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Nerve conduction topography in geriatric hand assessment

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Abstract—Motor nerve conduction is a noninvasive clinical test used to diagnose nerve problems such as carpal tunnel syndrome or peripheral neuropathy. Current techniques use a single-site recording over a superficial muscle. This traditional approach does not account for the electrical contributions from the other muscles innervated by the nerve being stimulated, which need to be considered with thumb carpometacarpal (CMC) degenerative joint disease (DJD) because these electrical contributions may change the anatomic relationship of the thenar muscles. This study recorded from 15 sites over the thenar eminence during motor nerve conduction studies of the median nerve of 12 young subjects with normal thenar anatomy and 25 elderly subjects with thumb CMC DJD. The maximum compound muscle action potential (CMAP) values did not occur in the same electrode position for the two groups, and traditional single-site recording would have resulted in smaller amplitudes and longer latencies for the elderly than the values noted with the multiple-site recordings. This pilot study of nerve conduction topography mapping with multiple-site recording illustrates that single-site studies may be misleading and supports further exploration of multichannel grid electrodes for topographic display and analysis of the CMAP.

Key words: CMAP amplitude, CMAP duration, CMAP latency, degenerative joint disease, hand with CMC DJD, median curve, nerve conduction, single-site recording, thenar muscle, topographic mapping.

INTRODUCTION

Nerve conduction studies are widely used in clinical medicine [1–2]. The technique is fairly simple and noninvasive. For motor nerve conduction studies, the nerve is stimulated at one site and the electrical response is recorded distally from a muscle innervated by that nerve. Traditionally, a single site over the motor point of a superficial muscle innervated by the nerve is selected as the recording site. A referential recording montage is commonly used with a "reference" electrode (E2) over an area considered to be relatively electrically inactive, such as a bone or tendon and a "recording" electrode (E1) over the motor point of a muscle.

Traditionally, a single muscle was considered to be the recording site, and the recorded compound muscle action potential (CMAP) was thought to reflect only the activity in that one muscle. With increasing sophistication in our understanding of the recorded CMAP, we now appreciate that the CMAP also reflects electrical activity of adjacent muscles innervated by the same nerve [3–8].

Abbreviations: CMAP = compound muscle action potential, CMC = carpometacarpal, DJD = degenerative joint disease, E1 = recording electrode, E2 = reference electrode, SD = standard deviation.

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This finding can be extremely important to recognize, especially if the anatomic positions of the contributing muscles change. The resultant “abnormal” CMAP may be misinterpreted as a nerve problem, instead of correctly identified as due to muscle anatomic change. A very practical example is the potential change in median motor CMAP due to thenar deformity from thumb carpometacarpal (CMC) degenerative joint disease (DJD). This pilot study recorded CMAPs from multiple sites over the thenar eminence in both young subjects and elderly subjects with deformity from thumb CMC DJD.

METHODS

Nerve conduction studies were conducted on 12 normal young subjects (7 males age 32 ± 8.8 [mean ± standard deviation (SD)] and 5 females age 33 ± 4.8) and 25 geriatric patients (14 males age 75 ± 3.29 and 11 females age 73 ± 5.6) with clinical findings of CMC DJD as evidenced by the classic “shoulder” deformity at the base of the thumb [9]. Informed consent was obtained from all subjects before they participated in the study, and this study was approved by the Department of Veterans Affairs and the Medical College of Wisconsin, Milwaukee. All subjects (both young and elderly) did not have any hand paresthesias, history of trauma, or any systematic diseases. All elderly subjects had thumb deformity due to CMC DJD but no peripheral neuropathy or carpal tunnel syndrome. The young subjects and elderly arthritic subjects represent two ends of the expected spectrum of thenar muscle architecture rearrangement.

Median motor nerve conduction studies were performed with multiple recording sites. The E1 was initially placed over the midpoint of the abductor pollicis brevis muscle, found by measurement from the distal wrist crease to the thumb metacarpophalangeal joint (**Figure 1**). The E1 was moved in equal increments (10 mm center to center) superiorly, inferiorly, medially, laterally, and diagonally. CMAPs were recorded at each site. A skin temperature of 32 °C to 36 °C was measured with a surface thermistor on the skin. The hand was immobilized in the neutral wrist position with thumb in midpalmar abduction to prevent CMAP changes due to muscle length changes. The recording parameters used were 2 Hz high-pass filter, 10 kHz low-pass filter, 5 ms/division sweep speed, and 1 mV to 5 mV/division gain. Conventional 1 cm Ag/AgCl recording disk electrodes were used. The E2 was placed distally over the volar surface of the thumb. Bar surface stimulating electrodes were placed over the median nerve at the wrist. Stimulation parameters used were 0.05 ms stimulus duration with gradually increasing intensity to a maximal response, then increasing by 25 percent to a supramaximal response. The CMAPs were recorded and stored for offline analysis. The amplitude, latency, duration, and area of each CMAP were calculated with the use of custom signal-processing software designed with MATLAB (The MathWorks, Natick, Massachusetts). These results were then visually mapped with the use of two-dimensional graphical topography.

Figure 1.
Example of degenerative joint disease hand.

RESULTS

An example of a DJD hand is shown in **Figure 1**. **Figure 2** illustrates the locations of the 15 recording sites on the thenar muscle group of the left hand where electrodes were placed. **Figure 3** illustrates topographic mapping of thenar CMAP amplitude for average young normal subjects, one young normal subject, an elderly subject with DJD, and another elderly subject with DJD. The gray scale bars under the respective hands have the same scale to allow visual comparison between young normal adults and elderly patients with DJD. We used average values for each recording site while generating these topographic mappings.

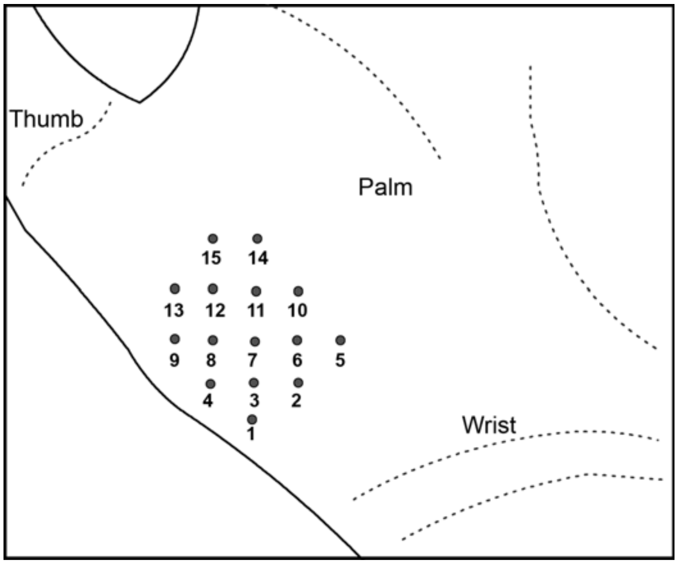

Figure 2.
Fifteen electrode positions on thenar muscle area of left hand.

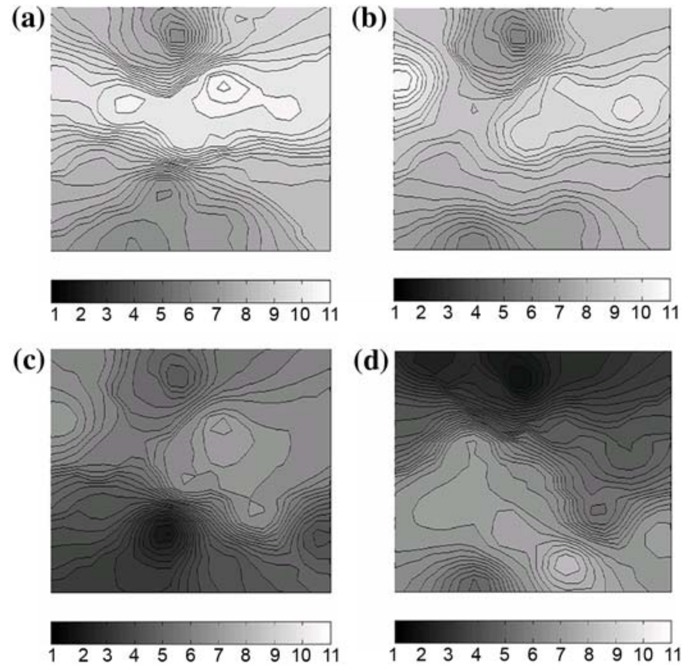

Figure 3.
Thenar compound muscle action potential amplitude (mV) for right hand: **(a)** mean amplitude map for young normal subjects, **(b)** amplitude map for one young normal subject, **(c)** amplitude map for elderly degenerative joint disease (DJD) subject, and **(d)** amplitude map for another elderly DJD subject.

In young normal adults, the thenar CMAP mean amplitude contour map has magnitudes larger than those observed in the elderly patients with DJD (**Figure 3**). **Figure 3** illustrates that in normal young adults, the CMAP amplitude distribution in the thenar muscle has similar pattern. Thus, a single recording site measurement can be applied to the hand of young normal adults (**Figure 3(a)–(b)**). On the contrary, the hands of two elderly subjects with DJD have significantly different CMAP amplitude distribution patterns (**Figure 3(c)–(d)**). The *t*-test (paired, two-tailed, $p < 0.05$) was applied to determine the statistical significance between the amplitude of these two groups. The amplitude map of these subjects with DJD shows significant ($p < 0.02$) dissimilarity both in pattern and magnitude with those of normal young subjects.

Figure 4 shows the CMAP latency patterns both in the hands of normal subjects and the hands of DJD subjects. This figure also illustrates that normal adults have almost similar patterns of latency map whereas subjects with DJD hands provide wide variation of latency map, which will make single-channel recording difficult without knowing the anatomic variation of the thenar muscle.

Table 1 shows the variability of the measurements of different electrodes in normal subjects and subjects with DJD. In young normal subjects, site 7 shows the maximum number of recorded highest amplitude among the 12 young subjects for both hands. In the elderly subjects with DJD, no single electrode site has recorded the maximum number of CMAP magnitudes; rather, site 5, site 6, site 7, site 8, and site 9, most of the time, recorded highest amplitude among the 25 elderly subjects with DJD. The amplitude difference between site 7 and the maximum amplitude recorded site for elderly subjects has a range of 0.2 to 2.2 mV. The electrode site with the highest CMAP amplitude is usually the most appropriate for a single-channel assessment. In the case of young normal subjects, site 7 will be the ideal choice for single-site recording. However, one cannot record the CMAP using a single electrode in the DJD hand using the same convention because of the distribution variability among the DJD subjects. The appropriate spot can only be found with mapping for the DJD subjects. Similar observation is found in the case of latency (**Table 2**).

Table 3 describes the mean ± SD of the CMAP metrics (amplitude, area under the curve, duration, and latency) for a conventional single-site recording (7) and from the multiple-site recordings. For single-site measurements, the mean value represents the average of single-site measurements (for instance, site 7) for all subjects, whereas for

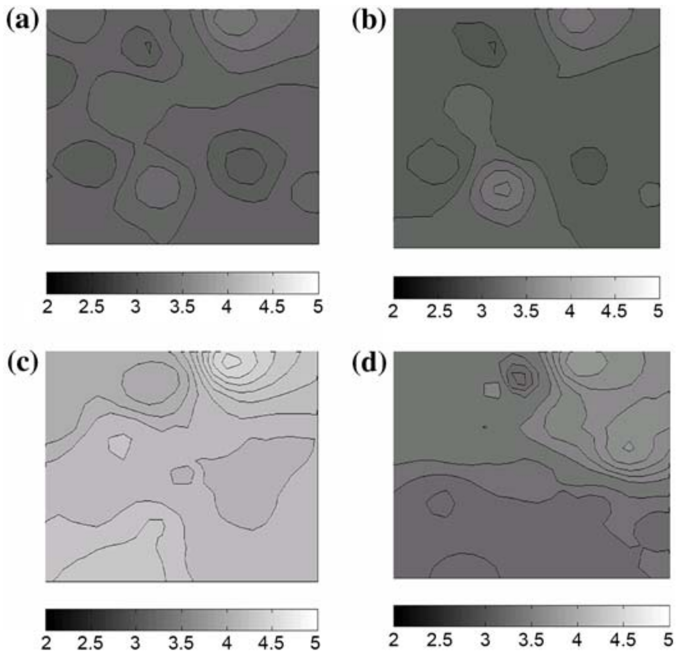

Figure 4.
Thenar compound muscle action potential amplitude latency (ms) for right hand: **(a)** mean latency for young normal subjects, **(b)** latency map for young normal subject, **(c)** latency map for elderly degenerative joint disease (DJD) subject, and **(d)** latency map for another elderly DJD subject.

multiple-site measurements, this mean value represents the average of all mean values of all single-site measurements. **Table 3** shows that single-electrode values are quite different and more variable than those of multiple-site recorded values.

DISCUSSION

Motor nerve conduction studies traditionally use a single recording site over a superficial muscle. Unfortunately, this long-standing traditional approach does not account for the electrical contributions from the other muscles in the region, which are also innervated by the nerve being stimulated. This pilot study explored the concept of nerve conduction topography by recording from multiple sites over the thenar eminence during motor nerve conduction studies of the median nerve.

Our results demonstrated that in the elderly individuals with thumb CMC DJD, smaller amplitudes and longer latencies might be seen with a traditional single recording site compared with multisite recordings. Results also showed that the maximum values of these CMAP did not occur in the same electrode position for the young normal hands and the hands of elderly individuals with thumb CMC DJD. Thus, the tradition of using a single electrode in a standardized location may not be adequate. This study illustrates the value of topographic thenar mapping with multiple-site recordings and lays the foundation for the development of multichannel topographic nerve conduction studies.

Table 1.
Frequency distribution of recording sites that registered largest compound muscle action potential amplitude of right and left hands (12 normal subjects and 25 degenerative joint disease [DJD] subjects).

Electrode Location	Normal		DJD	
	Left	Right	Left	Right
1	0	0	0	1
2	0	0	1	2
3	1	1	1	2
4	1	1	0	0
5	0	0	3	2
6	1	2	4	4
7	4	5	4	4
8	2	1	3	3
9	1	1	3	2
10	0	0	2	3
11	0	0	0	0
12	1	0	3	2
13	1	1	1	0
14	0	0	0	0
15	0	0	0	0

Table 2.
Frequency distribution of recording sites that registered smallest compound muscle action potential latency of right and left hands (12 normal subjects and 25 degenerative joint disease [DJD] subjects).

Electrode Location	Normal		DJD	
	Left	Right	Left	Right
1	0	0	1	2
2	0	0	2	1
3	1	0	1	0
4	1	2	3	4
5	0	0	3	3
6	1	2	3	4
7	4	4	2	3
8	1	1	4	2
9	2	1	2	3
10	0	0	1	2
11	1	1	1	0
12	0	0	0	1
13	1	1	1	1
14	0	0	1	1
15	0	0	0	0

Table 3.
Mean ± standard deviation of measured compound muscle action potential parameters obtained from conventional single-site recording (site 7) and from multiple-site recordings.

Measurement	Normal Subjects				DJD Subjects			
	Single Site		Multiple Site		Single Site		Multiple Site	
	Left	Right	Left	Right	Left	Right	Left	Right
Amplitude	10.8 ± 2.0	10.9 ± 3.1	9.0 ± 1.3	8.4 ± 1.5	6.8 ± 2.1	6.4 ± 2.4	5.9 ± 1.0	5.5 ± 1.2
Area	22.9 ± 9.5	25.9 ± 8.6	19.1 ± 3.4	20.2 ± 4.1	12.3 ± 9.3	15.4 ± 8.0	10.9 ± 3.0	11.5 ± 2.7
Duration	9.4 ± 2.9	10.4 ± 7.0	9.4 ± 1.8	9.8 ± 1.8	9.9 ± 4.8	8.9 ± 2.4	10.8 ± 1.5	9.7 ± 1.1
Latency	3.1 ± 0.4	3.1 ± 0.3	3.1 ± 0.0	3.2 ± 0.1	3.5 ± 0.3	3.7 ± 0.5	3.6 ± 0.1	3.8 ± 0.1

DJD = degenerative joint disease.

In the pilot study being reported, elderly individuals with thumb CMC DJD were chosen for the focus because we recognize that the positioning of the thenar muscles can affect the median motor CMAP [10]. In addition, it has been this senior author's experience over the past 25 years of performing clinical nerve conduction studies that, frequently, the median motor studies in elderly with CMC DJD deformity show unusually prolonged and small responses compared with their sensory studies. With mapping by slight movements (sometimes only a couple of millimeters) of the E1, the response often becomes normal, which was consistent with the clinical exam and sensory studies in these individuals. Avoiding false positive studies and unnecessary surgery for carpal tunnel syndrome in elderly individuals was the driving force behind this study to explore the need for multiple-site recordings during motor nerve conduction studies.

We used the 15 electrode sites to map the CMAP distribution on the thenar muscle for both young normal individuals and elderly individuals with thumb CMC DJD. We found it very interesting that the recording electrode site giving the largest amplitude was different for the elderly with CMC DJD compared with the young normal hands. As would be expected, for most of the young normal hands, one particular site (site 7) showed the maximum number of highest CMAP amplitude. In the case of DJD elderly hands, however, different electrode locations registered highest amplitude of CMAP. Thus, the maximum values of the median CMAP did not occur in the same electrode position for the young normal hands and the hands of elderly individuals with thumb CMC DJD. The traditional single-site recording would have resulted in smaller amplitudes and longer latencies for the elderly. Carpal tunnel syndrome results in the same pattern with longer latencies and smaller amplitudes. Even from this pilot study, the message is clear that the traditional single-site recording used for motor nerve conduction studies could result in false positive diagnosis of carpal tunnel syndrome in the elderly hand with CMC DJD.

The importance of the exact location of the E1 has been illustrated by several prior studies, which noted that subtle changes in position of the recording electrode showed significant differences in the recorded response [11–15]. Mapping the compound muscle action potential from 30 points on a 5 × 6 cm grid on hand and foot muscles, Swenson et al. showed areas of prolonged latency, low amplitude, and reduced area, but with waveform morphology consistent with electrode placement over a motor point [16]. These areas were termed false motor points [17]. Thus, it has been recognized that simply being over the motor point may not be sufficiently precise for electrophysiologic motor studies, and much more information may be available by recording from the entire group of muscles being activated.

The importance of the location of the E2 has also been explored. Brashear and Kincaid [18], Jonas et al. [19], and Wee and Ashley [6,20] demonstrated that the tendon site usually used for the reference electrode is electrically active and often substantially contributes to the CMAP wave shape. Some recent work by our group has shown that even the onset latency can be influenced by the location of the reference E2 [21]. The observation that the E2 position can influence the onset latency has a profound impact on our understanding of what the CMAP onset latency physiologically represents. Traditionally, the CMAP onset latency is interpreted to reflect the arrival time at the muscle of the fastest conducting nerve fiber action potentials and thus should not be influenced by the E2. The seemingly simple nerve conduction CMAP appears to be much more complex than initially thought, and our interpretation of nerve conduction data must include numerous anatomic and technical factors.

Several investigators have studied the CMAP by using multisite recordings and examining the influence of the location and size of the recording electrode on the configuration and variability of the CMAP [19–21]. Blok et al. used a 128-electrode array to record the spatial distribution of electrically evoked motor-unit action potentials in the thenar muscles [22]. Van Dijk et al. [11] and Lateva et al. [23] mapped the spatial distribution of CMAPs using a multielectrode with only eight or four recording surfaces, which had to be continuously repositioned. Van Dijk et al. found that larger electrodes reduce the variability of CMAP parameters associated with slight displacements of electrode position [20,24]. They further mapped the spatial and temporal distribution of CMAP amplitude in the hand and foot and found this distribution to vary in a complex manner between muscles and between individuals [25]. This variation explains why CMAP parameters are so sensitive to electrode position [26] and why larger electrodes, averaged over a wider area, reduce variability. Lateva et al. and McGill et al. used mathematical models and volume conductor theory to describe the way the electrical potential field throughout the limb evolves in space and time during the action potential [23,27]. Their results explain the differences in CMAP shapes associated with different recording montages and different joint configurations. They also demonstrate the way that volume-conducted potentials from relatively distant muscles can substantially contribute to the CMAP.

This pilot study of nerve conduction topography mapping in a specific clinical situation of elderly hand with thumb CMC DJD deformity illustrates that single-site measurement can be misleading. Future multichannel grid electrode for topographic display and analysis of the CMAP is realistic with current technology and would offer a significant technical advancement compared with the current single-site recording nerve conduction studies.

CONCLUSION

The traditional motor nerve conduction study uses a single recording site over a superficial muscle. This pilot study explored the concept of nerve conduction topographic mapping by the recording from multiple sites over the thenar eminence during median nerve motor nerve conduction studies. Young subjects with normal thenar anatomy and elderly subjects with thumb CMC DJD, which may change the anatomic relationship of the thenar muscles, were compared. The maximum values of the median CMAP did not occur in the same electrode position for these two populations. This pilot study illustrates the potential value of multisite recording with topographic display and analysis of the CMAP.

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