SPINE Volume 32, Number 1, pp 72–75

Assessment of Forearm Pronation Strength in C6 and C7 Radiculopathies

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Study Design. Consecutive case series of patients with C6 and C7 radiculopathies.

Objectives. To explore the clinical utility and reliability of manual muscle testing of forearm pronation strength in C6 and C7 radiculopathies.

Summary of Background Data. EMG evidence of denervation of the pronator teres was the most common finding in C6 radiculopathies, and frequently present in C7 radiculopathies. Clinical evaluation of the pronator teres through manual muscle testing of forearm pronation has never been explored; therefore, its clinical utility is unknown as compared with the muscle groups that are traditionally evaluated.

Methods. Fifty-five subjects with diagnostic imaging evidence of either C6 (n = 25) or C7 (n = 30) cervical root compression and clinical symptoms consistent with cervical radiculopathy were recruited for this study. These subjects underwent manual muscle testing of forearm pronation, wrist extension, elbow flexion, and elbow extension. The frequency of impaired strength was recorded and compared for C6 and C7 radiculopathies. A second examiner evaluated each subject, with his or her findings compared with the first examiner only for the determination of interrater reliability.

Results. In C6 radiculopathy subjects, forearm pronation weakness was present in 72%, was twice as common as wrist extension weakness, was present in all case where elbow flexion or wrist extension weakness was noted, and was found in all but 2 subjects where elbow extension weakness was present. In C7 radiculopathy subjects, forearm pronation weakness accompanies elbow extension weakness in 23% of subjects and was the only weakness in 10% of subjects. Manual muscle testing demonstrated adequate interrater reliability.

Conclusions. Forearm pronation weakness is the most frequent motor finding in C6 radiculopathies and may be noted is some cases of C7 nerve root compression.

Key words: cervical, radiculopathy, physical examination, clinical examination, diagnostic accuracy, reliability.
Spine 2007;32:72–75

The prevalence of cervical radiculopathy is between 0.8 and 3.5 per 100,000, with a peak incidence at the age of 50 to 54 years.[1,2] Approximately 74% of all cervical radiculopathies will be treated conservatively, with the large majority (90%) of patients either recovering fully or experiencing only mild residual disability.[2] Although the course of cervical radiculopathy is usually benign, the costs of cervical radiculopathy in terms days out of work, medically related expenses, and medicolegal claims are substantial.[2]

Cervical radiculopathies are caused by irritation of the nerve roots within the spinal canal or neural foramen. Degeneration and deformity of the intervertebral discs, uncovertebral joints, and facet joints have the potential to produce cervical radiculopathies.

The most distressing symptom of cervical radiculopathy is usually pain radiating into the upper extremity. Some patients report altered sensation in the arm or hand, and 15% to 34% complain about upper extremity weakness.[2,3] Apparently, actual weakness on physical examination is significantly more common than subjective weakness, with a range of 64% to 75% of patients exhibiting focal muscle weakness on physical examination.[2,3] Other neurologic sign of nerve root dysfunction are also common, with diminished deep tendon reflexes present in 84% and dermatomal sensory changes in 33% of patients.[2]

Numerous clinical examination findings have been used in the evaluation of cervical radiculopathy.[2–4] Unfortunately, the validity of these findings has been rarely studied, and the data that exist suggest that they have limited accuracy.[4] Two studies have assessed the reliability of the conventional neurologic examination of the upper extremity and showed moderate interrater reliability for sensory and strength testing with kappa values ranging from 0.23 to 0.69.[4,5]

C6 radiculopathies result from structural abnormalities within the spinal canal at the C5–C6 disc level. When compared with all cervical radiculopathies, those involving the C6 roots account for up to 48%.[3] Pain associated with a C6 radiculopathy can involve the neck, shoulder, lateral upper arm, and radial forearm, with occasional extension to the thumb and hand.[6] C6 radiculopathies can be associated with diminished or absent bicep, brachioradialis, or pronator teres reflex.[7] Strength testing of wrist extension has been the conventional manual muscle test for C6 radiculopathies and for C6 spinal cord level in spinal cord injuries and myelopathies.[8,9] The frequency of wrist extension weakness in C6 radiculopathies has been reported in only one paper, with Yoss *et al* noting this finding in 37% of patients.[3]

Levin *et al* studied electromyography (EMG) evidence of muscle involvement in surgically proven solitary-root cervical radiculopathies.[10] They found that C6 radiculopathies produced the greatest variability in EMG pre-

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Acknowledgment date: October 19, 2005. First revision date: January 4, 2006. Second revision date: March 1, 2006. Acceptance date: March 2, 2006.
The manuscript submitted does not contain information about medical device(s)/drug(s).
No funds were received in support of this work. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.
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sentations, with 50% of subjects demonstrating findings similar to C5 radiculopathies, and 50% with findings similar to C7 radiculopathies. The most distinguishing feature of C6 radiculopathies was the involvement of the pronator teres muscle, being abnormal in 80% of the subjects. They also noted that pronator teres was never abnormal in C5 but was abnormal in 60% of C7 radiculopathies. Unfortunately, this study did not examine the EMG characteristics of the extensor radialis longus/brevis muscles responsible for wrist extension, the conventional clinical test for C6 motor involvement. Additionally, manual muscle testing of study subjects was not reported. Therefore, the clinical value of manual muscle testing of forearm pronation for assessing C6 and C7 radiculopathies was not established.

This study explored the clinical utility of manual muscle testing of forearm pronation compared with wrist extension, elbow flexion, and elbow extension in subjects with C6 and C7 radiculopathies. We also determined the interrater reliability of these manual muscle tests between two examiners.

■ Methods

Study Subjects. Fifty-five subjects with clinical C6 or C7 radiculopathies were recruited for this study. Consecutive subjects were recruited from two medical practices specializing in spine problems located in a large metropolitan area. Inclusion criterion included arm pain, with or without neck pain, in patterns consistent with C6 or C7 dermatomes,[6] paresthesias involving the forearm, or hand, and/or complaints of weakness in the symptomatic extremity. All subjects had anatomic evidence of C6 or C7 nerve root compression on the symptomatic side by MRI or CT. Anatomic diagnosis included cervical disc herniations or stenosis of the neural foremen.

Exclusion Criteria. Subjects were excluded if they had any of the following characteristics: 1) MRI or CT imaging of the spine was not performed; 2) neurologic or muscular disease affected upper extremity motor or sensory function, such as structural brain abnormality, spinal cord dysfunction, peripheral neuropathy, or myopathy; 3) anatomic compression of more than one cervical root on the symptomatic side; 4) symptom magnification including global neurologic deficits and over reaction[11]; 5) bilateral radicular symptoms; 6) current symptoms from known shoulder, elbow, wrist, or hand arthritis that might interfere with manual muscle testing; 7) cancer under active treatment; and 8) severe psychiatric disorders or cognitive dysfunction.

Subjects were also excluded from the study if a second physician was not available to examine the subject during the clinical visit.

Informed consent was received in writing from all subjects. The investigational review board of our hospital approved this study.

Evaluation of Subjects. Demographic, symptom, and physical examination information was recorded on patient history forms used by our practices. The attending physicians reviewed information from these forms for accuracy and completeness, and extract data for the study questionnaire.

The attending physician reviewed all MRI or CT studies and recorded the spinal level of nerve compression, and the type of lesion as either disc herniations or stenosis of the neural foramen. The radiology report was then reviewed; and if a discrepancy concerning diagnosis existed between the radiology report and the reading of the attending physician, an independent radiologist was asked to review the studies. When required, the reading of the independent radiologist was used for this study.

Procedure for Evaluation Muscle Strength. Manual muscle testing was first performed on the asymptomatic, then the symptomatic extremity. The ability of the subject to perform an isometric contraction of the muscle group under evaluation, and resist any movement of the joint in a direction opposite to the direction of the muscle group's action, against the maximum force of the examiner was recorded as normal. Inability to resist movement of the joint was considered weakness. The following muscle groups were tested

1. Forearm pronation strength was tested with the elbow held against the subject's side and flexed to 90°, and the forearm placed in the neutral position (thumb facing up). The examiner firmly grasped the subject's hand in a handshake position. The subject was instructed to pronate the forearm using the command "flip your wrist over so that you palm faces downward" while the examiner attempts to turn the subjects wrist into supination. The inability of the subject to maintain the forearm in the neutral position, and resist the effort of the examiner to supinate the wrist was recorded as weakness.
2. Wrist extension strength was evaluated with the elbow held against the subject's side and flexed to 90°. With the subject's forearm pronated, and wrist and fingers extended with maximum effort, the examiner attempt to flex the wrist forward by applying force to the back of the hand. The inability of the subject to resist flexion of the wrist was recorded as weakness.
3. Elbow flexor strength was tested with the elbow held against the subject's side and flexed to 90°. The forearm was placed in supination, and the subject instructed to flex the elbow with maximum force while the examiner applied force at the distal forearm and attempted to extend the elbow. The inability of the subject to prevent extension of the elbow was recorded as weakness.
4. Elbow extension strength was tested with the elbow will be held against the subject's side and flexed to 90°. The forearm was placed in a neutral position (thumb pointing up) and the subject instructed to extend the elbow with maximum force while the examiner applied force to the distal forearm and attempted to flex the elbow with maximum force. The inability of the subject to prevent flexion of the elbow was recorded as weakness.

Reliability of Strength Testing. A second physician examined all subjects immediately after the examination of the first physician. The second examiner was informed as to the side of the subject's symptoms but was blinded as to the findings of the first examiner and to the level of the radiculopathy. The second examiner repeated the manual muscle testing of the 4 muscle groups on each extremity and recorded their findings.

Data Analysis. Collected data were entered into SPSS 8.0 data file (SPSS, Inc., Chicago, IL) for analysis. Characteristics of

Table 1. Characteristics of Study Subjects

	C6 Radiculopathy (n = 25)	C7 Radiculopathy (n = 30)
Age	43	47
Duration of symptoms (mo)	3.6	3.0
Neck pain intensity (0–10)	4.7	3.7
Arm pain intensity (0–10)	5.1	5.0
Males (%)	52	80*
Symptoms in right arm (%)	32	47
MRI (%)	100	97
CT (%)	0	3
Disc herniation (%)	76	80
Stenosis of neural foramen (%)	24	20
Pain location (%)		
Neck	81	89
Shoulder	72	77
Upper arm	80	83
Forearm	56	73
Hand	48	43
Subjective tingling/ numbness (%)		
Forearm	16	0*
Hand	63	83
Subjective weakness (%)		
Raising arm	8	0
Lifting with arm	24	7
Pushing with arm	8	37*
Hand/grip	3	13
Impaired sensation with pin prick (%)		
Forearm	26	3
Hand	20	27
Unilateral impaired reflexes (%)		
Biceps	28	7†
Brachioradialis	32	0†
Triceps	8	37†

* $P > 0.05$.
† $P > 0.01$.

subjects and findings on physical examination were analyzed using frequency and means calculations, and summarized for C6 and C7 radiculopathies. Results for C6 and C7 radiculopathies were compared with t test and χ^2 statistics.

Interrater reliability of manual muscle testing between the initial and second examiners was calculated using percent agreement and kappa values.

■ Results

Twenty-five subjects with C6 and 30 subjects with C7 radiculopathies were recruited for this study. Characteristics of subjects are reported in Table 1. Two thirds of subjects had radiculopathy symptoms for 3 months or less. Differences in symptoms did not distinguish between C6 and C7 radiculopathies, with the exception of subjective weakness for pushing with the symptomatic arm in subjects with C7 radiculopathies. Differences in reflexes consistent with established innervation patterns were noted.

Table 2. Manual Muscle Testing Results of the First Examiner

	C6 Radiculopathy (n = 25) (% weakness)	C7 Radiculopathy (n = 30) (% weakness)	χ^2	P
Forearm pronation	72	33	8.2	0.004
Wrist extension	32	5	5.8	0.02
Elbow flexion	28	3	6.7	0.01
Elbow extension	20	73	15.5	0.001

Table 3. Interrater Reliability of Manual Muscle Testing Between 2 Examiners

	% Agreement	Kappa
Forearm pronation	76	0.52
Wrist extension	89	0.86
Elbow flexion	95	0.69
Elbow extension	80	0.60

Five physicians recruited subjects for this study and were the initial examiner. A different member of the same 5 physicians performed 93% of the second examinations.

Results from manual muscle testing for the initial examiners of the 4 targeted muscle groups are reported in Table 2.

For C6 radiculopathies, impaired forearm pronation was the only weakness in 5 (20%) subjects. In all subjects with wrist extension or elbow flexion weakness, forearm pronation weakness was also present. Forearm pronation strength was impaired in all but in 2 (8%) subjects in which elbow extension weakness was present as the only finding.

For C7 radiculopathies, impaired forearm pronation was found to accompany elbow extension weakness in 7 (23%) subjects. Isolated forearm pronation weakness without concurrent elbow extension weakness was present in 3 (10%) subjects.

Interrater reliability results demonstrated moderate reliability between examiners for manual muscle testing. These are reported in Table 3.

To explore the possibility of a systematic error in detecting forearm pronation weakness between the first verses second examiners, the 23 cases for which both examiners agree that forearm pronation weakness was present were evaluated. Results revealed that 16 of the 23 cases (70%) had C6 radiculopathies and the remaining 7 cases (30%) had C7 radiculopathies, a finding compatible with the results reported from the initial examiner alone. These results are presented in Table 4.

Table 4. Comparison of Manual Muscle Testing Results for Pronation Strength Between Initial and Second Examiners

	Second Examiner	
Initial Examiner	Normal	Weakness
Normal	n = 19 C6 = 6 (32%) C7 = 13 (68%)	n = 8 C6 = 1 (12%) C7 = 7 (88%)
Weakness	n = 5 C6 = 2 (40%) C7 = 3 (60%)	n = 23 C6 = 16 (70%) C7 = 7 (30%)

■ Discussion

Forearm pronation strength can be easily and reliably assessed as part of the physical examination in patients with cervical radiculopathies. Interrater reliability for forearm pronation was similar to that for wrist extension, elbow flexion, and elbow extension in this study and compares favorably with manual muscle testing of the upper extremities reported by others.[4,5]

In this study, weakness of forearm pronation was the most frequent motor impairment in C6 radiculopathies, detected in 72% of subjects. Weakness of forearm pronation was twice as common as impaired wrist extension in C6 radiculopathies, and always present when the wrist extension or elbow flexion was impaired. These observations suggest that the clinical evaluation of forearm pronation is more sensitive than wrist extension and elbow flexion for detecting motor impairments in C6 radiculopathies, and may be incorporated as a useful aspect of the physical examination.

This frequency of forearm pronation weakness in C6 radiculopathies was strikingly similar to the EMG results reported by Levin *et al*,[10] who found evidence of pronator teres denervation in 80% of subjects with surgically proven C6 root lesions. We did not perform EMGs in our study. EMGs are not routinely acquired for the assessment or clinical care of cervical radiculopathies by the medical providers from whom these subjects were recruited, and therefore would be considered outside the standards of care for our practices. As such, we could not justify the expense or inconvenience of EMG evaluation as part of this study. Additionally, it is well established that there is only modest correlation between strength deficits on physical examination and EMG results in radiculopathies, with weakness detected in some individuals with normal EMG findings, and abnormal EMG results in cases with normal strength examinations.[4,12,13] Therefore, it is likely that correlation between weakness of forearm pronation and EMG results for the pronator teres would have been modest at best for our study subjects and would have added limited value to the clinical relevance of our results.

Similar to the observation of Levin *et al*,[10] a range of patterns of weakness was observed for C6 and C7 radiculopathies. This probably reflexes the variability in innervation patterns of muscles between individuals, and differences in the severity of root involvement from one subject to another. Although elbow extension weakness was the most frequent finding in C7 radiculopathies, forearm pronation weakness was present as the only finding in 10% and accompanied elbow extension weakness in an additional 23% of our subjects. Detectable weakness of forearm pronation was less frequent in our series of C7 radiculopathies than reported by Levin *et al*, who reported a 60% involvement.[10] This difference probably reflects the difference in sensitivities of EMG verses physical examination. Additionally, Levin *et al* included only subjects that required surgical treatment of their nerve root lesions, as opposed to our subjects, who required only confirmation of nerve root compression by CT or MRI.[10] This selection difference possibly resulted in greater neurologic involvement of the subjects of Levin *et al*.[10]

■ Conclusion

Assessment for weakness of forearm pronation in more sensitive than wrist extension for detecting motor involvement in C6 radiculopathies. Forearm pronation weakness frequently accompanies elbow extension weakness in C7 radiculopathies, suggesting that it not specific for C6 root lesions.

■ Key Points

- Forearm pronation strength can be reliably assessed as part of the physical examination of cervical radiculopathies.
- Forearm pronation weakness is the most frequent motor abnormality in C6 radiculopathies.
- Forearm pronation weakness is twice as frequent as wrist extension weakness in C6 radiculopathies.
- In C7 radiculopathies, forearm pronation weakness is sometimes noted, suggesting that it is not a specific finding for C6 radiculopathies.

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