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Clinical Study

Exploration of sensory impairments associated with C6 and C7 radiculopathies

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Abstact

BACKGROUND CONTEXT: Cervical radiculopathy is a common disorder caused by compression of the cervical nerve roots and is characterized by arm pain and altered sensory-motor function. Incongruity in the locations of C6 and C7 dermatomes in competing versions of historical dermatome maps has plagued interpretation of impaired sensation associated with C6 and C7 radiculopathies. Magnetic resonance imaging (MRI) allows accurate identification of the C6 or C7 nerve root compression and therefore makes it possible to explore sensory findings that are associated with compression of specific nerve root.

PURPOSE: This study compared the locations of impaired sensation in subjects with cervical radiculopathy from MRI-confirmed C6 and C7 nerve root compression.

STUDY DESIGN: Case series was used for this study.

PATIENT SAMPLE: A total of 122 subjects with symptoms suggestive of cervical radiculopathy were recruited by 11 spine specialist from 5 practice locations. Of these, 30 subjects had MRI-confirmed C6 and 40 subjects C7 radiculopathy.

OUTCOME MEASURES: Standardized pinprick sensory examination of the forearm and hand of every subject was performed, and the locations of sensory impairments were recorded.

METHODS: Sensory examination was performed before reviewing MRI results or performing motor or reflex examination. Areas of impaired sensation were recorded on drawings of the palmar and dorsal forearm and hand, and translated using a grid into 36 specific areas for analysis. Chi-square was used to compare frequencies of findings for each grid area for C6 and C7 radiculopathies. Power analysis suggested that a minimum of 27 subjects in each group were needed to detect a 30 percentage point difference in frequency of sensory impairments. Significance was set at $\leq .05$.

RESULTS: Approximately 80% of subjects had impaired sensation in at least 1 grid area, most often in the distal forearm and hand, and many had findings in multiple areas. There was nearly complete overlap for locations of impaired sensation for C6 and C7 radiculopathy, and the frequencies of impaired sensation differed only in the dorsal aspect of the distal radial forearm where it was twice as common in C6 radiculopathy ($p = .02$).

FDA device/drug status: Not applicable.

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CONCLUSIONS: The location of sensory impairments associated with symptomatic C6 and C7 nerve root compression overlap to the extent that caution should be exercised when predicting compression of either the C6 or C7 nerve roots based on locations of impaired sensation. Impaired sensation in the radial aspect of the distal forearm is more common in C6 radiculopathies.

Keywords: Cervical radiculopathy; Dermatomes; Physical examination; Sensory testing; MRI; Validity

Introduction

Cervical radiculopathy is characterized by pain and sensory-motor complaints involving the arm. It is caused by herniation of intervertebral discs, and hypertrophy and osteophyte formation from uncovertebral and facet joints that inflame, displace, and compress a cervical nerve root within the spinal canal or neural foramen. About 4% of the population experience cervical radiculopathy symptoms annually, with a peak incidence between age 50 and 59 [1,2].

Numerous neurologic examination findings are associated with cervical radiculopathy. Studies of surgically treated patients revealed that 64–75% of patients exhibit focal muscle weakness [1,3], 84% exhibit diminished deep tendon reflexes, and 33% exhibit impaired dermatome sensation [1]. The validity of physical examination findings has received limited study, but existing data suggest specific findings have moderate inter-rater reliability and marginal accuracy for identifying the involved nerve roots [4,5].

A standard component of the physical examination for cervical radiculopathy is assessment of sensory function of the affected arm. Here the clinician seeks subjective differences in the patient's perception of a sensory stimulus between similar areas of the symptomatic and non-symptomatic arm, and between different areas of the symptomatic arm. In clinical practice, sensory testing is usually limited to assessment of light touch using a soft object such as a cotton tip applicator, or pain using pinprick. In 1943, Keegan reported that patients with radiculopathy distinguished areas of diminished sensory function better through differences in pain intensity assessed with a pin than with light touch or temperature [6]. Even though Keegan's observation has not been confirmed by other studies, assessment of sensation with pinprick has been the preferred modality for assessing sensory loss in studies of dermatomes [7,8].

When areas of impaired sensation are detected, dermatome maps are used to decipher the most likely cervical nerve root responsible for these findings. Virtually all dermatome maps are exact duplicates or slight variations of maps originally published by either Foerester or Keegan [9,10]. These maps depict dermatomes as distinct bands around the thorax and longitudinal stripes along the limbs, and thereby imply that specific nerve roots are primarily responsible for sensory innervation of precise areas of the body. Unfortunately, these maps show significant disparities, especially in the distal upper extremity. For example, the Foerester dermatome map proposed that the index finger received innervation primarily from the C6 nerve root, whereas the Keegan dermatome map proposes that the index finger receives innervation primarily from the C7 root. In addition to the lack of consensus as to innervation patterns of cervical nerve roots, other studies have challenged the validity of dermatome maps based on observations that dermatome areas varied between individuals [11,12]. In an attempt to address this disparity, Lee et al. uses the best available evidence to consolidate results from all prior studies of human dermatomes into a new map [13]. The resulting map proposes an almost complete overlap of the C6 and C7 dermatomes (along with other dermatomes). If this proposal is correct, the sensory examination would be of limited value for differentiation of C6 and C7 radiculopathy. This proposal has not been confirmed with clinical studies.

Magnetic resonance imaging (MRI) and computed tomography (CT) can assess the cervical spine for abnormalities causing nerve root compression, and therefore these imaging studies can be used to define radicular signs and symptoms associated with specific nerve roots [5]. This ability allows the comparison of sensory findings associated with C6 and C7 radiculopathies and therefore, the ability to identify areas of the arm where sensory innervation is primarily associated with one or the other nerve root.

This study compared sensory deficits in the distal arm associated with cervical radiculopathies involving the C6 and C7 roots. The goal was to determine the value of impaired sensation in specific anatomic areas for differentiating C6 from C7 radiculopathies.

Methods

Recruitment

Subjects were recruited by 6 physiatrists and 5 orthopedic surgeons from 2 spine centers and 3 orthopedic practices in the United States. Inclusion criteria were 1) subjects aged 18–90 with suspected cervical radiculopathy because of unilateral symptoms of radiating pain in the shoulder, arm, or hand; 2) subjects with or without concurrent neurologic complaints of weakness, paresthesias, or numbness (Heller). Exclusion criteria were 1) neurologic diseases affecting the brain, spinal cord, or peripheral nerves that could impair arm sensory function; 2) distal compressive mononeuropathy such as carpal tunnel syndrome or ulnar neuropathy; 3) bilateral arm radicular symptoms (lack of asymptomatic side for comparison); 4) severe psychiatric disorders or cognitive dysfunction; and 5) absence of English language reading or writing skills required to complete study questionnaire. All recruited subjects signed an informed consent approved by the investigational review boards of the institutions affiliated with the recruitment sites.

Subjects were recruited, and sensory examinations were performed before reviewing diagnostic imaging, and before the motor and reflex parts of the structured physical examination. This was done to reduce test review bias (bias caused by knowledge of results from a prior test that influences the administration and interpretation of the target test) [14].

Because recruitment was done before review of diagnostic imaging, it was anticipated that many recruited subjects would be withdrawn after imaging was reviewed. Criterion for withdrawal were 1) CT or MRI of the cervical spine was never obtained; 2) lack of CT or MRI evidence of anatomic C6 or C7 nerve root impingement; 3) multilevel anatomic findings or central cervical spinal stenosis that could potentially be the cause of radicular symptoms; 4) other diagnoses found to be the cause of symptoms such as compressive neuropathies or pain producing medical conditions; and finally 5) areas of impaired sensation in the asymptomatic arm that precluded its use as a reference for testing of the symptomatic limb.

Collected data

Demographic and clinical information included age, gender, side of symptoms, duration of symptoms, and symptoms of arm weakness. MRI findings were recorded for the abnormal level(s) potentially causing symptoms; the involved root(s); and the type(s) of abnormality (cervical disc herniation, degenerative foraminal stenosis, central stenosis). Neck and arm pain intensity was recorded using 0–10 Numeric Pain Scales and disability recorded using the Neck Disability Index [15].

Procedure for evaluation of upper extremity sensation

Sensory testing using pinprick was performed as the first step of a standardized neurologic examination by the evaluating physician or surgeon. Subjects were asked to report areas where pinprick sensation was diminished or absent as compared to the same areas of the unaffected limb and adjacent areas of the arm with radicular symptoms.

Sensory testing proceeded from distal to proximal for each area tested. Hand sensation was evaluated by applying pinpricks at intervals of approximately 1 cm, starting at the tip of each digit and proceeding proximally along the midline of the digits, continuing over the associated metacarpal, and stopping at the crease of the wrist. Testing began with the dorsal surfaces of the digits, proceeding in order from the little, ring, middle, index fingers, and thumb. The palmar surfaces of the digits were then tested in the same manner. Forearm sensation was tested with the elbow flexed to 90° and the forearm in supination. Pinprick was applied every 2–3 cm along four lines starting at the wrist. The first line extended from the mid dorsal wrist to the posterior aspect of the elbow, the second line from the ulnar aspect of the wrist to the medial epicondyle of the elbow, the third from the center of the anterior wrist to the center of the antecubital fossa, and the fourth from the radial aspect of the wrist to the lateral epicondyle of the elbow. The boundaries of all areas with impaired pinprick were defined by testing proximal, distal, medial, and lateral from the identified area until a change to normal pinprick sensation was noted. Areas of sensory impairments were recorded on drawings of the anterior and posterior surfaces of the arms.

Additional physical examination tests

Manual muscle testing of the following muscle groups were performed: 1) elbow flexion (C5); 2) forearm pronation (C6) [5]; 3) elbow extension (C7); and 4) finger abduction (C8). Manual muscle testing results were recorded as normal if strength was equal to the asymptomatic side, or impaired if less than the asymptomatic side. The following muscle stretch reflexes were performed: 1) biceps reflex (C5); 2) brachioradialis reflex (C6); and 3) triceps reflex (C7). Results were recorded as normal if equal to the asymptomatic side, or impaired if diminished or absent compared to the asymptomatic side. Spurling sign was administered to the symptomatic side and the results recorded as positive if arm pain was reproduced, and negative if no symptoms or only neck pain resulted from this maneuver.

Statistical analysis

Statistical analyses were performed using SPSS for Windows (IBM, Armonk, NY, USA). Characteristics and clinical findings for subjects with C6 and C7 radiculopathies were compared using chi-square for nominal values. For continuous variables, Student *t* test was used if values had normal distribution or Mann-Whitney test if distributions were not normal. A grid was used to translate findings from sensory impairment drawings into 36 distinct areas for analysis. Any finding within a grid space was recorded as sensory loss for that area. Results were analyzed as for the symptomatic arm, and not separately for the right and left arm. The frequency of findings in each grid area was then compared for C6 and C7 radiculopathies using chi-square, with significance of the Fischer exact test used if less than 15% of responses were noted in any box of the chi-square table. Statistical significance was set at $p \leq .05$.

Power analysis was done before initiating this study. Based on the past reports, we suspected that specific areas of sensory impairment would be present in 35% of subjects in either C6 or C7 radiculopathy [1]. To be useful for discriminating C6 from C7 radiculopathy, we postulated that sensory impairments in these areas would be rare when there was compression of the other root, and we set the frequency of these findings at 5%. Thus there would be a 30 percentage point difference in the frequency of these findings. Setting

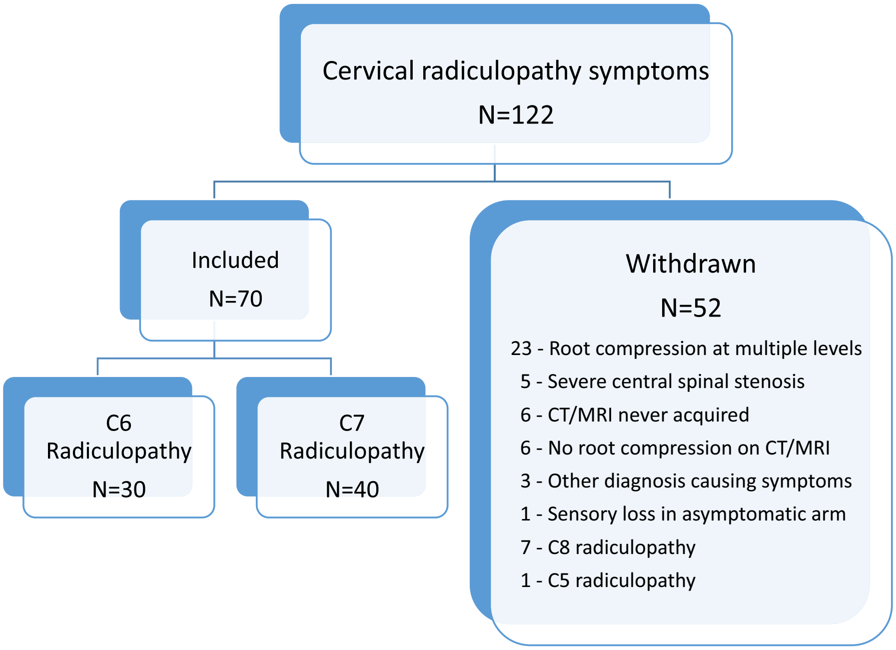

Fig. 1. Summary of recruitment and withdrawal of subjects.

two-tailed α=0.05 and β=0.20, a minimum of 27 subjects with each radiculopathy was needed to detect that difference.

Results

One hundred twenty-two subjects with symptoms suggestive of cervical radiculopathy were recruited for this study, of which 52 were withdrawn (Fig. 1). The remaining 70 subjects included 30 with C6 radiculopathy and 40 with C7 radiculopathy. Their demographics, clinical characteristics, and physical examination findings are compared in the Table. Subjects with C7 radiculopathy had slightly higher self-reported disability than those with C6 radiculopathy. Motor and reflex findings differed consistent with expected characteristics for C6 and C7 radiculopathy.

Eighty-three percent of C6 and 78 percent of C7 subjects had at least one grid area of impaired sensation to pinprick in the symptomatic arm with nearly complete overlap for locations of impaired sensation between radiculopathies. Comparisons of the frequencies of impaired sensation for each grid locations between C6 and C7 radiculopathies are presented in Figs. 2 and 3. For C6 radiculopathy, sensory impairments were most frequent in the palmar and dorsal thumb, the distal radial forearm, and palmar index finger. For C7 radiculopathy, findings were most frequent in the palmar and dorsal thumb and index finger, and the palmar middle finger. Though the frequencies of impaired sensation differed for many locations, statistical significance was only reached for grid location the distal radial aspect of the dorsal forearm, with a higher association with C6 radiculopathy (p=.02).

In addition to associations of sensory impairment with C6 or C7 radiculopathies, there were several notable observations from these subjects. Impaired sensation was most often found in the distal forearm and fingers. Most subjects had sensory impairments that extended to multiple grid areas, with some consistent associations between grid areas. For the digits, sensory impairments were most common on the anterior

Table
Comparisons of clinical characteristics and findings of subjects with C6 (N=30) and C7 (N=40) radiculopathy

	C6 Mean (SD)	C7 Mean (SD)	p[∞]
Age (years)	47 (12)	47 (8)	.80
Duration of symptoms (months)	3.0* (7.0)	2.0* (3.7)	.23
Neck pain (0–10)	4.6 (2.7)	5.3 (2.5)	.18
Arm pain (0–10)	4.5 (2.8)	5.4 (2.6)	.18
NDI (0–100)	24 (14)	31 (12)	.03
	Percent	Percent	p[‡]
Female/male	40/60	40/60	1.0
Right/left sided symptoms	50/50	43/57	.53
Prior cervical symptoms	20	22	.80
Type of abnormality herniation/DFS	63/37	78/22	.19
Motor impairments			
Elbow flexion	10	5	.42
Forearm pronation	33	15	.07
Elbow extension	10	65	.001
Finger abduction	0	15	.03
Reflex impairments			
Biceps	7	2	.39
Brachioradialis	20	0	.003
Triceps	3	25	.01
Spurling test positive	56	43	.27

N, number of subjects; SD, standard deviation; NDI, Neck Disability Index; DFS, degenerative foraminal stenosis.
[∞] Student *t* test or Mann-Whitney test.
* Median.
[‡] Chi-square or Fisher exact test.

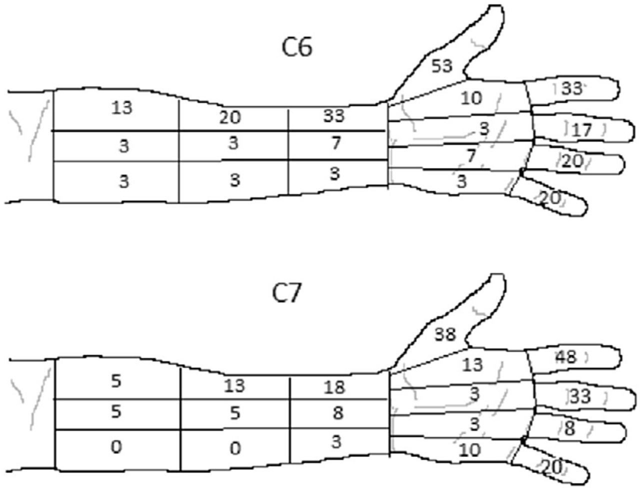

Fig. 2. The frequencies of sensory impairments on the palmar surfaces of the distal arm for C6 and C7 radiculopathies.

surfaces. Sensory loss of the dorsal digits was associated with concurrent sensory loss of the palmar aspect of that digit in 90% of the cases. Sensory impairments in the palm grid areas were uncommon, and impairments always continued in the corresponding palmar digit. Similar findings for the dorsal hand were noted, where sensory impairments were a continuation of impaired sensation of the corresponding dorsal digit for 87% of cases. Sensory impairments in the proximal palmar forearm grid areas were always continuations of sensory loss in the immediately distal forearm grid area, with similar findings noted for the dorsal forearm in 86% of cases.

Discussion

The findings reported in this study of near complete overlap of areas of sensory impairments for C6 and C7 cervical radiculopathies support the proposition of Lee et al. that in general, the C6 and C7 dermatomes innervate similar areas

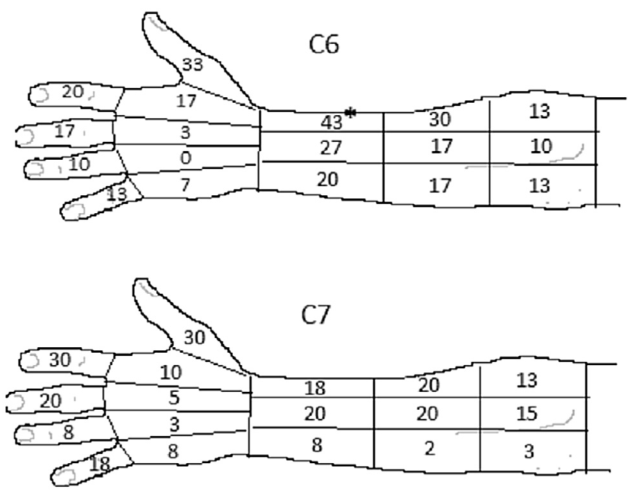

Fig. 3. The frequencies of sensory impairments on the dorsal surfaces of the distal arm for C6 and C7 radiculopathies. *p=.02.

of the distal arm [13]. These variability in areas of impaired sensation between individuals with C6 and C7 radiculopathies support the proposition that dermatomes are highly idiosyncratic [11,12]. These findings weaken the long-held proposition that distal upper extremity dermatomes reflect distinct areas where sensory innervation is dominated by specific nerve roots.

This study found that differences in frequencies of impaired sensation reached statistical significance only for the radial aspect of the distal dorsal forearm, where C6 was more common as C7 radiculopathy by 25 percentage points. The modest discriminating ability of this area had not been identified in the past and may be worth exploring further.

This study noted that sensory impairments were rarely isolated to the palm, dorsum of the hand, and proximal two thirds of the forearm; however, impairments in these areas were usually extensions of sensory impairments in the digits or distal forearm. Our findings support the earlier studies that suggested impaired sensation is most common in the distal extremes of dermatomes [6,16]. This study also demonstrated that the vast majority of sensory impairments from C6 and C7 radiculopathies could be detected by examining four areas, the radial aspect of the distal forearm, and the palmar aspects of the thumb, index, and middle fingers. These observations might be of use to those interested in clinical efficiency.

This study noted a more than two-fold higher frequency of impaired sensation than reported the epidemologic study by Radhakrishnan et al. [1]. We assume that the high frequency of impaired sensation resulted from the systematic search for impaired sensation that was the focus of our study.

A strength of this study was its intentional design to limit test review bias, defined as knowledge of prior test results that cause bias in the application and interpretation of the target test. By recruiting subjects based only on clinical presentation, and performing the systematic sensory examination before viewing imaging studies or performing other physical examination test, the examiners were not biased by preconceived knowledge about compression of either the C6 or C7 nerve roots. The importance of this sequencing of sensory testing was demonstrated in a prior study of MRI-documented lumbar radiculopathy in which the locations of sensory examination finding were less consistent with the compressed nerve root as documented by MRI when the examiner was not aware of the MRI findings at the time of the sensory examination [14]. It was postulated that knowledge of impaired motor function and diminished reflexes that have moderate specificity for C6 or C7 root compression could also introduce test review bias, and therefore, these aspects of the physical examination were performed after the sensory results had been recorded. Regardless of efforts to control bias, all recruiting clinicians have extensive experience with cervical radiculopathies and would likely have preconceived notions as to the most likely locations for C6 and C7 sensory impairments in cervical radiculopathy patients. The decision to include 11 recruiting clinicians was intended to dilute the impact of the bias of any one clinician.

A second strength of this study was the withdrawal of all recruited subjects with concurrent anatomic findings at both C5–C6 and C6–C7 that could potentially compress both the C6 and C7 roots, and also withdrawal of those with central stenosis that could impact sensory function at the level of the spinal cord in addition to the nerve roots. By retaining only focal pathology, we are reasonably confident that sensory findings could be attributed to a single nerve root. An additional strength was the use of the asymptomatic extremity as a reference standard, lessening the possibility that systemic disorders were responsible for the sensory findings.

The weakness of this study is that it was underpowered to detect statistically significant differences between C6 and C7 radiculopathies when those differences were only modest, such as the palmar thumb and dorsal distal radial forearm (15 percentage points more frequent in C6 radiculopathy) and anterior index finger and middle fingers (15 percentage points more frequent in C7 radiculopathy). Clearly, a larger sample size would have clarified the statistical significance of these trends, but would not have changed the need for caution before interpreting these findings as specific for either nerve root.

In summary, the findings from our study suggest that sensory impairments in the distal arm that are associated with C6 and C7 radiculopathies overlap in location, are inconsistent between individuals, and can be widespread. Sensory impairments in the radial aspect of the distal forearm were more frequent with C6 nerve root compression. In general, however, overlap in locations for sensory impairments were substantial enough that caution should be exercised when predicting compression of either the C6 or C7 nerve roots based on the locations of impaired sensation.

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