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Cervical Intraspinal Conduction Time by Magnetic Root Stimulation versus Conventional Electromyography in the Diagnosis of Cervical Radiculopathy

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Abstract

Background Cervical radiculopathy (CR) is a pathological procedure that encompasses root of the cervical nerve. Cervical disc herniation, accompanied by cervical spondylosis, is among the most common causes of radiculopathy. Clinical neurophysiology is a medical field focused mainly on assessing activity in the nervous system and muscles being an expansion of neurological assessment, using particular same anatomical localization criteria as clinical testing.

Objective To evaluate the sensitivity and specificity of conduction time of the intraspinal segment of peripheral motor neurons in the diagnosis of CR using cervical root magnetic stimulation and conventional electromyography (EMG) study.

Methods Fifty patients (15 males and 35 females) aged 46.02±9.76 years with reported CR were subjected to an electrophysiological examination and control group consisted of 50 (36 females and 14 males) healthy volunteers aged 36.24±12.09 years. Analysis of sensory and motor nerve conduction, conventional needle EMG test, and motor evoked potentials (MEPs) for all (recording abductor pollicis brevis (APB), abductor digiti minimi (ADM), biceps brachii (BB), deltoid muscles) was conducted to determine the peripheral nerves, muscles, sensory and motor pathways. The motor evoked potential (MEP) parameters studied for the median, ulnar musculocutaneous and axillary nerves include latency of the spinal root {peripheral motor conduction time} (PMCT).

Results During direct cervical root stimulation, the PMCT of the median nerve shows the highest specificity (59%) than that of the ulnar nerve (57%), while the intraspinal latency shows the same specificity for both nerves (57%). In comparison, PMCT by kimura formula recording ADM during direct stimulation of the cervical root have the highest sensitivity (56%) than that of PMCT by kimura formula recording APB. Additionally, the recording of direct cervical root stimulation amplitude after deltoid muscle showed the highest specificity and sensitivity (57.0%, 58.0% respectively). On the other hand, PMCT shows the highest specificity and sensitivity while the BB muscle is recoded (62.0%, 49.0%).

Conclusion Overall, the current motor evoked potential study shows abnormalities in less than 60% of patients with cervical radiculopathy relative to conventional EMG needle study abnormalities that reached 90%. The intraspinal latency of the median and ulnar show low sensitivity and specificity.

Keywords Cervical radiculopathy, electromyography, motor evoked potentials

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List of abbreviations: CV = Cervical radiculopathy, CNS = Central nervous system, CV = Conduction velocity, CMAP = Compound muscle action potential, EMG = Electromyography, Eps = Evoked potentials, SNAP = Sensory nerve action potential.

Introduction

Cervical radiculopathy (CR) is pathological process that involves cervical nerve root. This results from squeezing and

inflammation of the nerve root and or roots, which are at or adjacent to the cervical neural foramen. This happens periodically in 85 out of 100,000 people [1]. The cervical disc herniation followed by cervical spondylosis is most common cause for radiculopathy. It is less common than CR induced by intra spinal or extra spinal tumors, trauma with nerve root avulsion, synovial cysts, meningeal cysts, dural arteriovenous fistulae, or tortuous vertebral arteries [2,3]. CR is probable to take place without an identifiable cause. Upper limb nerve entrapment, shoulder disease, brachial plexus illnesses, and peripheral neuropathy are other situations that can simulate cervical radiculopathy; all ought to be incorporated in the distinctive diagnosis. The focus is about radiated pain that is subsequent to squeezing of (cervical nerve rootlets) by herniated disc element or pain that is linked with cervical spondylosis [4,5].

Clinical neurophysiology is a field of medical practice that fundamentally focused on evaluating function in the central nervous system, peripheral nervous system, and muscles as a complementary to neurological evaluation. It applies an identical anatomic origin of localization as clinical examination. It depends completely on the measurement of underway function that is either spontaneously, or in response to a defined stimulus by recording alterations in physiology as manifested by changes in electrical waveforms, electromagnetic fields, and force activities [6]. Nerve conduction readings are usually normal in radiculopathy; the electrodiagnosis is done by needle electromyography (EMG). Notwithstanding that nearly motor abnormalities are infrequently appreciated in radiculopathy, the further serious purpose to execute nerve conduction studies is to take away further conditions that may simulate radiculopathy particularly entrapment neuropathy and plexopathy [7].

Among the least accessible structures of the peripheral nervous system are roots. Late responses can be employed for estimating conduction along with the roots. Evaluation of F wave latency is proved to be very valuable in the field of clinical neurophysiology. It supplements routine nerve conduction study (NCS) especially for the proximal segment of the nerve which cannot be assessed via conventional NCS. F wave is essential to disorders that involve the nerve roots, plexuses and, evaluating patients with demyelinating polyradiculoneuropathies, and entrapment neuropathies [8]. However, the abnormalities, which are of late responses, are not specific to the diagnosis of radiculopathies because of their conduction over the entire length of peripheral motor pathways and lesions, which at any level, determine similar changes of late responses. Moreover, the measurement of the F wave latency is not very sensitive in revealing the slowing of the conduction that is along with the motor roots; this is because the slowing of conduction in the short segment of the compressed root is diluted in a much longer segment of normal conduction along all the remaining peripheral motor pathways. In root lesions, fibrillation potentials in the corresponding paraspinal muscles or myotomes may be documented by needle electromyographic studies; however, these electromyographic changes appear only after 2 to 3 weeks [9]. Because the proximal part of peripheral motor pathways is activated by noninvasive and painless magnetic paravertebral stimulation, it may be useful beside the aforementioned traditional techniques in the diagnosis of radiculopathies and in the assessment of those peripheral nerves, such as the thoracic nerves which cannot be directly explored by means of standard electrophysiological techniques [10]. The motor axons of peripheral nerves are activated by magnetic paravertebral stimulation at a point that is near their exit from the spine. This site is distal to that of root compression that is produced by disc disorders or spondylotic changes. Moreover, the latency of responses, which is evoked by magnetic

paravertebral stimulation, is normal in the case of root compression. The conduction time, along the proximal part of motor roots, can be estimated by subtracting the latency of motor responses, which is evoked via magnetic paravertebral stimulation, from the overall peripheral conduction time calculated by conventional EMG throughout a specific formula of Kimura [(F+M-1)/2] [(6)].

The goal of the present study is to evaluate the sensitivity and specificity of conduction time of the intraspinal segment of peripheral motor neurons in the diagnosis of CR using cervical root magnetic stimulation and conventional EMG study.

Methods

A case-control analysis was carried out for the period from August 2019 to February 2020 at the Neurophysiology Unit in Al-Imamein Al-Kadhimein Medical city. This research has been verified by the Institute Review Board (IRB) of the College of Medicine, Al Nahrain University. Informed consent for enrollment in the study was provided by each participant.

Subjects

Subjects enlisted in the study were split into two groups; control group and patients' group.

Control group

This group implicated of 50 (14 males and 36 female) apparently healthy volunteers, their mean age is 36.24±12.09 years; they were clinically examined by the neurosurgeon, orthopedician, rheumatologist to be included in the study.

Patients group

Fifty patients (15 males and 35 females), their mean age is 46.02±9.76 years, with certified CR diagnosis by a neurosurgeon, orthopedician, rheumatologist, or neurologist were substituted to enrolled in the study. Full history and the complete neurophysiologic study were achieved. Patients with a history of pacemaker or metal foreign body, epilepsy, pregnancy, peripheral neuropathy, brain surgery, stroke and cancer, chemo or radiotherapy were excluded from the study.

Methods

Neurophysiologic studies

The following neurophysiologic tests were done for all studied subjects:

1. Sensory nerve conduction study (SNCS) of the median, ulnar, and radial nerves (bilaterally).
2. Motor nerve conduction study (MNCS) and F wave studies of the median and ulnar nerves (bilaterally).
3. MNCS of musculocutaneous and axillary nerves (bilaterally).
4. Needle EMG studies of the deltoid, biceps brachii (BB), triceps, first dorsal interosseous (bilaterally).
5. Cervical root magnetic stimulation: this is accomplished by placing the center of the round coil over the C5, C7 spinous process for the commonly studied hand muscles (Abductor pollices brevis, Adductor digiti minimi) and often recommended for more proximal arm muscles (BB, deltoid) that may be recorded simultaneously by measurement of intraforaminal cervical spinal latency through the following methods:
   - Magnetic cervical root stimulation, peripheral motor conduction time PMCT = MEP (motor evoked potential) latency at the neuroforamina of upper limb muscles.
   - F wave technique, PMCT = (F + M - 1)/2
   - Intraforaminal cervical spinal latency = (F + M - 1)/2- MEP latency

(F: F wave latency; M: M-wave latency; 1, the time attributable to central delay at the level of spinal motor neurons).

Throughout the test procedures, the examination room temperature was set between 25-28 ^{o}C and skin temperature measured by a thermometer at the axilla and kept between 36-37 ^{o}C.

Instrumentation

For all electrodiagnostic tests, the following instruments were used: The EMG /EP machine,

Computerized EMG equipment (Micromed, 8-channel elecromyograph, B, model 1715, Italy) was used.

Electrophysiological Studies

Sensory nerve conduction study

In contrast to motor conduction studies, in which the compound muscle action potential (CMAP) reflects conduction along the motor nerve, neuromuscular junction (NMJ), and muscle fibers, in sensory conduction studies, only nerve fibers are assessed. Because most sensory responses are very small (usually in the range of 1-50 µV), technical factors and electrical noise assume more importance. For sensory conduction studies, the gain usually is set at 10-20 µV per division. A pair of recording electrodes (G1 and G2) are placed in line over the nerve being studied, at an interelectrode distance of 2.5-4 cm, with the active electrode (G1) placed closest to the stimulator. Recording ring electrodes are conventionally used to test the sensory nerves in the fingers. For sensory studies, an electrical pulse of either 100 or 200 ms in duration is used, and most normal sensory nerves require a current in the range of 5-30 mA to achieve supramaximal stimulation. This is less current than what is usually required for motor conduction studies. Thus, sensory fibers usually have a lower threshold to stimulation than do motor fibers. This can easily be demonstrated on yourself; when slowly increasing the stimulus intensity, you will feel the paresthesia (sensory) before you feel or see the muscle starts to twitch (motor). As in motor studies, the current is slowly increased from a baseline of 0 mA, usually in 3-5 mA increments, until the recorded sensory potential is maximized. This potential, the sensory nerve action potential (SNAP), is a compound potential that represents the summation of all the individual sensory fiber action potentials. SNAPs usually are biphasic or triphasic potentials. For each stimulation site, the onset latency, peak latency, duration, and amplitude are measured. Unlike motor studies, a sensory conduction velocity can be calculated with one stimulation site alone, by taking the measured distance between the stimulator and active recording electrode and dividing by the onset latency. No NMJ or muscle time needs to be subtracted out by using two stimulation sites [8].

Motor nerve conduction study and F wave

For motor conduction studies, the gain usually is set at 2-5 mV per division. Recording electrodes are placed over the muscle of interest. In general, the belly-tendon montage is used. The active recording electrode (also known as G1) is placed on the center of the muscle belly (over the motor endplate), and the reference electrode (also known as G2) is placed distally, over the tendon to the muscle. The designations G1and G2 remain in the EMG vernacular, referring to a time when electrodes were attached to grids (hence the G) of an oscilloscope. The stimulator then is placed over the nerve that supplies the muscle, with the cathode placed closest to the recording electrode. It is helpful to remember black to black," indicating that the black electrode of the stimulator (the cathode) should be facing the black recording electrode (the active recording electrode). For motor studies, the duration of the electrical pulse usually is set to 200 ms. Most normal nerves require a current in the range of 20-50 mA to achieve supramaximal stimulation. As current is slowly increased from a baseline, usually by 510 mA increments, more of the underlying nerve fibers are brought to action potential and, subsequently more muscle fiber action potentials are generated. The recorded potential, known as the CMAP, represents the summation of all underlying individual muscle fiber action potentials. When the current is increased to the point that the CMAP no longer increases in size, one presumes that all nerve fibers have been excited and that supramaximal stimulation has been achieved. The current is then increased by another 20% to ensure supramaximal stimulation [6]. The electromyographic setting was: 100-500 Hz frequency, 5 msec/division sweep speed, and sensitivity: 1 mV/division. The F wave response examination technique is practically the same

as that used for motor nerve conduction study (MNCV). The only difference is that the stimulating cathode was positioned proximally to prevent antidromic impulse anodal block. Manually adjusted the intensity of the stimulating current to activate a maximum muscle (M) response. After that, to ensure supermaximum stimulation, the intensity was increased by 20-30%. F wave latency measured from stimulus artifact to the beginning of the potential evoked. The electromyographic setting was: 16 Hz-16 kHz frequency, sweeping speed: 5-10 msec/division and sensitivity: 200 µV/division.

Electromyographic examination

They are studying the muscles at rest to detect spontaneous activity. The gain settings were 50 µv/cm, and 5-10 msec/cm sweep speed. Motor unit action potentials (MUAPs) were tested in order to activate 3-6 motor units with minimal muscle contraction. The gain was set at 200 µV/cm and was 3-5 msec/cm at sweep speed. Twenty or more single MUAP were separated, and the duration of the MUP, the amplitude of the MUAP, the percentage of polyphasia, and the places were investigated with a single needle puncture by progressing or removing the needle in small steps and adjusting the direction of the needle two or three times [(6)].

Evoked potentials

Done by placing the center of the round coil above the spinous C7 process for the commonly studied hand muscles [(11)], and is often recommended for more proximal arm muscles, which can be recorded simultaneously. The coil may also be placed lower at ~2 cm laterally at the T3 level, thus placing the C8 / T1 nerve roots under the coil's upper quadrant for optimal muscle recording of the APB. The optimal coil position for recordings from proximal arm muscles (BB and deltoid, C5, and C6 innervated) is 2-3 cm above C7, midline, or 2 cm lateral to this position [(12)].

Statistical analysis

The statistical analysis was accomplished applying the Statistical Package for Social Sciences (SPSS) version 23, and the 2010 Microsoft Office Excel. Whole data were represented as mean ± SD. For the measurement of discrepancies between groups, data from and patient and control groups were matched using an independent sample t-test. Within the same group, a paired t-test was used to compare the right and left sides. A P-value of 0.05 or lower was deemed significant.

Results

The duration, amplitude, and phases of MUAPs observed from both upper limbs' deltoid, BB, triceps and first dorsal interossi (FDI) muscles were significantly different between the patient and control using unpaired t test (Table 1).

Needle EMG study of the examined muscles shows no spontaneous activity in its variable types including positive sharp wave, fibrillation, and even fasciculation whereas interference pattern was significant for all muscles ($P<0.001$ for all muscles) (Table 2).

Table 1. Motor unit potential duration, amplitude and phases in patients with cervical radiculopathy

Muscle	Parameter	Patients N=100 Mean±SD	Control N=100 Mean±SD	P value
Biceps Brachii	Duration (ms)	15.36±2.23	10.75±1.11	<0.001
	Amplitude (µV)	1.45±0.65	0.6±0.14	<0.001
	Polyphasia (%)	15.67±4.17	9.28±2.17	<0.001
Deltoid	Duration (ms)	15.4±2.19	11.83±1.68	<0.001
	Amplitude (µV)	1.46±0.66	0.46±0.17	<0.001
	Polyphasia (%)	26.62±6.24	12.49±4.25	<0.001
Triceps brachii	Duration (ms)	16.24±1.3	11.75±1.68	<0.001
	Amplitude (µV)	1.7±0.7	0.6±0.13	<0.001
	Polyphasia (%)	17.51±3.42	8.48±3.45	<0.001
FDI	Duration (ms)	8.98±3.6	7.56±0.89	<0.001
	Amplitude (µV)	0.75±0.18	0.68±0.1	0.001
	Polyphasia (%)	9.11±3.63	8.13±2.53	0.028

The data presented as mean ±SD, FDI = First dorsal interosseous

Table 2. Percentage of abnormal EMG findings in patients with cervical radiculopathy and controls

Parameters	Muscle	Patients N=100	Control N =100	P value
SA (PSW, FIBS)	Biceps	Normal	Normal	1.000
	Deltoid	Normal	Normal	1.000
	Triceps	Normal	Normal	1.000
	FDI	Normal	Normal	1.000
IP	Biceps	Reduced	Normal	<0.001
	Deltoid	Reduced	Normal	<0.001
	Triceps	Reduced	Normal	<0.001
	FDI	Reduced	Normal	<0.001

SA = Spontaneous activity, PSW = Positive sharp waves, FIBS = Fibrillation potentials, IP = Interference pattern, FDI = First dorsal interosseous

Concerning sensory and motor parameters of the median, ulnar and radial nerves; unpaired t- test showed major differences between the patient and the control limbs nerve data except for radial sensory latency (SL), radial CMAP and median nerve conduction velocities (Table 3).

For motor parameters of the musculocutaneous and axillary nerves; unpaired t test showing a significant difference between the patient and control limbs nerve data of the latency parameters (P=0.001 and <0.001), otherwise amplitude parameters were not significant (Table 4).

Table 3. Sensory and motor nerve conduction parameters in patients with cervical radiculopathy and controls

Parameters	Nerve	Patients N=100	Control N=100	P value
SL (ms)	Median	2.92±0.95	2.2 ±0.24	<0.001
	Ulnar	2.01±0.27	2.23±0.33	<0.001
	Radial	1.72±0.25	1.71±0.15	0.784
SNAP (µV)	Median	41.26±24.0	28.44±4.2	<0.001
	Ulnar	55.07±32.29	30.9±6.41	<0.001
	Radial	43.26±18.82	34.15±7.12	<0.001
SNCV (m/s)	Median	46.92±11.56	55.63±6.63	<0.001
	Ulnar	55.07±5.84	57.34±6.58	<0.011
	Radial	63.13±9.96	58.49±5.55	<0.001
DML (ms)	Median	3.36±0.82	2.88±0.41	<0.001
	Ulnar	2.31±0.44	2.51±0.44	0.001
	Radial	2.25±0.56	2.47±0.2	0.001
Distal CMAP (mV)	Median	13.18±4.57	7.16±2.37	<0.001
	Ulnar	12.84±2.68	10.21±3.23	<0.001
	Radial	6.95±2.82	7.16±2.37	0.582
Proximal CMAP (mV)	Median	11.33±4.35	8.42±2.42	<0.001
	Ulnar	11.75±3.02	9.52±2.39	<0.001
	Radial	6.96±2.73	9.26±1.99	<0.001
MNCV (m/s)	Median	58.72±8.7	56.48±7.43	0.051
	Ulnar	61.84±8.37	57.52±7.57	<0.001
	Radial	61.68±9.28	56.72±7.26	<0.001

The data presented as mean±SD, SL = Sensory latency, SNAP = Sensory nerve action potentials, SNCV = Sensory nerve conduction velocity, DML= Distal motor latency, CMAP = Compound muscle action potential, MNCV = Motor nerve conduction velocity

Table 4. Motor nerve conduction parameters of axillary and musculocutaneous nerves in patients with cervical radiculopathy and controls

Parameters	Nerve	Patient N=100	Control N=100	P value
DML (ms)	Musculocutaneous	4.37±0.51	2.63±0.49	<0.001
	Axillary	3.96±0.84	2.83±0.37	<0.001
CMAP (mV)	Musculocutaneous	7.34±3.13	7.15±1.72	0.603
	Axillary	8.04±4.04	7.73±2.17	0.490

The data presented as mean±SD, DML= Distal motor latency, CMAP = Compound muscle action potential

Table 5 illustrates the data of MEPs of the patients and controls. No significant difference was observed between the two groups except (F+M-1\2) of ulnar nerve, recording ADM (0.013) were significant.

Table 5. Cervical root magnetic stimulation - motor evoked potentials data recorded from the median and ulnar nerves of cervical radiculopathy patients

Parameters	Muscles	Patient N = 100	Control N = 100	P value
F+M-1\2 (ms)	APB	14.34±1.53	14.03±1.17	0.108
	ADM	13.55±1.13	13.18±0.97	0.013
Spinal latency (ms)	APB	13.38±1.52	13.05±1.06	0.077
	ADM	12.7±1.26	12.41±1.12	0.090
Intraspinal latency (ms)	APB	0.96±0.75	1.05±0.8	0.402
	ADM	0.84±0.61	0.74±0.57	0.209

The data presented as mean±SD, F = F response, M = CMAP latency, 1 = Time in the anterior horn cell, APB = Abductor policies brevis, ADM=abductor digiti minimi

The cervical root evoked potential of BB and deltoid latency and amplitude were differed significantly between the patient and control groups in deltoid amplitude and BB latency (p = 0.019; 0.027; respectively) (Table 6).

Table 6. Motor evoked potentials data recorded from the musculocutaneous and axillary nerve of patient with cervical radiculopathy

Parameters	Muscles	Patient N=100	Control N=100	P Value
Amplitude (mV)	Deltoid	6.6±2.49	7.42±2.41	0.019
	Biceps	5.92±2.47	6.23±2.64	0.395
Latency (ms)	Deltoid	8.02±1.13	7.74±0.98	0.061
	Biceps	11.37±1.76	10.85±1.57	0.027

Table 7 illustrates specificity and sensitivity of EMG parameters according to the cut-off values of the prolonged MUAP durations, higher amplitudes, and polyphasia recorded from previously selected muscles. The MUAP duration of it, show the highest specificity and sensitivity than that of other muscles, while the amplitudes of it show the highest specificity and sensitivity than that of the other muscles, moreover, the polyphasia of deltoid muscle show highest specificity and sensitivity than that of other muscles.

Table 7. Area under curve, sensitivity, specificity and cut-off value of conventional needle EMG study parameters

Muscle	Parameter	AUC	Sensitivity	Specificity	Cut-off value
Biceps brachii	Duration (ms)	0.946	81.0%	90.0%	12.2
	Amplitude (mV)	0.966	90.0%	92.0%	0.85
	Polyphasia (%)	0.887	79.0%	94.0%	11.0
Deltoid	Duration (ms)	0.896	78.0%	95.0%	14.95
	Amplitude (mV)	0.982	93.0%	94.0%	0.75
	Polyphasia (%)	0.940	87.0%	91.0%	19.5
Triceps Brachii	Duration (ms)	0.984	96.0%	100%	14.95
	Amplitude (mV)	0.999	99.0%	100%	0.95
	Polyphasia (%)	0.961	54.0%	100%	15.5
First dorsal interossi	Duration (ms)	0.582	54.0%	59.0%	7.6
	Amplitude (mV)	0.597	44.0%	71.0%	0.725
	Polyphasia (%)	0.558	52.0%	52.0%	9.75

AUC = Area under curve

Table 8 showed specificity and sensitivity of median and ulnar nerves cervical root (F+M-1)/2-APB and ADM, spinal and intraspinal latency according to the cut-off values of the prolonged latencies, recorded from APB and ADM muscle. The spinal latency of the median shows the highest specificity than that of the ulnar nerve, whereas, the intraspinal latency show the same specificity for both nerves. Moreover, the cervical root (F+M-1)/2-ADM shows the highest specificity than that of cervical root (F+M-1)/2-APB. As regards the intraspinal sensitivity of the median nerve which was the highest than that the other sensitivities, whereas, cervical root (F+M-1)/2-ADM has the highest sensitivity than the other sensitivities.

Table 8. Area under curve, sensitivity, specificity and cut-off value of the median and ulnar motor evoked potentials

Muscle	Parameter	AUC	Sensitivity	Specificity	Cut-off value
APB	F+M-1\2 (ms)	0.540	47.0	49.0	14.15
	Spinal latency (ms)	0.538	50.0	59.0	13.15
	Intraspinal latency (ms)	0.532	53.0	57.0	0.85
ADM	F+M-1\2 (ms)	0.594	56.0	56.0	13.35
	Spinal latency (ms)	0.568	54.0	57.0	12.7
	Intraspinal latency (ms)	0.549	51.0	57.0	0.75

AUC = Area under curve, APB = Abductor pollicis brevis, ADM = Abductor digiti minimi, F = F response, 1 = Time in the anterior horn cell

Table 9 illustrates the specificity and sensitivity of musculocutaneous and axillary nerves direct cervical root stimulation according to the cut-off values of the prolonged latencies, lower amplitudes recorded from BB and deltoid muscles.

Table 9. Area under curve, sensitivity, specificity and cut-off value of the musculocutaneous and axillary motor evoked potentials

Muscle	Parameter	AUC	Sensitivity	Specificity	Cut-off value
Biceps brachii	Amplitude (mV)	0.522	50.0	50.0	5.9
	Latency (ms)	0.585	49.0	62.0	11.15
Deltoid	Amplitude (mV)	0.600	58.0	57.0	7.05
	Latency (ms)	0.562	47.0	61.0	8.05

AUC = Area under curve

Discussion

Conventional motor and sensory nerve conduction study

Though normal motor and sensory conduction studies are typically common in CR, they remain an integral part of their diagnostic evaluation. Mononeuropathy, polyneuropathy, and plexopathy may all need to be excluded before electrodiagnosis of CR can be performed; all of these require relevant motor and sensory conduction studies [6,13]. For CR patients, motor and sensory conduction tests were within the control group's normal limits and had no side-to-side difference, finding that was similar to other researchers' results [14,15]. In this study, the sensory and motor parameters of the median, ulnar and radial nerves, showed significant differences in nerve data between the patient and the control limbs except for radial SL, radial CMAP, and median velocities of nerve conduction. Besides, the motor parameters of the musculocutaneous and axillary nerves; shows a substantial difference in latency nerve data between the patient and the control limbs, otherwise amplitude parameters were not significant. These changes in CMAP were due to the chronic effects of CR contributing to secondary axonal degeneration, and changes of DML, SL, and SNAPs due to peripheral entrapment neuropathies.

The conventional needle EMG study

In the current research, for CR patients, some upper limb muscle EMG needle (FDI, BB, TB, and deltoid), shows no spontaneous activity in its variable types including Positive sharp waves (PSW), fibrillations, and even fasciculation although IP was significant for all muscles. While the duration, amplitude, and phases of MUAPs examined from the deltoid, BB, TB, and FDI muscles of both upper limbs were significantly different among the patients and controls. Such results suggest a variable degree of secondary axonal degeneration and have been identified by Pezzin as signs of denervation due to compression of the nerve root [16].

Cervical magnetic root stimulation study

In this study, MEP parameters reported after stimulation of median, ulnar, musculocutaneous and axillary nerves and recording from (APB, ADM, Biceps, and Deltoid respectively), other than the cervical spinal root were not significantly different in CR patients except for ADM (F+M-1\2) [17]. Similarly, musculocutaneous and axillary nerve data indicate substantial variations between CR patients and control subjects for cervical spinal root-BB latency and deltoid amplitude. No substantial difference between patient CR and control group was observed in the current study.

The sensitivity and specificity of conventional needle EMG study

Specificity and sensitivity of traditional needle EMG analysis of selected muscles (biceps brachii, triceps, deltoid, and first dorsal interossei) based on the cut-off values of prolonged MUAP durations, higher amplitudes, and polyphasia reported by needle EMG from previously selected muscles. The MUAP duration of triceps shows the highest specificity and sensitivity (96.0%) than that of other muscles, while the amplitudes of triceps show the highest specificity and sensitivity (100%,

99%) than that of the other muscles, Moreover, the polyphasia of deltoid muscle show highest specificity and sensitivity (91%, 87%) than that of other muscles table [18].

Sensitivity and specificity of MEPs

Median and ulnar nerves

During direct cervical root stimulation, the spinal latency of the median and ulnar nerves shows low specificity not exceedingly more than (59%), while for both nerves, the intraspinal latency shows the same specificities (57%). In addition, the cervical root PMCT by Kimura formula recording ADM and APB during direct stimulation of the cervical root displays low specificity of less than (56%). As for the median nerve's intraspinal latency sensitivity which was low of less than (53%) as the other sensitivities; this is in agreement with other researches [19-21].

Musculocutaneous and axillary nerves

Direct cervical root stimulation amplitude and latency following recording of the deltoid muscle exhibits of low specificity and sensitivity of both nerves (of less than 62%). Overall, the current motor evoked potential study shows abnormalities in fewer than 60% of patients with cervical radiculopathy relative to conventional needle EMG study abnormalities that reached 90%. This is in agreement with findings of other researchers [19-21], who found that low sensitivity and specificity of MEPs in comparing with conventional EMG in the diagnosis of cervical radiculopathy.

In conclusions, the study of motor and sensory conduction in CR could be normal, and no significant side to side difference was found. Conventional EMG findings revealed various abnormalities that denote an inconsistent degree of secondary axonal degeneration and were considered as signs of denervation due to nerve root compression. During magnetic cervical root stimulation, the spinal latency of the median and ulnar nerves during direct cervical root stimulation shows the low specificity and sensitivity. The intraspinal latency of the median and ulnar show low sensitivity and specificity. Direct cervical root stimulation amplitude following deltoid and BB muscle was recording shows the low specificity and sensitivity. In more than 90 % of CR cases, EMG reported abnormalities compared to less than 60 % for MEPs.

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Author contribution

Dr. Abdulhameed: Collection of patients, performing the electrophysiological tests, writing the manuscript. Dr. Kaddori: supervised the study, and final revision of the article.

Conflict of interest

Authors declare no conflict of interest.

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References

1. Carette S, Fehlings MG. Clinical practice. Cervical radiculopathy. N Engl J Med. 2005; 353(4): 392-9. doi: 10.1056/NEJMcp043887.
2. Tsai CP, Huang CI, Wang V, et al. Evaluation of cervical radiculopathy by cervical root stimulation. Electromyogr Clin Neurophysiol. 1994; 34(6): 363-6.
3. Fouyas IP, Statham PF, Sandercock PA. Cochrane review on the role of surgery in cervical spondylotic radiculomyelopathy. Spine (Phila Pa 1976). 2002; 27(7): 736-47. doi: 10.1097/00007632-200204010-00011.
4. Davidson RI, Dunn EJ, Metzmaker JN. The shoulder abduction test in the diagnosis of radicular pain in cervical extradural compressive monoradiculopathies. Spine (Phila Pa 1976). 1981; 6(5): 441-6. doi: 10.1097/00007632-198109000-00004.
5. Benzel EC. Spine surgery: techniques, complication avoidance, and management. 2nd ed. Churchill Livingstone; 2004.
6. Kimura J. Electrodiagnosis in disease of nerve and muscle: Principles and practice. Oxford University Press; 2013. p. 74-93.
7. Kaddori H. Value of transcranial magnetic stimulation and somatosensory evoked potentials versus conventional EMG in the diagnosis of cervical myelopathy. PhD thesis in Physiology. College of Medicine, Al-Nahrain University. 2015.
8. Preston D, Shapiro B. Electromyography and neuromuscular disorders: Clinical-electrophysiologic-

ultrasound correlations. 4th ed. Elsevier; 2020. p. 557-76.
9. Macdonell RA, Cros D, Shahani BT. Lumbosacral nerve root stimulation comparing electrical with surface magnetic coil techniques. Muscle Nerve. 1992; 15(8): 885-90. doi: 10.1002/mus.880150804.
10. Banerjee TK, Mostofi MS, Us O, et al. Magnetic stimulation in the determination of lumbosacral motor radiculopathy. Electroencephalogr Clin Neurophysiol. 1993; 89(4): 221-6. doi: 10.1016/0168-5597(93)90099-b.
11. Attarian S, Azulay JP, Lardillier D, et al. Transcranial magnetic stimulation in lower motor neuron diseases. Clin Neurophysiol. 2005; 116(1): 35-42. doi: 10.1016/j.clinph.2004.07.020.
12. Campbell PG, Yadla S, Malone J, et al. Early complications related to approach in cervical spine surgery: single-center prospective study. World Neurosurg. 2010; 74(2-3): 363-8. doi: 10.1016/j.wneu.2010.05.034.
13. Mann KS, Khosla VK, Gulati DR. Cervical spondylotic myelopathy treated by single-stage multilevel anterior decompression. A prospective study. J Neurosurg. 1984; 60(1): 81-7. doi: 10.3171/jns.1984.60.1.0081.
14. Khedr EM, Fathi N, Imam HM, et al. Early diagnosis of rheumatoid cervical myelopathy Neurophysiological study and magnetic resonance imaging. Egypt J Neur Psych Neurosurg. 2002; 39(1): 13-20.
15. Pezzin LE, Dillingham TR, Lauder TD, et al. Cervical radiculopathies: relationship between symptom duration and spontaneous EMG activity. Muscle Nerve. 1999; 22(10): 1412-8. doi: 10.1002/(sici)1097-4598(199910)22:10<1412::aid-mus11>3.0.co;2-u.
16. Matsumoto H, Hanajima R, Terao Y, et al. Neurophysiological analysis of the cauda equina in POEMS syndrome. Neurol Sci. 2013; 34(1): 121-2. doi: 10.1007/s10072-012-0950-z.
17. Wassermann EM. The motor-evoked potential in health and disease. In: Epstein C, Wassermann EM, Ziemann U, et al (eds). Oxford handbook of transcranial stimulation. 1st ed. Oxford University Press; 2008. p. 201-10.
18. Fisher MA. Electrophysiology of radiculopathies. Clin Neurophysiol. 2002; 113(3): 317-35. doi: 10.1016/s1388-2457(02)00018-4.
19. Lo YL. The role of electrophysiology in the diagnosis and management of cervical spondylotic myelopathy. Ann Acad Med Singap. 2007; 36(11): 886-93.
20. Kalupahana NS, Weerasinghe VS, Dangahadeniya U, et al. Abnormal parameters of magnetically evoked motor-evoked potentials in patients with cervical spondylotic myelopathy. Spine J. 2008; 8(4): 645-9. doi: 10.1016/j.spinee.2006.11.010.
21. Nakamae T, Tanaka N, Nakanishi K, et al. Quantitative assessment of myelopathy patients using motor evoked potentials produced by transcranial magnetic stimulation. Eur Spine J. 2010; 19(5): 685-90. doi: 10.1007/s00586-009-1246-8.

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