CONCENTRIC-NEEDLE ELECTROMYOGRAPHY ASSESSMENT: RESULTS FROM HEALTHY INDIVIDUALS AND INDIVIDUALS WITH C5 OR C6 RADICULOPATHY

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INTRODUCTION

Concentric needle electromyography (EMG) is used by neurologists and physiatrists in the diagnosis of neurological and myopathic conditions. The most common tests are insertional activity and spontaneous activity, which involve the identification of positive sharp waves (PSW) or fibrillation potentials (FP) within EMG signals acquired while the muscle is at rest. Such signals are indicative of neuropathy or myopathy but are not specific to either condition.[1] A second measure, the recruitment frequency (RF) of motor units, may also be performed. The RF is the firing frequency of the first motor unit just before a second motor unit begins firing and is assessed during a very light, but gradually increasing contraction.[2] The RF varies according to the muscle being tested, but generally ranges from 10 to 15 Hz. Nerve damage may cause the RF to increase considerably.[3] Finally, analysis of the morphology of individual motor unit potentials (MUP) is performed during a light contraction. Characteristics such as MUP amplitude, duration, area and the number of turns and phases are assessed.[4] Neurological and myopathic conditions cause characteristic changes in these parameters, which vary over the course of the disease process.

Typically, clinicians analyse these parameters in real time, using qualitative means. The EMG signal is displayed on an oscilloscope using customary sweep and gain settings, and analyses are made both visually and by auditory identification of characteristic sounds when the waveforms are presented through a speaker. Often the auditory representation is deemed more important than the visual information. The subjective nature of the analysis makes these methods unsuitable for research purposes.

Although insertional and spontaneous activity are commonly-performed clinical tests, their use has not been conclusively validated and limited normative data exist. Clinical studies are not often performed with comparison to healthy control subjects and thus it is difficult to determine if the test results are due to pathology or due to acceptable variations of normal. For example, the prevalence of positive sharp waves in the cervical paraspinals of healthy individuals was found to be 12% in one study.[5] A review by the American Association of Electrodiagnostic Medicine found the sensitivity of needle electromyography for the diagnosis of cervical radiculopathy to be between 50% and 71%.[6] One study found the inter-rater reliability of needle EMG in lumbosacral radiculopathy to be only 47%.[7] The RF is not used as commonly in the assessment of radiculopathy as are insertional and spontaneous activity and no published research has been found on the validity, sensitivity or specificity of this test.

Morphological changes in MUPs affected by myopathy or neuropathy are based on the underlying physiology. Little research had been done to validate the use of the qualitative assessment of MUPs in the diagnosis of pathology. One recent study showed a poor inter-rater reliability (r=-0.22 to 0.66) for most MUP parameters.[8] Computer software programs are now available to decompose EMG data into their constituent MUPs. There is some evidence that quantifying the morphological changes is of value in determining pathological changes in myopathy[9] and neuropathy.[10] These systems appear to have improved test-retest reliability (r=0.72 to 0.97) compared to subjective methods.[11]

The first purpose of this study was to determine if there are differences in insertional or spontaneous activity, RF or MUP parameters between muscles or between sides in healthy control subjects. The second purpose of this study was to determine if there are differences in concentric needle EMG measures between a small group of patients with clinically-suspected C5 or C6 radiculopathy and a control group, in order to determine if these measures might be useful in a larger study aimed at detecting radiculopathy affecting the rotator cuff muscles.

METHODS

<u>Subjects</u>

The study was approved by the Queen's University Health Sciences Research Ethics Board. Healthy adults without neurological signs or symptoms were recruited from the community. Individuals with chronic C5 or C6 radiculopathy but who were otherwise healthy were recruited by health professionals. Chronic radiculopathy was defined as unilateral pain radiating along the lateral aspect of the arm and forearm to the thumb and index finger, occurring for at least 3 months. The pain had to be accompanied by weakness in the deltoid or biceps as well as one of the following signs: reduced muscle stretch reflexes, altered sensation in the lateral shoulder, or a reduction of pain with either cervical distraction or placing the ipsilateral hand on top of the head.

Instrumentation and Procedures

Four muscles were tested bilaterally: the supraspinatus, infraspinatus, biceps and cervical spine paraspinal muscles. The supraspinatus and infraspinatus are innervated by the C5 and C6 nerve roots via the suprascapular nerve. The biceps are also innervated by the C5 and C6 nerve roots, but via the axillary nerve. Therefore, if damage is evident at the spinati but not the biceps, the peripheral nerve would be assumed to be injured rather than the nerve root. Involvement of the paraspinals is common in nerve root injuries, and is considered an early sign of damage.

Each subject's skin was prepared and adhesive surface cathode electrodes (20 mm x 25 mm, Ag/AgCl HH5000 EKG, Harris Healthcare, Hudson, Massachusetts) were placed over the central portion of each of the muscle bellies bilaterally, avoiding the motor point in a monopolar configuration. Anodes were placed over the posterior acromia and a 5 cm x 10 cm 5000 Series TENS/NMES self-adhering electrode (Empi, St. Paul, Minnesota) was centred across the C7 spinous process to act as the reference electrode.

The subject was placed comfortably in a side-lying position on a plinth with their arm supported. A 'flip of a coin' determined if the right or left side was studied first. After cleaning the area with rubbing alcohol, a concentric needle electrode (Ambu® Neuroline, Ballerup, Denmark) was inserted into the centre of the muscle belly, such that the tip of the needle was situated beneath the corresponding active surface electrode. For each trial, thirty seconds of EMG activity was recorded using Comperio™ hardware (Neuroscan Medical Systems, Neurosoft, Inc., Stirling, Virginia) and custom Acquire EMG™ and DQEMG™ software (Waterloo, Ontario). The Comperio™ EMG amplifier has a common mode rejection ratio of 100 dB at 60 Hz, an input impedance of greater than 100 MΩ and a high-frequency filter of greater than 25 dB. The band-pass frequencies are 5 Hz to 5 kHz for the surface electrode and 10 Hz to 10 kHz for the concentric needle electrode. Data were acquired at a resolution of 20 bits, with a sampling rate of 32 kHz per channel. Data were saved on a personal computer for later analysis.

For each muscle, several sites at least 5 mm apart were tested. At least eight locations within each of the eight muscles were tested for the presence of insertional and spontaneous activity while the muscle remained at rest. To test for RF, a minimal contraction was recorded at two locations in each of the muscles except the paraspinals, which had one recording made. The subject attempted, using visual and auditory feedback, to recruit a single motor unit, and then increase the contraction slightly such that a second motor unit was recruited. Several attempts were made at each muscle location. Not all subjects underwent this component of the examination. For the quantitative EMG MUP analysis, only two muscles were tested, the supraspinatus and the infraspinatus. At least 20 MUPs were sampled within each muscle while the subject was contracting the muscle between 5 and 15% of their maximum voluntary contraction.

Analysis and Statistics

Data analysis for insertional and spontaneous activity and for RF was performed using MATLAB™ software (version 7.0.4.365 R14, The Math Works Inc., Natick, Massachusetts, 2005). A display was set up to mimic the oscilloscope screen used clinically and visual analysis of the EMG data was performed off-line. Distinct criteria were used to define insertional and spontaneous activity, and to determine the RF.

While a small amount of insertional activity is normal, the presence of PSWs or FPs beginning within the first second after needle movement and lasting for at least 300 ms was considered a positive test. A positive test for spontaneous activity was defined as PSWs or FPs beginning more than 1 s after any movement of the needle and continuing for at least 3 s. In clinical practice the results for a muscle are graded from 0 to +4. For our purposes, if two or more locations within a muscle fulfilled these criteria, the muscle was considered positive for insertional or spontaneous activity. This corresponds to grade +1.

To quantify the RF, the firing frequency (in Hz) of the first motor unit was determined just before the second motor unit began to fire. If there was more than one successful attempt at a single muscle location on the recording, the RFs were averaged. Averaging from two locations produced a mean RF for each muscle.

DQEMG™ software was used to identify individual MUPs within each data set and analyse characteristics of the concentric needle MUP (CNMUP) and the surface MUP (SMUP) signals. CNMUP characteristics included peak to peak voltage, duration, the number of phases and turns and area to amplitude ratio. SMUP characteristics included peak to peak voltage, area, negative peak amplitude, negative peak area and duration.

The presence or absence of insertional and spontaneous activity was compared between sides, between muscles and between groups using Fisher's Exact test (α = 0.05).

For the quantitative MUP parameters, repeated-measures analyses of variance (ANOVAs) were used to assess side, group or muscle main effects and significant two-way interactions (α = 0.05). Post-hoc Scheffe's analyses were performed as required. Z-scores (α = 0.05) were used to investigate individual patient data when significant group differences were found. Group was not included in the RF ANOVA as there was only one patient with useable data; this single subject was compared to the control group using Z-scores.

RESULTS

Eight healthy subjects and three patients with suspected C5 or C6 radiculopathy participated. Recruitment was difficult because of the rarity of C5 and C6 radiculopathy and because of the length of time of the protocol, which required 3 to 4 hours.

In the healthy subjects no differences in insertional or spontaneous activity were found between sides or among muscles (p>0.48). There were no differences between the patient and control groups (p=0.57) or between the affected and unaffected sides in the patient group (p=1.00).

In healthy subjects there was a significant difference in RF between the deltoid (12.5 ± 3.2 Hz) and the cervical paraspinals (7.6 ± 1.3 Hz), (p<0.05). Otherwise there were no differences between sides or among muscles. RF data was obtained from only one patient. He showed a somewhat increased RF on the affected side (z=1.99) compared to the control group and a slightly reduced RF on the unaffected side (z=-1.20) compared to the control group. These findings were isolated to the infraspinatus muscle.

Means and standard deviations for each SMUP and CNMUP parameter and differences between muscles and between sides are presented in Table 1. Most SMUP parameters showed significant differences between groups (p<0.01) whereby the amplitudes and areas were larger, but only in the supraspinatus muscle on the affected side. CNMUP parameters mainly showed no group effects. The z-scores indicated that two of the three subjects with suspected C5 or C6 radiculopathy had larger SMUPs on their affected side whereas the third patient did not (Table 2). The third patient had no weakness in external rotation, while the first two patients were weaker by at least 10% on their affected side.

Table 1: Mean values (± standard deviation) of MUP parameters in healthy individuals. VPP – peak to peak voltage, dur – duration, AAR – area to amplitude ratio, pkamp – negative peak amplitude, pkarea– negative peak area. *difference between muscles, p<0.05. †difference between sides, p<0.05.

		CNMUP Parameters					SMUP Parameters				
		VPP* (μV)	dur (ms)	phases	turns*	AAR (ms)	VPP*† (μV)	area*† (μV*ms)	pkamp* (μV)	pkarea (μV*ms)	dur (ms)
Infra	R	354.4± 188.9	15.3± 6.8*	2.5± 0.6*	2.9± 0.9	1.9± 0.8	45.1± 23.7	242.9± 149.7	26.1± 14.6	95.5± 56.0*†	25.1± 8.1*
	L	383.4± 184.3	15.1± 6.8	2.6± 0.6	3.0± 1.0	2.0± 0.7	51.4± 18.8	309.2± 167.5	30.5± 11.4	132.7± 71.7†	25.0± 8.6
Supra	R	480.7± 235.1	12.8± 5.5*†	2.7± 0.6*	3.4± 1.3	1.9± 0.7	62.5± 33.5	271.6± 186.9	40.1± 19.9	127.8± 86.2*	19.4± 7.4*
	L	463.4± 258.1	14.9± 6.8†	2.6± 0.6	3.3± 1.2	2.0± 0.8	63.6± 40.5	327.4± 242.4	36.9± 22.0	115.6± 88.6	23.9± 8.5

Table 2: Z-scores comparing each patient's affected side (always left) with that of the healthy control subjects (either both sides combined, or left side if there was a difference between sides).

	CNMUP Parameters					SMUP Parameters				
	VPP	dur	phases	turns	AAR	VPP	area	pkamp	pkarea	dur
Patient 1 infra	-0.04	0.01	0.41	0.19	0.01	-0.14	-0.53	0.07	-0.63	-0.73
supra	-0.33	-0.32	-0.02	-0.33	-0.33	0.52	0.35	0.97	0.83	0.02
Patient 2 infra	0.31	-0.20	-0.56	0.22	-0.62	-0.72	-0.99	-0.22	-0.94	-1.16
supra	-0.28	0.18	-0.13	-0.17	0.13	0.47	0.93	0.40	0.89	0.89
Patient 3 infra	0.24	0.51	0.21	0.05	0.29	-0.52	-0.74	-0.35	-0.76	-0.73
supra	-0.29	-0.29	0.36	0.11	-0.29	-0.93	-0.98	-1.04	-1.00	-0.42

DISCUSSION

The supraspinatus and infraspinatus have not previously been used in studies such as these and no normative data exist for them. There is utility in examining these muscles because of their innervation from the C5 and C6 nerve roots, and the fact that they are innervated by different peripheral muscles than the deltoid and biceps, muscles more commonly studied. By combining the investigation of several muscles, a more thorough picture of the distribution of pathology might be discerned.

This pilot study fails to show the utility of using insertional and spontaneous activity for the identification of cervical radiculopathy. Because our numbers are very small, this result is not definitive, however it suggests that these tests on their own might not be sensitive or specific enough for diagnostic purposes, a conclusion that has been drawn by others.[6]

The RF varies somewhat with respect to muscle, thus comparisons to normative data should be muscle-specific. With only one patient, conclusions are difficult to make. In this one patient, there was a side-to-side difference suggesting that the RF might be increased on the side affected by radiculopathy.

Most SMUP and CNMUP parameters showed differences between sides and/or between muscles. This differences need to be taken into account when comparing patients to normative data. Handedness was not investigated in our small sample, as only one of the healthy subjects was left-handed (his data showed no outliers so he was included in the analysis) and all three patients were right-handed with left-sided involvement. Future studies should include sufficient numbers of left- and right-handed individuals such that the effect of handedness might be discerned.

The supraspinatus SMUP area, negative peak amplitude, negative peak area and duration showed the most promise in the differentiation of the radiculopathy group from the control group. This was most evident for the two patients who had a demonstrated difference in external rotation strength of at least 10% between the affected and the unaffected sides. The patients' SMUP parameters on their affected side were larger than the control group's, which is consistent with the belief that chronic neuropathy results in collateral sprouting of the nerves in an attempt to re-innervate orphaned motor units. This produces MUPs with larger amplitudes, durations and areas. SMUP parameters appear to be more sensitive to these changes than CNMUP parameters, likely because the CNMUP parameters are highly influenced by the location of the needle tip relative to the active motor units, whereas the SMUP parameters are not. The quantitative method of MUP analysis has been demonstrated to increase the reliability of clinical EMG evaluations[11], and should be used for diagnostic purposes.

CONCLUSION

Methods are presented for the analysis of insertional and spontaneous activity, RF, and quantitative MUP parameters at several shoulder muscles. SMUP parameters appear to have the greatest potential to differentiate between individuals with C5 or C6 radiculopathy and healthy control subjects. Further studies need to be performed to fully investigate the sensitivity, specificity and reliability of these methods for clinical and research purposes.

ACKNOWLEDGEMENTS

The authors wish to thank Alexander Andrews for his assistance in MATLAB™ programming.

REFERENCES

1. Levin KH. Electrodiagnostic approach to the patient with suspected radiculopathy. Neurologic Clinics 2002; 20:397-421.
2. Preston DC, Shapiro BE. Electromyography and neuromuscular disorders: clinical-electrophysiological correlations. Philadelphia: Butterworth-Heinemann; 2005.
3. Sandbrink, Friedhelm and Culcea, Eliad. Motor Unit Recruitment in EMG. Berman, Stephen A., Talavera, Francisco, Busis, Neil A., Baker, Matthew J., and Lorenzo, Nicholas. eMedicine from World Medical Library . 2005.
4. Kimura J. Electrodiagnosis in Diseases of Nerve and Muscle: Principles and Practice. New York: Oxford University Press; 2001.
5. Date ES, Kim B-J, Yoon JS, Park BK. Cervical paraspinal spontaneous activity in asymptomatic subjects. Muscle Nerve 2006; 34:361-364.
6. American Association of Electrodiagnostic Medicine. The electrodiagnostic evaluation of patients with suspected cervical radiculopathy: literature review on the usefulness of needle electromyography. Muscle Nerve 1999; 22:S213-S221.
7. Kendall R, Werner RA. Interrater reliability of the needle examination in lumbosacral radiculopathy. Muscle Nerve 2006; 34:238-241.
8. Chu J, Takehara I, Li TC, Schwartz I. Skill and selection bias has least influence on motor unit action potential firing rate/frequency. Electromyogr Clin Neurophysiol 2003; 43:387-392.
9. Podnar S, Zidar J. Sensitivity of motor unit potential analysis in facioscapulohumeral muscular dystrophy. Muscle Nerve 2006; 34:451-456.
10. Cuturic M, Palliyath S. Motor unit number estimate (MUNE) testing in male patients with mild to moderate carpal tunnel syndrome. Electromyogr Clin Neurophysiol 2000; 40:67-72.
11. Boe SG, Stashuk DW, Doherty TJ. Within-subject reliability of motor unit number estimates and quantitative motor unit analysis in a distal and proximal upper limb muscle. Clin Neurophysiol 2006; 117:596-603.