

Systematic Review

e Diagnostic Utility of Selective Nerve Root Blocks in the Diagnosis of Lumbosacral Radicular Pain: Systematic Review and Update of Current Evidence

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Background: Lumbosacral selective nerve root blocks and/or transforaminal epidural injections are used for diagnosis and treatment of different disorders causing low back and lower extremity pain. A clear consensus on the use of selective nerve root injections as a diagnostic tool does not currently exist. Additionally, the validity of this procedure as a diagnostic tool is not clear.

Objective: To evaluate and update the accuracy of selective nerve root injections in diagnosing lumbar spinal disorders.

Study Design: A systematic review of selective nerve root blocks for the diagnosis of low back and lower extremity pain.

Methods: Methodological quality assessment of included studies was performed using the Quality Appraisal of Reliability Studies (QAREL) checklist. Only diagnostic accuracy studies meeting at least 50% of the designated inclusion criteria were utilized for analysis. Studies scoring less than 50% are presented descriptively and analyzed critically.

The level of evidence was classified as good, fair, or limited or poor based on the quality of evidence grading scale developed by the United States Preventive Services Task Force (USPSTF).

Data sources included relevant literature identified through searches of PubMed and EMBASE from 1966 to September 2012, and manual searches of the bibliographies of known primary and review articles.

Outcome Measures: In this review, we evaluated studies in which controlled local anesthetic blocks were performed using at least 50% pain relief as the reference standard.

Results: There is limited evidence for the accuracy of selective nerve root injections as a diagnostic tool for lumbosacral disorders. There is limited evidence for their use in the preoperative evaluation of patients with negative or inconclusive imaging studies.

Limitations: The limitations of this systematic review include a paucity of literature, variations in technique, and variable criterion standards for the diagnosis of lumbar radicular pain.

Conclusions: There is limited evidence for selective nerve root injections as a diagnostic tool in evaluating low back pain with radicular features. However, their role needs to be further clarified by additional research and consensus.

Key words: Low back pain, lower extremity pain, selective nerve root block, transforaminal epidural injection, discogenic pain, radiculitis, sciatica radiculopathy, nerve root pain

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Lumbar discectomy is the most common surgical procedure performed in the United States for patients having back and leg symptoms (1). The up to 15-fold variation in regional discectomy rates in the United States, and dramatically lower rates internationally, raise questions regarding the appropriateness of some of these surgeries (2,3). The Spine Patient Outcomes Research Trial (SPORT) (1), which enrolled patients from 13 multidisciplinary spine clinics in 11 U.S. states from 2000 to 2004 included 501 surgical candidates with radiologically-confirmed lumbar intervertebral disc herniation and persistent signs and symptoms for at least 6 weeks. This study showed significant improvement in all parameters at long-term follow-up. A subgroup analysis of these patients showed a lack of improvement in patients undergoing epidural steroid injections, though patients allocated to surgery who did receive epidural steroid injections were more likely to crossover to non-surgical treatment (4). However, this analysis was rife with methodological flaws and conflicts with numerous controlled studies and systematic reviews that have demonstrated the effectiveness of epidural injections (5-41). One of the challenges in evaluating these studies is that none have rigorously addressed the role of selective nerve root blocks in selecting patients for surgical interventions, specifically in the lumbar spine. It is well-documented that lumbar disc herniation is often seen on imaging studies in the absence of symptoms (42-50), and can regress over time without surgery (44-46), yet the role of selective nerve root blocks in confirming radicular pain has not been systematically evaluated (50-62).

In view of the fact that abnormalities found on imaging studies are frequently painless, pain originating from the spine can be difficult to diagnose, and the particular structure(s) responsible for symptoms can be challenging to isolate (42,43,48-62). Excluding fractures, disorders of the spine that can produce pain may be categorized as compressive, inflammatory, degenerative, and/or multifactorial.

In a recent editorial, Shah (62) outlined the problems with diagnostic selective nerve root blocks. He argued that, whereas many practitioners consider the premise behind selective nerve blocks to be valid "prima facie" (self-evident), rendering any hypothesis immune to challenge damages its scientific integrity (62-64). Despite the untenability of this philosophy, (62), the value and validity of diagnostic nerve blocks continue to be extensively described and debated (65-75). Shah (62) criticized the current debate on the grounds that it

focuses on diagnostic accuracy, technique optimization and patient selection, contending that selective nerve root blocks cannot be used to diagnose pain. Nevertheless, substantial literature has been published on the utility of diagnostic selective nerve root blocks, even without the procedure being validated (51,62,76-88).

For a structure to be painful, it must have a nerve supply (58), be susceptible to disease or injury, and a connection must be established between the injury or disease and a clinical pain condition. Methods have been developed to test painful structures using fluoroscopically (X-ray) guided injections of local anesthetics. If a structure is selectively anesthetized and the individual describes pain relief for the duration of action of the anesthetic, that structure is suspected to be the source of pain (58). For compressive and inflammatory disorders of spinal nerve roots, the likely area for the presence of pathology is within the bony channel created between adjacent vertebrae at the neural foramen (53).

The International Association for the Study of Pain (IASP) (54) defines radicular pain as pain perceived as arising in a limb or trunk that is caused by ectopic activation of nociceptive afferent fibers in a spinal nerve or its root(s), or related neuropathic mechanisms. The IASP defines lumbar radiculopathy as the objective loss of sensory and/or motor function as a result of a connection block in the axons of a spinal nerve or its root(s). The term lumbar radiculitis implies that the inflammatory process is solely responsible for the causation of radicular signs and symptoms, which is often incorrect. Hence, the term "lumbar radicular syndrome" may be most accurate in that it correctly suggests a constellation of clinical signs and symptoms of variable etiologies secondary to pathology or dysfunction of nerve root(s) or dorsal root ganglia. Although chronic low back pain is highly prevalent (50,54), the prevalence of radicular pain is somewhat lower, ranging from 17% to a little over 50% using validated instruments (89-93). In 2 studies using strict criteria, the lifetime prevalence of radiculopathy due to a herniated lumbar disc was estimated to be 4% in females and 5% in males (57,94). The 2 most common causes of neuropathic spinal pain are lateral recess/ foraminal stenosis and herniated disc (59-61). In some cases, both etiologies may be present, as well as central spinal stenosis. Apart from mechanical compression, various biochemical, toxic factors have been identified as a cause of radiculitis. Schoenfeld et al (56) characterized the incidence and risk factors for the development of lumbar radiculopathy based on the US

Department of Defense Medical Epidemiology Database for the years 2000 to 2009. They estimated the overall incidence of lumbar radiculopathy to be 4.86 per 1,000 person-years. They also found that service members 30 years of age and older had a greater than 3-fold risk of developing lumbar radiculopathy when compared to individuals less than 20 years old.

These distinctions illustrate that radiculopathy is not synonymous with radicular pain or nerve root pain. The terms "radicular pain" and "nerve root pain" specifically apply to a single symptom – pain – that arises from one or more spinal nerve roots (95). The accurate diagnosis of spinal pain is important in helping clinicians make individual treatment decisions (65-74,96-101). It is well-known that obtaining a precise diagnosis can often be elusive. Many authors have attempted to investigate improved methods of classifying or diagnosing patients with spine-related pain. It is widely held that accurate diagnosis is derived from a combination of history taking, physical examination, and radiological assessment. However, the evidence shows that these assessments may not be accurate, especially with regard to specificity (47,50-74,102). One of the impediments that can hinder accurate diagnosis is that nerve root pain does not necessarily follow along a specific dermatome pattern or may involve multiple dermatomes (55,103-108). In an experimental study of 25 patients with radicular pain in the lower extremity, Bove et al (106) reported that all patients reported the pain as deep, rather than on the skin, which questions the value of classic dermatomal maps. In a study involving the evaluation of 30 patients with cervical radiculopathy and multi-level spinal degeneration using selective nerve root blocks, Anderberg et al (107) found only a 28% correlation between the dermatomal distribution of neurological deficits/radicular pain and the putative symptomatic nerve root. In an assessment of 226 nerve roots in 169 patients, Murphy et al (55) found that pain related to cervical nerve roots was non-dermatomal in over two-thirds (69.7%) of cases and was non-dermatomal in just under two-thirds (64.1%) of cases in the lumbar spine. The nerve roots with the highest degree of sensitivity and specificity were C4 in the cervical spine (sensitivity 60%, specificity 72%) and S1 in the lumbosacral spine (sensitivity 65%, specificity 80%). The authors concluded that, in most cases, nerve root pain does not follow a specific dermatome pattern, and that the distribution of pain is not generally a useful historical factor in the diagnosis of radicular pain, with the possible exception of S1. In a retrospective study evaluating adjacent

double nerve root blocks in 132 patients with unilateral radiculopathy, Bartynski et al (108) demonstrated adjacent double-level replication of the patient's familiar pain in 62% of patients, single root replication in 37 (28%), and no response in 13 or 10%. The authors concluded that adjacent double-level contributions to lumbar radiculopathy are common, and that clinical imaging clues should be assessed to ensure an optimum response to nerve root block/steroid injection (108).

Spinal injections have generated considerable interest in the medical community, particularly epidural steroid injections in which precision placement has been facilitated by the use of radiological imaging (5-40). The indications for epidural steroid injections include radicular pain, spinal stenosis, and possibly discogenic pain (5-40). However, there is no consistent method for using foraminal and nerve root injections as diagnostic tools. Controversy surrounds even the nomenclature itself (51,62,109-121). Manchikanti (118) and Manchikanti and Singh (121) noted that the terminology describing transforaminal injections has varied from nerve root injections to selective nerve root blocks, selective nerve root sleeve injections, selective epidurals, selective spinal nerve blocks, selective ventral ramus blocks, and periradicular injections. Bogduk (75) labeled the procedure as a lumbar nerve block, in which an aliquot of local anesthetic is delivered onto lumbar spinal nerve (or the S1 spinal nerve) in order to selectively anesthetize the nerve and its roots.

Gajraj (76) noted that "...to be selective, a nerve root block should be performed extraforaminally, distal to the division of the ventral and dorsal rami; otherwise the dorsal rami and all its innervated structures will also be anesthetized...it has therefore been suggested that the therapeutic procedure be referred as a 'transforaminal epidural steroid injection' and that the diagnostic procedure be referred to as a 'selective spinal block' or 'selective ventral ramus block.'" Datta and Pai (77) noted that the term "transforaminal" is a misnomer and gives the false impression that the needle actually traverses the foramen, when in actuality it is positioned paraforaminally. They suggested that the term "selective nerve root block" be rephrased as a "paraforaminal injection" because no preferential distribution of the injected medication extends to the ventral ramus. Other suggested nomenclature includes the terms "periradicular," "nerve root infiltration," "transforaminal selective nerve root block," "segmental nerve root block," and "lumbar nerve block" (51,75-81,117,118,120).

Most recently, Shah (62) postulated that selective nerve root blocks, as commonly performed and interpreted, are incapable of diagnosing spinal pathology. He asserted that there was no role for diagnostic selective nerve root blocks in the identification of pain generators, and that it be considered only therapeutic.

In the United States, the official term for this procedure is "transforaminal epidural injection." There is no other code to communicate with insurers and the government. Some use anesthetic alone; others use a low steroid dose, arguing that the steroid should not effectuate an immediate response. The volumes used in the injection also vary, with some using a large volume and others using a smaller volume consistent with the amount necessary to reach the lateral recess. Manchikanti and Singh (121) noted that Karppinen et al (112,117,120) injected 0.5–1.0 mL of contrast for diagnostic purposes, followed by a therapeutic injection of methylprednisolone 40 mg, bupivacaine, or isotonic sodium chloride solution in a volume of 2 mL for L4 or L5 blocks, and 3 mL for S1, presumably based on anatomical differences. Higher volumes of injectate may result in more extensive blockade, thereby undermining the specificity. In a 2008 study by Furman et al (82), the authors found that lumbar segmental nerve root blocks cannot be considered diagnostically selective if volumes exceed 0.5 mL. These results are consistent with those of Castro et al (122), who randomized 94 patients to undergo CT-guided L4 nerve root injections using 0.5 mL, 1 mL, or 2 mL of contrast. Epidural spread was noted in 48% of patients in the 0.5 mL group, 67% in the 1 mL group and 75% of subjects injected with 2 mL. Definitive spread to an adjacent nerve root was also common, occurring in 24% of the 0.5 ml group, 27% of the 1 ml group and 33% of injections done with 2 ml of contrast. Spread into the psoas muscle, where the nerve roots converge to become a plexus, was found to occur in 12% of patients in the 0.5 ml group, 33% of subjects who received 1 ml injections, and 68% of people who were injected with 2 ml contrast. In the cervical region, Anderberg et al (123) found that selective nerve blocks performed with 0.6 ml were equally effective, but more sensitive, than those done with 1.1 ml or 1.7 ml of contrast. Specifically, the use of higher volumes increased the likelihood of anesthetizing an adjacent nerve root. Ironically, in later publications, Furman et al (83,84) reported that the volume of contrast needed to reach specific landmarks in lumbar transforaminal epidural injections was 4 mL for lumbar levels and 3 mL for S1. Purists insist on describing selective nerve root block

and transforaminal injections as 2 separate and distinct techniques, though over the years many have used the terms interchangeably. Despite variations in practice, the technique holds promise as a diagnostic tool, but its reliability is unclear (51,85,118).

The value of provocative and analgesic spinal injections was recognized in 1938 by Steindler and Luck (85). In 1971, MacNab (86) demonstrated the value of diagnostic selective nerve root blocks in the preoperative evaluation of patients with negative or inconclusive imaging studies and clinical findings of nerve root irritation. Since then, nerve blocks have been used to diagnose the source of radicular pain when imaging studies suggested possible compression of several nerve roots (51).

Lumbar spinal nerve blocks have been considered to have concept validity because anesthetizing a nerve should theoretically relieve symptoms mediated by that nerve (75). Face validity is established by injecting contrast and local anesthetic under fluoroscopy to delineate the targeted nerve root and ensure that contrast has not spread to other structures. To establish construct validity, selective nerve root blocks must be performed under controlled conditions to avoid false-positive results. Thus far, there are no descriptions of the procedure using these parameters. When selective nerve root blocks are performed, they are often assumed to be specific (i.e. no false-positive results) (75). However, Shah (62) questioned this contention, noting that rendering hypotheses such as this one immune to challenge damages their scientific integrity (62-64).

In 1992, Nachemson (87) analyzed the literature on low back pain and concluded that diagnostic, selective nerve root blocks provided important prognostic information about surgical outcomes. Van Akkerveeken (88) described the sensitivity, specificity, and predictive value for diagnostic, selective nerve root blocks. He also asserted that for a block to be considered positive, it required both symptom reproduction during root stimulation and complete relief of pain following anesthetic infusion. A systematic review from 2007 (51) concluded that there was limited evidence to support the validity of selective nerve root injections as a diagnostic tool for spinal pain, but that the available literature did support selective nerve root injections as a diagnostic test for equivocal radicular pain. The review stated that there was moderate evidence for use in the preoperative evaluation of patients with negative or inconclusive imaging studies. The potential benefits of performing selective nerve root blocks must be balanced against the potential for complications related to se-

lective nerve blocks/transforaminal epidural injections (7,36,47,124-149).

This systematic review was undertaken to update the previous review, and to determine if selective nerve root injections are an effective method for diagnosing spinal disorders (51).

1.0 METHODS

The methodology utilized in this systematic review followed the review process derived from evidence-based systematic reviews and meta-analyses of diagnostic accuracy studies (37,72-74,150-156).

1.1 Criteria for Considering Studies for This Review

1.1.1 Types of Studies

Diagnostic accuracy studies evaluating selective nerve root injections.

1.1.2 Types of Participants

Participants of interest were adults aged at least 18 years with chronic low back and lower extremity pain of at least 6 weeks duration.

Participants must have failed previous pharmacotherapy, exercise therapy, etc., prior to starting diagnostic interventional pain management techniques.

1.1.3 Types of Interventions

The interventions were selective nerve root injections appropriately performed with proper technique under fluoroscopic or CT guidance.

1.1.4 Types of Outcome Measures

- ◆ The primary outcome parameter was concordant pain relief.
- ◆ The secondary outcome measure was the ability to perform previously painful movements without significant pain or complications.
- ◆ At least 2 of the review authors independently, in an unblinded standardized manner, assessed the outcomes measures. Any disagreements between reviewers were resolved by a third author and consensus.

1.2 Literature Search

Searches were performed from the following sources without language restrictions:

1. PubMed from 1966
www.ncbi.nlm.nih.gov/sites/entrez?db=pubmed

2. EMBASE from 1980
www.embase.com/
3. Cochrane Library
www.thecochranelibrary.com/view/0/index.html
4. U.S. National Guideline Clearinghouse (NGC)
www.guideline.gov/
5. Previous systematic reviews and cross references
6. Clinical Trials
clinicaltrials.gov/

The search period was from 1966 through September 2012.

1.3 Search Strategy

The search strategy emphasized lumbar radicular pain and diagnostic selective nerve root injections.

The search terms included: "low back pain", "lumbar radiculitis", "lumbar radicular pain", "selective nerve root injection", "nerve root block", "segmental nerve root block", and "transforaminal epidural injection."

This systematic review focused only on selective nerve root injections performed under fluoroscopic or CT imaging techniques. Interventional techniques performed blindly or using other identification modalities were excluded. All studies describing appropriate outcome evaluations with proper statistical evaluations were reviewed. Reports without appropriate diagnosis, non-systematic reviews, book chapters, and case reports were excluded.

At least 2 of the review authors independently, in an unblinded standardized manner, performed each search. Accuracy was confirmed by a statistician. Searches were combined to obtain a unified search strategy. Any disagreements between reviewers were resolved by a third author and consensus.

1.4 Data Collection and Analysis

The quality of each individual article used in this assessment was based on the Quality Appraisal of Reliability Studies (QAREL) checklist (Table 1) (150). This checklist has been validated and utilized in multiple systematic reviews (151). Each study in the final sample of eligible manuscripts was assessed using a 12-item appraisal checklist designed to assess the quality and applicability of studies. The face validity of these checklists was established by consultation with methodology experts (150) and comparison with quality appraisal checklists used in other systematic reviews examining diagnostic reliability

Table 1. *Quality Appraisal of Diagnostic Reliability (QAREL) checklist.*

Item	Yes	No	Unclear	N/A
1. Was the test evaluated in a spectrum of subjects representative of patients who would normally receive the test in clinical practice?				
2. Was the test performed by examiners representative of those who would normally perform the test in practice?				
3. Were raters blinded to the reference standard for the target disorder being evaluated?				
4. Were raters blinded to the findings of other raters during the study?				
5. Were raters blinded to their own prior outcomes of the test under evaluation?				
6. Were raters blinded to clinical information that may have influenced the test outcome?				
7. Were raters blinded to additional cues, not intended to form part of the diagnostic test procedure?				
8. Was the order in which raters examined subjects varied?				
9. Were appropriate statistical measures of agreement used?				
10. Was the application and interpretation of the test appropriate?				
11. Was the time interval between measurements suitable in relation to the stability of the variable being measured?				
12. If there were dropouts from the study, did these people account for less than 20% of the sample?				
TOTAL				

Lucas N, et al. The development of a quality appraisal tool for studies of diagnostic reliability (QAREL). *J Clin Epidemiol* 2010; 63:854-861 (150).

(157-162). This checklist was also developed in accordance with the Standards for Reporting Studies of Diagnostic Accuracy (STARD) (153), and the Quality Assessment of Diagnostic Accuracy Studies (QUADAS) (154,156) appraisal tools. Studies were not given an overall numeric quality score; instead, each item was considered separately and graded as "yes," "no," "unclear," or "not applicable."

1.4.1 Selection of Studies

- ◆ In an unblinded standardized manner, 2 review authors screened the abstracts of all identified studies against the inclusion criteria.
- ◆ All articles with possible relevance were then retrieved in full text for comprehensive assessment of internal validity, quality, and adherence to inclusion criteria.

1.4.2 Inclusion and Exclusion Criteria

The following were the inclusion and exclusion criteria:

1. Are the patients described in sufficient detail to allow one to decide whether they are comparable to those who are treated in interventional pain management clinical practices?
 - A. Setting – office, hospital, outpatient, inpatient.
 - B. Physician – interventional pain physician, general physician, anesthesiologist, physiatrist,

neurologist, rheumatologist, orthopedic surgeon, neurosurgeon, etc.

- C. Patient characteristics - duration of pain.
- D. Noninterventional techniques or surgical interventions in the past.
2. Is the intervention described in sufficient detail to enable one to apply its use to patients in interventional pain management settings?
 - A. Nature of intervention.
 - B. Frequency of intervention.
 - C. Duration of intervention.
3. Were clinically relevant outcomes measured?
 - A. Proportion of pain relief.
 - B. Disorder/specific disability.
 - C. Functional improvement.
 - D. Allocation of eligible and non-eligible patients to return to work.
 - E. Ability to work.

1.4.3 Clinical Relevance

The clinical relevance of the included studies was evaluated according to 5 questions recommended by the Cochrane Back Review Group (Table 2) (163,164). Each question was scored as positive (+) if the clinical relevance item was met, negative (-) if the item was not met, and unclear (?) if data were not available to answer the question.

Table 2. *Clinical relevance questions.*

	P (+)	N (-)	U (unclear)
A) Are the patients described in detail so that one can decide whether they are comparable to those who are treated in practice?			
B) Are the interventions and treatment settings described in sufficient detail to apply its use in clinical practice?			
C) Were clinically relevant outcomes measured and reported?			
D) Is the size of the effect clinically meaningful?			
E) Do the likely treatment benefits outweigh the potential harms?			

Scoring adapted and modified from Staal JB, et al. Injection therapy for subacute and chronic low-back pain. *Cochrane Database Syst Rev* 2008; 3:CD001824 (164).

Table 3. *Method for grading the overall strength of the evidence for an intervention.*

Grade	Definition
Good	Evidence includes consistent results from well-designed, well-conducted studies in representative populations that directly assess effects on health outcomes (at least 2 consistent, higher-quality RCTs or studies of diagnostic test accuracy).
Fair	Evidence is sufficient to determine effects on health outcomes, but the strength of the evidence is limited by the number, quality, size, or consistency of included studies; generalizability to routine practice; or indirect nature of the evidence on health outcomes (at least one higher-quality trial or study of diagnostic test accuracy of sufficient sample size; 2 or more higher-quality trials or studies of diagnostic test accuracy with some inconsistency; at least 2 consistent, lower-quality trials or studies of diagnostic test accuracy, or multiple consistent observational studies with no significant methodological flaws).
Limited or Poor	Evidence is insufficient to assess effects on health outcomes because of limited number or power of studies, large and unexplained inconsistency between higher-quality trials, important flaws in trial design or conduct, gaps in the chain of evidence, or lack of information on important health outcomes.

Adapted and modified from methods developed by U.S. Preventive Services Task Force (37,166,167).

1.4.4 Methodological Quality or Validity Assessment

Each study was evaluated by at least 2 authors for stated criteria and any disagreements discussed with a third reviewer. Authors with a perceived conflict of interest for any manuscript were recused from reviewing the manuscript.

Only diagnostic accuracy studies meeting at least 50% of applicable inclusion criteria were included for analysis. Studies scoring less than 50% are reported descriptively with critical analysis.

1.4.5 Data Extraction and Management

Two review authors independently, in an unblinded standardized manner, extracted the data from the included studies. Disagreements were resolved by discussion between the 2 reviewers; if no consensus could be reached, a third author was called in to break the impasse.

1.4.6 Assessment of Heterogeneity

Whenever meta-analyses were conducted, the I-squared (I²) index was used to identify heterogeneity

(165). Combined results with I² > 50% were considered substantially heterogenous.

1.4.7 Measurement of Treatment Effect in Data Synthesis (Meta-Analysis)

Data were separately summarized using meta-analysis when at least 5 studies were included.

1.5 Summary Measures

Summary measures included at least 50% pain relief with the capability of performing previously painful movements concordant with the duration of action of local anesthetic.

1.6 Analysis of Evidence

The analysis of the evidence was performed based on United States Preventive Services Task Force (USPSTF) criteria (166), as illustrated in Table 3, which has been utilized by multiple authors (37,65-71,167).

The analysis was conducted using 3 levels of evidence: good, fair, or limited or poor.

At least 2 of the review authors independently, in an unblinded standardized manner, analyzed the

evidence. Any disagreements between reviewers were resolved by a third author and consensus. If there were any conflicts of interest (e.g., authorship), those reviewers were recused from assessment and analysis.

1.7 Outcome of the Studies

Outcomes included the accuracy of selective nerve root injections in the lumbar spine. Based on the above parameters, the reliability of the data derived from each study was assessed.

2.0 RESULTS

Figure 1 shows a flow diagram of study selection. There were 58 studies considered for inclusion (79-85,88,94-121,123,168-188). The list of select excluded studies of diagnostic lumbar nerve root injections is provided in Table 4 (83-87,106,108,123,168,176-181,185).

2.1 Diagnostic Accuracy Studies

Table 5 illustrates the characteristics of studies considered for inclusion. Overall, 19 studies were included (78-82,88,169-175,182,183,185-188). Among these, 3 studies assessed contrast flow selectivity or flow patterns (80-82). One study assessed the distinct sensory effects of selective nerve root block (79). One study assessed the role of adjacent double-nerve root contributions in unilateral lumbar radiculopathy (108). A total of 15 studies evaluated diagnostic accuracy (88,169-175,182-188).

2.2 Clinical Relevance

Among the 19 studies assessed for clinical relevance (78-82,88,169-175,182,183,185-188), all studies met criteria with a score of 3 of 5 or greater. Table 6 illustrates the assessment of clinical relevance.

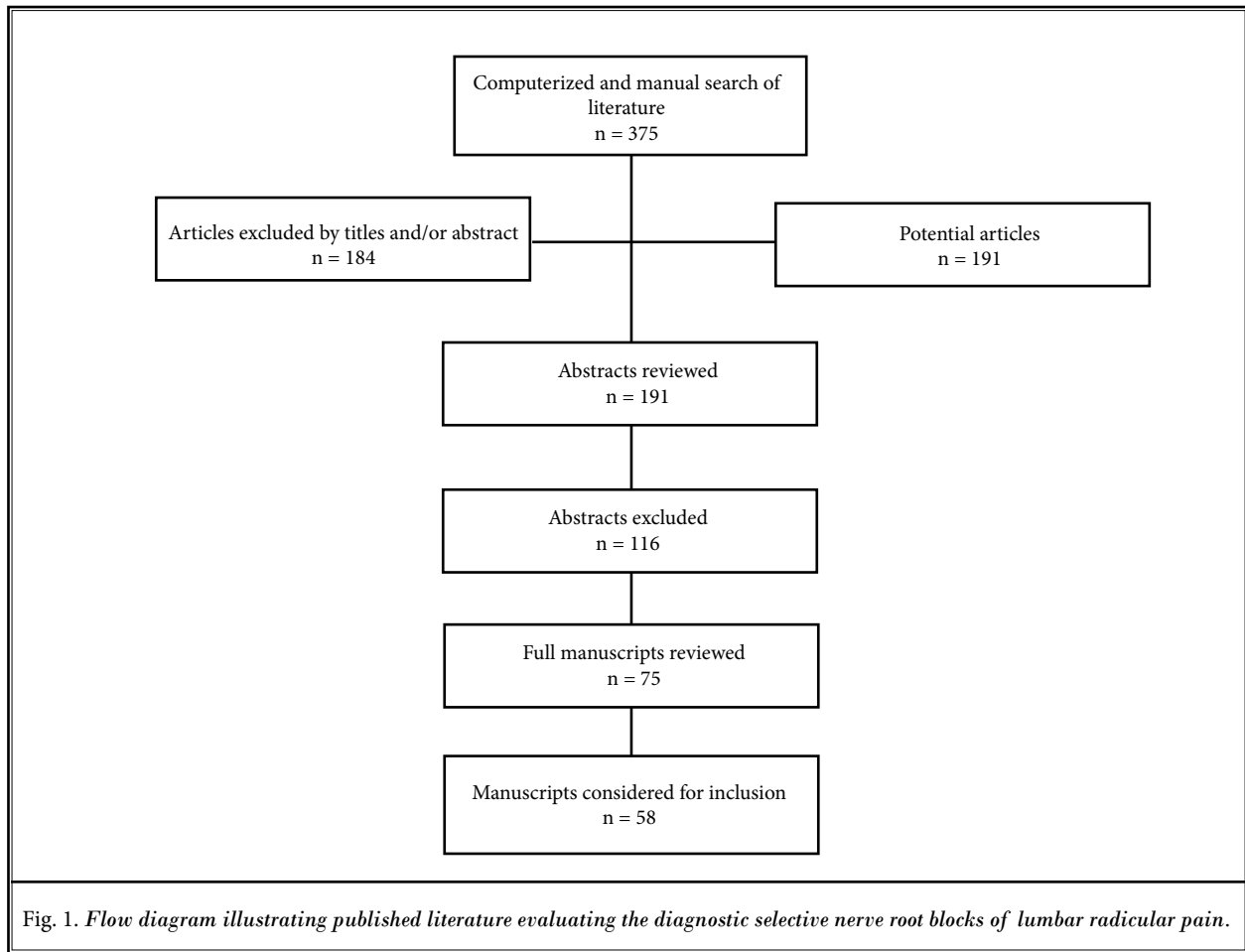


Table 4. List of select excluded studies of diagnostic lumbar nerve root injections.

Manuscript Author(s)	Reason for Exclusion
Furman et al, 2010 (83)	The authors studied injectate volumes needed to reach specific landmarks for lumbar transforaminal epidural injections, showing that 4 mL of contrast was needed.
Furman et al, 2012 (84)	The authors studied injectate volumes needed to reach specific landmarks for S1 transforaminal epidural injections and showed that 3 mL was required to reach the superior aspect of the L5/S1 intervertebral disc.
Steindler & Luck, 1938 (85)	This is the first description of identifying the source of pain using the procaine hydrochloride method described by the authors. Despite its importance, the study does not describe the accuracy of selective nerve root blocks.
MacNab, 1971 (86)	Analyzed the causes of nerve root involvement with negative surgical findings in 68 patients in one of the earliest published studies. However, the accuracy of selective nerve root blocks was not evaluated.
Nachemson, 1992 (87)	Nachemson described various issues related to low back pain without assessing the accuracy of selective nerve root blocks.
Bove et al, 2005 (106)	This study assessed the incidence of superficial versus deep pain localization among patients with lumbar radicular pain, noninvasively by questioning, without selective nerve root blocks.
Bartynski et al, 2010 (108)	In this evaluation, unilateral lumbar nerve root block was performed in 350 patients with lumbar radicular pain. The accuracy of selective nerve root blocks was not assessed. The study was geared to evaluate adjacent double-nerve root contributions in unilateral lumbar radiculopathy.
Hoppenstein, 1980 (168)	The authors evaluated a new approach to failed back surgery syndrome by performing a series of differential nerve blocks followed by microsurgical dorsal root rhizotomy. The accuracy of selective nerve root blocks was not evaluated.
Pfirschmann et al, 2001 (176)	Authors assessed the response to selective nerve root blocks for the treatment of sciatica based on the injection site. However, there was no diagnostic information.
Wagner, 2004 (177)	The author evaluated the technique, results, procedure time, and radiation dose of selective nerve root blocks. However, accuracy was not studied.
Kim et al, 2012 (178)	The authors studied contrast dispersal patterns in retrodiscal transforaminal epidural steroid injections.
Miyakoshi et al, 2007 (179)	In this preliminary study, total dorsal ramus block for the treatment of chronic low back pain was described.
Chua et al, 2011 (180)	This study evaluated whether diagnostic blocks have a beneficial effect on pain processing. It did not assess diagnostic accuracy.
Anderberg et al, 2006 (123)	The study evaluated distribution patterns of transforaminal injections in the cervical, rather than lumbar spine.
Slipman et al, 1998 (181)	The study evaluated symptom provocation for fluoroscopically cervical nerve root stimulation, rather than lumbar spine.
Anderberg et al, 2004 (184)	The authors correlated selective nerve root block results with clinical symptoms and magnetic resonance imaging pathology in the cervical, but not lumbar spine.

2.3 Methodological Quality Assessment

A methodological quality assessment of diagnostic accuracy studies meeting inclusion criteria was carried out utilizing QAREL criteria as shown in Table 7. Studies achieving 50% or higher scores were included. Scores of 67% or higher were considered to be high quality, 50%-66% were considered to be moderate quality, and studies scoring less than 50% were considered to be of poor quality and excluded.

2.4 Meta-Analysis

All diagnostic accuracy studies were evaluated for homogeneity for inclusion in the meta-analysis. No meta-analysis was performed due to the lack of homogeneity among the studies.

2.5 Analysis of Evidence

The evidence was synthesized based on the relief criteria when selective nerve root injections were performed. Table 8 illustrates the results of diagnostic accuracy studies.

Based on the USPSTF criteria, the evidence was classified to be good, fair, or limited or poor.

The evidence is limited based on 10 of 14 studies providing positive evidence assessing accuracy.

3.0 COMPLICATIONS

The most common and worrisome complications of transforaminal epidural steroid injections in the lumbar spine are related to neural trauma, vascular trauma, intravascular injection, and infection (189-

Table 5. Characteristics of reported diagnostic accuracy studies.

Study/Year	Participants	Interventions(s)	Outcomes	Result(s)	Conclusion(s)
Faraj and Mulholland, 2006 (78) Prospective case series	96 patients with leg pain	Nerve root block with and without a nerve stimulator, epidurogram obtained	Comparison of response rate of SNRB with and without use of a neurostimulator.	Response rate 89%. The response rate for lateral canal stenosis and battered root syndrome were higher than for post-discectomy or disc prolapse pain. Response rate was 96% when blocks were guided by a neurostimulator vs. 79% when no neurostimulator was used.	Neurostimulation may improve the accuracy of nerve root blocks. Accuracy of diagnostic SNRB was not assessed.
Wolff et al, 2006 (79) Prospective, randomized, double blind, crossover study	10 patients with radiculopathy	Lumbar SNRB at L4 with ropivacaine 0.25% or lidocaine 1%	Comparison of SNRB with baseline measurements in patients with chronic low back pain radiating to leg with maximum pain in one dermatome	Asymptomatic hypoesthesia variable in extent and nondermatomal in 7/10 patients. SNRB produced no consistent change in extent and distribution of hypoesthetic area.	Pre-block assessment of sensory function is essential to assess net effects of SNRB. Accuracy of diagnostic SNRB was not assessed.
Wolff et al, 2006 (80) Prospective, observational study	71 patients for L4, L5, and S1 SNRB	Using electrostimulation, 0.5 mL of lidocaine and iohexol injected	Evaluation of epidural spread and spread to adjacent nerve roots	Epidural spread in 47% of L4 and 28% of L5 blocks. Spread into adjacent nerve roots occurred in 5% of injections. Risk of epidural and/or adjacent nerve root spread present even with low injection volume of 0.5 mL, increasing with more medial needle position. Suggest using electrostimulation along with fluoroscopy to achieve optimal results.	This study suggests that the validity of SNRB is questionable.
Vassiliev, 2007 (81) Observational study	39 patients with chronic lumbar radiculopathy	SNRB with injection of contrast in 1 mL increments 10 seconds apart up to 3 mL at each level.	Positive "spread" was defined as visualization of the adjacent nerve root with contrast.	During L4 and L5 SNRB, contrast spread to the subjacent nerve root occurred in 46.1% and 57.7% of subjects, respectively. There was significant difference between the spread of contrast onto the medially located nerve root in the same lumbar segment and nerve roots in the lumbar segment above. Injection of 1 mL of contrast under fluoroscopic guidance does not guarantee selective spread of contrast around targeted nerve roots.	This study reinforces the questionable accuracy of SNRB.
Furman et al, 2008 (82) Prospective evaluation	30 patients with lumbar radiculitis	SNRB with injection of 4 mL of nonionic contrast in incremental doses of 0.5 mL.	Assessment of contrast flow selectivity during transforaminal lumbosacral epidural steroid injections	After administration of 0.5 mL of contrast, 30% of injections were no longer "selective" for specified root level. After administration of 1 mL, 1.5 mL and 2.5 mL of contrast, 67%, 87% and 95% of injections, respectively, were no longer "selective".	Even with low volumes, this study also raises questions regarding the selectivity of nerve root injections.
Van Akkerveeken, 1993 (88) Prospective case series	46 (37 patients with disc protrusions and 9 with metastases)	Mechanical stimulation followed by SNRB with Marcaine	Comparison of SNRB response to imaging and surgical pathology	Sensitivity 100%, specificity 90% for injections. Positive predictive value for good surgical result ranged between 70-95% depending on statistics.	SNRB was highly sensitive and specific, with a high positive predictive value for a good surgical outcome.
Krempen & Smith, 1974 (169) Observational study	22 patients with sciatica	Mechanical stimulation and selective nerve root injections	Concordant pain response to injection and surgical outcome in 16 of 22 patients	18 patients had a positive result. In the 16 patients that underwent surgery after positive response to the injection all improved with surgery and had corresponding lesions at the level suggested.	SNRB is helpful diagnostically in surgical planning, with 100% sensitivity.

SNRB = selective nerve root block; MRI = magnetic resonance imaging

Selective Nerve Root Blocks in the Diagnosis of Lumbosacral Radicular Pain

Table 5 (cont.). *Characteristics of reported diagnostic accuracy studies.*

Study/Year	Participants	Interventions(s)	Outcomes	Result(s)	Conclusion(s)
Tajima et al, 1980 (170) Prospective case series	106 patients	Mechanical stimulation with needle and SNRB compared with surgical exploration	Comparison of SNRB response to imaging and surgical findings	In patients with positive SNRB, imaging and surgical pathology were concordant	SNRB was helpful diagnostically in patients when mechanical stimulation and SNRB were concordant. The site of entrapment was usually consistent with surgical findings.
Hauelsen et al, 1985 (171) Retrospective study	105 patients with sciatica	SNRB post laminectomy with surgical reexploration	Comparison of surgical findings using SNRB versus myelography and electromyography.	SNRB identified site of pathology in 93% of cases, vs. 24% and 38% with myelography and electromyography, respectively.	SNRB more accurate than myelography and electromyography in identifying a symptomatic nerve root. At 1-5 year follow-up, 49% of surgical patients had minimal or no pain.
Castro & van Akkerveeken, 1991 (172) Observational study	24 patients with lumbar radiculitis	Selective lumbar root sheath infiltration.	Assessment of the diagnostic value of SNRB.	In 24 patients with classic disc protrusion syndrome the sensitivity was 100%. The predictive value in patients with nerve root entrapment due to degenerative narrowing of the nerve root was 70% to 80%.	Very high sensitivity in disc protrusion, and moderate predictive value with foraminal stenosis.
Kikuchi et al, 1984 (173) Anatomic and clinical studies of radicular symptoms – an observational study	Anatomic study included cadavers of elderly people with dissection. Clinical study included examination of nerve root infiltration on 332 cases with assessment of relationship between neurological symptoms and the morphologic findings of the contrast study.	Dissection of the cadavers, SNRB	Examination of nerve root infiltration and analysis of the relation between neurologic symptoms and the morphologic findings of the contrast study.	Anatomic study showed sensory rootlets had unusual segmental arrangements in many cases, however, no such arrangements were observed with motor rootlets. In 65 of 322, neurologic findings did not correspond with the results of the contrast results. In these cases, nerve root infiltration was a very useful ancillary method of investigation. In 47 of not-corresponding cases, contrast studies showed abnormalities at another level or multiple levels, though the neurologic findings were at a single level. In 18 cases, no abnormality was found in contrast studies in spite of existence of neurologic symptoms. In the cases of post surgery in 13 cases, the cases associated with vascular insufficiency (2 cases), spinal cord injury (one case), perineural sacral cyst (one case), and sclerotic pedicle of L4 (one case), nerve root infiltration was very useful in assessing the responsible level. Analysis of radicular symptoms with nerve root infiltration showed radicular pain or intermittent claudication caused by degenerative spondylolisthesis was abolished by single nerve root infiltration in 29 of 38 cases. In 81 of 91 cases, with intermittent claudication, the pain was abolished following single-nerve root infiltration, and in only 10 cases it was not effective.	Authors in this evaluation show the value of SNRB in patients without correlation with contrast study in a pre-MRI era.

SNRB = selective nerve root block; MRI = magnetic resonance imaging

Table 5 (cont.). *Characteristics of reported diagnostic accuracy studies.*

Study/Year	Participants	Interventions(s)	Outcomes	Result(s)	Conclusion(s)
Herron, 1989 (174) Retrospective study	215 patients with leg pain (78 underwent surgery)	SNRB prior to surgery	Comparison of surgical findings and outcomes	78 patients underwent surgery. 38 patients (53%) had a good surgical result, 16 patients (23%) a fair result, and 17 patients (24%) a poor result.	SNRB helpful diagnostically in patients without prior surgery. 76% sensitivity
Yeom et al, 2008 (175) Prospective controlled study	47 consecutive patients with pure radiculopathy	SNRB were performed at the symptomatic level in 47, along with 58 blocks performed at the adjacent asymptomatic "control" level in 47 patients.	Authors sought to evaluate the accuracy of diagnostic lumbar SNRB and analyze potential costs of inaccurate results. They defined a positive block as a 70% pain relief.	Diagnostic lumbar SNRB anesthetics had a sensitivity of 57%, a specificity of 86%, a positive predictive value of 77%, a negative predictive value of 71%, and an overall accuracy of 73%. False-negatives were due to insufficient infiltration, insufficient passage of the injectate and epineural injections. False-positive results were due to overflow of the injectate from the injected asymptomatic level into either the epidural space or symptomatic level.	This study showed moderate evidence for accuracy of diagnostic lumbar selective nerve root blocks.
Wolff et al, 2001 (182) Prospective study	29 patients	Selective nerve root injections	Sensory testing after SNRB	Hypesthetic areas post-block were variable and larger than paresthetic areas pre-block. Nerve root block patterns may differ from classic dermatomal maps.	This study illustrates substantial variability in segmental effects of lumbosacral segmental nerve blocks with local anesthetics..
Stanley et al, 1990 (183) Prospective consecutive series	50 patients with leg pain	SNRB, CT and radiculography results compared with surgery	Comparison of SNRB and radiculography to surgical findings and outcomes	SNRB identified the symptomatic level in 18 of 19 cases vs. 14 and 12 that were identified with CT and radiculography, respectively.	SNRB may be helpful in selecting patients for surgery with single level involvement.
Dooley et al, 1988 (185) Retrospective case series	62 patients with radicular symptoms	Mechanical stimulation with needle and SNRB compared with surgery	Comparison of surgical outcome with SNRB response	44 patients had a positive result. Surgery confirmed local pathology in all cases.	SNRB helpful diagnostically when mechanical stimulation and SNRB are concordant.
Schutz et al, 1973 (186) Retrospective study	23 patients with sciatica	SNRB and surgery	Comparison of SNRB to surgical findings and outcomes	15 patients had positive test results and underwent surgery. Surgical findings agreed in 13 (87%). 18% of the tests failed because of failure to stimulate the desired root.	SNRB may be helpful in selection of level of surgery.
Sasso et al, 2005 (187) Observational report	101 patients with sciatica	Selective nerve root injections	Comparison of surgical outcome between MRI and selective nerve root injection	91% of patients with a positive selective nerve root injection had good surgical outcomes, whereas 60% of patients with a negative selective nerve root injection had good outcomes. Of the patients with a positive MRI result, 87% had good surgical outcomes, whereas a similar percentage of patients with a negative MRI, 85% had good surgical outcome.	SNRB with negative results are helpful in predicting the absence of an offending lesion in cases when MRI findings were equivocal, multilevel, and/or do not agree with patients' symptoms.
Porter et al, 1999 (188) Retrospective evaluation	56 patients with sciatica	SNRB	To assess the results of CT-directed perineural root infiltration	34 patients had a diagnostic perineural root infiltration to determine whether surgery was appropriate. Among 18 patients who had surgery, 14 had a successful, 2 a moderate, and 2 a poor outcome.	SNRB may be a useful adjunct in patients with abnormalities at multiple levels and with poor correlation with clinical findings.

SNRB = selective nerve root block; MRI = magnetic resonance imaging

Table 6. *Clinical relevance of included studies.*

Manuscript Author(s)	A) Patient description	B) Description of interventions and treatment settings	C) Clinically relevant outcomes	D) Clinical importance	E) Benefits vs potential harms	Total Criteria Met
Faraj and Mulholland, 2006 (78)	+	+	+	+	+	5/5
Wolff et al, 2006 (79)	+	+	+	+	+	5/5
Wolff et al, 2006 (80)	+	+	+	+	+	5/5
Vassiliev, 2007 (81)	+	+	+	+	+	5/5
Furman et al, 2008 (82)	+	+	+	+	+	5/5
Van Akkerveeken, 1993 (88)	+	+	+	+	+	5/5
Krempen & Smith, 1974 (169)	+	+	+	+	+	5/5
Tajima et al, 1980 (170)	+	+	+	+	+	5/5
Haueisen et al, 1985 (171)	+	+	+	+	+	5/5
Castro & van Akkerveeken, 1991 (172)	+	+	+	+	+	5/5
Kikuchi et al, 1984 (173)	+	+	+	+	+	5/5
Herron, 1989 (174)	+	+	+	+	+	5/5
Yeom et al, 2008 (175)	+	+	+	+	+	5/5
Wolff et al, 2001 (182)	+	+	+	+	+	5/5
Stanley et al, 1990 (183)	+	+	+	+	+	5/5
Dooley et al, 1988 (185)	+	+	+	+	+	5/5
Schutz et al, 1973 (186)	+	+	+	+	+	5/5
Sasso et al, 2005 (187)	+	+	+	+	+	5/5
Porter et al, 1999 (188)	+	+	+	+	+	5/5

211). None of the studies included in the diagnostic accuracy assessment reported any major complications (79-85,88,94-121,123,168-188).

In an academic physiatry practice over a 7-year period, McGrath et al (208) retrospectively evaluated the incidence and characteristics of complications from 3,964 lumbar transforaminal injections. They identified a lack of major complications and reported 103 minor complications, for an overall complication per injection rate of 2.4%.

Karaman et al (129) assessed the complications of transforaminal lumbar epidural steroid injections. They reported a total of 1,305 episodes of lumbar transforaminal epidural steroid injections in 562 patients. The overall incidence of vascular penetration encountered was 7.4%. However, major complications were not observed. The overall rate of minor complications was 11.5%. In this study they reported an 8.7% incidence of vasovagal reactions.

Botwin et al (145) reported complications in 207 patients who underwent 322 transforaminal lumbar epidural steroid injections. Complications included

transient headaches in 3.1%, increased back pain in 2.4%, increased leg pain in 0.6%, facial flushing in 1.2%, vasovagal reaction in 0.3%, increased blood sugar in 0.3%, and hypertension in 0.3%. The incidence of minor complications was 9.6% per injection, with no major complications.

Furman et al (196) reported that among 761 transforaminal epidural steroid injections, the overall rate of intravascular injection was 11.2%, with a higher rate (21.3%) at the S1 level compared with those at lumbar levels (8.1%).

Manchikanti et al (119) reported intravenous needle placement in 22% of transforaminal epidural injections. Other complications included back and leg pain during the injection in 43% and 22% of patients, respectively. Post-procedure complications were reported in 34% of patients, with soreness at the injection site occurring in 18%, increased pain in 5%, muscle spasms in 4%, swelling in 4%, headache in 3%, minor bleeding in 2%, dizziness in 1%, nausea and vomiting in 1%, fever in 1%, numbness in 1%, and voiding difficulty in 1%.

Huston et al (197) reported no major complica-

Table 7. Quality Appraisal of Diagnostic Reliability checklist.

	Faraj and Mulholland (78)	Wolff et al (79)	Wolff et al (80)	Vassiliev (81)	Furman et al (82)	Van Akkerveeken (88)	Krempen & Smith (169)	Tajima et al (170)	Haueisen et al (171)
1. Was the test evaluated in a spectrum of subjects representative of patients who would normally receive the test in clinical practice?	+	+	+	+	+	+	+	+	+
2. Was the test performed by examiners representative of those who would normally perform the test in practice?	+	+	+	+	+	+	+	+	+
3. Were raters blinded to the reference standard for the target disorder being evaluated?	-	-	-	-	-	-	-	-	-
4. Were raters blinded to the findings of other raters during the study?	+	+	-	-	+	-	+	+	+
5. Were raters blinded to their own prior outcomes of the test under evaluation?	+	+	+	+	+	+	+	+	+
6. Were raters blinded to clinical information that may have influenced the test outcome?	-	-	-	-	-	-	-	-	-
7. Were raters blinded to additional cues, not intended to form part of the diagnostic test procedure?	+	+	+	+	+	+	+	+	+
8. Was the order in which raters examined subjects varied?	+	+	+	+	+	+	+	+	+
9. Were appropriate statistical measures of agreement used?	+	+	+	+	+	+	+	+	+
10. Was the application and interpretation of the test appropriate?	+	+	+	+	+	+	+	+	+
11. Was the time interval between measurements suitable in relation to the stability of the variable being measured?	NA	NA	NA	NA	NA	NA	NA	NA	NA
12. If there were dropouts from the study, was this less than 20% of the sample.	+	+	+	+	+	+	+	+	+
TOTAL	9/11	9/11	8/11	8/11	9/11	8/11	9/11	9/11	9/11

+ = yes; - = no; U = unclear; N/A = not applicable
 Lucas N, et al. The development of a quality appraisal tool for studies of diagnostic reliability (QAREL). J Clin Epidemiol 2010; 63:854-861 (150).

Table 7 (cont.). Quality Appraisal of Diagnostic Reliability checklist.

	Castro & van Akkerveeken (172)	Kikuchi et al (173)	Herron (174)	Yeom et al (175)	Wolff et al (182)	Stanley et al (183)	Dooley et al (185)	Schutz et al (186)	Sasso et al (187)	Porter et al (188)
1. Was the test evaluated in a spectrum of subjects representative of patients who would normally receive the test in clinical practice?	+	+	+	+	+	+	+	+	+	+
2. Was the test performed by examiners representative of those who would normally perform the test in practice?	+	+	+	+	+	+	+	+	+	+
3. Were raters blinded to the reference standard for the target disorder being evaluated?	-	-	-	-	-	-	-	-	-	-
4. Were raters blinded to the findings of other raters during the study?	+	+	+	+	+	+	+	+	+	+
5. Were raters blinded to their own prior outcomes of the test under evaluation?	+	+	+	+	+	+	+	+	+	+
6. Were raters blinded to clinical information that may have influenced the test outcome?	-	-	-	-	-	-	-	-	-	-
7. Were raters blinded to additional cues, not intended to form part of the diagnostic test procedure?	+	+	+	+	+	+	+	-	-	-
8. Was the order in which raters examined subjects varied?	+	+	+	+	+	+	+	+	+	+
9. Were appropriate statistical measures of agreement used?	-	-	+	+	+	+	+	-	+	-
10. Was the application and interpretation of the test appropriate?	+	+	+	+	+	+	+	+	+	+
11. Was the time interval between measurements suitable in relation to the stability of the variable being measured?	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
12. If there were dropouts from the study, was this less than 20% of the sample.	+	+	+	+	+	+	+	+	+	+
TOTAL	8/11	8/11	9/11	9/11	9/11	9/11	9/11	7/11	8/11	7/11

+ = yes; - = no; U = unclear; N/A = not applicable
 Lucas N, et al. The development of a quality appraisal tool for studies of diagnostic reliability (QAREL). J Clin Epidemiol 2010; 63:854-861 (150).

Table 8. Summary of diagnostic accuracy studies.

Manuscript Author(s)	Methodological Quality Scoring	Number of Subjects	Results
Van Akkerveeken, 1993 (88)	8/11	46	P
Krempen & Smith, 1974 (169)	9/11	22	P
Tajima et al, 1980 (170)	9/11	106	P
Haueisen et al, 1985 (171)	9/11	105	P
Castro & van Akkerveeken, 1991 (172)	8/11	24	P
Kikuchi et al, 1984 (173)	8/11	62	P
Herron, 1989 (174)	9/11	78	P
Yeom et al, 2008 (175)	9/11	47	N
Wolff et al, 2001 (182)	9/11	29	N
Stanley et al, 1990 (183)	9/11	50	P
Dooley et al, 1988 (185)	9/11	62	P
Schutz et al, 1973 (186)	7/11	23	P
Sasso et al, 2005 (187)	8/11	101	N
Porter et al, 1999 (188)	7/11	56	N

P = positive; N = negative

tions, with 91% of patients experiencing no side effects during cervical and lumbar selective nerve root blocks. The most common side effect was increased pain at the injection site, which was observed after 17.1% of lumbar injections.

In their review of complications and pitfalls of lumbar interlaminar and transforaminal epidural injections, Goodman et al (207) concluded that complications from lumbar epidural injections are extremely rare. Most, if not all, complications can be avoided by careful technique with accurate needle placement, sterile precautions, and a thorough understanding of the relevant anatomy and contrast patterns on fluoroscopic imaging.

However, complications from transforaminal injections have been reported to include spinal cord injury and infarction, resulting in paraplegia (127,131). Side effects related to the administration of steroids are generally attributed either to chemistry or pharmacology (198). The major theoretical complications of corticosteroid administration include the suppression of pituitary adrenal axis, hyperadrenocorticism, Cushing syndrome, osteoporosis, avascular necrosis, steroid myopathy, epidural lipomatosis, weight gain, fluid retention, and hyperglycemia (198). Radiation exposure is also a potential problem, with resultant damage to the eyes, skin, and gonads (205,210).

4.0 DISCUSSION

This systematic review evaluating the diagnostic accuracy of selective nerve root blocks found limited efficacy in identifying lumbar radicular pain when radiologic abnormalities are not correlated with clinical symptomatology. Diagnostic selective nerve root blocks have often been used to confirm the pain-generating nerve root. Despite their widespread use, the reported accuracy of these blocks for determining a symptomatic level varies from 31% to 100%. In addition to the wide range in accuracy, most of the studies have been retrospective in nature, have had a small sample size, and have failed to describe their methodologies in detail (211). In addition, in all the studies on the topic to date, the definition of a positive or negative result based on the degree of pain relief has either been arbitrarily set between 50% and 100% or has not been clearly defined. A majority of studies have analyzed the sensitivity, specificity, accuracy, and predictive values because they focus on the results of diagnostic selective nerve root block on the presumed lesion level alone, and many employed "control" injections at "unaffected roots." Consequently, the diagnostic accuracy of selective nerve root blocks continues to be questioned (52,211-213).

Only one controlled blinded study by Yeom et al

(175) assessed the control root levels and defined a positive block as > 70% pain relief, as determined by receiver-operator characteristic (ROC) analysis. They arrived at a sensitivity of 57%, a specificity of 86%, an accuracy of 73%, a positive predictive value of 77%, and a negative predictive value of 71%. They confirmed the findings of other investigators that false-positives were frequently the result of overflow of the injectate from the injected level into either the epidural space or to another level that was symptomatic. They demonstrated that false-negative blocks were due to insufficient infiltration, insufficient spread of injectate, and intra-epineural injections. Multiple other studies have demonstrated difficulty in localizing injections without inadvertent spread to the epidural space or another level, even when low volumes (i.e. 0.5 mL) are employed (81,82). In the study by Yeom et al (175), the evidence was shown to be only moderate, and the diagnostic value was relatively low compared with previous reports (88,169,171,174,183,185-188,214,215) most of which did not attempt to quantify false-positive results. In this and other studies, significant false-negative blocks occur concomitantly with false-positives. Almost all studies were characterized by significant limitations.

Overall, this systematic review suggests that the diagnostic value of selective nerve root blocks in the lumbar spine is not high, confirming the hypothesis of Shah (62). The value may be improved by using a nerve stimulator and utilizing a meticulous injection technique with extremely low volume; however, this contention is based on only one high quality study (175).

A diagnostic test is useful only to the extent that it distinguishes between the reference condition and other disorders that might otherwise be misdiagnosed. Many tests can distinguish healthy persons from severely affected ones or those with appropriate abnormalities on radiologic investigations, but being able to differentiate these 2 types of patients reveals very little about the clinical utility of a test. The true pragmatic value of a test can only be established in a study that closely resembles clinical practice. Studies evaluating the accuracy of facet joint nerve blocks have provided us with reliability and validity data for controlled diagnostic blocks, with a criterion standard of > 75% pain relief during the performance of previously painful movements following dual blocks being designated as accurate (69-71). However, extrapolating these criteria to selective nerve root blocks may not be justified.

A systematic review is defined as, "the application

of scientific strategies that limit bias by the systematic assembly, critical appraisal, and synthesis of all relevant studies on a specific topic" (216,217). Systematic reviews are labor intensive and require expertise in both the subject matter and review methods. Thus, expertise in only one area is not sufficient, and may lead to inaccurate conclusions and inappropriate recommendations (218-222). This systematic review provides not only crucial expertise in the subject matter, but synthesizes that expertise via the application of stringent methodology. A systematic review differs from a narrative review in that the former attempts to minimize bias by the comprehensiveness and reproducibility of its search and selection strategies, and through the transparent grading of methodological quality (218-222). In this systematic review, we attempted to answer specific clinical questions in depth – how accurate and valid are diagnostic selective nerve root blocks?

The Institute of Medicine (IOM) standards for systematic reviews (223) described 4 major standards:

- 1) Standards for initiating the systematic review;
- 2) Standards for finding and assessing individual studies;
- 3) Standards for synthesizing the body of evidence; and
- 4) Standards for reporting systematic reviews.

The IOM also described multiple challenges and methods to overcome these challenges when developing guidelines (224). The IOM notes that the literature assessing the best methods for guideline development have evolved dramatically in the 20 years since the IOM's first report on the subject (225).

The outcomes of most therapeutic options depend on proper diagnosis. Selective nerve root blocks may be used as a diagnostic entity prior to surgical interventions. If one operates under the premises that a treatment (i.e. decompression surgery) is more efficacious when performed on the correct level on an appropriate patient than it is when performed on the wrong level, then one can prove through deductive reasoning — i.e. without virtue of a clinical trial — that identifying the affected spinal level improves treatment outcomes. Currently, there are numerous available modalities for the diagnosis and management of low back pain, with escalating costs and untoward effects that can adversely impact health care resources (226-270). Selective nerve root blocks can encompass many of the disadvantages of a diagnostic test. One of the major challenges is that, unlike facet joint nerve blocks, sacroiliac joint nerve blocks, and even discography, selective nerve

root blocks are not generally performed as dual blocks in a controlled environment, which can serve to reduce false-positive results (66-68). Because of this, and the fact that no reference standard such as a tissue or biopsy diagnosis can confirm the results, the validity of selective nerve root blocks in the diagnosis of lumbosacral radiculitis has not been established. In addition, the effects that potential confounding factors, such as psychological disorders, opioid usage, age, and obesity, have on the results of selective nerve root blocks, have not been studied.

Not only has the construct validity of selective nerve root blocks been questioned, but also the face validity. Local anesthetic injected accurately onto the targeted nerve root(s) should theoretically alleviate pain only in the distribution of the nerve(s). Yet, in addition to there being significant dermatomal overlap between adjacent nerve roots, even when the procedure is performed with low volumes under fluoroscopic visualization, the injectate frequently extravasates to adjacent potential pain generators, which can undermine face validity.

Despite these obstacles, there is evidence that does support the validity of selective nerve root blocks. In an early study performed in 105 patients with radicular pain, 57% of whom had undergone previous surgery, Hauelsen et al (171) compared the diagnostic accuracy of spinal nerve root injections with lidocaine to myelography and electromyography with regard to surgical findings and treatment outcomes. Among the 55 patients who underwent surgical exploration, selective nerve root injections were accurate in identifying the surgical pathology in 93% of patients, which favorably compared to accuracy rates of 24% for myelography, 58% for discography, and 38% for electrodiagnostic studies. At follow-up periods ranging from 1-5 years, 49% of patients had minimal or no pain vs. 16% of patients who were treated non-operatively. The authors concluded that in patients with surgically altered anatomy, selective nerve root blocks are helpful in making an accurate diagnosis.

Herron (174) examined the response to selective nerve root blocks as a means to confirm the spinal origin of pain. The surgical outcomes were as expected, with the best outcomes noted for lumbar disc herniation (83% good outcomes) and spinal stenosis (55% good results), while those with a history of prior surgery experienced the poorest results (29% good outcomes). The response to injection was helpful in narrowing potential surgical patients from 215 to 71 patients.

In a 1980 study, Tajima et al (170) descriptively compared mechanical stimulation and anesthetic response to nerve root injections against myelography. Comparison to normal dye patterns in reference patients and cadavers was also used to clarify the role of radiculography as a diagnostic imaging tool. The disorders studied were diverse, but selective nerve root block deemed helpful in determining the painful segment in the majority of patients, with corresponding abnormalities found on surgical repair. The authors also felt it was helpful in limiting surgical decompression to the area of primary pain generation.

A retrospective study by Schutz et al (186) reported on the accuracy of selective nerve root blocks in 23 patients. Among the 15 patients in whom an operation was performed at the level indicated by the selective nerve root block, 13 (87%) had findings that correlated with the results of the diagnostic block. Eighteen percent of blocks failed because of either intolerable pain during the procedure or failure to stimulate the desired root, most often at S1.

With respect to accuracy, it is generally measured in terms of sensitivity and specificity. Specificity is a relative measure of the prevalence of false-positives, whereas sensitivity is the relative prevalence of false-negative results. There are several factors that can lead to a false-positive selective nerve root block despite precautions, including the close proximity of numerous potential pain-generating structures that can be anesthetized by the aberrant extravasation of local anesthetic. Consequently, selective nerve root blocks are considered to have a higher degree of sensitivity than specificity.

The sensitivity and specificity of diagnostic selective nerve root blocks range from 45% to 100% (88,123,169,171,175,183-186). Schutz et al (186) reported finding a corroborative lesion at the time of surgery in 87% of patients with a positive diagnostic block. Krempen and Smith (169) reported 100% surgical confirmation following a positive block. Dooley et al (185) reported 3 out of 51 blocks to be false-positive, for a specificity of 94% while Stanley et al (183) reported 95% specificity. Van Akkerveeken (88) attempted to establish the diagnostic value of selective nerve root injections by comparing 37 patients with confirmed lumbar radiculopathy to 9 patients with pain due to metastases. The authors found the sensitivity for pain neuropathic spinal to be 100%, with the specificity, as determined by comparison to a normal level on imaging, around 90%. When calculating the positive predic-

tive value, there was a 95% chance that patients with a positive selective nerve block would experience a good surgical outcome. If all patients who declined surgery were included in the analysis as surgical failures, the positive predictive value declined to 70%. Other reported specificities are 96% by Anderberg et al (184), 93% by Haeisen et al (171), and 85% by Dooley et al (185).

In a small prospective study comparing the specificity of 0.6 mL, 1.1 mL and 1.7 mL, Anderberg et al (123) found that the use of lower volumes was associated with comparable "sensitivity," but increased specificity. A well-controlled prospective study by Yeom et al (175) showed a sensitivity of 57%, a specificity of 86%, a positive predictive value of 77%, and a negative predictive value of 71% based on 70% pain relief determined by receiver-operator characteristic analysis. Overall, the accuracy was determined to be 73%. In view of the findings by North et al (215) that showed that all uncontrolled nerve blocks are non-specific, the high reported levels of sensitivity and specificity need to be confirmed in controlled studies.

The injection of local anesthetics may result in extravasation beyond the target nerve root to surrounding structures, including adjacent dorsal rami, spinal or sinuvertebral nerves, muscles, and even facet joints, causing a false-positive result (80-82,122,123). For CT guided lumbar selective nerve root blocks, Castro et al (122) demonstrated epidural spread in 48% of cases, and diffusion to an adjacent nerve root in 27%, even with their lowest injected volume (i.e., 0.5 mL). Wolff et al (182) utilized a combination of fluoroscopy and electrostimulation to perform the selective nerve root blocks, but still found epidural spread in 47% of L4, and 28% of L5 blocks, with spread to adjacent nerve roots occurring in 5% of procedures. Anatomical variations, such as nerve root abnormalities, were found in 14% of individuals (271). A furcal nerve usually arises from the L4 root level and contributes to both the lumbar and sacral plexuses. Neurologic symptoms, suggestive of 2 root involvement, frequently result from furcal nerve compression (272). Pain relief resulting from blockade of a spinal nerve cannot be used to distinguish between pathology of the nerve itself, or pain transmitted through that nerve from distal sites. Ongoing sciatic pain can be relieved by sciatic nerve block, distal or collateral to any pathology (273,274). Distal referred pain in response to paraspinal noxious stimuli (i.e. hypertonic saline) can be prevented by peripheral somatic blockade in the area of referral (275). Finally, pain is always

subjective, and may be influenced by psychological, social, financial and legal factors, as well as by concurrent therapies. Because the placebo effect has been shown to be proportional to the invasiveness of a procedure (276,277), performing injections on 2 or more occasions may minimize this confounding effect.

In summary, the role of selective nerve root blocks in providing an accurate diagnosis prior to surgical intervention is limited, but still emerging.

5.0 CONCLUSION

This systematic review shows limited evidence for selective nerve root blocks as a diagnostic test for equivocal radicular pain.

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Conflict of Interest:

Dr. Calodney is a consultant for Stryker, Inc.; Medtronic, Inc.; and Nimbus Concepts.

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