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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 not uncommon for patients to describe non-dermatomal symptom patterns or 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: To characterize potential lumbosacral radicular symptom referral patterns induced during transforaminal epidural injections.

STUDY DESIGN/SETTING: Observational descriptive study.

PATIENT SAMPLE: 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.

METHODS: 71 consecutive patients undergoing 125 fluoroscopically guided lumbosacral transforaminal epidural injections at an outpatient interventional spine practice were included.

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) following 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. 38 injections did not provoke referred pain symptoms and were excluded from further analysis. 4 nerve roots were tested at L1 and 8 at L2. Due to the small number of subjects, composite diagrams and statistical analysis was not completed for these levels. 11 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 through S1 was buttock, posterior thigh and posterior calf.

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

Keywords: Epidural Injection; Pain; Referral Pattern; Dermatome; Sclerotome

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 and/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 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]. Foerester used a similar concept in humans who had suffered nerve root injury. He found that human dermatomal maps were similar to Sherrington's findings in rhesus monkeys [2]. 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 were used to create dermatomal maps [2]. Modifications of this dermatomal map are routinely used today in clinical settings (Figure 1).

In the cervical spine, it has been demonstrated that cervical radicular pain referral patterns after nerve root irritation are different than those predicted by dermatomal maps [3]. In the lumbar spine, sensory and motor electrostimulation of the dorsal root ganglion often elicits paresthesia outside classic dermatomal maps [4]. 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 following injection of contrast media and anesthetic test dose.

Material 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 (PM&R) or orthopedic spine specialist and found to have symptoms consistent with lumbosacral radicular pain. All patients were sent for a 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 receive a fluoroscopically guided, contrast enhanced epidural injection such as: pregnancy, current infection, contrast allergy, and/or known allergy to injected medications. Patients with lumbosacral transitional segments, renal insufficiency, peripheral neuropathy, 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 were consented before the procedure. Their data was 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 (i.e. subpedicular technique) was used for each injection (7, 8). The subject, with the assistance of one of the investigators or a nurse, recorded the provoked symptom locations on an anatomic diagram (Figure 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) following 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 subject described symptoms, , they were recorded. The distribution of referred symptoms, when present, was then recorded after injection of contrast and lidocaine. Both have the potential to create fluid pressure and/or chemical irritation of the nerve root.

Individual pain diagrams were then digitally scanned and composites for each lumbosacral segmental level were created. Distinct anatomic 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 anatomic region were calculated and results including 95% confidence intervals 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 this study, and 125 lumbar transforaminal epidural injections performed. Of the 125 injections, 87 provoked referred symptoms and were included in the analysis. 38 injections did not provoke referred pain symptoms and were excluded from further analysis. See Table 1 for demographics. Of the 71 patients, 38 (53.5%) were male and 33 (46.5%) were female. The average study participant age was 63 years old (range 28-87 years old). 22 (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 left and right sided injections was combined.

4 nerve roots were tested at L1 and 8 at L2. Due to the small number of subjects, composite diagrams and statistical analysis was not completed for these levels. Composite symptom referral pattern maps were created for levels L3, L4, L5, and S1 (Figures 3-6, Tables 2-5).

15 nerve roots were tested at L3. 11 nerve roots were included in the analysis. 4 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 (5 nerve roots [45%], 95% CI 9.5-57.2%), followed by the posterior thigh (4 nerve roots [36%], 95% CI 4.3-49.0%). Referred pain below the knee occurred infrequently (Figure 3, Table 2).

40 nerve roots were tested at L4. 28 nerve roots were included in the analysis. 12 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%), posterior thigh (7 nerve roots [25%], 95% CI 9.0-41.0%) and posterior calf (5 nerve roots [18%], 95% CI 3.7-32%) (Figure 4, Table 3).

42 nerve roots were tested at L5. 34 nerve roots were included in the analysis. 8 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%), posterior thigh (20 nerve roots [59%], 95% CI 42.3-75.4%), 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) (Figure 5, Table 4).

16 nerve roots were tested at S1. 11 nerve roots were included in the analysis. 5 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 (7 nerve roots [64%], 95% CI 35.2-92.1%), followed by the posterior calf (5 nerve roots [45%], 95% CI 16-74.9%) and the posterior thigh (4 nerve roots [36%], 95% CI 7.9-64.8%). S1 nerve root irritation did not refer symptoms to the anterior thigh or anterior lower leg (Figure 6, Table 5).

The L5 and S1 nerve root were likely to refer symptoms to the buttock, posterior thigh and calf. The L3 and L4 nerve root may also refer symptoms to the buttock, posterior thigh and occasionally to the posterior calf. The most common symptom referral pattern for levels L3 through S1 was buttock, posterior thigh and 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 dorsal root ganglion. Disc herniation and spinal stenosis are the most common causes with inflammation playing a key role [5]. 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 to 3 inches 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 [2].

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 thigh and leg frequently radiate to segments suggested by dermatomal maps. Most interestingly, referred pain to the buttock, posterior thigh or posterior calf is variable and may come from any of the ipsilateral lumbosacral segments, L3, L4, L5, or S1 nerves. This 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, posterior thigh and 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 evaluated 87 subjects undergoing 134 fluoroscopically guided cervical transforaminal injections. They purposely mechanically stimulated the C4 to 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 [3]. This suggests that dermatomal maps are flawed and inaccurate or it may be that radicular pain referral patterns are different than dermatomes.

The accuracy and variability of dermatome maps has been an area of contention [6]. The most widely used dermatome map in standard anatomical and medical reference texts is Keegan and Garrett's dermatome map [7]. This 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 "light pin-scratch". 1264 patients with disc herniations from L3-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 appear on the map. Truncal dermatomes (thoracic) also were not studied but also appear 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 [7].

Keegan and Garrett's dermatome map is at odds with most published data which shows a high degree of variability especially proximally [8] and a high degree of dermatomal overlap [4,6,8,9]. A study by Davis et al. 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. 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. They 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 confirms that proximal sensory loss is variable and often not present with disc herniation [8]. Following selective nerve root blocks, Nitta et al found a continuous band-like zone from the proximal to the periphery in only 42% of L4 blocks, 44% of L5 blocks, and 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 due to extensive dermatome overlap. Nitta did confirm that the areas of distinctive regions subserved by the L4, L5 or S1 nerve roots is distally in the lower leg and foot [10].

The variability is likely due to the type of disc herniation and variable nerve root compression (e.g. compression of the DRG, part of the DRG, 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 extremity is innervated by two or more spinal nerve roots [8,9]. Intrathecal anastomoses between dorsal rootlets is also common. Moriishi et al. studied 100 patients and found that 22% of lumbar dorsal roots had intrathecal intersegmental anastomoses spanning one segment. This 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 found that ~92% had the typical vertebral enumeration of 24 mobile presacral segments (i.e. 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 and 3% have 25 mobile presacral segments [11]. 11% of patients have an anomalous number of thoracolumbar segments. Transitional segments at the lumbosacral junction occur in 15% of patients and in 4% of patients at the thoracolumbar junction. Transitional lumbosacral segments have variation in radicular pain referral patterns and alteration in function of the respective lumbosacral nerve root. Patients with lumbosacral

transitional vertebrae have dermatomal variation and alteration in function of the lumbosacral nerve roots [12–14]. This was not known at the time historical dermatome maps were recreated and thus adds to the variability.

Wolff et al created adapted dermatomal maps which 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 [4].

This present study has limitations. The sample size was relatively low especially for upper lumbar levels resulting in broad confidence intervals. 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 of cervical radicular symptoms [3].

Another limitation of this 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, the inferior spinal segment 60% of the time and 1.6 ml of contrast was shown to extend beyond midline with rare coverage of the contralateral side in 13% of patients [15]. 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 was shown to extend beyond midline with rare coverage of the contralateral side in 8% of patients [17]. 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 [15–17]. 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 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 than that predicted by classic lumbosacral dermatomal maps. Referred pain to the anterior, medial and lateral thigh and leg frequently, but not always, follow levels predicted by dermatomal maps. However, referred pain to the buttock,

posterior thigh or 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, as compared to a dermatomal map, to determine the most likely level of pathology. Our data shows that lumbar radicular symptom referral patterns are clearly different than dermatomal distributions. Thus, the clinician must carefully correlate a patient's history (reported symptom distribution), physical examination and MRI imaging to effectively plan a lumbosacral intervention that targets the appropriate symptomatic segmental level.

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Figure Legends

Figure 1. Classic Dermatomal Map. Haggstrom, M (2011). Dermatomes and Cutaneous Nerves. (Public Domain).

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

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

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

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

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

Table 1. Study Demographics

Number (N) of subjects	71
Nerve root levels tested	124
Left sided procedures	64 (51.6%)
Right sided procedures	60 (48.4)
Male	38 (53.5%)
Female	33 (46.5%)
Average age	63 (range 28-87)
History of prior lumbar surgery	22 (31%)

Table 2. L3 nerve root. 11 nerve roots were included in analysis. 4 nerve roots did not provoke symptoms and were excluded from analysis.

Symptom Referral Zone	Number and Percent of Nerve Roots Tested	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%)	

Table 3. L4 nerve root. 28 nerve roots were included in analysis. 12 nerve roots did not provoke symptoms and were excluded from analysis.

Symptom Referral Zone	Number and Percent of Nerve Roots Tested	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

Table 4. L5 nerve root. 34 nerve roots were included in analysis. 8 nerve roots did not provoke symptoms and were excluded from analysis.

Symptom Referral Zone	Number and Percent of Nerve Roots Tested	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%)	

Table 5. S1 nerve root. 11 nerve roots were included in analysis. 5 nerve roots did not provoke symptoms and were excluded from analysis.

Symptom Referral Zone	Number and Percent of Nerve Roots Tested	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%)	

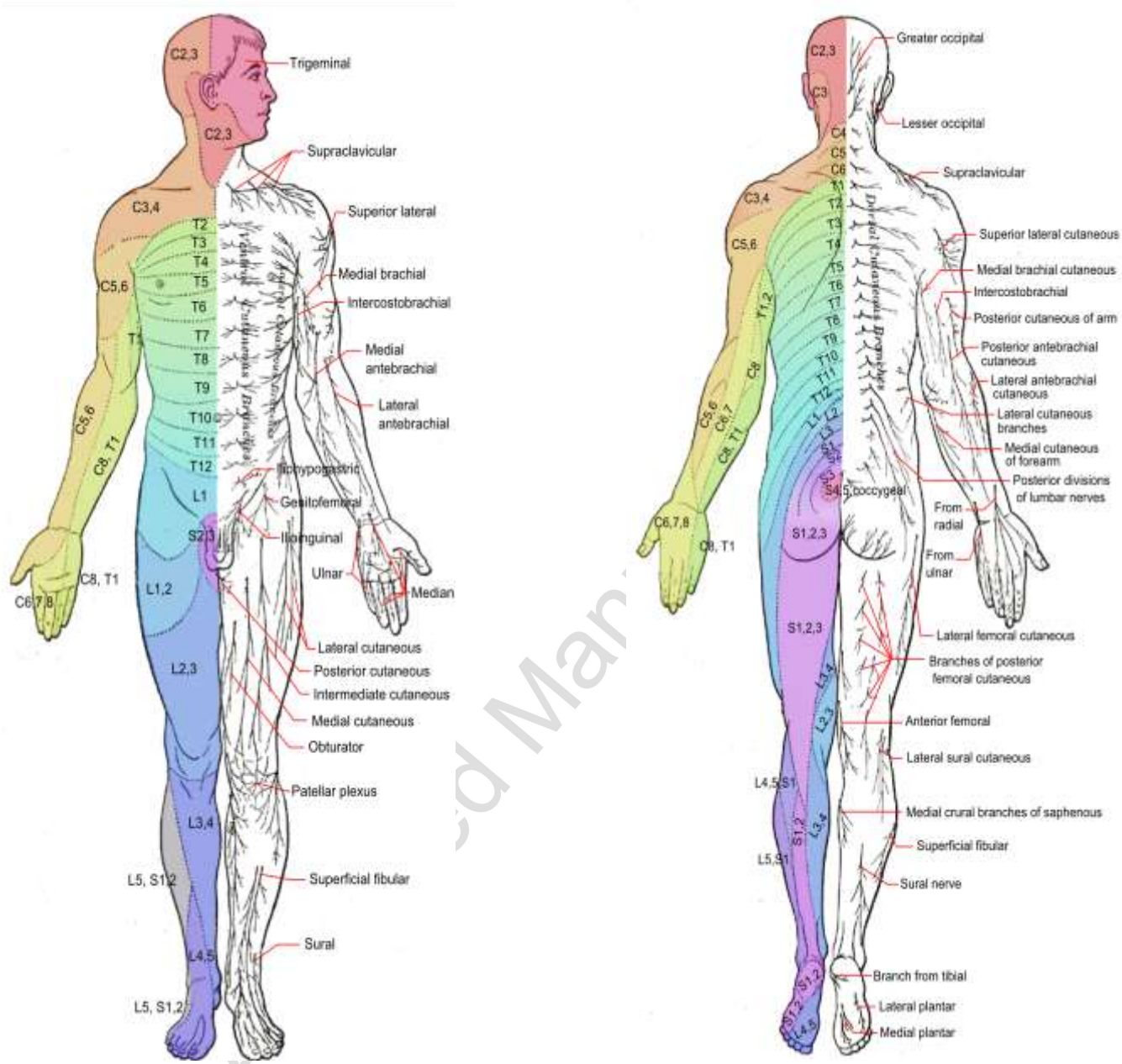
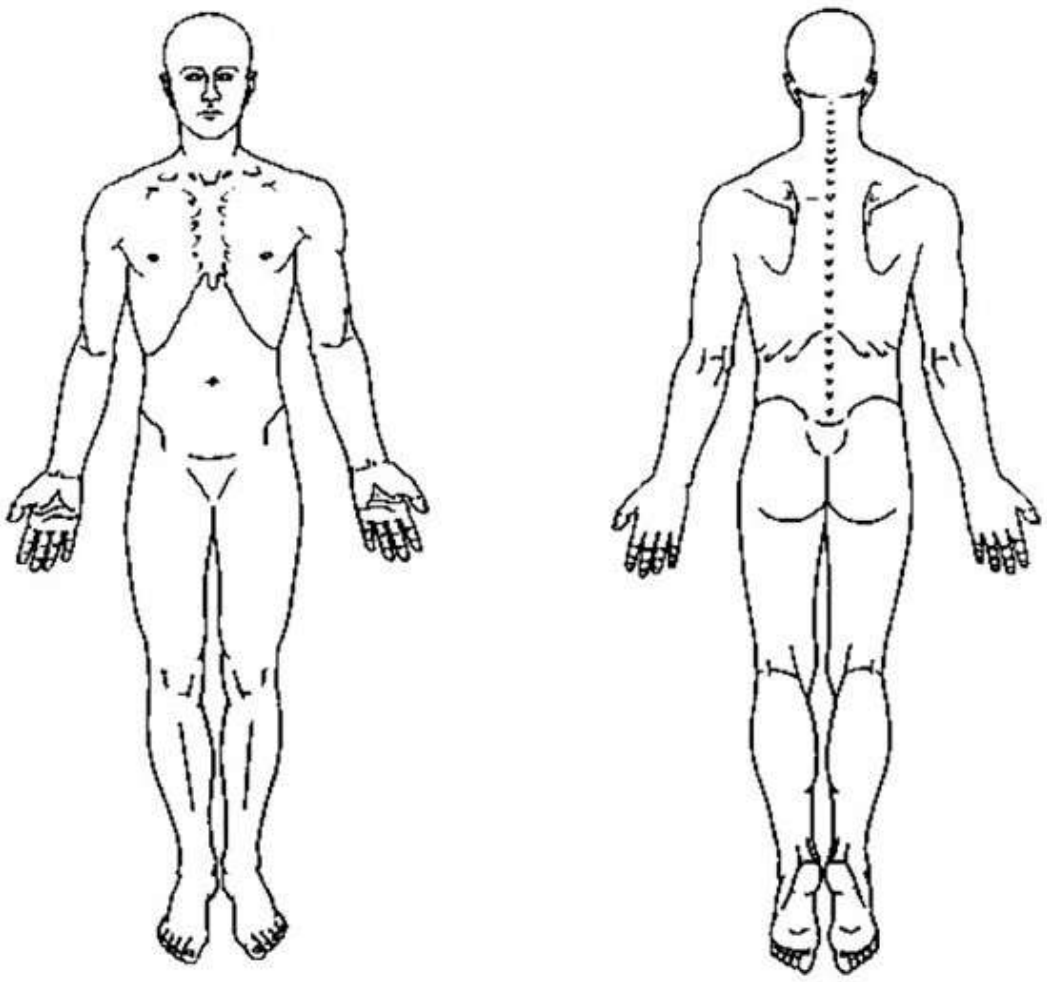


Figure 1.

1

Description: Pain Numbness Tingling
(circle) Pressure Hot Cold Other:



No Symptoms

2

3

4 Figure 2.

5

6

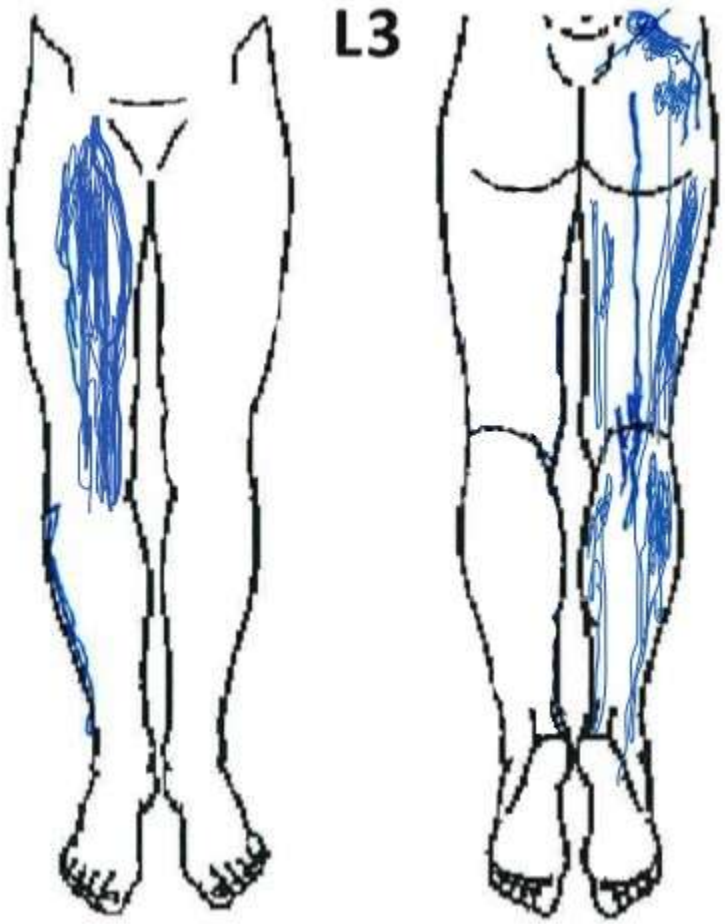


Figure 3.

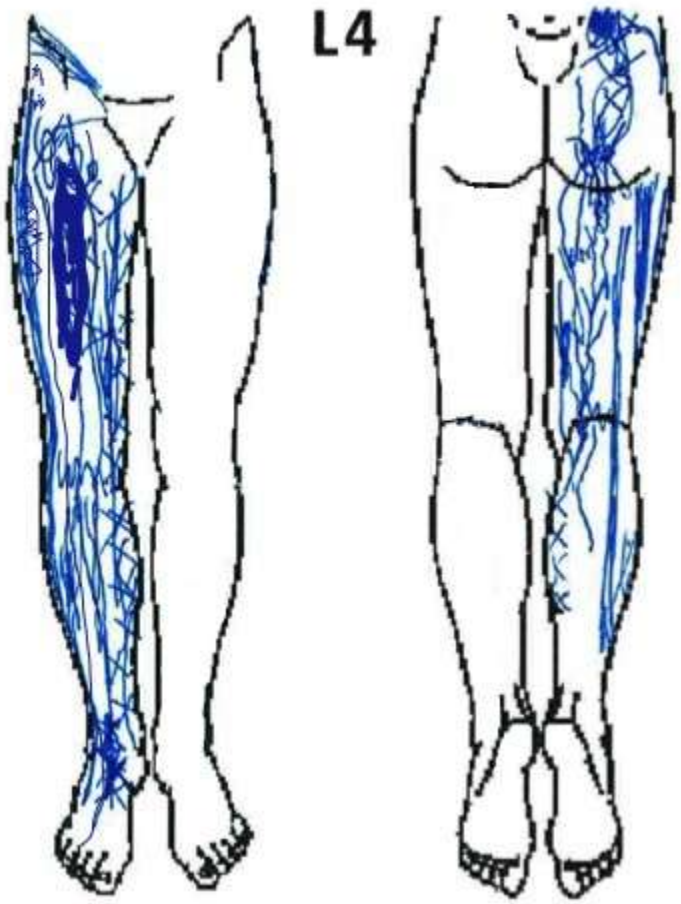


Figure 4.

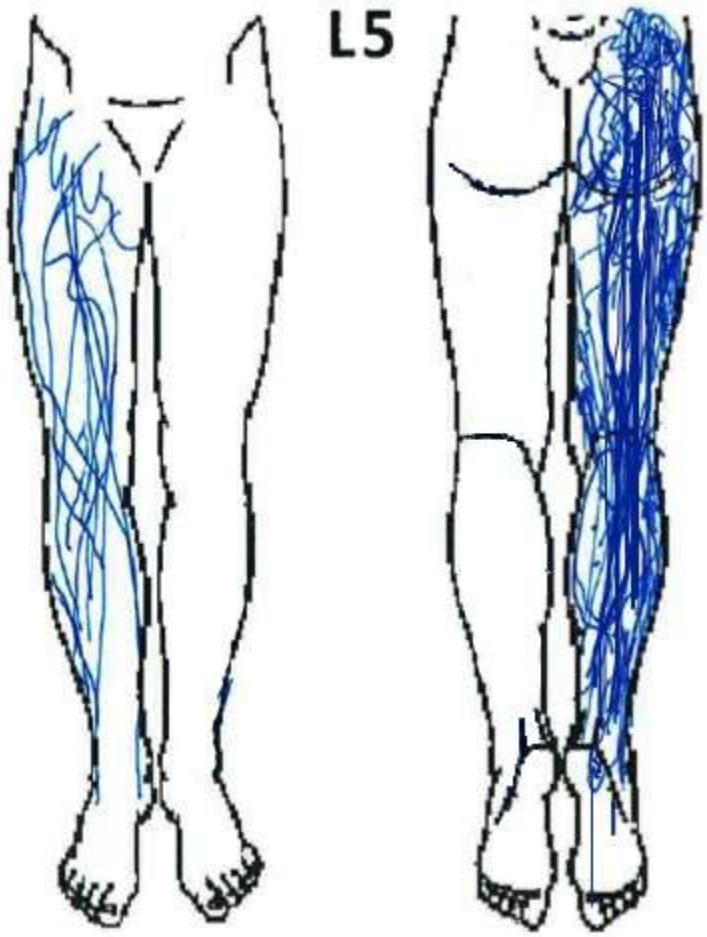


Figure 5.

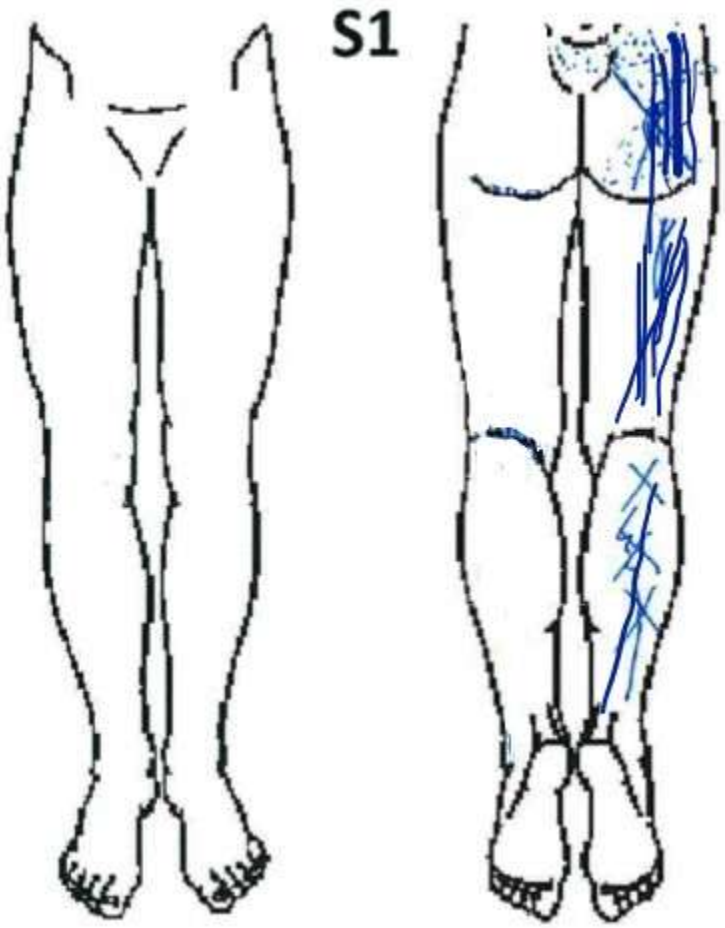


Figure 6.