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Reliability and Diagnostic Accuracy of the Clinical Examination and Patient Self-Report Measures for Cervical Radiculopathy

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Study Design. A blinded, prospective diagnostic test study was conducted.

Objectives. To assess the reliability and accuracy of individual clinical examination items and self-report instruments for the diagnosis of cervical radiculopathy, and to identify and assess the accuracy of an optimum test-item cluster for the diagnosis of cervical radiculopathy.

Summary of Background Data. Although cervical radiculopathy remains largely a clinical diagnosis, the reliability and diagnostic accuracy of clinical examination items, individually or in combination, for cervical radiculopathy is largely unknown.

Methods. Patients with suspected cervical radiculopathy or carpal tunnel syndrome received standardized electrophysiologic examination of the symptomatic upper quarter followed by a standardized clinical examination by physical therapist examiners blinded to diagnosis. Diagnostic properties were assessed using a neural impairment reference criterion standard.

Results. The study involved 82 patients. More than two thirds of 34 clinical examination items had reliability coefficients rated at least fair or better, and 13 items had likelihood ratio point estimates above 2 or below 0.50. A single diagnostic test item cluster of four variables was identified and produced a positive likelihood ratio point estimate of 30.3. The 95% confidence intervals for all likelihood ratio point estimates in this study were wide.

Conclusions. Many items of the clinical examination were found to be reliable and to have acceptable diagnostic properties, but the test item cluster identified was

more useful for indicating cervical radiculopathy than any single test item. Upper limb tension Test A was the most useful test for ruling out cervical radiculopathy. Further investigation is required both to validate the test item cluster and to improve point estimate precision. [Key words: cervical radiculopathy, clinical examination, diagnostic accuracy, diagnostic test cluster, reliability] *Spine* 2003;28:52-62

Cervical radiculopathy is, by definition, a disorder of the cervical spinal nerve root,¹² and most commonly is caused by a cervical disc herniation or other space-occupying lesion, resulting in nerve root inflammation, impingement, or both.⁴⁷ A number of other less common causes have also been reported.^{3,7,14,20,23,37,41,44,45,51,61,63,73} The diagnostic criteria for cervical radiculopathy are not well defined, and no universally accepted criteria for the diagnosis of cervical radiculopathy have been established.^{9,47}

Diagnostic imaging and electrophysiologic studies are most commonly used to establish a diagnosis of cervical radiculopathy. Although not perfect, these tests are considered to be the most accurate means of diagnosis available.^{31,43} Given the expense and discomfort associated with these studies, it would be useful to establish accurate clinical examination findings for a diagnosis of cervical radiculopathy. Numerous clinical examination findings are purported to be diagnostic of cervical radiculopathy.^{40,50-57} The validity of these findings has been studied sparsely, and the data that do exist suggest they are not very accurate.^{6,66}

Given the frequency of surgical intervention⁵⁰ and the wide variety of nonsurgical treatment procedures⁶⁰ offered to patients with cervical radiculopathy, there is a definite need to establish a cost-effective, reliable, and accurate means for establishing the diagnosis of cervical radiculopathy. The purpose of this study was twofold: to assess the reliability and accuracy of selected clinical examination findings for the diagnosis of cervical radiculopathy using an electrophysiologic reference criterion, and to identify and assess the accuracy of an optimum cluster of clinical examination findings for the diagnosis of cervical radiculopathy.

Methods

Subjects and Design. A total of 82 patients (41 men and 41 women, mean age 45 ± 12 years) from the following four medical facilities were enrolled in the study from December

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1998 to April 2000: University of Pittsburgh, Wilford Hall USAF Medical Center, Brooke Army Medical Center, and Blanchfield Army Community Hospital. Consecutive patients, ages 18 to 70 years, referred to the electrophysiologic laboratories of participating facilities with suspected cervical radiculopathy (CR) or carpal tunnel syndrome (CTS) were informed about the study by laboratory personnel. Only patients judged by the electrophysiologic laboratory provider to have signs and symptoms compatible with CR or CTS were eligible to participate. Patients with the following conditions were disqualified from participation in the study:

- systemic disease known to cause a generalized peripheral neuropathy
- primary report of bilateral radiating arm pain
- history of conditions involving the affected upper extremity that might adversely affect the individual's level of function
- discontinuation of work more than 6 months because of the condition
- history of surgical procedures for pathologies giving rise to neck pain or CTS
- previous needle electromyography (EMG) and nerve conduction study (NCS) testing the symptomatic limb for CR, CTS, or both
- workman's compensation received or pending litigation for condition.

All the subjects gave informed consent for participation as approved by the respective facility's institutional review board.

Patient Self-Report Items

Visual Analog Scale. The patient rated his or her pain on a 10-cm visual analog scale (VAS). Each patient made three VAS ratings: one for the worst pain in the preceding 24 hours, one for the least pain in the preceding 24 hours, and one for current pain. Although the VAS has been used extensively as an outcome measure,^{11,39,69} its use for diagnostic purposes has not been reported.

Neck Disability Index. The NDI, a self-report disability measure for patients with neck pain,⁶⁴ contains seven items related to activities of daily living, two items related to pain, and one item related to concentration (ability to read). Each item is scaled from 0 to 5, and the total score is expressed as a percentage, with higher scores representing greater levels of disability. The NDI has been studied as an outcome measure,^{49,64,68} but not as a diagnostic tool.

Standardized Electrophysiologic Examination Procedure. Needle electromyography and NCS procedures served as the reference criterion for cervical radiculopathy. All the participants underwent the same standardized electrophysiologic examination. Board certified personnel conducted all the EMG and NCS procedures. Nerve conduction studies consisted of palmar sensory and routine motor nerve conduction studies for both the median and ulnar nerves.^{8,10,34} Median and ulnar nerve F-wave responses (minimum latency) were also obtained. If abnormalities were observed in the median and ulnar nerves of the same limb, nerves in the opposite upper limb, one lower limb, or both were performed to rule out a generalized peripheral neuropathy.^{27,28} All NCS procedures were performed in

accordance with guidelines for measurement, temperature, safety precautions, and electrode placement.¹⁰

After the NCS, EMG of the following muscles was performed during rest and contraction using a monopolar needle electrode: middle and lower cervical paravertebral, deltoid, triceps brachii, extensor carpi radialis longus/brevis, flexor carpi radialis, abductor pollicis brevis, and first dorsal interosseus. In addition, EMG/NCS providers sampled additional cervical and limb muscles when indicated by a patient's clinical presentation. For each muscle site sampled, the tester used the standard quadrant/level method for a total of 12 EMG observations at each sampling site.¹⁰ Observations of insertional activity, normal and abnormal spontaneous activity, and motor unit firing frequency were made when needle EMG was recorded.¹⁰

Previously published criteria were used to determine the normality of NCS^{8,34} and EMG¹ parameters. Diagnoses were based on electrophysiologic examination findings and categorized into six classifications (Table 1). All patients with cervical radiculopathy findings (Classifications 5 and 6) were further classified according to the severity of their respective EMG findings as follows: mild: (1+ spontaneous activity in one or more muscles, other EMG/NCS parameters normal, moderate (2+ to 3+ spontaneous activity in two or more muscles, increased recruitment, polyphasicity, and perhaps increased amplitude/duration of some MUAPs). There were no patients with severe EMG findings, so this classification was eliminated.

Seven different EMG/NCS providers performed the nerve conduction studies, needle electromyography procedures, and subsequent diagnostic classification of patients. At one center, three different evoked potential technicians performed nerve conduction procedures only.

Needle electromyography is considered the hallmark diagnostic sign and the single most accurate electrophysiologic procedure for establishing the diagnosis of both lumbar and cervical radiculopathy.^{15,36,43,54,72} Both EMG and NCS have moderate sensitivity (Sn) and high specificity (Sp) for establishing the diagnoses of cervical radiculopathy and peripheral nerve entrapments.^{1,2}

Standardized Clinical Examination Procedure. A standardized clinical examination consisting of 34 items was performed by a physical therapist (Examiner 1) after the standardized EMG/NCS examination was completed, and after a 15- to 30-minute rest period. The examination was repeated by a second physical therapist (Examiner 2) after a 10-minute rest period to assess reliability. Both examiners were blinded to the subjects' suspected diagnosis, EMG/NCS test results, and diagnostic classification. Nine different physical therapists performed the standardized clinical examination procedures.

History. All the patients were asked six questions thought to be diagnostic of CR. Examiner 2 obtained responses to the same questions 1 or 2 days later. The questions and their respective response options are listed in the Appendix.^{16,58,65}

Conventional Neurologic Examination and Provocative Tests. Strength testing was conducted through manual muscle testing of the deltoid (C5), biceps brachii and extensor carpi radialis longus/brevis (C6), triceps brachii and flexor carpi radialis (C7), abductor pollicis brevis (C8), and dorsal interossei (T1). All manual muscle testing was conducted using the methods of Kendall and McCreary.³² Each muscle test was graded

Table 1. Descriptive Statistics of Subjects Age and Duration of Symptoms by Diagnostic Classification

EMG/NCS-Based Dx	Gender	N	Age (y)/Symptoms (d)			SD
			Mean/ Median	Minimum	Maximum	
1. Normal	Female	23	41.4/123.5	24/31	70/5415	12.8
	Male	17	39.1/184.5	21/21	68/7220	10.2
2. Unilateral CTS	Female	4	58.5/1095	48/82	68/1460	9.1
	Male	3	35.6/275	28/184	45/365	8.6
3. Bilateral CTS	Female	9	44.7/250	28/31	61/5475	11.5
	Male	6	47.2/61	36/21	60/365	10
4. CTS w/ulnar neuropathy	Female	1	43.0/30	—	—	—
	Male	0	—	—	—	—
5. Radiculopathy	Female	2	56.5/42	55/42	58/42	2.1
	Male	12	50.3/77	39/42	61/1095	7.7
6. Radiculopathy w/CTS (1 with concomitant ulnar neuropathy at the elbow)	Female	2	52.0/97	46/87	52/100	4.2
	Male	3	62.0/31.5	60/21	64/42	2.8

Classifications are as follows:

1. Normal: No nerve conduction (NCS) or needle electromyography (EMG) abnormalities.
2. Unilateral Carpal Tunnel Syndrome (CTS): Any abnormal median sensory or motor latency of symptomatic extremity; ulnar sensory and motor NCS parameters normal.
3. Bilateral CTS: Same as unilateral CTS, but findings bilateral.
4. CTS with concomitant ulnar neuropathy: Any abnormal median sensory or motor latency NCS parameters and concomitant abnormal ulnar sensory and/or motor NCS parameters.
5. Radiculopathy: Muscle membrane instability (fibrillations of any variety) observed at rest during needle EMG.
6. Radiculopathy with concomitant CTS or ulnar neuropathy: Same radiculopathy with concomitant CTS or ulnar NCS abnormalities as described above.

as markedly reduced, reduced, or normal, as compared with the uninvolved extremity. Muscle stretch reflexes of the biceps (C5–C6), brachioradialis (C5–C6), and triceps (C7) were tested bilaterally using a standard reflex hammer. Each reflex was graded as absent/reduced, normal, or increased, as compared with the uninvolved extremity. Pin-prick sensation testing was performed for the cervical dermatomes (C5–C8) by touching the skin in a key area⁶⁵ for each respective sensory level with a paper clip, which was discarded after testing. Each sensory level was graded as reduced, normal, or increased.

Provocative Tests. The following provocative tests were used in this study: Spurling test (A and B), shoulder abduction test, Valsalva maneuver, neck distraction test, and upper limb tension test (A and B). The tests along with their operational definitions are listed in the Appendix. The reliability and validity of both conventional neurologic examination items and provocative tests used in this study have been summarized and previously reported.⁶⁷

Cervical Range of Motion. Cervical flexion, extension, bilateral side bending, and bilateral rotation measurements were obtained. Before measurement, the patient was seated in a chair and asked to assume a neutral neck position while the examiner applied a piece of tape to the wall at eye level. The examiner referred to this as the “neutral position.” The patient was then asked to perform warm-up movements consisting of two repetitions in each motion direction. Immediately after the warm-up procedure, the examiner recorded a single range-of-motion (ROM) measurement for flexion, extension, and bilateral side bending using an inclinometer as described by Hole et al.²⁴ Rotation was measured using a standard long-arm goniometer.⁷¹ Reliability coefficients for cervical spine ROM parameters range from 0.81 to 0.84 (ICC 2, 1).²⁴

Examiner Training. A videotape of all clinical examination procedures and handbooks detailing the performance of each

clinical examination and electrophysiological measure were distributed to each participating center before data collection. All the examiners viewed the videotape and read the handbooks to familiarize themselves with the procedures. All the examiners practiced all the clinical examination measures at least twice. They practiced applying the specified amount of compression or distraction force required for the Spurling test, distraction test, mechanical traction device, and pinch gauge, respectively.

Data Analysis. Dichotomized findings from the involved limb were used to compute reliability for each neurologic and provocative clinical examination measure. Dichotomization of test results for dermatomes, reflexes, and muscle strength into normal or abnormal findings was performed because of the low observed base rates for “increased” or “markedly reduced” responses. Reliability for neurologic, ROM, and provocative tests was assessed by a kappa statistic.⁵⁶ Reliability for cervical ROM was reported as an intraclass correlation coefficient (ICC 2, 1) and corresponding standard error of measurement (SEM).⁵⁵ 95% confidence intervals (95CI) were calculated for all reliability coefficients.

The following qualitative interpretation for kappa described by Fleiss et al.¹⁸ was used in this study: excellent (≥ 0.75), fair to good (0.40–0.74), poor (< 0.40). The clinical examination results obtained by Examiner 1 were used for all computations of diagnostic test accuracy. To calculate Sn and Sp for each test item, 2×2 contingency tables were used. Patients with a diagnosis of CR (Classifications 5 and 6), including those with concomitant CTS or ulnar neuropathy, formed the disease-positive group, and patients classified as normal or as having CTS (Classifications 1 to 4) served as the disease-negative or control group. When a zero cell value was encountered, 0.5 was added to all cell values in the table to permit calculation of LRs and their 95% CI (Simel, personal communication). Receiver operator characteristic (ROC) curves were used to determine cutoff values for self-report and

Table 2. Reliability of Clinical Examination Items

Variable	Kappa 95 CI	ICC 95 CI	SEM (°)
Question 1—"Most bothersome symptoms..."	0.74 (0.55–0.93)		
Question 2—"Where most bothersome..."	0.82 (0.68–0.96)		
Question 3—"Symptom behavior..."	0.57 (0.35–0.79)		
Question 4—"Entire limb numb..."	0.53 (0.26–0.81)		
Question 5—"Symptoms keep from sleep..."	0.70 (0.48–0.92)		
Question 6—"Neck movement improves..."	0.67 (0.44–0.90)		
C5 Dermatome	0.67 (0.33–1.0)		
C6 Dermatome	0.28 (0.00–0.58)		
C7 Dermatome	0.40 (0.06–0.74)		
C8 Dermatome	0.16 (0.00–0.50)		
T1 Dermatome	0.46 (0.04–0.88)		
MMT deltoid	0.62 (0.28–0.96)		
MMT biceps brachii	0.69 (0.36–1.0)		
MMT extensor carpi radialis longus/brevis	0.53 (0.26–1.0)		
MMT triceps brachii	0.29 (0.00–0.79)		
MMT flexor carpi radialis	0.23 (0.00–0.69)		
MMT abductor pollicis	0.39 (0.00–0.80)		
MMT first dorsal interosseus	0.37 (0.00–0.80)		
Biceps brachii MSR	0.73 (0.38–1.0)		
Spurling's A	0.60 (0.32–0.87)	—	—
Spurling's B	0.62 (0.25–0.99)	—	—
Shoulder abduction	0.20 (0.00–0.59)	—	—
Valsalva	0.69 (0.36–1.0)	—	—
Distraction	0.88 (0.64–1.0)	—	—
ULTT A	0.76 (0.51–1.0)	—	—
ULTT B	0.83 (0.65–1.0)	—	—
Cervical flexion	—	0.79 (0.65–0.88)	4.6
Cervical extension	—	0.84 (0.70–0.95)	4.8
Cervical left rotation	—	0.75 (0.59–0.85)	6.6
Cervical right rotation	—	0.63 (0.22–0.82)	7.3
Cervical left sidebending	—	0.63 (0.40–0.78)	5.3
Cervical right sidebending	—	0.68 (0.62–0.87)	5.4

ICC = intraclass correlation coefficient; SEM = standard error of the mean; 95 CI = 95% confidence intervals.
 Reliability of tricep brachii and brachioradialis not assessed because of low prevalence.

cervical ROM measures.²² Because patients with a diagnosis of cervical radiculopathy may be treated surgically or with costly nonsurgical interventions,⁵⁰ the cutoff value that minimized false-positive results (*i.e.*, highest specificity) was selected.

Positive and negative likelihood ratios and their associated 95% CIs were computed for all clinical examination items.⁵⁷ For the multilevel response items (Questions 1 to 3) and the test item cluster (TIC), positive likelihood ratios were reported for each response level.¹³ The positive likelihood ratio (LR+) was calculated as sensitivity/1-specificity and the negative likelihood ratio (LR-) as 1-sensitivity/specificity. Likelihood ratios are convenient summary measures of diagnostic test performance that indicate how much a given diagnostic test will raise or lower the pretest probability of the target disorder of interest.^{13,30} The diagnostic accuracy of individual clinical examination variables was considered acceptable if either LR+ was 2 or more or LR- was 0.50 or less.²⁵ On the basis of an estimated prevalence or pretest probability for CR of 20% in this sample, LR+ values exceeding 2 and LR- values less than 0.5 would result in posttest probability changes of at least 15%.

A binary logistic regression model was used to identify the most accurate TIC for diagnosing CR.²⁵ Only variables with acceptable accuracy as defined previously were entered into the model. A forward stepwise selection procedure was used to enter variables, with *P* values of 0.1 for entrance to the model and 0.15 for exit from the model. The method of entry and liberal *P* values were chosen to prevent potentially useful variables from being excluded from the model.¹⁹ The Hosmer-Lemeshow (HL) summary goodness-of-fit statistic was used to

assess the fit of the model to the data, and to test the hypothesis that the model fits the data. Higher *P* values indicated a better fit.²⁶ Variables selected by the regression model as diagnostic of CR were combined into a TIC and treated as a single test item. The sensitivity, specificity, and LRs for the TIC were calculated as previously described for other dichotomous variables.

■ Results

The descriptive statistics for age and duration of symptoms of the 82 participants in the study are listed by diagnostic classification in Table 1. The prevalence of CR and CTS was 23% (19 patients) and 35% (28 patients), respectively. The diagnostic report indicated involvement of the C6 or C7 root for 18 subjects, with possible involvement of the C5 root in two of these patients, and the C8 root for 1 subject. The left extremity was involved in 11 subjects, and the right extremity in 8 subjects. The patients with cervical radiculopathy were classified according to severity of EMG findings, with 13 classified as mild, 6 as moderate, and none as severe. One patient classified as having CR (mild) with concomitant CTS and ulnar neuropathy at the elbow dropped out of the study after the standardized electrophysiologic examination. Diagnostic accuracy was computed using the remaining 18 patients classified as having CR.

Table 3. Validity of Historical Questions

Variable	Sn 95 CI	Sp 95 CI	LR- 95 CI	LR+ 95 CI
Question 1—"Most bothersome Sx's."			*	0.99 (0.56-1.7)
i. Pain	0.47 (0.23-0.71)	0.52 (0.41-0.65)		1.1 (0.6-1.9)
ii. Numb/tingling	0.47 (0.23-0.71)	0.56 (0.42-0.68)		0.74 (0.09-5.9)
iii. Loss of feeling	0.06 (0.00-0.17)	0.92 (0.85-0.99)		
Question 2—"Where most bothersome..."				1.9 (0.54-6.9)
i. Neck	0.19 (0.00-0.35)	0.90 (0.83-0.98)	*	2.3 (1.0-5.4)
ii. Shoulder/scap.	0.38 (0.19-0.73)	0.84 (0.75-0.93)		0.41 (0.02-7.3)
iii. Arm AE	0.03 (0.14-0.61)	0.93 (0.86-0.99)		0.39 (0.05-2.8)
iv. Arm BE	0.06 (0.0-0.11)	0.84 (0.75-0.93)		0.73 (0.37-1.4)
v. Hand or fingers	0.38 (0.14-0.48)	0.48 (0.36-0.61)		
Question 3—"Sx. behavior..."			*	0.74 (0.18-3.1)
i. Constant	0.12 (0.00-0.27)	0.84 (0.75-0.93)		0.93 (0.45-1.9)
ii. Intermittent	0.35 (0.13-0.58)	0.62 (0.50-0.74)		1.2 (0.68-1.9)
iii. Variable	0.53 (0.29-0.77)	0.54 (0.42-0.66)		0.87 (0.34-2.3)
Question 4—"Entire limb numb..."	0.24 (0.03-0.44)	0.73 (0.62-0.84)	1.1 (0.77-1.4)	1.19 (0.66-2.1)
Question 5—"Sx's. keep from sleep..."	0.47 (0.23-0.71)	0.60 (0.48-0.72)	0.88 (0.54-1.4)	2.23 (1.3-3.8)
Question 6—"Neck move improves..."	0.65 (0.42-0.87)	0.71 (0.60-0.82)	0.50 (0.26-0.97)	

Sensitivity = Sn; specificity = Sp, negative likelihood ratios = LR-; positive likelihood ratios = LR+; 95 CI = 95% confidence intervals.

Reliability

Reliability was computed using the results from one rater pair that examined 50 patients. The 32 subjects not included in the reliability analysis did not differ from the other 50 subjects with regard to age, NDI, or pain ratings ($P > 0.05$).

Nineteen variables had kappa values at least fair or better (kappa, ≥ 0.40). No abnormal findings for the triceps and brachioradialis muscle stretch reflexes were recorded, so reliability was not computed for these variables. The reliability coefficients for the items of clinical examination and their associated 95% CIs are listed in Table 2.

Diagnostic Accuracy

The following 11 variables were found to have acceptable diagnostic accuracy: upper limb tension test A

(ULTTA), cervical rotation to the involved side less than 60°, cervical flexion less than 55°, involved biceps muscle stretch reflex (MSR), distraction test, MMT-involved bicep, Question 2 ("Where are your symptoms most bothersome?"), Valsalva test, Spurling test A, shoulder abduction test, Question 9 ("Do your symptoms improve with moving or positioning of your neck?"), and involved C5 dermatome sensation. The sensitivity, specificity, and likelihood ratios for each variable and their associated 95% CIs, are listed in Tables 3 and 4.

Diagnostic Test Item Cluster

The aforementioned 11 variables were entered into the regression model as potential predictors for CR. After list-wise deletion, a total of 73 subjects (16 subjects with cervical radiculopathy and 57 control subjects) were

Table 4. Validity of Conventional Neurologic Examination Items, Provocative Tests, and Cervical ROM

Variable	Sn 95 CI	Sp 95 CI	LR- 95 CI	LR+ 95 CI
C5 Dermatome	0.29 (0.08-0.51)	0.86 (0.77-0.94)	0.82 (0.60-1.1)	2.1 (0.79-5.3)
C6 Dermatome	0.24 (0.03-0.44)	0.66 (0.54-0.78)	1.16 (0.84-1.6)	0.69 (0.28-1.8)
C7 Dermatome	0.18 (0.0-0.36)	0.77 (0.66-0.87)	1.07 (0.83-1.4)	0.76 (0.25-2.3)
C8 Dermatome	0.12 (0.0-0.27)	0.81 (0.71-0.90)	1.09 (0.88-1.4)	0.61 (0.15-2.5)
T1 Dermatome	0.18 (0.0-0.36)	0.79 (0.68-0.89)	1.05 (0.81-1.4)	0.83 (0.27-2.6)
MMT deltoid	0.24 (0.03-0.44)	0.89 (0.81-0.97)	0.86 (0.65-1.1)	2.1 (0.70-6.4)
MMT biceps brachii	0.24 (0.03-0.44)	0.94 (0.88-1.0)	0.82 (0.62-1.1)	3.7 (1.0-13.3)
MMT extensor carpi radialis longus/brevis	0.12 (0.0-0.27)	0.90 (0.83-0.98)	0.98 (0.81-1.2)	1.2 (0.27-5.6)
MMT triceps brachii	0.12 (0.0-0.27)	0.94 (0.88-1.0)	0.94 (0.78-1.1)	1.9 (0.37-9.3)
MMT flexor carpi radialis	0.06 (0.0-0.17)	0.89 (0.82-0.97)	1.05 (0.91-1.2)	0.55 (0.07-4.2)
MMT abductor pollicis brevis	0.06 (0.0-0.17)	0.84 (0.75-0.93)	1.12 (0.95-1.3)	0.37 (0.05-2.7)
MMT first dorsal interosseus	0.03 (0.0-0.10)	0.93 (0.87-0.99)	1.05 (0.94-1.2)	0.40 (0.02-7.0)
Biceps brachii MSR	0.24 (0.3-0.44)	0.95 (0.90-1.0)	0.80 (0.61-1.1)	4.9 (1.2-20.0)
Brachioradialis MSR	0.06 (0.0-0.17)	0.95 (0.90-1.0)	0.99 (0.87-1.1)	1.2 (0.14-11.1)
Triceps MSR	0.03 (0.0-0.10)	0.93 (0.87-0.99)	1.05 (0.94-1.2)	0.40 (0.02-7.0)
Spurling's A	0.50 (0.27-0.73)	0.86 (0.77-0.94)	0.58 (0.36-0.94)	3.5 (1.6-7.5)
Spurling's B	0.50 (0.27-0.73)	0.74 (0.63-0.85)	0.67 (0.42-1.1)	1.9 (1.0-3.6)
Shoulder abduction	0.17 (0.0-0.34)	0.92 (0.85-0.99)	0.91 (0.73-1.1)	2.1 (0.55-8.0)
Valsalva	0.22 (0.03-0.41)	0.94 (0.88-1.0)	0.83 (0.64-1.1)	3.5 (0.97-12.6)
Distraction	0.44 (0.21-0.67)	0.90 (0.82-0.98)	0.62 (0.40-0.90)	4.4 (1.8-11.1)
Upper limb tension test A	0.97 (0.90-1.0)	0.22 (0.12-0.33)	0.12 (0.01-1.9)	1.3 (1.1-1.5)
Upper limb tension test B	0.72 (0.52-0.93)	0.33 (0.21-0.45)	0.85 (0.37-1.9)	1.1 (0.77-1.5)
Cervical flexion (<55°)	0.89 (0.74-1.0)	0.41 (0.29-0.53)	0.27 (0.07-1.0)	1.5 (1.2-2.0)
Involved rotation (<60°)	0.89 (0.74-1.0)	0.49 (0.37-0.62)	0.23 (0.06-0.85)	1.8 (1.3-2.4)

Sensitivity = Sn; specificity = Sp; negative likelihood ratios = LR-; positive likelihood ratios = LR+; 95 CI = 95% confidence intervals.

Table 5. Test Item Cluster for the Diagnosis of Cervical Radiculopathy

Criteria for a Positive Test	Sn 95 CI	Sp 95 CI	LR+ 95 CI	Post-test Probability
Two positive tests	0.39 (0.16–0.61)	0.56 (0.43–0.68)	0.88 (1.5–2.5)	21%
Three positive tests	0.39 (0.16–0.61)	0.94 (0.88–1.0)	6.1 (2.0–18.6)	65%
All four tests positive	0.24 (0.05–0.43)	0.99 (0.97–1.0)	30.3 (1.7–538.2)	90%

ULTTA, involved cervical rotation <60°, Distraction, and Spurling's A. Sensitivity (Sn), Specificity (Sp), and Positive Likelihood Ratio (LR+) of clinical examination variables with 95% confidence intervals (95 CI). The associated post-test probability values for each criteria level is based on a pre-test probability of 23%.



Figure 1. Spurling A.



Figure 2. Neck distraction test.

used in the analysis. The results of the HL test indicated that the model fit the data ($P = 0.92$). The following four test variables were chosen by the model and are therefore considered the best CR TIC: ULTTA, involved cervical rotation less than 60°, distraction test, and Spurling A. The four variables and their diagnostic properties according to the number of abnormalities required for a positive test are listed in Table 5. Figures 1 through 9 show the provocative tests included in the CR TIC.

■ Discussion

This is the first study to assess simultaneously the diagnostic properties of historical questions, patient self-report mea-



Figure 3. ULTT A, Step 1: Scapular depression.



Figure 4. ULTT A, Step 2: Shoulder abduction.

asures, and cervical ROM for cervical radiculopathy. Several observations can be made from the study results. First, most of the clinical examination items demonstrated a fair or better level of reliability. Second, test items from each major component of the clinical examination demonstrated useful diagnostic properties. Finally, a single TIC was identified that produced larger posttest probability changes than any single test item. None of the patient self-report measures had acceptable diagnostic accuracy values, which is not surprising because these instruments were developed for evaluative and not predictive purposes.³⁵

Although similarities exist between the current results and the only other comparable published study,⁶⁶ there are some notable differences. Viikari-Juntura⁶⁵ reported



Figure 5. ULTT A, Step 3: Forearm supination, wrist and finger extension.



Figure 6. ULTT A, Step 4: Shoulder lateral rotation.



Figure 7. ULTT A, Step 5: Elbow extension.

poor and fair reliability for the ULTT and distraction test, both of which demonstrated excellent reliability in the current study and resulted in the best LR- and second best LR+, respectively. The difference in ULTT reliability was most likely the result of the authors' operational definition, but would not account for the higher



Figure 8. ULTT A, Step 6a: Contralateral side-bending.



Figure 9. ULTT A, Step 6b: Ipsilateral cervical side-bending.

reliability of the distraction test found in the study. The authors also found much lower Sn for the shoulder abduction test. One possible reason is that they repeatedly questioned patients regarding the symptoms throughout the test in an open-ended fashion (*i.e.*, "Does that change your symptoms in any way?"). It is unclear whether this was done in the study by Viikari-Juntura.⁶⁵ Viikari-Juntura et al⁶⁶ did not directly study the validity of the conventional neurologic examination. However, calculation of the diagnostic accuracy of their neurologic examination items compared with the myelography reference criterion was possible according to the data presented in their report. Depending on the number of root dysfunction signs (atrophy, strength, MSRs, and sensation) required for a positive test, Sn and Sp values were computed that ranged from 0.59 to 0.80, with sensitivity values always predominating.⁶⁶ In contrast, items of the neurologic examination that had acceptable values in the current study were associated with high Sp and low Sn values, which is consistent with reports of the validity of neurologic examination items for lumbar radiculopathy.⁶²

Items of the patient's history have demonstrated powerful diagnostic properties in other reports.^{21,52} Two questions in the current study were found to have acceptable LR+ values (Questions 2 and 6). Question 2 pertains to predominant scapula symptoms and appears to support Cloward's⁵ work. Question 6 pertains to how neck movement influences symptoms. Unfortunately, these two questions generate only small posttest probability changes. Whereas the six questions in this study are thought to be important historical items for the diagnosis of CR,^{42,70} the inclusion of other important questions may have been neglected.

The three test items with the best transformed LR values²⁵ in this study were items of the physical component of the clinical examination (ULTTA, biceps MSR, and distraction test). The ULTTA in this study was perfectly sensitive and appeared to support the claim by Kenneally et al³³ that the ULTT is the "straight-leg raise test" of the upper extremity. The ULTTA appears to be a useful screening test for CR given its high Sn and small LR- value, and is analogous to the straight-leg-raise test for lumbar radiculopathy.⁴ Both the biceps MSR and distraction test had high Sp and large LR+ values, which are useful for diagnostic purposes. Although these three tests have been described in the literature, the descriptions either have been unclear⁶⁵ or have differed.^{53,58} Disparate diagnostic properties were found for the two variations of the ULTT and Spurling test used in this study. The current results demonstrate that a clear operational definition is critical to defining a test's diagnostic properties.

A large number of single clinical examination items were found to have high point estimates of Sn and Sp for assessing the presence or absence of cervical radiculopathy (Tables 3 and 4). Faced with an array of potentially useful tests, the obvious question is "Which test or tests should I use?" Using the single best test (ULTTA) in this study to screen for CR results in a change in probability of the condition from 23% to 3%, a 20% decrease when the test is negative. If the ULTTA is negative, then CR can essentially be ruled out, and the need for further workup or treatment for CR is minimized. Use of the single best test (biceps brachii MSR) to diagnose CR results in a change in probability of the condition from 23% to 59%, a 36% increase when the biceps MSR is reduced or absent. In contrast, use of a parsimonious cluster of test items (TIC) identified in this study to diagnose CR produces larger posttest probability changes than the best single test item. If a patient has positive findings for three of the four TIC variables (ULTTA, involved cervical rotation less than 60°, distraction, and Spurling A) the probability of the condition increases to 65%, and if all four variables are present, the probability increases to 90%. Patients with positive test results for three or more variables are likely to have the condition and may indicate a need for further definitive diagnostic procedures and intervention. The clinical utility of the TIC for diagnosis of cervical radiculopathy compared with that of the single best test item is illustrated in Figure 1, as is the utility of the ULTTA for screening purposes.

The TIC found in this study to have the best clinical utility included three provocative tests and a range-of-motion measure. None of the history questions and none of several test items of the conventional neurologic examination with acceptable LRs were included in the TIC. The current findings are in contrast to classic reports^{42,70} and expert opinion¹⁷ that muscle stretch reflexes, loss of sensation, and motor weakness are classic diagnostic findings of CR. However, this should not be surprising considering the methodology and severely involved patients in these earlier studies.^{42,70}

The current study has several shortcomings. The minimal EMG findings required to establish the diagnosis of CR in this study may arguably have resulted in misdiagnosis in some cases (*i.e.*, false-positives), but the specificity of EMG is considered to be high and minimizes this concern.¹ The increased variability resulting from the number of EMG/NCS providers, clinical examiners, and practice locations included in this study may have attenuated the properties of the clinical examination items studied. Although this possibility exists, the results obtained from the large number of examiners and sites in the project enhances the generalizability of the current findings. Finally, the CR patients in the study sample represented predominantly mild to moderate cases and were almost exclusively representative of C6 and C7 root level involvement. Although the incidence of root level involvement in this study is consistent with all reported case series,⁶⁷ the diagnostic properties of the tests in this study and the posttest probabilities generated from them may be different when the C5 or C8 root level is involved or in a different spectrum of disease.³⁸

Despite the numerous textbooks devoted to the description and application of diagnostic tests for neuromusculoskeletal lesions,^{40,48} descriptions of the diagnostic properties of the tests are almost uniformly omitted.⁵⁹ The current study assessed the reliability and diagnostic properties of common clinical examination items and patient self-report measures used in the management of cervical radiculopathy. No single clinical examination item had diagnostic properties that produced larger posttest probability changes than that produced by a parsimonious, single TIC. Although the TIC with a positive test criterion of three findings produced an LR with a 95% CI lower limit of 2, which met the lower limit of acceptability, point estimates of the Sn/Sp and LRs for most test items were associated with wide 95% CIs. Therefore, these estimates are imprecise and should be interpreted cautiously.

A study using a larger sample is required to increase the precision of the diagnostic accuracy point estimates obtained in this study, and to validate the items and properties of the CR TIC. The validation of a CR TIC will enhance the diagnostic utility of the clinical examination, thereby allowing clinicians to select better the need for additional diagnostic studies and the most appropriate therapeutic interventions, and researchers to establish a more homogeneous patient sample for clinical trials. If validated, a trial assessing patient outcomes and

cost outlays to determine whether patients are benefited by having the tests would be a next logical step. Currently, however, studies of the clinical examination for other common peripheral mononeuropathies (e.g., carpal tunnel syndrome and lumbar radiculopathy) using methodology similar to that described in this study are necessary to distinguish between useful and useless diagnostic tests.

■ Key Points

- The diagnostic criteria for cervical radiculopathy are not well defined, and no universally accepted criteria for the diagnosis of cervical radiculopathy have been established.
- Cervical radiculopathy remains primarily a clinical diagnosis, but the diagnostic accuracy of numerous clinical examination items purported to be useful for the diagnosis of cervical radiculopathy has seldom, if ever, been studied.
- Most individual items of the clinical examination in this study were found to have at least a fair level of reliability, and several were found to have an acceptable level of accuracy for the diagnosis of cervical radiculopathy using a neural impairment reference criterion standard.
- A parsimonious test item cluster composed of individual items of the clinical examination was identified that produced larger posttest probability changes for the diagnosis of cervical radiculopathy than any single test item of the clinical examination.
- The 95% CIs associated with the diagnostic accuracy point estimates for individual clinical examination items and the test item cluster were wide because of the limited sample size and condition prevalence. Further investigation is required both to validate the test item cluster and to improve point estimate precision.

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■ Appendix

Questions of History and Provocative Tests	Responses
1. Which of the following symptoms are most bothersome for you?	Pain Numbness & Tingling Loss of feeling
2. Where are your symptoms most bother some?	Neck Shoulder or shoulder blade Arm above elbow Arm below elbow Hands and/or fingers
3. Which of the following best describes the behavior of your symptoms?	Constant Intermittent Variable (comes and goes)
4. Does your entire affected limb and/or hand feel numb	Yes or No
5. Do your symptoms keep you from falling asleep?	Yes or No
6. Do your symptoms improve with moving your neck?	Yes or No

Provocative Tests

• Spurling's Test – Part A was performed as originally described by Spurling.⁵⁸ The patient is seated, the neck is passively side-bent towards the symptomatic side, and overpressure (~7kg) is applied to the patient's head (Figure 1)

Part B - Variations of the Spurling's test have been reported, in which rotation,⁶⁵ or rotation and extension are used. In this study, sidebending and rotation toward the symptomatic side were coupled with extension before applying overpressure and designated Spurling's B..

• Shoulder Abduction Test – The patient is seated and asked to place the hand of the symptomatic extremity on the head.† A positive test occurs with reduction or elimination of symptoms.

• Valsalva Maneuver – The patient is seated and instructed to take a deep breath and hold it while attempting to exhale for 2-3 seconds. A positive response occurs with reproduction of symptoms

• Neck Distraction Test – The patient is supine. The examiner grasps under the chin and occiput, flexes the patient's neck to position of comfort, and gradually applies a distraction force up to ~14 kg. A positive test occurs with reduction or elimination of symptoms. (Figure 2)

• Upper Limb Tension Test – Part A was performed similar to Elvey's description¹⁶. With the patient supine the examiner sequentially introduced the following movements to the symptomatic upper extremity: 1) scapular depression, 2) shoulder abduction, 3) forearm supination, wrist and finger extension, 4) shoulder lateral rotation, 5) elbow extension, and 6) contralateral then ipsilateral cervical side-bending. (Figures 3 – 9)

Part B – With the patient supine and the shoulder abducted 30°, the examiner sequentially introduced 1) scapular depression, 2) shoulder medial rotation, 3) full elbow extension, 4) wrist and finger flexion, and 5) contralateral then ipsilateral cervical side-bending. In both parts the patient was questioned regarding symptom reproduction throughout the maneuver.

Positive Test Criteria

Symptoms Reproduction*

Symptom Diminution

Symptoms Reproduction

Symptom Diminution

Any one of the following:

- 1) Patient's symptoms reproduced
- 2) Side-to-side differences (>10 degrees) in elbow extension (Part A) or wrist flexion (Part B) upon completion of all motion sequences
- 3) Symptomatic limb side: contralateral neck side-bending increased symptoms or ipsilateral side-bending decreased symptoms.

* Symptom always refers only to the symptoms associated with the patient's condition.

† For 30 seconds.