Original Article

The Use Of Ultrasonography In Selective Lumbar Nerve Root Injection For Treatment Of Radicular Pain

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Abstract

Lumbar radicular pain also known as sciatica in the past, is a very common condition with high impact on patients' lives, its precise definition is not clearly understood, radicular pain definition is based on its mechanism as pain evoked by stimulation of the sensory (dorsal) root of a spinal nerve or its dorsal root ganglion (DRG). The morphological pattern of the herniated disc plays an important role in LRP and is correlated strongly with the clinical picture, prognosis, and suitable treatment strategy. Chronic radicular pain is not merely an extension of the acute phase. However, local, spinal and supraspinal mechanisms interplay in the development of chronic pain. Mechanical events, particularly abnormal motion or loads to neural tissues, may trigger the mechanisms of chronic pain. Local axonal injury in particular has been shown to increase excitability and spontaneous activity of the DRG neurons. Steroids have been demonstrated to have a therapeutic role, owing to their anti-inflammatory and nociceptive signal stabilising properties. Selective nerve root injection (SNRI) or trans-foraminal epidural steroid injection (TFESI) is a technique that enables precise delivery of corticosteroid and local anesthetic in close proximity to nerve root under radiological guidance, thereby optimising the therapeutic effect. With the ultrasound growing popularity as a useful diagnostic tool and as a guiding tool in lumbar spine procedures, it has been suggested that ultrasound can aid in reducing the use of fluoroscopy or replace it completely in performing selective lumbar nerve root injection.

Keywords: Lumbar radicular pain; ultrasonography; lumbar nerve root injection.

INTRODUCTION

Lumbar radicular pain also known as sciatica in the past (1), is a very common condition with high impact on patients' lives, its precise definition is not clearly understood, radicular pain definition is based on its mechanism as pain evoked by stimulation of the sensory (dorsal) root of a spinal nerve or its dorsal root ganglion (DRG). (2) Many other definitions of radicular pain based on clinical pictures are present in the literature. These definitions were very vague and provide a wide variety of subjective descriptions of the characteristics of pain. Moreover, the anatomic distribution of pain is highly variable due to the difference in the affected nerve roots and the normal variation in dermatomal distribution of cutaneous nerve supply among patients. Furthermore, many patients diagnosed clinically with LRP show normal radiologic and electrodiagnostic investigations. (3)

This definition of radicular pain is not synonymous of radiculopathy. Radiculopathy is a pathologic condition in which there functional impairment of nerve roots resulting in any combination of sensory deficit, motor deficit, and pain. Meanwhile, radicular pain is a single subjective clinical furthermore that can be a part of radiculopathy, but it can occur alone. So, the term radiculopathy is better reserved for patient having other objective features as motor, sensory, and autonomic dysfunctions.(4) The morphological pattern of the herniated disc plays an important role in LRP and is correlated strongly with the clinical picture, prognosis, and suitable treatment strategy. A classification by Fardon et al. helps in the description of various forms of herniated discs and arranges them into 4 categories; protrusion (the

fragment doesn't have a neck that is narrower than the fragment in any dimension), extrusion (the fragment has a neck that is narrower than the fragment in >=1 dimensions), sequestration (a type of disc extrusion that has lost continuity with the disc origin), Migration (the extruded disc fragment has migrated away from the origin. This fragment may or may not be in continuity with the origin) as shown in figure 2.(5)

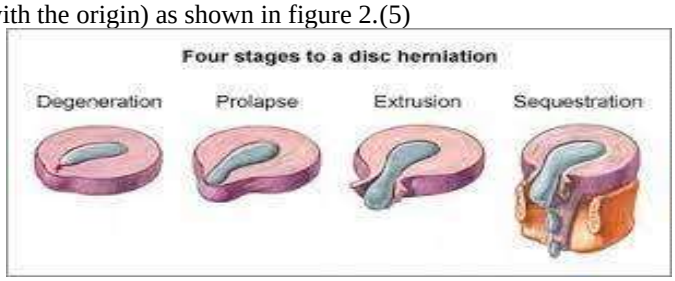

Figure (1) Stages of disc herniation

A disc herniation is defined as localized displacement of disc material beyond the intervertebral disc space of 25% of the disc circumference when measured axially. But a disc bulge is defined as a generalized displacement of disc material > 25% of disc circumference. Furthermore, disc herniation is also categorized by the specific region of nerve root compression regarding its position within the spinal canal. There are 4 anatomic zones of compression: central, subarticular, foraminal, extraforaminal. (6, 7)

Pathophysiologic Mechanisms

The pathophysiologic processes leading to lumbosacral discogenic radicular pain can be divided into the following causes mechanical deformation, inflammatory, immune, neurophysiologic mechanisms.

Mechanical deformation

It was proposed in 1934 by Mixter and Barr(8) that a herniated lumbar disc was commonly the cause of lumbar radicular pain. The pressure of the prolapsed disc on the nerve root was proposed to be the causative mechanism
Various studies suggest other mechanisms in the development of LRP. In animal study, where the material of nucleus pulposus was placed next to nerve roots with no compression, there were conduction abnormalities. These studies suggest biochemical mechanism with inflammatory reaction affecting the nerve roots.(10)

Inflammatory Mechanisms

In 1951, a study made by Lindahl and Rexed has shown that there were histologic changes indicating inflammation in nerve roots of patients with LRP undergoing laminectomy. Following this study many other studies on humans and animals was conducted to explore inflammation as a causative factor for the development of LRP.(11)
Many studies have focused on nucleus pulposus as the material causing the inflammation around the nerve root leading to impairment of its Electrophysiologic function. Studies have shown that nucleus pulposus has proinflammatory and leucotactic effect and that disc material can produce nitric oxide which is a potent inflammatory mediator(12, 13). In one study on porcine models, titanium chambers filled with autologous nucleus pulposus material was injected subcutaneously leading to attraction of significantly higher number of leucocytes compared to empty or fat filled champers. Autologous nucleus pulposus was shown to cause microvascular thrombosis and increased vascular permeability(13). In another study, autologous nucleus pulposus was injected into rats around lumbar nerve roots causing reduction in blood flow to the DRG and increased endoneural fluid pressure. Also, it has been shown to cause sustained discharge in Aδ and Aβ fibers, in addition to increased mechanical hypersensitivity. Also, it affects the DRG leading to delay in nerve conduction velocity. This reduction in conduction velocity has been shown to be improved by intravenous injection of methylprednisolone.(14)
Furthermore, an important study by Zwart et al. showed the importance of inflammation in the induction of radicular pain. Previous studies had established that mechanical compression of nerve roots to have a proportionally greater impairment of myelinated Aδ fibers, responsible for cold sensation, compared with unmyelinated C fibers (responsible for warm sensation), and the inverse was true for inflammation of a nerve root. Zwart et al., assessing the warm and cold thresholds in patients with unilateral radicular pain involving L_5 and S_1 nerve roots, found that warm sensation was more impaired compared to cold sensation, in patients with confirmed disc herniation. This finding suggests that inflammation is more important than compression alone in the development of LRP.(15)

Immune mechanisms

Recent studies have demonstrated that immune mechanisms may play a significant role in the progress of LRP especially in development of chronic pain. Some markers of nerve damage were found in higher levels in specimens

taking from patients with LRP undergoing disc surgery suggesting immune reaction to nerve tissue. Other studies have shown that patients with disc herniation have increased levels of autoantibodies to neural cell components. These antibodies are increased in other neural autoimmune diseases as Guillain-Barré syndrome and chronic inflammatory demyelinating polyradiculoneuropathies, suggesting autoimmune process as a potential cause in LRP.(16, 17)

Neurophysiologic Mechanisms

Early studies suggested that there are neurophysiologic mechanisms involved in the development of radicular pain. The neurotransmitter, glutamate, showed increased levels in the disc specimens taken from patients having LRP undergoing surgery indicating that it may play an important role in development of pain. Moreover, radiolabeled glutamate injected into the epidural space in rats was significantly taken by the DRG. This study indicates that glutamate from degenerated disc proteoglycans may diffuse into DRG and affect sensory neurons by stimulating glutamate receptors.(18)

Chronic Radicular Pain

Chronic radicular pain is not merely an extension of the acute phase. However, local, spinal and supraspinal mechanisms interplay in the development of chronic pain. Mechanical events, particularly abnormal motion or loads to neural tissues, may trigger the mechanisms of chronic pain. Local axonal injury in particular has been shown to increase excitability and spontaneous activity of the DRG neurons. (19)

Role of selective nerve root injections in the management of lumbar radicular pain

Steroids have been demonstrated to have a therapeutic role, owing to their anti-inflammatory and nociceptive signal stabilising properties. (20-22) Selective nerve root injection (SNRI) or trans-foraminal epidural steroid injection (TFESI) is a technique that enables precise delivery of corticosteroid and local anesthetic in close proximity to nerve root under radiological guidance, thereby optimising the therapeutic effect. (23, 24)

With our growing understanding of LRS, it has been well-known that biomechanical nerve root compression by a prolapsed disc is not the singular cause for symptoms. (25) The two major clinical observations which support this notion that on many occasions, there is minimal correlation between inter-vertebral disc (IVD) size and the severity of radiculopathy, also significant mitigation of symptoms may occur without concurrent resolution of the disc herniation.(26, 27) As this association between local inflammatory pathology and lumbar radicular pain was substantiated, targeted corticosteroid delivery modalities have been progressively accepted as useful treatment options. (28, 29)

Mechanism of action of corticosteroids

Several mechanisms have been suggested to explain the role of corticosteroids in LRP. Firstly, disc herniations enhance local production of prostaglandins (via phospholipase A2), which leads to inflammation around the dorsal root ganglion and pain. (30) Corticosteroids inhibit production of arachidonic acid and thereby block this pain-generating pathway. Secondly, steroids have been shown to curtail ectopic discharges from unmyelinated C-fibers. (31, 32) Thirdly, steroid administration can also directly relieve central pain sensitization.(33-35) Fourthly, injection of substances (even certain volumes of plain fluids) into the epidural space itself can push the dura forward and inward; and thereby stretch nerve roots. This can consequently result in lysis of neural adhesions, thereby allowing for enhanced pain relief. (33, 34) Other described mechanisms include cell membrane stabilization, improvement in neuronal blood flow and washing out of various inflammatory mediators including interleukin-1 and tumor necrosis factor.

Procedural techniques

Different approaches have been described for selective nerve root injections. The subpedicular approach used to be the most common method used clinically. In this method, the injection needle is progressed towards the safe triangle under the inferior surface of the pedicle to locate the spinal nerve related to symptoms. This location is favored because agents can be injected into the anterior extradural space, i.e. the inflammatory site between the back of the herniated intervertebral disc and the anterior nerve root dural sleeve. (36) The risk of damaging dura mater is decreased, as the injection needle goes through the border of the lateral upper intervertebral foramen. However, Murthy et al. (37) reported that the Adamkiewicz artery (AKA artery) runs through the safe triangle and injection at this site might transfer agents within the artery or directly damage the vessel.

In 1972, Kambin (38) introduced endoscopic intervertebral discectomy by posterolateral approach, defining the Kambin's triangle as the site to approach the intervetebral disc. The Kambin's triangle is defined as a right triangle

over the dorsolateral disc. The hypotenuse is the exiting nerve root, the base (width) is the superior border of the caudal vertebra and the height is the dura/traversing nerve root. This approach can protect the epidural and nervous system, and prevent chronic nerve edema, epidural bleeding and epidural scarring. Thus, safety can be secured when this site is used for epidural injection. According to Murthy et al. (37), when the radiculomedullary artery was located by spinal angiography in the intervertebral foramen, 97% of the cases showed that the artery was located on the upper half of the intervertebral foramen and no artery was found in the area of less than 20%. When the injection needle was located on the site of <20% of the intervertebral foramen, the risk of injecting agents into radiculomedullary artery and vessel damage could be prevented as shown in figure 3.

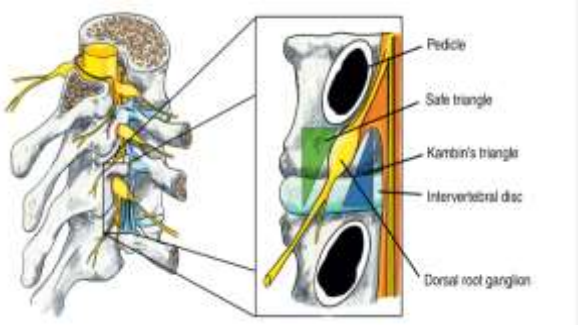

Figure (2) Safe triangle and Kambin's triangle

Conventionally, SNRI is administered around the involved nerve root, ie. for a L4-5 paracentral disc herniation with L5 radiculopathy, the drug is administered around the exiting L5 root (L5-S1 neural foramen). (39)

Trans-foraminal injections are performed under image guidance, namely fluoroscopic, CT, or ultrasound guided. The latter approach has been reported to have the specific advantage of reducing radiation exposure to health personnel. (40)

Fluoroscopic technique

The patient is positioned prone on a radiolucent table, An antero-posterior image is taken by the c-arm then the target vertebra is identified. Alignment of the lower end plate of the vertebra is done by cephalo-caudal tilting of the c-arm. Then the C-arm is tilted to ipsilateral oblique view until the "Scottie dog" appearance is seen. Below the eye of the Scottie dog we can identify the foramen from which the nerve root exits. After injection of local anesthesia subcutaneously a 22 gauge needle is inserted until the tip is positioned at the exiting root location in the "Kambin triangle". The needle position is confirmed in the lateral view then contrast agent is injected, the dye will take the track of the nerve root if the needle positioning is correct as shown in figure 4. Radicular pain reproduction is expected and after visualizing a good radiculogram, then local anesthetic and corticosteroid mixture is injected. (39)

Types of radiculogram: The term "radiculogram" describes the pattern of dye distribution on AP imaging after foraminal injection. In 2001, Pfirrmann et al .(41) described three different types of contrast flows, based on a cadaveric study. Type 1 radiculogram indicates intra-epineural contrast flow (showing tubular appearance), type 2 radiculogram describes extra-epineural flow (where nerve root is visible as a filling defect) and type 3 denotes para-neural flow (where nerve root is not visualized). Intra-epineural injections are painful, with a high risk of chemical neuritis. During SNRI, dye is preferably injected extra-epineurally.

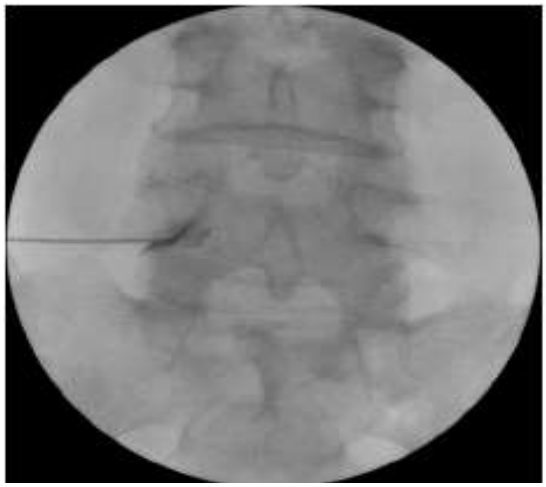

Figure (4) contrast spread pattern in selective lumbar nerve root injection of L4 nerve root.

Ultrasound-guided technique

With the ultrasound growing popularity as a useful diagnostic tool and as a guiding tool in lumbar spine procedures, it has been suggested that ultrasound can aid in reducing the use of fluoroscopy or replace it completely in performing selective lumbar nerve root injection. Especially with the presence of new ultrasound machines which can provide much better image quality. Also, ultrasound can be portable and widely available leading to increasing its use in outpatient settings. Moreover, it can provide real-time imaging which is not affected greatly by slight changes in patient position. Also an added advantage to ultrasound is that it can provide color Doppler which can help in avoiding vascular structures. But in can of uncertainty of needle position minor adjustment can be aided by taking very few image of x-ray reducing its use, or by the help of nerve stimulator. (42)

Using a curved array probe the spinous processes are identified through a midline scan by applying the probe in the sagittal orientation. First, the sacrum and the fifth lumbar spinous process were identified, and then the target spinal level for the injection was confirmed by cephalad counting of the spinous processes. Then the probe is positioned in the transverse orientation in a paramedian position and in between two transverse processes so we can identify the foramen between the vertebral body anteriorly and the facet joint posteriorly, and the emerging nerve root can be identified. After injection of local anesthesia subcutaneously at the point of entry, 22 gauge needle is inserted in an in-plane approach, then after confirmation of needle position by fluoroscopy aspiration was done to confirm that no blood is present, injection is done. (43, 44)

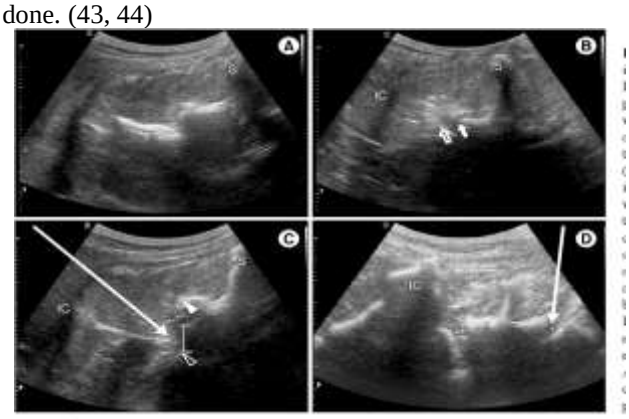

Figure (5) ultrasound guided needle insertion**. (A)** At the level of the lower margin of the L5 transverse process. **(B)** L5~S1 facet joint was identified between the inferior articular process (filled arrow) and the superior articular process (unfilled arrow). **(C)** L5 nerve root injection. The target point level was identified as the mid-point between **(A) and (B)** cephalocaudally. The target depth was showed as the lower half between the lateral border of the L5 lamina (filled arrowhead) and the most medial border of the vertebral body (unfilled arrowhead). Arrow shows the needle approaching **(D)** S1 foramens () are shown bilaterally. Arrow shows the needle approaching. IC iliac crest, S spinous process, T transverse process

Medications

Various combinations of medications have been tried. (45, 46) The study by Vad et al. (46) comparing fluoroscopic trans-foraminal injections of steroids versus control saline revealed 84% success rates in the former group, as compared with 48% in the latter. In a prospective, randomised study by Ghahreman et al. (45), involving 4 groups, trans-foraminal epidural injections of steroid plus LA, LA-only, normal saline, and intramuscular injections, the first group demonstrated statistically greater pain improvement.

The initial radiculogram is obtained by injection of a water-soluble contrast. The most popular contrast agent is iohexol (usual volume of 0.5–3 ml). It is a low-osmolality contrast agent (in contrast to the older, high osmolality agents like diatrizoate). (47)

The total volume of injectate (usually steroid plus LA) has varied between 3 and 9 ml (usually around 4 ml). The popular LA agents include 1–2% lidocaine and 0.25–0.5% bupivacaine. (48)

Steroids: The steroid preparations for use in the epidural space are broadly classified into two groups, namely particulate (methylprednisolone, betamethasone and triamcinolone) and non-particulate (dexamethasone phosphate) agents. (49, 50)

The particulate steroids have a longer duration of action (due to local depot effect causing continuous release of active drug) with slightly improved outcomes. On the other hand, the non-particulate agents are considered safer as they are water-soluble, smaller sized and subjected to limited particle aggregation. Hence, they are rapidly cleared from the spinal canal but they have shorter durations of action. (49, 50)

Complications

While SNRI is a fairly safe procedure, devastating complications including neural trauma, vascular trauma, intra-vasation of drug and infection have rarely been reported. The most dangerous complication following this procedure is spinal cord infarction, resulting in paraplegia of which there are a few case reports. These major neurological

complications have been attributed to

a. Embolisation of particulate steroids causing vascular occlusion

b. Anatomic profile of the “safe triangle”, which although may be safe with respect to neural elements, can contain radicular arteries. Although arteria radicularis magna or artery of Adamkiewicz usually lies around the thoraco-lumbar region, variants of this vessel can arise anywhere down to the sacral vertebrae and thus an inadvertent injury

or dissection of this artery can lead to conus medullaris infarction.

c. Transient vasospasm secondary to needle placement (typically described after SP approach).

d. In addition, patients on chronic anti-platelet or anti-coagulant medications may develop epidural hematomas and neuro-deficits.

Adverse effects related to steroids including pituitary-adrenal axis suppression, Cushing’s syndrome, osteoporosis, avascular necrosis of bone, myopathy, weight gain, fluid retention and hyperglycemia, although rare, are theoretical possibilities following these injections. These image-guided procedures can also cause significant radiation exposure to patients, practitioners and OR personnel. (32, 51, 52)

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