Proximal Forearm Ulnar Nerve Conduction Techniques

Gerald Felsenthal, MD, Paul S. Brockman, MD, Dean L. Mondell, MD, E. Bruce Hilton, MD
Department of Rehabilitation Medicine, Sinai Hospital of Baltimore, MD 21215


Compression of the ulnar nerve across the elbow is a common clinical diagnosis frequently referred for electrodiagnostic evaluation. Motor conduction studies with recording over the abductor digiti minimi and stimulating proximal and distal to the ulnar notch have been the standard technique employed in these evaluations—mean, 60.0m/s; SD 5.0m/s. Two other techniques are described, with data from normal subjects, recording from proximal forearm muscles. One technique is a refinement of a previously described method recording from the flexor carpi ulnaris—mean, 63.0m/s; SD, 4.7m/s. The second is a newly developed technique recording from the flexor digitorum profundus—mean, 63.0m/s; SD, 5.5m/s. All three methods were found to have a small range of comparable normal values, and appear to be easily and quickly performed with reliable and reproducible information. The techniques described enhance specific localization of ulnar nerve lesions, and may prove useful when more distal recording sites are unavailable.

KEY WORDS: Electrodiagnosis; Electromyography; Nerve compression syndromes; Neural conduction; Peripheral nerve diseases

Ulnar nerve entrapment most commonly occurs at the elbow, as the nerve passes either behind the medial epicondyle in the ulnar groove or through the cubital tunnel.6-8,10-12 The most common electrodiagnostic technique used to evaluate ulnar nerve lesions is motor nerve conduction proximal and distal to the elbow with surface electrode recording over the abductor digiti minimi (ADM). Through modifications of previous studies and clinical observations, we have developed two methods to evaluate the elbow segment of the ulnar nerve utilizing proximal forearm recording sites.

METHOD

Twenty-four subjects were selected for the study, 19 women and five men, ranging in age from 19 to 52 years, with a mean of 29 years. All subjects were asymptomatic and had normal results on neuromuscular examinations. The ulnar nerves of each subject were examined bilaterally using supramaximal stimulation and with the elbow flexed to 70°.4 All patients were examined using a Neurodiagnostic NDI electromyograph. Skin temperature was measured using a thermistor taped over the wrist crease.

Muscle action potentials (MAP) of the ulnar nerve were recorded using the technique of segmental stimulation, recording over the ADM, as previously described.4 Using this technique, the distal elbow (DE) stimulation point was at the distal aspect of the ulnar groove, and the proximal elbow (PE) stimulation point was 100mm proximal to the DE point, along the course of the nerve, on the posteromedial aspect of the arm. The DE and PE points were marked carefully and used in both of the techniques to be described.

Ulnar nerve MAPS were next determined by recording over the flexor carpi ulnaris (FCU), using a modification of the techniques described by Payan7 and Thompson and Coté.12 The active recording surface disc electrode was placed over the motor point of the FCU, as described by Delagi and Perotto,2 two fingerbreadths volar to the ulna at the junction of the proximal and middle thirds of the forearm. The reference electrode was placed over the shaft of the ulna at the same distance (fig 1). The ulnar nerve was stimulated at the previously described DE and PE points, recording the MAP at a sweep speed of 1ms per division and a gain setting of 1mV per division. The latency to onset and the peak to peak amplitude were recorded for each response.

Recording of an ulnar nerve MAP also was made over the flexor digitorum profundus (FDP). TECA bar mounted surface electrodes were placed just volar to the shaft of the ulna over the FDP, with the active recording electrode 100mm distal to...
the DE stimulation point and the reference electrode placed further distally (fig 2). This method was selected because use of the bar facilitated applying pressure and obtaining a clear initial negative deflection. The observed response easily was obtained and consistent in configuration, obviating the need for separate disc electrodes. The nerve then was stimulated at the DE and PE points previously described. Recording of the MAP was made at a sweep speed of 1ms per division and a gain of 500uV per division. The initial phase of the MAP was examined, recording the latencies to onset and peak, and the amplitude of each response was measured from the peak of the initial negative deflection to the peak of the positive deflection.

The ulnar nerves of each subject were examined bilaterally using the three described techniques. The skin temperature averaged 33.5C, ranging from 30 to 34C. The mean and standard deviation were calculated for all latency, conduction velocity, and amplitude measurements. Paired student t-tests were performed on conduction times for right vs left comparisons for the elbow segments and forearm segments.

CASE REPORTS

Data from three cases of ulnar nerve compression across the elbow using all three techniques are summarized in table 1. Case 1 was a patient who complained of numbness and tingling of the fourth and fifth digits of the left hand. Physical examination revealed diminished sensation in the ulnar distribution, weakness of ulnar innervated hand and forearm muscles, and a positive Tinel sign all in the symptomatic arm only. Case 2 was a patient with bilateral complaints of numbness of the fingers and muscle cramps of the left forearm and both hands. Sensory loss was noted in ulnar nerve distribution bilaterally. Case 3 was a patient who complained of numbness in ulnar nerve distribution of the right hand. Physical examination revealed diminished sensation in ulnar nerve distribution bilaterally, positive Tinel's sign bilaterally at the elbow, and weakness of the right ulnar innervated flexor digitorum profundus. The inching technique described by Miller and Miller and Camp was applied from the DE stimulation point in all three cases and revealed no abnormality. In these three cases, all techniques detected abnormalities equally well.

Case 4 (table 1) was a patient specifically referred to rule out cubital tunnel syndrome. Numbness was noted in the ulnar nerve distribution and weakness was found of ulnar nerve innervated muscles. Tenderness was found with palpation distal to the olecranon sulcus at the margin of the FCU. Using the traditional ADM technique, the responses obtained with DE and PE stimulation were highly multiphasic, dispersed, and small in amplitude, with normal elbow and forearm segment conduction velocities. Using the FCU technique, the results were normal. Using the FDP technique there were prolonged latencies from both the DE and PE stimulation points as well as a markedly abnormal MAP amplitude stimulating at both points. The DE MAP amplitude became normal as the stimulator was inched distally. This case was surgically confirmed as cubital tunnel syndrome, with compression of the ulnar nerve to 50% of its normal diameter as it entered the cubital tunnel, and illustrates potential usefulness for the described techniques in localizing ulnar nerve lesions.

RESULTS

A total of 48 ulnar nerves were examined by the previously described methods; results are summarized in tables 2-4. With segmental stimulation of the ulnar nerve recording from the ADM (table 2), the values obtained were comparable with the data previously reported. In the FCU technique (table 3), the distance from the DE stimulation point to the recording

Table 1: Abnormal Cases

<table>
<thead>
<tr>
<th>Case</th>
<th>Forearm velocity (m/s)</th>
<th>Elbow segment velocity (m/s)</th>
<th>% Decrease amplitude across elbow</th>
<th>Onset latency DE (ms)</th>
<th>Elbow segment velocity (m/s)</th>
<th>% Decrease amplitude across elbow</th>
<th>Onset latency DE (ms)</th>
<th>Flexor digitorum profundus technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>R 55</td>
<td>55</td>
<td>0</td>
<td>2.3</td>
<td>4.0</td>
<td>0</td>
<td>2.5</td>
<td>4.3</td>
</tr>
<tr>
<td></td>
<td>L 40</td>
<td>31</td>
<td>12</td>
<td>2.1</td>
<td>1.8</td>
<td>12</td>
<td>2.7</td>
<td>5.4</td>
</tr>
<tr>
<td>2</td>
<td>R 39</td>
<td>37</td>
<td>3</td>
<td>2.9</td>
<td>5.3</td>
<td>42</td>
<td>Increased</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>L 52</td>
<td>39</td>
<td>2</td>
<td>2.8</td>
<td>5.1</td>
<td>43</td>
<td>Increased</td>
<td>4.0</td>
</tr>
<tr>
<td>3</td>
<td>R 50</td>
<td>48</td>
<td>16</td>
<td>2.3</td>
<td>4.5</td>
<td>45</td>
<td>2.7</td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td>L 60</td>
<td>40</td>
<td>10</td>
<td>2.4</td>
<td>4.4</td>
<td>50</td>
<td>3.1</td>
<td>5.0</td>
</tr>
<tr>
<td>4</td>
<td>R 53</td>
<td>56</td>
<td>98</td>
<td>5.2</td>
<td>4.9</td>
<td>54</td>
<td>3.5</td>
<td>5.3</td>
</tr>
</tbody>
</table>
In this study, the decrement range seen in a prior study comparing the evoked response for all comparisons using all three techniques. The side-to-side amplitude comparisons fell within the 40% to 60% range.

For the ADM technique, the amplitude decrement for the mean +2 SD was 17.5%. For the FDP technique, 9 of the 48 nerve segments had a proximal MAP greater than the distal MAP. The amplitude decrement for the mean +2 SD was 17.5%. For the ADM technique, the amplitude decrement for the mean +2 SD was 10.4% reported in a prior study. In each subject, the proximal MAP was equal to or smaller than the distal MAP. For the FCU technique, 17 of the 48 nerve segments had a proximal MAP greater than the distal MAP. The amplitude decrement for the mean +2 SD was 17.5%. For the FDP technique, 9 of the 48 nerve segments had a proximal MAP greater than distal MAP. The amplitude decrement for the mean +2 SD was 20.6%.

Side-to-side comparisons of the latencies and conduction velocity for the cross elbow segment are reported in table 5. Side-to-side amplitude comparison was calculated using the formula 100% - 100% (smaller MAP/larger MAP). For the ADM technique, the amplitude decrement for the mean +2 SD was 7.2% and is similar to the mean +2 SD of 10.4% reported in a prior study. In each subject, the proximal MAP was equal to or smaller than the distal MAP. For the FCU technique, 17 of the 48 nerve segments had a proximal MAP greater than the distal MAP. The amplitude decrement for the mean +2 SD was 17.5%. For the FDP technique, 9 of the 48 nerve segments had a proximal MAP greater than distal MAP. The amplitude decrement for the mean +2 SD was 20.6%.

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DISCUSSION

The three techniques described in this report are performed easily and quickly and provide reliable and reproducible information. The 100mm across elbow segment had a minimum conduction velocity of between 50m/s and 53m/s using any method, with a conduction time across the elbow of from 1.9ms to 2.0ms. The side-to-side comparisons of conduction velocity across the elbow revealed a difference for the mean +2 SD of 8.1m/s to 9.5m/s. The small range in which these normal values fall for three different methods of evaluating the ulnar nerve segment across the elbow attests to the reliability and reproducibility of all three methods.

Payan described a technique of studying the ulnar nerve in the elbow region with recording from the FCU and stimulating 90mm to 150mm proximal to the recording electrode. He found a maximal latency of 3.7ms. This value is less than our latency of 5.0ms from the PE stimulation point, which can be explained by a longer stimulation distance. Payan found that in three of his cases, results recording from the FCU were abnormal with normal findings from the ADM. He concluded that by using multiple techniques, one can increase sensitivity in the evaluation of ulnar nerve lesions at the elbow.

Benecke and Conrad described a technique of studying the ulnar nerve at the elbow region with recording from the FCU and stimulating 90mm to 150mm proximal to the recording electrode. They found a maximal latency of 3.7ms. This value is less than our latency of 5.0ms from the PE stimulation point, which can be explained by a longer stimulation distance. Payan found that in three of his cases, results recording from the FCU were abnormal with normal findings from the ADM. He concluded that by using multiple techniques, one can increase sensitivity in the evaluation of ulnar nerve lesions at the elbow.

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Table 2: Segmental Ulnar Nerve Stimulation Recording From the Abductor Digiti Minimi

<table>
<thead>
<tr>
<th>Onset latencies (ms)</th>
<th>Conduction velocities (m/s)</th>
<th>Amplitudes (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>DE</td>
<td>PE</td>
</tr>
<tr>
<td>Mean</td>
<td>2.7</td>
<td>6.5</td>
</tr>
<tr>
<td>SD</td>
<td>3.3</td>
<td>0.75</td>
</tr>
<tr>
<td>Observed range</td>
<td>2.2 - 3.5</td>
<td>5.1 - 8.7</td>
</tr>
</tbody>
</table>

Table 3: Segmental Ulnar Nerve Stimulation Recording from the Flexor Carpi Ulnaris

<table>
<thead>
<tr>
<th>Onset latencies (ms)</th>
<th>Conduction velocity (m/s)</th>
<th>Amplitudes (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DE</td>
<td>PE</td>
<td>Elbow segment</td>
</tr>
<tr>
<td>Mean</td>
<td>2.6</td>
<td>4.2</td>
</tr>
<tr>
<td>SD</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Observed range</td>
<td>2.3 - 3.5</td>
<td>3.4 - 5</td>
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</table>
This confirms the anatomical studies of Sunderland,11 who found that the first branch could originate between 4.0 cm above to 4.4 cm below the medial epicondyle and that the initial branches usually follow the course of the nerve. Similarly, 9 of 48 nerve segments had a larger MAP amplitude recorded from the FDP when stimulating at the PE point, as compared with the DE point. This indicates that innervation to this muscle may arise proximal to the distal end of the olecranon sulcus. Thus, the electromyographer must exercise caution in making judgement of abnormality using amplitude criteria, unless a greater than normal amplitude decrement is observed across the elbow segment of the ulnar nerve.

In the FCU technique, the distance between the recording electrode over the FCU and the distal below stimulation point varied with an individual’s forearm length. Moreover, as previously mentioned with this technique, the recording electrode placement must occasionally be adjusted to obtain a clear initial negative deflection. However, the normal distal latency from the DE stimulation point was remarkably consistent, regardless of forearm length. This method also had the smallest standard deviation for the velocity across the elbow segment and greatest symmetry in side-to-side comparisons.

The technique of recording over the FDP had not been previously described. The waveform recorded has an initial, sharp negative deflection corresponding to the onset of the MAP of the FDP. It is followed by highly variable muscle depolarizations from other portions of the ulnar innervated FDP, confirmed on electromyograph (EMG) examination. Sunderland11 found that, in one of 20 dissections, the FDP was completely innervated by the median nerve. In a patient with that anomaly, it would be expected, with stimulation of the ulnar nerve, to record no MAP from the FDP. No subjects in this study were observed to have this innervation pattern. The FDP technique appears to be the simplest, and probably the quickest, to perform of the three methods described. The subject’s forearm length is not a factor because two 10 cm segments always are used. The latencies to both onset and peak can be measured reliably and accurately. Recording and stimulating electrodes were reversed to see if the initial response was a mixed nerve action potential, but latencies and configurations of the evoked potentials were not identical. The EMG studies with kinesiologic confirmation showed that the recording electrode was over the ulnar innervated FDP.

When considering the anatomy of the ulnar nerve, two common and distinct lesions are the cubital tunnel syndrome and compression in the ulnar groove. Miller12 and Miller and Camp13 attempted to differentiate these two syndromes through an inching technique and successfully localized ulnar nerve compression to the cubital tunnel in nine patients, seven of these compressions were surgically confirmed. By using the FCU and FDP techniques as described, one may potentially differentiate these two syndromes—as indicated in our case reports. The FCU usually is innervated proximal to the cubital tunnel. Thus, cubital tunnel syndrome could be identified, on stimulation at the DE, by prolonged distal latencies or abnormal MAP when recording over the ADM and FDP but not the FCU, whereas ulnar groove compression should produce slowed conduction velocities or abnormal MAP in the across the elbow segment. However, Sunderland11 does report that occasionally the first branch innervating the FCU may arise up to 4.4 cm distal to the medial epicondyle and thus potentially distal to our distal stimulation point, in which case results from all methods might be abnormal.

In summary, compression of the ulnar nerve most frequently occurs in the elbow region. Diagnosis of lesions in this area previously has been limited to studying the ulnar nerve using the conventional technique of segmental stimulation, recording over the ADM. We have described two techniques, using proximal forearm recording sites over the FCU and the FDP, that have the potential to improve the diagnosis and localization of ulnar nerve lesions in the cubital tunnel and ulnar groove. Both techniques are quick, simple,

### Table 4: Segmental Ulnar Nerve Stimulation Recording from the Flexor Digitorum Profundus

<table>
<thead>
<tr>
<th>Technique</th>
<th>DE (ms)</th>
<th>PE (ms)</th>
<th>Elbow segment (ms)</th>
<th>Velocity (ms) across elbow difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADM onset</td>
<td>0.5</td>
<td>0.4</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>FCU onset</td>
<td>0.6</td>
<td>0.4</td>
<td>0.2</td>
<td>0.6</td>
</tr>
<tr>
<td>FDP onset</td>
<td>0.4</td>
<td>0.4</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>FDP peak</td>
<td>0.4</td>
<td>0.4</td>
<td>0.2</td>
<td>0.4</td>
</tr>
</tbody>
</table>

### Table 5: Side-to-Side Differences in Normal Subjects

<table>
<thead>
<tr>
<th>Technique</th>
<th>DE (ms) difference</th>
<th>PE (ms) difference</th>
<th>Elbow segment (ms) difference</th>
<th>Velocity (ms) across elbow difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADM onset</td>
<td>0.5 (0.0-0.6)</td>
<td>0.4 (0.0-0.5)</td>
<td>0.2 (0.0-0.2)</td>
<td>0.5 (0.0-0.5)</td>
</tr>
<tr>
<td>FCU onset</td>
<td>0.6 (0.0-0.7)</td>
<td>0.4 (0.0-0.6)</td>
<td>0.2 (0.0-0.6)</td>
<td>0.6 (0.0-0.6)</td>
</tr>
<tr>
<td>FDP onset</td>
<td>0.4 (0.0-0.4)</td>
<td>0.4 (0.0-0.4)</td>
<td>0.2 (0.0-0.2)</td>
<td>0.4 (0.0-0.4)</td>
</tr>
<tr>
<td>FDP peak</td>
<td>0.4 (0.0-0.3)</td>
<td>0.4 (0.0-0.5)</td>
<td>0.2 (0.0-0.3)</td>
<td>0.3 (0.0-0.5)</td>
</tr>
</tbody>
</table>
and easily reproducible. In addition, these techniques may be
used when it is not possible to use the distal recording site
over the ADM.

ADDRESS REPRINT REQUESTS TO:
Gerald Felsenthal, MD
Department of Rehabilitation Medicine
Sinai Hospital of Baltimore
Belvedere and Greenspring Avenues
Baltimore, MD 21215

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