 patients who underwent surgical exploration of a level identified with SNRBs. He determined that SNRBs were more accurate in identifying the level of surgical pathology than myelography or electromyography (93% vs 24% and 38%, respectively). At 20 months post surgery, 73% improvement was noted. Therefore, he reached the conclusion that SNRBs were helpful in making a correct diagnosis.[41]

Derby et al reported on 78 patients who underwent SNRBs before going on to surgery. Patients who had experienced radicular symptoms for less than a year reported good surgical outcomes (89%) regardless of their response to selective nerve root steroid injections. Eighty-five percent of the patients who had good responses to selective nerve root steroid injections had good surgical outcomes. However, in 95% of patients who had pain for more than a year and had a negative response to the SNRB, surgical outcome was poor.[42] It seems, then, according to the authors' suggestion, that prolonged compromise of the nerve root may cause changes in the nerve that are not reversible by decompression.

In a prospective study by Stanley et al of 50 patients with radicular pain who underwent radiculography, CT, and SNRB as presurgical workups, concordant reproduction of pain during selective nerve root injection was seen in only 20 patients followed by analgesia after local anesthetic infiltration. Of these 20 patients, one had complete long-term pain relief and therefore did not proceed to surgery. The remaining 19 were surgically treated. Of these, correct nerve root level identification by SNRBs was surgically confirmed in 18 patients, comparing favorably to predictive values of CT (14 patients) and radiculography (12 patients).[43]

Schutz et al published his retrospective study on 23 patients who underwent SNRB. In 15 of them, decompressive surgery was performed at the level established by the injection. The level of pathology, determined by the SNRB, was surgically confirmed in 87% of them.[44] In another retrospective study published by Krempen and Smith, 22 patients underwent SNRBs for sciatica. Twenty-one of these patients had previous spine laminectomies or laminectomies with fusions. The level of injection was determined by clinical examination and diagnostic studies (myelograms, discograms, and electromyography). Two avoided surgery after reporting 100% pain relief after the injection; 4 had a negative block, while the remaining 16 who underwent surgery had pain relief of varying degrees (follow-up for 8 to months postoperatively).[45]

Although the supportive literature on SNRBs as diagnostic tools for equivocal radicular pain is scarce and proof is limited, there is moderate[46] to strong[47] evidence that these injections may improve the ability to accurately discern the appropriate causative level when symptoms conflict with imaging studies. They, therefore, may be considered as effective preoperative tests to evaluate patients with multilevel spinal pathology. Their positive predictive value is low, but their negative predictive value is high; therefore, they could be used as tools to possibly limit the laboriousness or extent of the surgical procedure or as information to dissuade surgical intervention.[48]

Conclusions

The answer to the question of validity of the results of SNRBs as predictors of surgical outcome is one that undoubtedly needs further extensive investigation. To date, the rationale behind subjecting patients to these procedures lays much on assumptions rather than on statistical evidence. The paucity of prospective randomized controlled trials is evident and therefore is a query that needs to be specifically addressed. The need to address this subject relies on several factors. First, a reliable response to a SNRB could accurately determine the source and level of pathology to be treated.

Second, a negative response to a SNRB could potentially eliminate unwarranted spinal surgeries and possibly permit other less invasive therapeutic modalities, both of which would impact health care costs.

Additional high-quality investigations need to be carried out to answer the question of whether these injections are indicated as diagnostic tools to identify patients that may positively respond to surgical decompression for the treatment of radicular pain. Standardization in the performance of these procedures needs to be addressed as well to guarantee the adequacy of the technical execution of these blocks.

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