Normal ulnar nerve conduction velocity across the thoracic outlet: comparison of two measuring techniques

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SYNOPSIS Comparison of ulnar nerve conduction across the thoracic outlet in 30 normal individuals using caliper and steel tape measurements is reported. A difference of 11.3 m/s was noted between the two methods (58.9 ± 4.20 m/s by caliper; 70.2 ± 5.20 m/s by tape). Comparison of these values with previous studies and the use of the opposite limb as a control are discussed. This procedure is of clinical importance in the diagnosis of nerve compression in the thoracic outlet syndrome.

There has been increasing interest in recent years in the thoracic outlet syndrome because of improved understanding of the disorder as well as better methods of diagnosis and therapy (Urschel et al., 1968; Lord and Rosati, 1971; Hurlbut et al., 1972; Kaye, 1972; Urschel and Razzuk, 1972). Nerve conduction velocity studies of the ulnar nerve across the thoracic outlet have been important (Urschel et al., 1971). Unfortunately, there have been only two studies of which the author is aware that have attempted to establish normal values for this segment of the ulnar nerve (Jebsen, 1967; Caldwell et al., 1971). These studies have differed both in the measuring techniques used and the final results obtained. Many electromyographers have therefore resorted to using the opposite limb as a control without documentation in the literature of the ability to reproduce the same results for this portion of the ulnar nerve in the other arm. It was the purpose of this investigation to study motor conduction velocity of both ulnar nerves across the thoracic outlet in a group of normal individuals using the measuring techniques reported by others.

METHODS

Sixty ulnar nerves were studied in 30 healthy volun-

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(Accepted 11 April 1975.)

teers from 20 to 44 years of age (mean 28 years). There were 18 males and 12 females. All were carefully screened for any history of injury to the clavicle, shoulder, elbow, or wrist and for symptoms of pain, weakness, or sensory abnormalities in the upper extremities. None was taking medications known to cause neuropathic change. All had a normal range of movement of the neck, shoulder, and elbow. Motor strength, sensation, deep tendon reflexes, the Adson’s manoeuvre, hyperabduction, and the costoclavicular manoeuvre for testing thoracic outlet nerve compression were normal.

A TECA TE-3 or TE-4 electromyograph was used. The arm was placed in 10 degrees of abduction at the shoulder with the elbow extended and the arm supinated. Silver disc surface electrodes were placed over the belly of the abductor digiti minimi muscle and its tendon to record the compound muscle action potential (Figure). A supramaximal electrical stimulus was delivered with a duration of 0.05–0.2 ms and a potential of 100–300 V. The stimulus was applied at the wrist (W), elbow (E), 10 cm above the elbow (AE), and at Erb’s point (N), which is at the angle formed by the clavicle and the posterolateral fibres of the sternocleidomastoid muscle (Figure).

Steel tape was used to measure all segments. In addition, the N–AE segment was measured with a sharpened obstetric caliper as described by Jebsen (1966).

The room temperature was kept constant for all recording sessions. Surface skin temperature was measured in seven of the subjects just before begin-
Normal ulnar nerve conduction velocity across the thoracic outlet

### Table 1

<table>
<thead>
<tr>
<th>Segment</th>
<th>Mean motor distal latency (ms)</th>
<th>Mean motor conduction velocity (m/s)</th>
<th>Standard deviation (m/s)</th>
<th>Range (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-AE (caliper)</td>
<td>58.9 ± 4.20</td>
<td>50–67.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N-AE (tape)</td>
<td>70.2 ± 5.02</td>
<td>58–82.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-W</td>
<td>58.1 ± 3.73</td>
<td>50–65.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>2.45 ± 0.318</td>
<td>1.9–3.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 2

<table>
<thead>
<tr>
<th>Measurement technique</th>
<th>Mean (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caliper</td>
<td>23.3</td>
</tr>
<tr>
<td>Steel tape</td>
<td>27.8</td>
</tr>
</tbody>
</table>

### Table 3

<table>
<thead>
<tr>
<th>Segment</th>
<th>Mean velocity difference (m/s)</th>
<th>Standard deviation (m/s)</th>
<th>Range (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-AE (caliper)</td>
<td>3.46 ± 2.66</td>
<td>0.3–10.2</td>
<td></td>
</tr>
<tr>
<td>N-AE (tape)</td>
<td>3.65 ± 2.65</td>
<td>0–11.9</td>
<td></td>
</tr>
<tr>
<td>E-W</td>
<td>2.16 ± 1.47</td>
<td>0.1–4.7</td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE** Sites of ulnar nerve stimulation at the wrist (W), elbow (E), 10 cm above the elbow (AE), and Erb's point (N). The active electrode is over the abductor digiti minimi muscle.

**RESULTS**

The wrist distal motor latency (Table 1) was 2.45 ± 0.318 ms (range 1.9 to 3.2) and the motor conduction velocity from elbow to wrist was 58.1 ± 3.73 m/s (range 50 to 65.8), which are well within the range of normal values established by others (Henriksen, 1956; Thomas and Lambert, 1960; McQuillen and Gorin, 1969). The motor conduction velocities across the thoracic outlet were 58.9 ± 4.20 m/s (range 50 to 67.7) with caliper measuring technique and 70.2 ± 5.02 m/s (range 58 to 82.4) using the steel tape.

The mean N–AE distance (Table 2) with the obstetric caliper was 23.3 cm and with the steel tape was 27.8 cm yielding a difference of 4.5 cm.

The mean difference between the two ulnar nerves across the thoracic outlet in the same patient (Table 3) was 3.46 ± 2.66 m/s (range 0.3 to 10.2) with the caliper measuring technique. For the steel tape measuring technique the mean right–left difference was 3.65 ± 2.65 m/s (range 0 to 11.9). The mean difference for the E–W segment was 2.16 ± 1.47 m/s (range 0.1 to 4.7).
DISCUSSION

Credit for grouping a large number of conditions causing compression of the neurovascular bundle at the superior apex of the thorax under the term ‘thoracic outlet syndrome’ is given to Rob and Standeven (1958). These entities include the scalenus anticus, costoclavicular, hyperabduction, cervical rib, first thoracic rib, and Paget-Schroetter (effort thrombosis) syndromes. Although others had suggested the first thoracic rib as the common denominator for the compression of the subclavian vessels and lower brachial plexus, it was Clagett (1962) who strongly emphasized this point. The development of improved surgical operations including the posterior thoracoplasty and more particularly the transaxillary approach for first rib resection yielded better clinical and cosmetic results (Roos, 1966, 1971; Longo et al., 1970; Roeder et al., 1973).

TABLE 4
STUDIES OF NORMAL ULNAR NERVE CONDUCTION VELOCITY ACROSS THORACIC OUTLET USING CALIPER AND STEEL TAPE MEASUREMENT TECHNIQUES

<table>
<thead>
<tr>
<th></th>
<th>Jebsen caliper (m/s)</th>
<th>London caliper (m/s)</th>
<th>Caldwell tape (m/s)</th>
<th>London tape (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>61.3 ± 5.4</td>
<td>58.9 ± 4.20</td>
<td>72.2</td>
<td>70.2 ± 5.02</td>
<td></td>
</tr>
<tr>
<td>(52-78)</td>
<td>(50-67.7)</td>
<td>(58-75)</td>
<td>(58-82.4)</td>
<td></td>
</tr>
</tbody>
</table>

Careful diagnosis and selection of patients for surgery is important. Compression of arterial or venous structures is uncommon but readily diagnosed clinically (Urschel et al., 1968). This can be confirmed by arteriography, venography, or plethysmography (Hill, 1939; Sanders et al., 1968; Lord and Rosati, 1971). Compression of the lower brachial plexus occurs far more commonly but objective clinical criteria are frequently lacking. While pain and paraesthesias will be present in 95% of cases only 16% will have sensory changes and 10% will have motor weakness (Urschel et al., 1968). Ninety per cent of these symptoms and signs will occur in the ulnar nerve distribution (Urschel et al., 1971).

Demonstration of delayed ulnar nerve conduction velocity across the thoracic outlet provides objective means of diagnosing compression of these neural structures.

The present results are compared in Table 4 with those of Jebsen (1967) and Caldwell et al. (1971). Jebsen (1967) used a sharpened obstetric caliper to obtain his measurements and Caldwell et al. (1971) used a steel tape. The normal mean conduction values for the segment of ulnar nerve across the thoracic outlet compare very closely with those previously reported.

One particular difference is that with our steel tape measurement the normal range of 24.4 m/s is much greater than the normal range of 7 m/s in the study of Caldwell et al. (1971). The latter may be too small for a normal range. Low et al. (1962) found that conduction velocity in an individual subject fluctuated by as much as 8 m/s in 15 minutes, and Honet et al. (1968) noted a difference of 4–6 m/s in the same individual at intervals of greater than one week. A range of 7 m/s would therefore reflect only possible technical factors and biological variation within the same individual. The suspicion that Caldwell’s range of normal is too narrow is further strengthened by the poor and fair surgical results obtained by Urschel et al. (1971) in patients studied by Caldwell et al. (1971) whose mean preoperative ulnar nerve motor conduction velocities were 60 and 61 m/s. These values would fall within the normal range in the present study. Good operative results were obtained in patients whose mean conduction velocity was 51 m/s, a figure which was clearly abnormal in the present study.

The 4.5 cm difference in apparent mean length for the N–AE segment (Table 2) using the two measuring techniques yields a difference of 11.3 m/s (Table 1) in the calculated motor conduction velocity. This would account for the different values across the thoracic outlet in the previous two studies (Table 4) as postulated by Caldwell et al. (1971). In my experience the rigid obstetric caliper is easy to use and eliminates much of the difficulty of measuring in this area. Jebsen (1967) has demonstrated in cadaver studies that the mean in situ length of proximal ulnar nerve fibres was found to be longer than the caliper measurement by 5.1 ± 2.7%. Using the mean caliper distance of 23.3 cm (Table 2) in the present study, the measurement would be only
1.18 cm shorter than the true length. The steel tape measurement of 27.8 cm (Table 2) would be 3.32 cm longer than the actual nerve length. The caliper measurement therefore more closely approximates the true ulnar nerve length than does the steel tape for this segment. If one consistently uses either measurement technique, however, meaningful results will be obtained.

The mean and range for the difference between the N–AE segment in the two arms in the same patient is greater than encountered for the E–W segment (Table 3). Trojaborg (1964) found similar results in comparing the right–left difference in the ulnar nerve from axilla to elbow and elbow to wrist. The sources of error and biological variation in nerve conduction studies have been extensively evaluated (Gassel, 1964; Simpson, 1964; Maynard and Stolov, 1972). The results of Low et al. (1962) and Honet et al. (1968) have been mentioned earlier. Temperature difference between the two limbs is important and nerve conduction velocity varies by 2.4 m/s for each 1°C (Maynard and Stolov, 1972). In this study the maximum surface temperature difference at the same site in the seven subjects in whom it was measured was 1°C. Other factors might be of particular significance in explaining the mean and range of right–left difference in the present investigation. The depth of the skin–nerve interface is probably greater and subject to more variability at Erb’s point than at other sites. Furthermore, a larger current is frequently required to obtain a supramaximal stimulus at Erb’s point than at other areas. In this situation, Wiederholt (1970) has shown that the effective point of stimulation is not necessarily underneath the cathode. Thus, the effective point of stimulation might differ for the two sides.

If the examiner is aware of the mean and range of differences between the two ulnar nerves for conduction velocity across the thoracic outlet as demonstrated in these normal individuals then the opposite limb may be used as an adequate control. If both values are within the established range of normal but differ by 9.0 m/s (Table 3—mean plus two standard deviations) then the slower conducting ulnar nerve might require careful serial study.

Ulnar nerve conduction velocity across the thoracic outlet is technically feasible and easily obtained. It is of clinical importance as an objective criterion for nerve compression in the thoracic outlet syndrome. It is hoped that this further delineation of the normal values for this segment of the ulnar nerve will increase its application in clinical practice.

The author wishes to thank Mr Roy Burson and Mr Robert Barton for their technical assistance; Doctor Maung H. Aung for his encouragement in conducting this investigation; and Doctor Marjorie E. Seybold for her review of the manuscript.

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*J Neurol Neurosurg Psychiatry* 1975 38: 756-760
doi: 10.1136/jnnp.38.8.756

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