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Symptom Provocation of Fluoroscopically Guided Cervical Nerve Root Stimulation

Are Dynatomal Maps Identical to Dermatomal Maps?

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Study Design. This prospective study consisted of mechanical stimulation of cervical nerve roots C4 to C8 in patients with cervical radicular symptoms undergoing diagnostic selective nerve root block.

Objectives. To document the distribution of pain and paresthesias that result from stimulation of specific cervical nerve roots and compare that distribution to documented sensory dermatomal maps.

Summary of Background Data. Cervical dermatomes were first studied in the late 19th century. The results of those studies underpin current clinical decision making for patients with neck and arm pain. However, it has been observed that patients with radicular symptoms may have cervical pathology by radiographic imaging that is not corroborative, or have imaging studies that suggest a lesion at a level other than the one suggested by the patient's dermatomal symptoms. These observations may suggest that cervical dermatomal mapping is inaccurate or the distribution of referred symptoms (dynatome) from cervical root irritation is different than the sensory deficit outlined by dermatomal maps.

Methods. Inclusion criteria consisted of consecutive patients undergoing fluoroscopically guided diagnostic cervical selective nerve root blocks from C4 to C8. Immediately preceding contrast injection, mechanical stimulation of the root was performed. An independent observer interviewed and recorded the location of provoked symptoms on a pain diagram. Visual data was subsequently compiled using a 793 body sector bit map. Forty-three clinically relevant body regions were defined on this bit map. Frequencies of symptom provocation and likelihood of symptom location from C4 to C8 stimulation of each nerve root were generated.

Results. One hundred thirty-four cervical nerve root stimulations were performed on 87 subjects. There were 4 nerve root stimulations at C4, 14 at C5, 43 at C6, 52 at C7, and 21 at C8. Analyzing the frequency of involvement of the predetermined clinically relevant body regions either individually or in various combinations yielded more than 1,000 bits of data. Although the distribution of symptom provocation resembled the classic dermatomal maps for cervical nerve roots, symptoms were frequently provoked outside of the distribution of classic dermatomal maps.

Conclusion. The current study demonstrates a distinct difference between dynatomal and dermatomal maps. [Key words: dermatome, radiculopathy, selective nerve root block] **Spine 1998;23:2235–2242**

Sherrington[9,10] first studied dermatomes in the late 19th century. He mapped remaining areas of sensation to skin pinch in Rhesus monkeys who had undergone sectioning of several roots above and below an intact root. Foerster,[2] in 1933, used a similar mapping technique to study humans who had suffered root injury. He found that human dermatomal maps varied little from the animal model. Keegan and Garrett[5] set forth the most widely used dermatomal mapping system in 1948 after studying the distribution of hypoalgesia in the extremities from single level focal disc protrusions in 1,329 patients and 10 nerve root injections in healthy volunteers. This system continues to be the standard of reference in most anatomy textbooks,[1] and is, therefore, used extensively by clinicians to diagnose segmental injury of the spinal cord or roots.

The above studies addressed loss of sensation as a result of root injury. To date, there has been no study that attempts to correlate these sensory dermatomes with the distribution of pain and paresthesias at the time of nerve root irritation. Despite the paucity of scientific inquiry about symptom patterns caused by radicular injury, clinical decisions are made, in large part, by correlating a patient's symptoms and imaging study with

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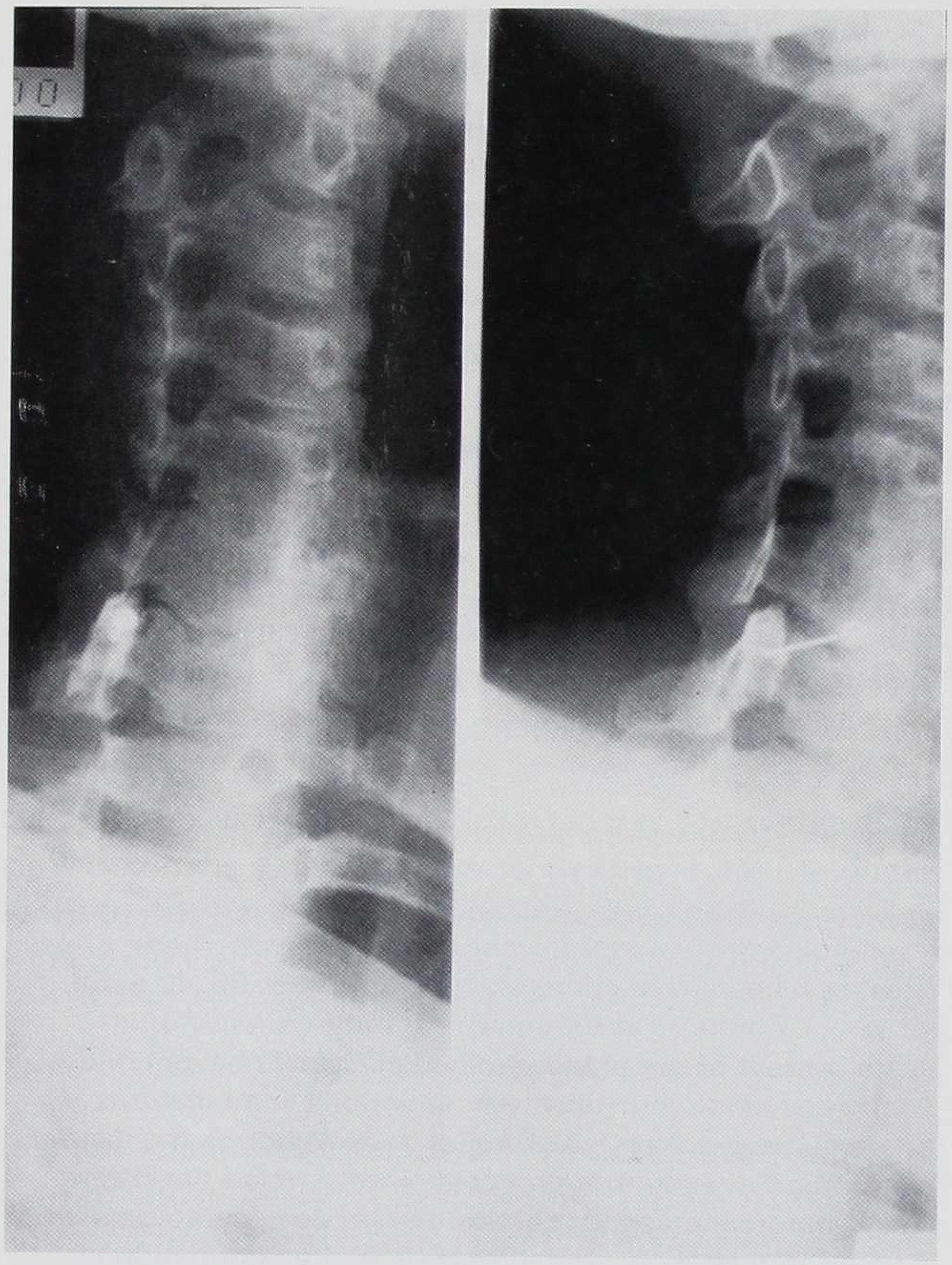

Figure 1. Fluoroscopically guided C7 block. Right, contrast pre-root stimulation. Left, appropriate needle placement post-root stimulation.

sensory dermatomal maps, assuming that pain and paresthesias will follow the same distribution. It is not uncommon, however, for a patient with a focal root lesion to describe seemingly non-dermatomal symptoms or for a patient's imaging study to demonstrate root involvement at a level other than the one predicted by a dermatomal map.

We investigated whether a cervical nerve root's dynatome, or pattern of referred symptoms, would differ from its classic sensory dermatome.

■ Materials and Methods

Subjects consisted of consecutive patients with cervical radicular symptoms who underwent fluoroscopically guided diagnostic selective nerve root block at the C4 to C8 levels. Cervical radicular symptoms were defined as pain that radiated through the upper extremity distal to the elbow. These symptoms could be reproduced with Spurlings maneuver and root tension maneuver. All subjects had normal reflexes and no motor deficits. All subjects had a cervical magnetic resonance imaging scan performed before testing. None had a focal protrusion. Each subject with arm symptoms had undergone electrodiagnostic testing. None demonstrated acute electromyographic abnormalities. Each subject was informed that the cervical nerve root would be stimulated with a 22-gauge, 3-cm needle just after contrast (Omnipaque, Nycomed, Princeton, NJ) injection and just before contrast and local anesthetic injection (Figure 1). They were instructed to remember the location of pain and paresthesias created at the time their nerve root was stimulated. Each subject had only one nerve root stimulated per session. Immediately after the procedure, an independent observer interviewed each patient and recorded the location of provoked symptoms on a pain diagram. Visual data was subsequently compiled using a 793 body sector bit map (Figure 2). Forty-three clinically relevant body regions were defined on the bit map (Figure 3). Dynatomal maps for each nerve root were created (Figure 4).

■ Results

Eighty-seven subjects underwent 134 cervical nerve root stimulations. There were 4 at C4, 14 at C5, 43 at C6, 52 at C7, and 21 at C8. Analyzing body regions effected independently or in combinations yielded more than 1,000 bits of data. Frequencies of symptom provocation and likelihood of symptom location for each nerve root in each clinically relevant body region were generated (Tables 1 and 2). A summary of some of the clinically relevant results is provided below.

Subjects who underwent C4 root stimulation reported symptoms in the posterior upper trapezius (100%), pos-

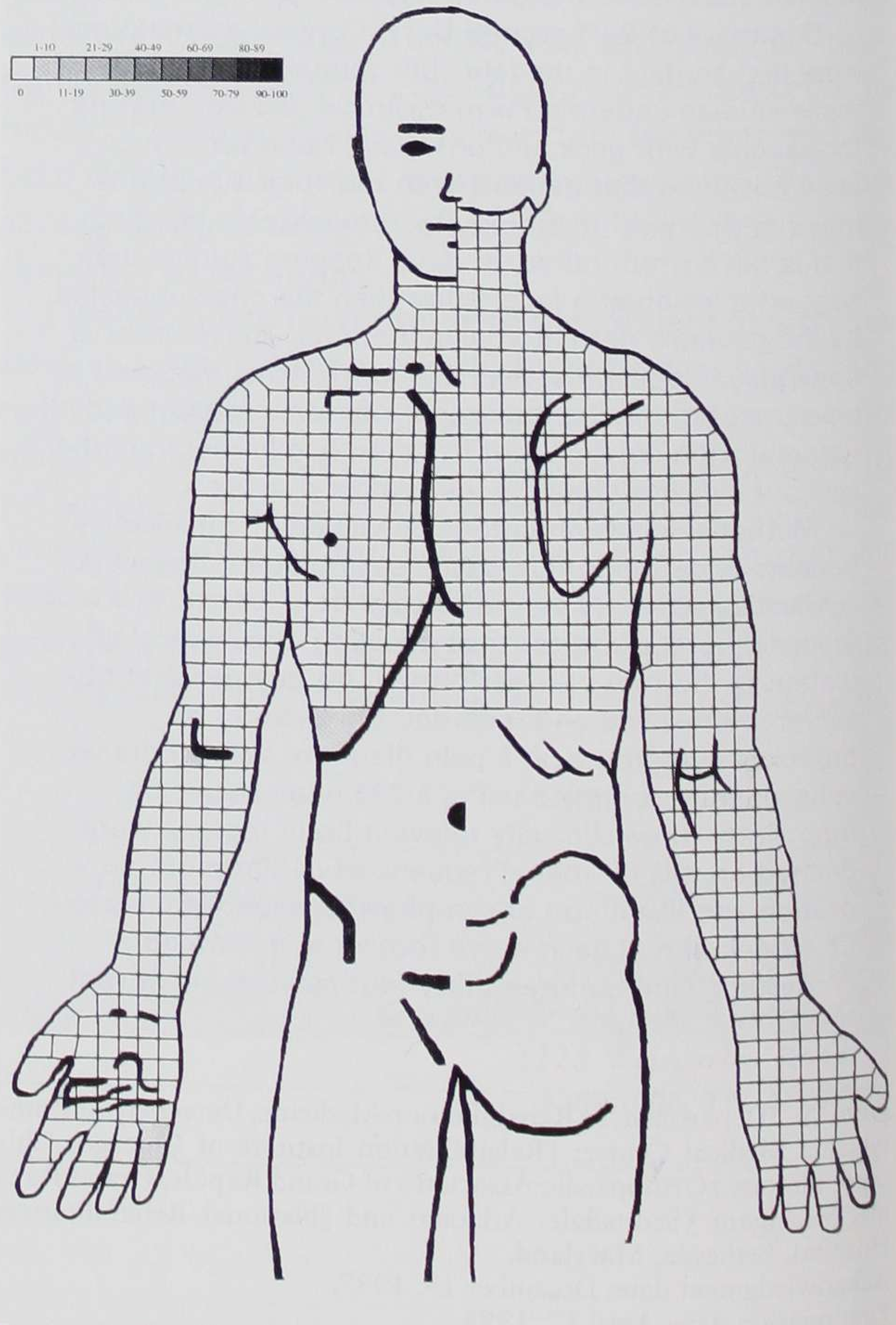

Figure 2. Combined ventral (left) and dorsal (right) map divided into 793 bits.

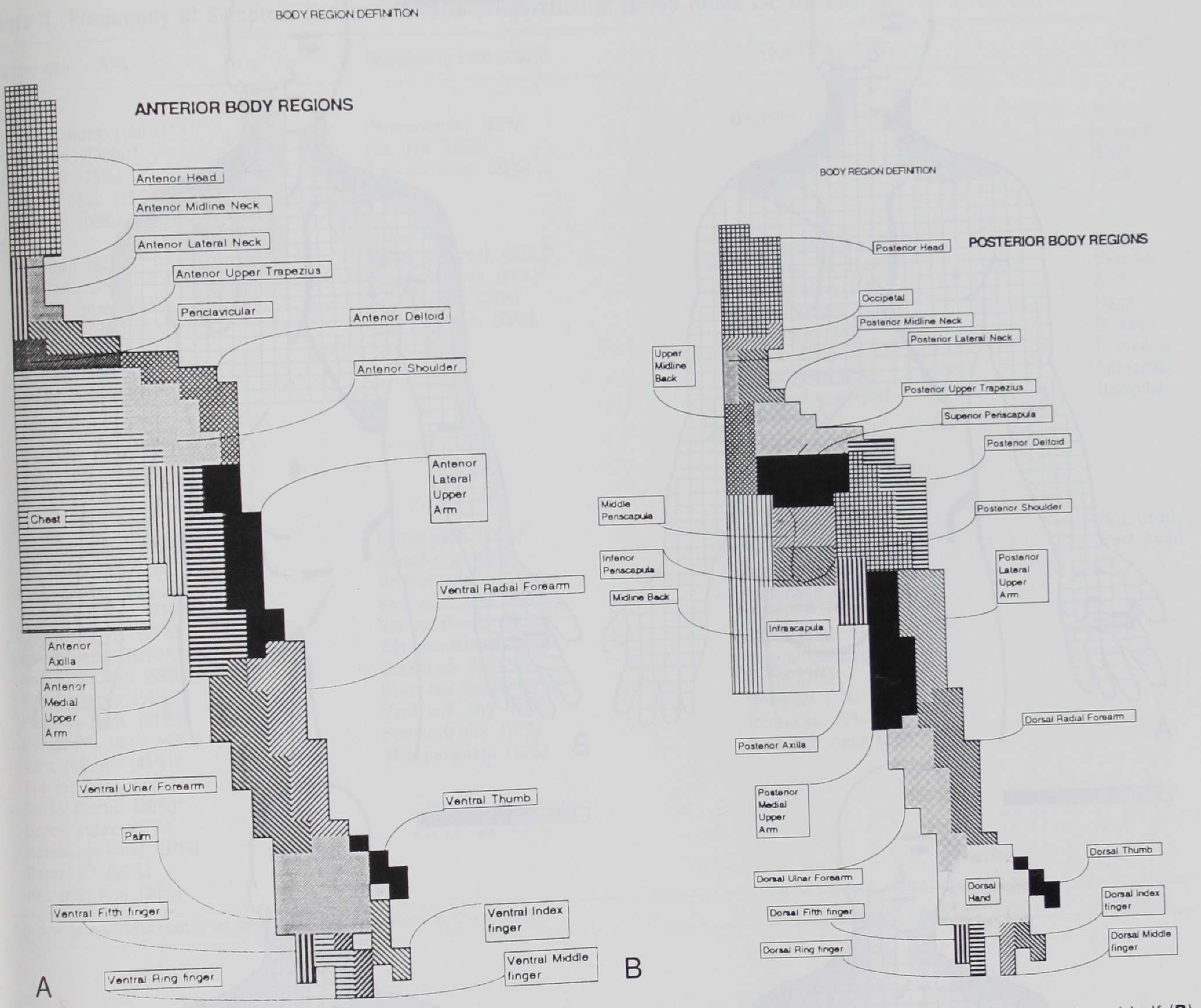

Figure 3. Body map demonstrating the distribution of clinically relevant body regions divided into a ventral half (**A**) and dorsal half (**B**).

terior lateral neck (100%), and/or posterior deltoid (75%), in the vast majority of cases. In 25% of subjects, C4 stimulation caused symptoms in the periclavicular region, anterior deltoid, or superior periscapular region. Occipital symptoms were provoked in 8% of subjects.

Stimulation of C5 caused symptoms in the posterior trapezius (92%), posterior deltoid (79%), or posterior lateral neck (64%) most frequently. Of C5 stimulations, 57% caused symptoms in the anterior deltoid, and the anterior lateral upper arm was involved in 29% of stimulations. The C5 root was found to be the most likely root to refer symptoms to the periclavicular region (43% of all C5 root stimulations). Stimulation of C5 caused symptoms in the ventral radial forearm in only 14% of cases and was just as likely to cause symptoms in the ulnar palm. Patients reported symptoms in the thumb 7% of the time. They never reported symptoms in the other digits, dorsum of the hand, or head.

Of the 43 C6 root stimulations, symptoms were provoked in the posterior trapezius (74%), posterior deltoid (79%), posterior lateral arm (79%), or dorsal radial forearm (67%) with great regularity. Symptoms in the anterior deltoid were also reported in 74% of cases. The dorsal radial hand, dorsal thumb, and dorsal index finger were involved less commonly with symptoms reported in 49%, 40%, and 37%, respectively. Stimulation of the C6 root was also likely to cause symptoms in the dorsal ulnar hand, dorsal 5th finger, or dorsal ring finger, with frequencies being 37%, 30%, and 28%, respectively. The only body regions that were not reported by at least one subject were the anterior and posterior head.

Stimulation of C7 provoked symptoms in the posterior deltoid (79%), posterior upper trapezius (77%), posterior lateral arm (65%), posterior shoulder (63%), or dorsal radial hand (67%) most frequently. Symptoms in the dorsal radial forearm, dorsal index finger, or dor-

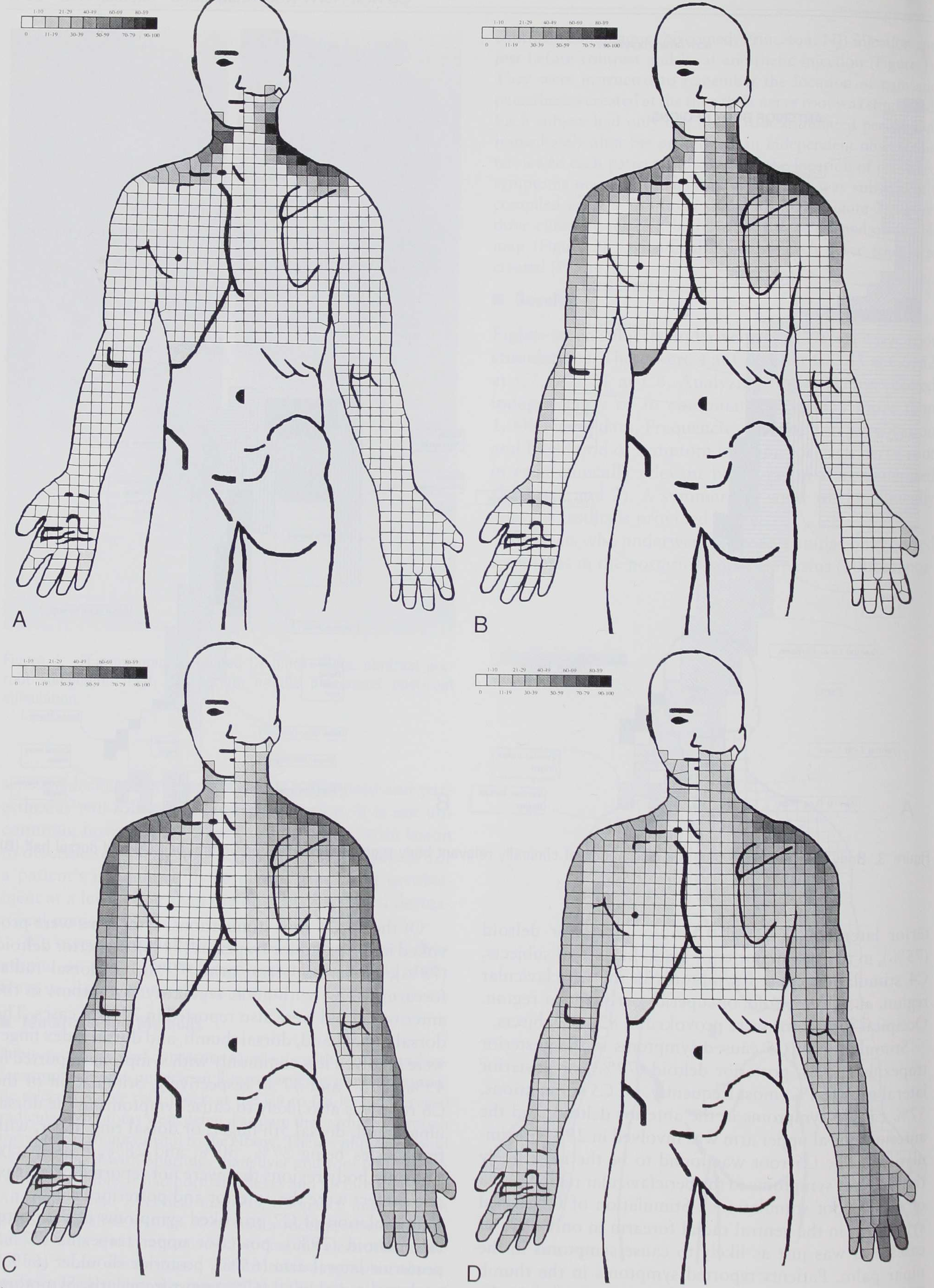

Figure 4. Percent occurrence of symptom provocation per bit for the C4 to C7 roots. **A**, C4 dynatome; **B**, C5 dynatome; **C**, C6 dynatome; **D**, C7 dynatome.

Table 1. Frequency of Symptom Production With Stimulation of Nerve Roots C4, C5, and C6

Primary pain >30%	Secondary Pain <30%	Rare Pain <15%	Never
C4 Post lat. neck (100%)* Post trap (100%)* Post delt (75%) Ant. lat. neck (75%)* Ant. trap (50%)	Periclavicular (25%) Ant. delt. (25%) Sup. periscap. (25%)	Occipital (8%)	Arm Forearm Hand Head
C5 Post. trap (92%) Post. delt. (79%) Post. lat. neck (64%) Ant. delt. (57%) Ant. trap. (50%) Periclavicular (43%)* Ant. lat. neck (43%)	Upper mid back (29%)* Post. mid neck (21%)* Ant. lat. arm (29%) Sup. periscap. (29%)	Ulnar palm (14%) Vent. rad. FA (14%) Ant. shoulder (14%) Post. shoulder (14%) Mid. back (14%) Thumb (7%) Radial palm (7%) Ant. med arm (7%) Chest (7%) Post. lat. arm (7%) Mid. periscap (7%) Inf. periscap. (7%)	Fingers Vent FA Axilla Head D. hand P. med. A Infrascap Occipital
C6 Post. lat. arm (79%)* Ant. delt. (74%)* Post. delt. (74%) Post upper trap (74%) Dorsal rad. FA (67%) Ant. lat. arm (58%)* Ant. upper trap (58%)* Sup. periscap (51%)* Post. lat. neck (51%) Dorsal rad. hand (49%) Vent. rad. FA (44%)* Ant. lat. neck (43%) Dorsal thumb (40%)* Dorsal index (37%) Dorsal uln hand (37%) Dorsal 5th (30%) Ant. med arm (30%)	Radial palm (28%)* Dorsal ring (28%) Ventral index (26%)* Post med. arm (26%) Ventral thumb (23%)* Ant. shoulder (23%) Dorsal uln FA (23%) Dorsl mid finger (21%) Vent. mid. fing. (16%) Periclavicular (16%) Mid. periscap. (16%)	Ulnar palm (14%) Vent. uln. FA (14%) Upper mid. back (14%) Mid. back (13%) Vent. 5th (11%) Chest (9%) Inferior periscap. (9%) Axilla (7%) Occipital (5%) Infrascap. (2%) Post. mid. neck (2%)	Ant. head Post. head

* Indicates no other root is as likely to cause symptoms in this location.

sal long finger were reported in 58%, 52%, and 50% of cases, respectively. Thirty percent of the subjects reported symptoms on the dorsum of the thumb, and symptoms on the ventral thumb were reported 9% of the time. The C7 root was as likely to cause symptoms on the ventral aspect of the fifth digit as it was on the ventral aspect of the index finger (13% each). The radial and ulnar palm also had nearly identical frequencies (21% and 19%, respectively). C7 was the only root to cause symptoms in the anterior head. There was no body region that was not reported at least once.

Stimulation of the C8 nerve root caused symptoms in the posterior deltoid (71%), posterior medial arm (76%), posterior lateral arm (62%), dorsal ulnar forearm (67%), or dorsal ulnar hand (62%) most frequently. The dorsal fifth and ring fingers were reported in 48% and 43% of cases, respectively. Symptoms in the anterior deltoid were also reported in 43% of C8 root stimulations. The dorsal radial hand and ventral thumb were reported 33% and 14% of the time, respectively. The C8 root was more likely to cause symptoms on the ventral aspect of the thumb (14%) than the ventral aspect of the fifth finger (5%). The C8 root never caused head symptoms.

Other findings included:

- Symptoms in all 5 fingers were reported in 12% of C6 stimulations, 10% of C7 stimulations, and 5% of C8 stimulations.
- The fifth digit was the only symptomatic finger in 2% of C6 stimulations, and only the ring and fifth were symptomatic in 16% of C6 stimulations.
- The thumb and index finger were the only fingers involved in 10% of C8 stimulations.
- The index and middle finger were the only fingers involved in 11% of C6, C7, and C8 stimulations.
- Symptoms in the dorsal index finger were caused with some regularity by C7 (52%), C6 (37%), and C8 (24%). Dorsal fifth digit symptoms were described in 48% of C8, 33% of C7, and 30% of C6 stimulations.
- An analysis was performed of how frequently a given nerve root stimulation would provoke symptoms in only one digit, and it was found that the

Table 2. Frequency of Symptom Production With Stimulation of Nerve Roots C7 and C8

Root	Primary pain >30%	Secondary Pain <30%	Rare Pain <15%	Never
C7	Post. delt. (79%)*	Dorsal thumb (29%)	Vent. index (13%)	None
	Post. upper trap (77%)	Vent. rad FA (23%)	Vent. 5th (13%)	
	Dorsal rad. hand (67%)*	Vent. uln. FA (23%)	Ant. lat. neck (13%)	
	Post. lat. arm (65%)	Radial palm (21%)	Upper mid. back (12%)	
	Post. shoulder (63%)	Ant. axilla (21%)	Vent. thumb (9%)	
	Dorsal uln. hand (60%)	Ulnar palm (19%)	Occipital (8%)	
	Dorsal rad. FA (58%)	Periclavicular (19%)	Mid back (8%)	
	Post. med. arm (58%)	Vent. mid finger (17%)*	Infrascapular (6%)*	
	Dorsal index (52%)*	Vent. ring (17%)*	Post. mid. back (6%)	
	Dorsal mid fing. (50%)*	Chest (17%)*	Ant. head (4%)*	
	Ant. deltoid (48%)	Ant. shoulder (17%)	Post. head (2%)	
	Ant. lat. arm (42%)	Post. axilla (17%)		
	Dorsal uln. FA (42%)	Mid periscap. (17%)		
	Sup. periscap. (42%)	Inferior periscap. (17%)		
	Dorsal ring (38%)			
	Post. lat. neck (38%)			
	Ant. upper trap (37%)			
	Dorsal 5th (32%)			
C8	Post. med arm (76%)*	Anterior axilla (29%)*	Mid. back (14%)*	Ant. head
	Post. deltoid (71%)	Posterior axilla (29%)*	Vent. thumb (14%)	Infrascap
	Post. shoulder (67%)*	Mid. periscap. (29%)	Vent. index (14%)	Post. mid. neck
	Dorsal uln. FA (67%)*	Ant. upper trap (24%)	Radial palm (14%)	Occipital
	Dorsal uln. hand (62%)*	Dorsal index (24%)	Ant. lat. arm (14%)	Post. head
	Post. lat. arm (62%)	Post. lat. neck (24%)	Chest (14%)	
	Post. upper trap (52%)	Inferior periscap. (24%)*	Vent. rad. FA (10%)	
	Dorsal 5th (48%)*	Ulnar palm (19%)	Post. med. neck (6%)	
	Ant. med. arm (43%)*	Periclavicular (19%)	Vent. mid. finger (5%)	
	Ant. deltoid (43%)		Vent. ring (5%)	
	Dorsal ring (43%)*		Ant. lat. neck (5%)	
	Vent. uln. FA (38%)*		Dorsal thumb (5%)	
	Sup. periscap. (38%)		Upper mid. back (5%)	
	Ant. shoulder (33%)			
	Dorsal mid. fing (33%)			
	Dorsal rad. hand (33%)			
	Dorsal rad. FA (33%)			

* Indicates no other root is as likely to cause symptoms in this location.

thumb was the only digit involved in 100% of C5, 8% of C6, and 5% of C7 stimulations that caused symptoms in the fingers. For the fifth digit, the percentages were 17% of C8 and 3% of C6 stimulations.

- Ventral or dorsal fifth finger along with ventral forearm symptoms were only caused by C6 or C7 stimulation and never C8.

Discussion

The classic dermatomes described by Keegan and Garrett[5] are discrete bands with little if any overlap. The C4 dermatome includes the posterior, lateral, and anterior neck in its entirety. In the posterior neck, the band does not extend below the C5 spinous process or to the occipital region, and laterally, it includes the most proximal aspect of the anterior and posterior upper trapezius. The C5 dermatome extends as a narrow band from the C5 spinous process over the upper trapezius to include the anterior upper trapezius, the periclavicular region, the anterior shoulder, the ventral radial arm, and the ventral radial forearm down to, but not including, the wrist. The C6 dermatome originates between the C6 and C7 spinous processes and extends to the posterior deltoid, posterior lateral arm, radial forearm and wrist to the ventral and dorsal thumb. The C7 dermatome includes a band between the C7 and T1 spinous processes that extends to the posterior shoulder, posterior lateral arm, dorsal radial forearm, and dorsal and ventral radial hand including the dorsal and ventral index and middle fingers. The C8 dermatome includes a band from the C8 spinous process to the posterior shoulder, posterior medial arm, dorsal and ventral ulnar forearm, and dorsal and ventral hand to include the ring and fifth digits.

Although our results suggest that some of the symptoms provoked by stimulation of a given nerve root will fall within the classic dermatomal distribution a *relatively* high percentage of the time, it was not uncommon for stimulation to provoke unexpected symptoms outside the classic dermatomal map for that root. There may be several explanations for the disparity between these results and the classic literature.

First, the most widely used human dermatomal maps of Foerster[2] and Keegan and Garrett[5] were meant to be comprehensive but also simplistic and discrete enough to be clinically useful. As such, their undoubtedly voluminous and complex data had to be distilled to the point that an understandable map could be generated. Normal variations may have been excluded and, throughout the years, forgotten. Indeed, if one reviews the animal work of Sherrington,[9,10] one finds that individual dermatomes overlapped to such an extent that sectioning of a single nerve root did not result in any detectable loss of skin sensibility. After Sherrington's work, Head and Campbell[4] constructed human dermatomal maps after observing the skin eruptions of patients with herpes zoster. They found much more discrete dermatomes for each nerve root with very little overlap. Foerster's[2] work makes reference to this discrepancy and then sets out to resolve the issue. He concluded, "the dermatomes of man overlap to the same large degree as do those of the monkey. I have never found that resection of one single root in man was followed by loss of sensibility. . ." In addition, he points out that if only a single "filament" of a given root was intact, there was no corresponding loss of sensibility within that root's dermatome. This has significant bearing on subsequent studies that draw conclusions from loss of skin sensibility in humans from simple root compression, and may suggest that the distribution of symptoms from compression would be a more accurate way to construct maps. Keegan and Garrett[5] note that their dermatomal maps did not overlap significantly, but do point out that, occasionally, a "secondary zone of very slight hyposensitivity can be found." They call their maps the "dermatome areas of *primary* hyposensitivity" and admit "they obviously do not represent the full area of cutaneous distribution of nerve fibers entering over a single nerve root."

Secondly, the work of Keegan and Garret[5] had important technical flaws. Only 29% of the clinical root lesions were confirmed by surgery, leaving open the possibility that scleratomal referral patterns were mistakenly included in their dermatomal maps. The vast majority of root lesions were confirmed by imaging study only. Myelography is assumed to have been used because computed tomography did not become readily available for another 25 years. It appears the authors correlated the clinical anatomy with the level of disc protrusion seen on myelography to determine which root was likely involved, as opposed to documented lack of root filling. They assumed that the majority of disc herniations would be posterolateral and therefore compress the root crossing the disc space. These assumptions, although accurate a large percentage of the time, do not account for foraminal stenoses, lateral, extra-foraminal and foraminal herniations, or sequestered or migrated disc fragments. Also, the experimental nerve root blocks in healthy volunteers were performed with 2 ml of 2% Xylocaine (Astra USA, Westborough, MA), which would likely anesthetize adjacent nerve roots.[3,7]

Third, intrathecal root anastomoses that occur with regularity in the cervical spine and infrequently in the lumbar spine may account for the lack of consistent and discrete dermatomal patterns in the upper extremity. Schwartz[8] first described these anatomic variants in 1956. He studied the cervical spines of 13 cadavers and found at least one anastomosis connecting one dorsal root to the dorsal root of an adjacent level in all specimens. The frequency varied from one anastomosis found unilaterally to six anastomotic rami on each side. The majority occurred between C6 and C7. They did not necessarily occur symmetrically. Moriishi et al,[6] in 1989, dissected the entire spine of more than 100 human cadavers and found the frequency of dorsal root intersegmental anastomoses to be 61% in the cervical spine, 7% in the thoracic spine, and 22% in the lumbar spine. The frequency of ventral root anastomoses were 10%, 0%, and 5% for cervical, thoracic, and lumbar regions, respectively. None of the cervical root levels stimulated in the current study were reported to cause symptoms exclusively in the classic dermatome in more than 50% of subjects. These results seem to correlate well with those of Moriishi et al.

Fourth, the variability of symptom distribution from documented single level root irritation could be explained by the pre or post-fixed plexus, but the frequency of abnormal symptom provocation in the current study could not be entirely explained by this relatively rare occurrence.

Finally, no study has definitively demonstrated that the symptoms provoked by nerve root irritation will occur only within that nerves' dermatomal map. The results of the current study would either suggest that they may be referred in a dynatomal pattern or that the classic dermatomal maps are, to some extent, inaccurate. In either case, our findings may explain some patient's seemingly non-dermatomal pain complaints.

■ Conclusion

This study demonstrates a distinct difference between dynatomal and dermatomal maps. Further study is necessary to assess their relative clinical use.

References

1. Adams AE. Grant's Atlas of Anatomy, 7th ed. Baltimore: Williams and Wilkins; 1978:5–41.
2. Foerster O. The dermatomes in man. Brain 1933;102:1–39.
3. Haueisen DC, Smith BS, Myers SR, Pryce ML. The diagnostic accuracy of spinal nerve injection studies. Their role in the evaluation of recurrent sciatica. Clin Orthop Rel Res 1985; 198:179–83.
4. Head H, Campbell AW. The pathology of herpes zoster and its bearing on sensory localization. Brain 1900;23:353–523.
5. Keegan JJ, Garrett FD. The segmental distribution of the cutaneous nerves in the limbs of man. Anat Rec 1948;102:409–37.
6. Moriishi J, Otani K, Tanaka K, Inoue S. The intersegmental anastomoses between spinal nerve roots. Anat Rec 1989; 224:110–6.
7. Schutz H, Lougheed WM, Wortzman G, Awerbuck BG. Intervertebral nerve-root in the investigation of chronic lumbar disc disease. Can J Surg 1973;16:217–21.

8. Schwartz HG. Anastomoses between cervical nerve roots. Neurosurgery 1956;13:190–4.

9. Sherrington CS. Experiments in examination of the peripheral distribution of the fibbers of the posterior roots of some spinal nerves. Part I. Phil Trans Roy Soc London, Ser. B, 1893; 184:641–763.

10. Sherrington CS. Experiments in examination of the peripheral distribution of the fibres of the posterior roots of some spinal nerves. Part II. Phil Trans Roy Soc London, Ser. B, 1898;190:45–187.

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