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Clinical Study

Induced lumbosacral radicular symptom referral patterns: a descriptive study

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Abstract

BACKGROUND CONTEXT: Lumbosacral radicular symptoms are commonly evaluated in clinical practice. Level-specific diagnosis is crucial for management. Clinical decisions are often made by correlating a patient's symptom distribution and imaging with sensory dermatomal maps. It is common for patients to describe non-dermatomal symptom patterns and for imaging to demonstrate pathology at levels not predicted by a dermatomal map. These observations suggest that the referred symptom distribution from lumbosacral nerve root provocation is different from dermatomal maps. This phenomenon has been demonstrated in the cervical spine but not in the lumbosacral spine.

PURPOSE: The objective of this study was to characterize potential lumbosacral radicular symptom referral patterns induced during transforaminal epidural injections.

STUDY DESIGN/SETTING: This is an observational descriptive study.

PATIENT SAMPLE: The patient sample included 71 consecutive patients with lumbosacral radicular pain undergoing lumbosacral transforaminal epidural injections at an outpatient interventional spine practice.

OUTCOME MEASURES: Each subject drew the location of provoked lumbosacral radicular symptoms on a pain diagram.

MATERIALS AND METHODS: Seventy-one consecutive patients undergoing 125 fluoroscopically guided lumbosacral transforaminal epidural injections at an outpatient interventional spine practice were included in the study. The described location of provoked symptoms was recorded (1) after final needle positioning, (2) after injection of up to 0.5 mL of contrast solution, and (3) after injection of up to a 1 mL test dose of 1% lidocaine. Each subject drew the location of provoked symptoms on a diagram. The provoked symptom diagrams for each lumbosacral segmental level were combined to create composite nerve root, level-specific, symptom referral pattern maps.

RESULTS: Of the 125 injections, 87 provoked referred symptoms and were included in the analysis. Thirty-eight injections did not provoke referred pain symptoms and were excluded from further analysis. Four nerve roots were tested at L1 and eight were tested at L2. Because of the small number of subjects, composite diagrams and statistical analysis were not completed for these levels. Eleven nerve roots were analyzed at L3, 28 at L4, 34 at L5, and 11 at S1. Composite symptom referral pattern maps were created for levels L3, L4, L5, and S1. Although the symptom distribution occasionally followed the expected dermatomal maps, most often the referral was outside of the patterns expected for each level. The most common symptom referral pattern for levels L3–S1 was the buttock, the posterior thigh, and the posterior calf.

CONCLUSIONS: The level-specific provoked symptom distribution during lumbosacral transforaminal epidural injections is frequently different from that predicted by classic lumbosacral dermatomal maps. Referred pain to the buttock, the posterior thigh, or the posterior calf may come from L3, L4, L5, or S1 nerve root segmental irritation.

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Consulting and malpractice reviews refer to all legal work Furman does regarding all clinical case reviews for lawyers or insurance companies.

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Introduction

Lumbosacral transforaminal epidural steroid injections are often used therapeutically as part of a multimodal treatment plan to ease lumbar radicular pain recalcitrant to activity modification, physical therapy, or oral medications [1].

In clinical practice, the treatment level for lumbosacral transforaminal epidural steroid injections is often determined by correlating a patient's symptoms, physical examination, and imaging studies with sensory dermatomal maps. This treatment level choice assumes that radicular symptoms will travel in the same distribution. However, it is common for a patient with a focal nerve root lesion to describe a non-dermatomal symptom distribution. It is also common for a patient's imaging study to demonstrate root involvement at a segmental level other than the one predicted by a dermatomal map.

Sherrington first studied dermatomes in rhesus monkeys by sectioning nerve roots above and below an intact nerve root. He then mapped the area of intact sensation [2]. Foerster used a similar concept in humans who had suffered nerve root injury. He found that human dermatomal maps were similar to the findings of Sherrington in rhesus monkeys [3]. Keegan and Garrett developed the most widely used dermatomal map in 1948. They studied presumed single-level disc protrusions in the cervical and lumbar spine. In the lumbar spine, 1,264 patients with presumed single-level disc protrusions, 707 of which were verified by surgery, were evaluated for diminished cutaneous sensitivity. These sensory findings were used to create dermatomal maps [4]. Modifications of this dermatomal map are routinely used today in clinical settings (Fig. 1).

In the cervical spine, it has been demonstrated that cervical radicular pain referral patterns after mechanical nerve root irritation are different from those predicted by dermatomal maps [6]. In the lumbar spine, sensory and motor electrostimulation of the dorsal root ganglion (DRG) often elicits paresthesia outside classic dermatomal maps [7]. No study in the lumbar spine has evaluated lumbosacral radicular pain referral patterns after mechanical or chemical irritation of lumbosacral nerve roots.

The objective of this descriptive study was to investigate lumbosacral nerve root radicular symptom referral patterns provoked during transforaminal epidural needle placement and after injection of contrast media and anesthetic test dose.

Materials and methods

Seventy-one consecutive patients undergoing 125 fluoroscopically guided lumbosacral transforaminal epidural injections at an outpatient interventional spine practice were included. The subjects had previously been evaluated by a board-certified physical medicine and rehabilitation or orthopedic spine specialist and had been found to have symptoms consistent with lumbosacral radicular pain. All patients were sent for fluoroscopically guided lumbosacral transforaminal epidural injections at specific levels (L1, L2, L3, L4, L5, and S1). Exclusion criteria included any reason for the inability to undergo a fluoroscopically guided, contrast-enhanced epidural injection, such as pregnancy, current infection, contrast allergy, or known allergy to injected medications. Patients with lumbosacral transitional segments, renal insufficiency, peripheral neuropathy, and communication deficits and those who could not tolerate the additional procedure time, such as those with high pain acuity or high anxiety, were also excluded. Patients gave their written consent before the procedure. Their data were included only if they experienced referred appendicular symptoms during the procedure.

Patients subsequently completed their scheduled fluoroscopically guided lumbosacral transforaminal epidural injections. A supraneural approach (ie, subpedicular technique) was used for each injection [8,9]. The subject, with the assistance of one of the investigators or a nurse, recorded the provoked symptom locations on an anatomical diagram (Fig. 2) at the following time points: (1) after final needle positioning, (2) after injection of up to 0.5 mL of contrast solution, and (3) after injection of up to a 1.0 mL volume of 1% lidocaine. We did not purposely irritate or contact the nerve root. If the nerve root was mechanically stimulated at final needle positioning and the subjects described pain, pressure, numbness, tingling, hot, cold, or other sensations, these symptoms were recorded on the diagram shown in Fig. 2. The distribution of referred symptoms, when present, was also recorded after injection of contrast and lidocaine. Both have the potential to create fluid pressure or chemical irritation of the nerve root.

Individual pain diagrams were then digitally scanned, and composites for each lumbosacral segmental level were created. Distinct anatomical regions were defined as the buttock, thigh (subdivided into anterior, posterior, medial, and lateral), groin, leg (subdivided into anterior, posterior, medial, and lateral), knee, and foot. Proportions of the patients with referred symptoms in each anatomical region were calculated, and results, including 95% confidence intervals (CIs), determined by chi-squared test were reported. This process was used to create symptom referral pattern maps for lumbosacral nerve segmental levels.

Results

There were 71 subjects in the present study, and 125 lumbar transforaminal epidural injections were performed. Of the 125 injections, 87 provoked referred symptoms and were included in the analysis. Thirty-eight injections did not provoke

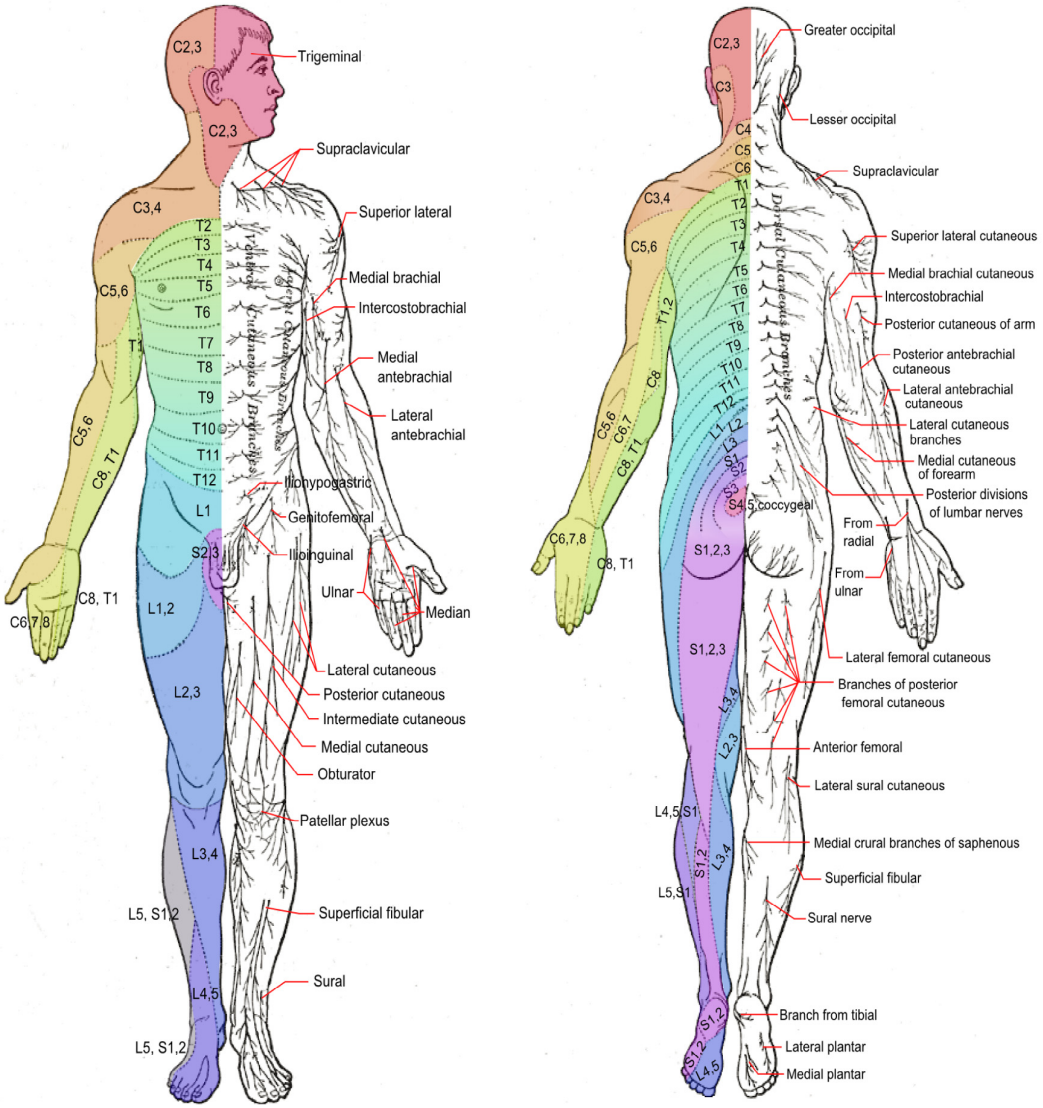

Fig. 1. Classic dermatomal map. By Mikael Häggström, used with permission. Dermatomes and Cutaneous Nerves [5]. (Public Domain).

referred pain symptoms and were excluded from further analysis. See Table 1 for demographics. Of the 71 patients, 38 (53.5%) were men and 33 (46.5%) were women. The average age of the study subjects was 63 years old (range 28–87 years old). Twenty-two (31%) had a history of prior lumbar surgery. Near-equal numbers of left-sided (51.6%) versus right-sided (48.4%) procedures were performed. Data from the left- and right-sided injections were combined.

Table 1
Study demographics

Number (N) of subjects	71
Nerve root levels tested	125
Left-sided procedures, n (%)	64 (51.6)
Right-sided procedures, n (%)	60 (48.4)
Men, n (%)	38 (53.5)
Women, n (%)	33 (46.5)
Average age	63 (range 28–87)
History of prior lumbar surgery, n (%)	22 (31)

Four nerve roots were tested at L1 and eight were tested at L2. Because of the small number of subjects, composite diagrams and statistical analysis were not completed for these levels. Composite symptom referral pattern maps were created for levels L3, L4, L5, and S1 (Figs. 3–6, Tables 2–5).

Fifteen nerve roots were tested at L3. Eleven nerve roots were included in the analysis. Four nerve roots did not provoke symptoms and were excluded from analysis. The most common zone of referral for the L3 nerve root was the buttock (five nerve roots [45%], 95% CI 9.5%–57.2%) followed by the posterior thigh (four nerve roots [36%], 95% CI 4.3%–49.0%). Referred pain below the knee occurred infrequently (Fig. 3, Table 2).

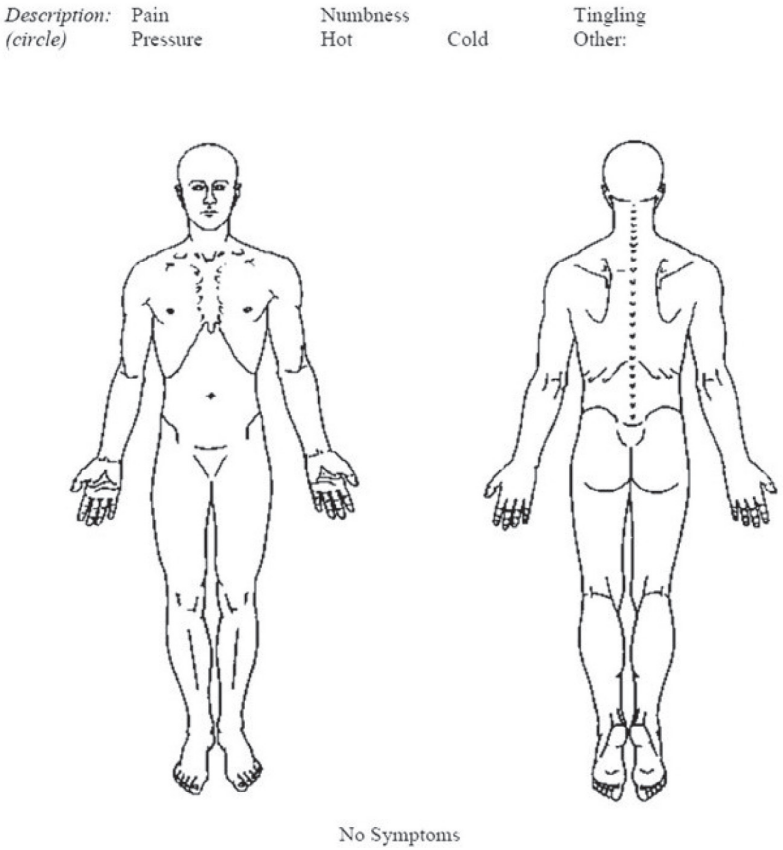

Fig. 2. Blank preinjection pain diagram provided to each patient.

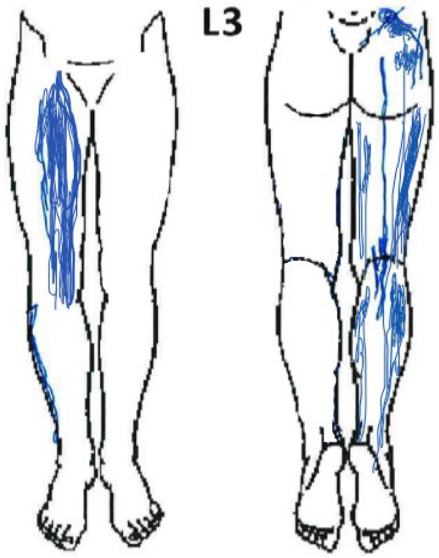

Fig. 3. Composite symptom referral map for L3 nerve root segmental level (n=15).

Table 2
L3 nerve root

Symptom referral zone	Nerve roots tested, n (%)	Confidence interval (%)
Buttock	5 (45)	9.5–57.2
Anterior thigh	3 (27)	0–40.2
Posterior thigh	4 (36)	4.3–49.0
Medial thigh	2 (18)	0–30.5
Lateral thigh	0 (0)	
Groin	0 (0)	
Anterior lower leg	0 (0)	
Posterior lower leg	2 (18)	0–30.5
Medial lower leg	0 (0)	
Lateral lower leg	1 (9)	0–19.3
Knee	1 (9)	0–19.3
Foot	0 (0)	

Eleven nerve roots were included in the analysis. Four nerve roots did not provoke symptoms and were excluded from analysis.

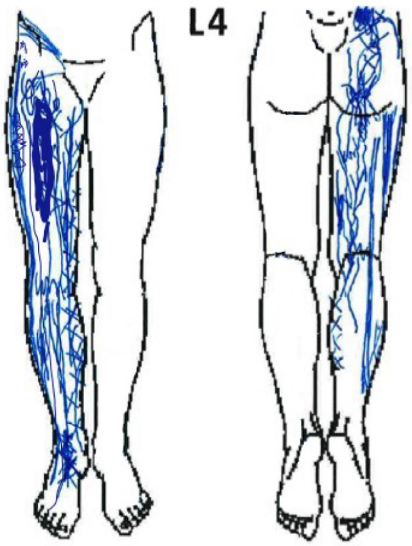

Fig. 4. Composite symptom referral map for L4 nerve root segmental level (n=40).

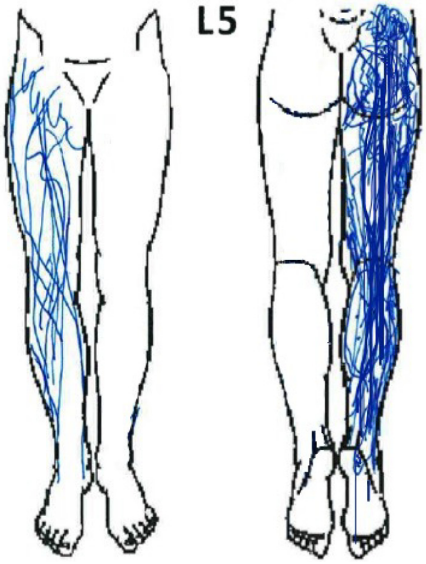

Fig. 5. Composite symptom referral map for L5 nerve root segmental level (n=42).

Forty nerve roots were tested at L4. Twenty-eight nerve roots were included in the analysis. Twelve nerve roots did not provoke symptoms and were excluded from analysis. The most common zone of referral for the L4 nerve root was the buttock (12 nerve roots [43%], 95% CI 24.5%–61.2%) followed by the anterior thigh (8 nerve roots [29%], 95% CI 11.8%–45.3%), the posterior thigh (7 nerve roots [25%], 95% CI 9.0%–41.0%), and the posterior calf (5 nerve roots [18%], 95% CI 3.7%–32%) (Fig. 4, Table 3).

Forty-two nerve roots were tested at L5. Thirty-four nerve roots were included in the analysis. Eight nerve roots did not provoke symptoms and were excluded from analysis. The most common zones of referral were the buttock (21 nerve roots [62%], 95% CI 45.4%–78.1%), the posterior thigh (20 nerve roots [59%], 95% CI 42.3%–75.4%), the posterior calf (17 nerve roots [50%], 95% CI 33.2%–66.8%), and the lateral lower leg (8 nerve roots [24%], 95% CI 9.3%–37.8%) (Fig. 5, Table 4).

Sixteen nerve roots were tested at S1. Eleven nerve roots were included in the analysis. Five nerve roots did not provoke symptoms and were excluded from analysis. The most common zone of referral for the S1 nerve root was the buttock (seven nerve roots [64%], 95% CI 35.2%–92.1%) followed by the posterior calf (five nerve roots [45%], 95% CI 16%–74.9%) and the posterior thigh (four nerve roots [36%], 95% CI 7.9%–64.8%). S1 nerve root irritation did not refer symptoms to the anterior thigh or the anterior lower leg (Fig. 6, Table 5).

The L5 and the S1 nerve roots were likely to refer symptoms to the buttock, the posterior thigh, and the posterior calf.

Table 3
L4 nerve root

Symptom referral zone	Nerve roots tested, n (%)	Confidence interval (%)
Buttock	12 (43)	24.5–61.2
Anterior thigh	8 (29)	11.8–45.3
Posterior thigh	7 (25)	9.0–41.0
Medial thigh	3 (11)	0–22.2
Lateral thigh	4 (14)	1.3–27.2
Groin	1 (3)	0–10.4
Anterior lower leg	4 (14)	1.3–27.2
Posterior lower leg	5 (18)	3.7–32.0
Medial lower leg	2 (7)	0–16.7
Lateral lower leg	4 (14)	1.3–27.2
Knee	2 (7)	0–16.7
Foot	1 (3)	0–10.4

Twenty-eight nerve roots were included in the analysis. Twelve nerve roots did not provoke symptoms and were excluded from analysis.

Table 4
L5 nerve root

Symptom referral zone	Nerve roots tested, n (%)	Confidence interval (%)
Buttock	21 (62)	45.4–78.1
Anterior thigh	4 (12)	0.9–22.6
Posterior thigh	20 (59)	42.3–75.4
Medial thigh	1 (3)	0–8.6
Lateral thigh	3 (9)	0–18.4
Groin	0 (0)	
Anterior lower leg	1 (3)	0–8.6
Posterior lower leg	17 (50)	33.2–66.8
Medial lower leg	2 (6)	0–13.8
Lateral lower leg	8 (24)	9.3–37.8
Knee	2 (6)	0–13.8
Foot	0 (0)	

Thirty-four nerve roots were included in the analysis. Eight nerve roots did not provoke symptoms and were excluded from analysis.

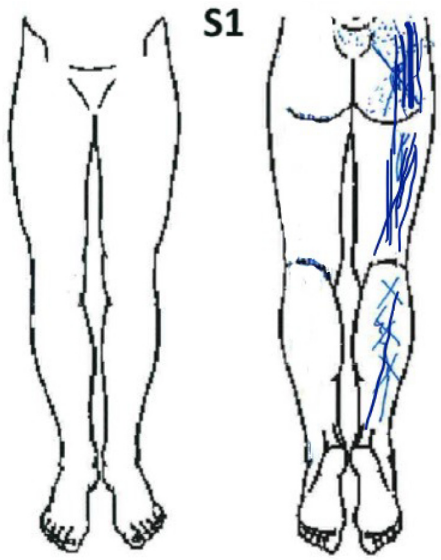

Fig. 6. Composite symptom referral map for S1 nerve root segmental level (n=16).

The L3 and the L4 nerve roots may also refer symptoms to the buttock, the posterior thigh, and occasionally to the posterior calf. The most common symptom referral pattern for levels L3–S1 was the buttock, the posterior thigh, and the posterior calf (Tables 2–5). Although the symptom distribution occasionally followed the expected dermatomal maps, most often the referral was outside of the patterns expected for each level.

Discussion

Lumbar radicular symptoms are evoked by ectopic discharges originating from a dorsal root or a DRG. Disc herniation and spinal stenosis are the most common causes, with inflammation playing a key role [10]. Early studies evaluated radicular pain in the setting of patients undergoing surgery for disc herniation. In one study, affected nerve roots and adjacent "healthy" nerve roots were evaluated by squeezing them with forceps. A second study placed a suture around the nerve roots during surgery and later pulled on the suture end. The pain evoked was documented as a "lancinating" pain, traveling the length of the lower limb in a narrow band 2–3 in. wide. Pain evoked by these methods resulted in similar radicular pain referral patterns for L4, L5, and S1. These early investigations hinted at one key point, that the level of origin of radicular pain cannot be determined from its distribution. L4, L5, and S1 radicular pain patterns are often similar [11].

Table 5
S1 nerve root

Symptom referral zone	Nerve roots tested, n (%)	Confidence interval (%)
Buttock	7 (64)	35.2–92.1
Anterior thigh	0 (0)	
Posterior thigh	4 (36)	7.9–64.8
Medial thigh	0 (0)	
Lateral thigh	0 (0)	
Groin	0 (0)	
Anterior lower leg	0 (0)	
Posterior lower leg	5 (45)	16–74.9
Medial lower leg	0 (0)	
Lateral lower leg	0 (0)	
Knee	1 (9)	0–26.1
Foot	0 (0)	

Eleven nerve roots were included in the analysis. Five nerve roots did not provoke symptoms and were excluded from analysis.

Our results confirm that history and pain mapping alone cannot predict the segmental specific symptom source. As suspected, referred pain to the anterior, medial, and lateral thighs and legs frequently radiates to segments suggested by dermatomal maps. Most interestingly, referred pain to the buttock, the posterior thigh, or the posterior calf is variable and may come from any of the ipsilateral lumbosacral segments, L3, L4, L5, or S1 nerves. This finding accounts for the fact that oftentimes, patients with predicted "S1 radiculitis" in these posterior locations do not have imaging supporting S1 pathology.

Our study showed that the L3, L4, L5, and S1 nerve roots most commonly refer pain to the buttock, the posterior thigh, and the posterior calf. Clearly, the distribution of referred symptoms for each nerve root was often outside the expected dermatomal distribution. A discrepancy between radicular pain patterns and classic dermatome maps has been demonstrated in the cervical spine. Slipman et al. [6] evaluated 87 subjects undergoing 134 fluoroscopically guided cervical transforaminal injections. They purposely mechanically stimulated the C4–C8 nerve roots and recorded the location of provoked symptoms. The distribution of induced radicular symptoms often resembled classic dermatomal maps, but frequently radicular symptoms were provoked outside the distribution of standard dermatome maps [6]. This finding suggests that dermatomal maps are flawed and inaccurate or it may be that radicular pain referral patterns are different from dermatomes.

The accuracy and variability of dermatome maps have been areas of contention [12]. The most widely used dermatome map in standard anatomical and medical reference texts is the Keegan and Garrett [4] dermatome map. This map was developed in 1948 and shows neatly non-overlapping bands extending down from the midline of the lumbar spine to the lower extremities. The map was based on patients with disc herniation causing nerve root compression and diminished light touch sensation, which was tested by a "light pin scratch." A total of 1,264 patients with disc herniations from L3 to S1 were included, but only 707 (56%) were confirmed at surgery. Although this is the most widely used map, it is also the most flawed. The L1 and L2 dermatomes were not studied, yet they appeared on the map. Truncal dermatomes (thoracic) also were not studied but also appeared on the map. Keegan and Garrett found that the areas of diminished light touch sensation for lumbar dermatomes extended from the proximal midline down

the limb in a thin band. The authors reported that the area of decreased sensation in individual patients was highly reproducible and did not vary by more than a centimeter [4].

The Keegan and Garrett dermatome map is at odds with most published data, which show a high degree of variability especially proximally [13] and a high degree of dermatomal overlap [3,7,12,13]. A study by Davis et al. [14] contradicts Keegan and Garrett's findings of low variability and proximal sensory loss. The authors studied 500 patients with lumbar disc herniations confirmed by myelography and surgery. A total of 327 patients had sensory changes which were mapped using pinprick and light pin scratch. The areas of diminished sensation for L5 and S1 nerve root compression varied widely between individuals and between assessors. Their data did not demonstrate a narrow band of sensory loss extending from the proximal lumbar spine to the distal lower extremity. Over half of the patients had sensory changes in the leg and foot only. This finding confirms that proximal sensory loss is variable and often not present with disc herniation [13]. After selective nerve root blocks, Nitta et al. [15] found a continuous band-like zone of sensory impairment from the proximal lower limb to the periphery in only 42% of L4 blocks, in 44% of L5 blocks, and in 92% of S1 blocks. This variability may be due to the lack of cutaneous branches of the dorsal rami of the L4 and L5 spinal nerves or may be due to the extensive dermatome overlap. Nitta et al. [15] did confirm that the distinctive skin regions subserved by the L4, L5, or S1 nerve roots are distally in the lower leg and foot.

The variability is likely due to the type of disc herniation and variable nerve root compression (eg, compression of the DRG, part of the DRG, or an entire nerve root or compression of multiple nerve roots). Creating dermatome maps using data from patients with disc herniation is thus quite variable and not altogether reliable. What is most apparent with dermatome maps is a high degree of variability and overlap.

The variability has several causes. Dermatome overlap is evident. Each area of skin in the upper and lower extremities is innervated by two or more spinal nerve roots [3,13]. Intrathecal anastomoses between dorsal rootlets are also common. Moriishi et al. [16] studied 100 patients and found that 22% of lumbar dorsal roots had intrathecal intersegmental anastomoses spanning one segment. These intersegmental anastomoses allows for sensory neurons (potentially carrying pain signals) with a ganglion cell at one DRG to enter the spinal cord at an adjacent level, creating variability in the distribution of the corresponding dermatome and potentially in the distribution of radicular pain.

Another cause of variability is inconsistency in the number of mobile presacral segments (vertebrae). In a study of 147 patients, Carrino et al. [17] found that ~92% had the typical vertebral enumeration of 24 mobile presacral segments (ie, vertebrae or segments) with 7 cervical vertebrae (8 spinal nerves), 12 thoracic vertebrae (12 spinal nerves), and 5 lumbar vertebrae (5 spinal nerves). However, 5% have 23 mobile presacral segments and 3% have 25 [17]. Eleven percent of patients have an anomalous number of thoracolumbar segments. Transitional segments at the lumbosacral junction occur in 15% of patients and those at the thoracolumbar junction occur in 4% of patients. Transitional lumbosacral segments have variation in radicular pain referral patterns and alteration in the function of the respective lumbosacral nerve root. Patients with lumbosacral transitional vertebrae have dermatomal variation and alteration in the function of the lumbosacral nerve roots [18–20]. This finding was not known at the time historical dermatome maps were created and thus adds to the variability.

Wolff et al. [7] created adapted dermatomal maps that take in to account dermatomal overlap with neighboring dermatomes. The result is a broader distribution for each dermatome. They found that paresthesias after sensory and motor electrostimulation of spinal nerve roots (L2–S1) and spontaneous pain present in a dermatomal distribution after a spinal nerve root injection occurred more often in the "expected" dermatomal distribution when the expanded dermatomal maps were used [7].

The present study has limitations. The sample size was relatively low especially for upper lumbar levels resulting in broad CIs. We were not able to create radicular pain referral maps for L1 or L2. Another limitation is the qualitative nature of our study. We relied on individual patients tracing or "mapping" out their symptoms during the actual procedure. The accuracy of this technique has not been validated and may be limited by the patient's understanding of the pain diagram locations, pain, anxiety, variance in the density and total area mapped by each patient, and a desire not to interrupt the procedure flow. For future studies, it is recommended that a validated drawing or recording tool be used, in particular, one that is four sided and better depicts the medial and lateral lower limbs than the ones we used. We are not aware of a validated tool for superimposing pain referral patterns in the lumbar spine. A body sector bitmap technique has been used for recording cervical radicular symptoms [6].

Another limitation of the present study is that of possible non-selectivity. For each transforaminal injection, a total volume of up to 1.5 mL (0.5 mL of contrast followed by 1.0 mL of 1% lidocaine) was potentially injected. In a study of 60 patients undergoing lumbar transforaminal injections, it has been shown that a volume of 1.5 mL of contrast will spread to the ipsilateral adjacent superior spinal segment 67% of the time and the inferior spinal segment 60% of the time, and 1.6 mL of contrast has been shown to extend beyond midline with rare coverage of the contralateral side in 13% of patients [21]. In a similar study of 37 patients undergoing S1 transforaminal injections, it has been shown that a volume of 1.5 mL of contrast will spread to the ipsilateral adjacent superior spinal segment 57% of the time, and 2.1 mL of contrast has been shown to extend beyond midline with rare coverage of the contralateral side in 8% of patients [22]. Thus, in our study, there is a possibility that we evoked radicular symptoms from not only the targeted spinal nerve root but also adjacent levels [21–23]. A standardized supraneural (subpedicular) approach was used for all injections. However,

it is possible that slight variances in final needle position and the uniqueness of each patient's anatomy may place the needle at varying locations along the nerve root. This needle tip placement has the potential to change the distribution of referred symptoms.

Conclusions

The level-specific provoked symptom distribution during lumbosacral transforaminal epidural needle placement and injections is frequently different from that predicted by classic lumbosacral dermatomal maps. Referred pain to the anterior, medial, and lateral thighs and legs frequently, but not always, follows levels predicted by dermatomal maps. However, referred pain to the buttock, the posterior thigh, or the posterior calf is variable and may come from the ipsilateral L3, L4, L5, or S1 nerve root irritation.

These observations confirm that the spine care specialist cannot solely rely on a patient's reported symptom distribution, compared with a dermatomal map, to determine the most likely level of pathology. Our data show that lumbar radicular symptom referral patterns are clearly different from dermatomal distributions. Thus, the clinician must carefully correlate a patient's history (reported symptom distribution), physical examination, and available imaging to effectively plan a lumbosacral intervention that targets the appropriate symptomatic segmental level.

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