Introduction

Although diagnosis of the carpal tunnel syndrome (CTS) is made clinically, electrodiagnosis is necessary for differential diagnosis. The most reliable method is the sensory nerve conduction study. Pure median nerve-innervated thumb (D1) and digit (D3) are generally used and these are compared with ulnar-innervated digit (D5). Distal motor latencies from wrist to abductor pollicis brevis muscle (APB) and abductor digit minimi muscle (ADM) are also determined (1). On the other hand, the distal two phalanges of the ring finger (D4) are innervated by both median and ulnar nerves. Sensory conduction along this finger provides evaluation of function of both nerves simultaneously. This might shorten the electrophysiological study for CTS. The purpose of this study to determine the value of sensory conduction along ring finger in the diagnosis of CTS.

Material and Methods

Twenty female patients (43.5±9.8 years old) in whom CTS was established according to the criteria described by Buchtal et al. (1) were included in this study. These patients had symptoms and signs consistent with CTS and slowed sensory conduction velocity from D1 or D3 to the wrist or prolonged distal motor latency from wrist to the APB. The chief complaint was paraesthesia in 13 patients, pain in 5 patients, and both in 2. Four cases had tenar atrophy, 13 had weakness of the abduction of thumb, and 5 patients had median hypoesthesia. None of the patients had symptoms or signs of involvement of the median nerve at the elbow and none had ulnar nerve involvement. DISA Neuromatic 2000 was used for electrophysiological studies. APB and ADM were examined by qualitative electromyography. The method described by Buchtal et al (1) was used for sensory motor nerve conduction studies. D1, D3, D4 and D5 were stimulated by ring electrodes. Sensory nerve action potential (SNAP) was recorded at wrist and elbow for the median nerve and at wrist for the ulnar nerve by needle electrodes placed near the relevant nerve. Reference electrodes were placed at the same level with the recording electrodes at a distance of 30-40 mm. Reference electrodes were placed medially for D1 and D3, laterally for D4 and D5 at the wrist and laterally at the elbow. Active electrodes were adjusted to obtain a clear compound muscle action potential at the oscilloscope (sensitivity 0.1 mv/division and stimulus intensity <1.0 mA). 20 to 1000 sweeps were averaged to

Key Words: Sensory conduction; carpal tunnel syndrome; median nerve; fourth finger

Abstract: The aim of this study was to examine the value of sensory conduction along the median and ulnar nerves of the fourth finger in the diagnosis of carpal tunnel syndrome. 20 females with carpal tunnel syndrome as diagnosed by clinical and routine electrophysiological examinations were included in the study. By using the near-nerve technique, orthodromic sensory conduction along the thumb, 3rd, and 4th fingers for median; and 4th and 5th fingers for ulnar nerve study was performed. 't test' was used for statistical analysis in 19 of 20 patients with carpal tunnel syndrome, the conduction velocity was reduced along the median sensory fibers of digit 4 compared to ulnar nerve conduction of the same digit, while in 1 patient there was no sensory action potential. Mean amplitude of the median sensory potential at the wrist was significantly smaller than that of the ulnar nerve. We conclude that testing sensory conduction along the ring finger has a similar value to digit 1 and digit 3 for the diagnosis of carpal tunnel syndrome.
obtain a SAP. A surface electrode referred to the fin-

ger was used for motor nerve conduction study. All

amplitudes were measured peak to peak and sensory

latencies to the first peak. The sensory conduction

velocity from D1, D3 and D5 to the wrist and SAP

amplitude at the wrist; sensory conduction from wrist
to elbow and SAP at the elbow by D1 and D3 stimu-

lation; distal motor latency (DML) from APB and ADM
to the wrist, the amplitude of CMAP and the motor

conduction velocity from elbow to wrist were com-

pared with our age-related laboratory normal values,

obtained by the same methods (Table 1). The mean

values of SAP amplitudes and SCV by stimulation of

D1, D3, D4 and D5 were evaluated by 'paired t test'.


Results

Qualitative evaluation of the EMG of APB showed a

neurogenic abnormality (at least two of the following

signs indicated and abnormality of the muscle; dener-
vation activity, reduced recruitment pattern during full

effort, increased mean duration or amplitude of the

potentials) in 10 of the 20 patients. The results of

median and ulnar nerve motor and sensory conduction

studies of each patient were compared with our labor-

atory reference values. Exceeding 95% confidence limit

was considered as abnormal. DML from wrist to APB

was increased in 19 patients. The amplitude of CMAP

was reduced in 9 patients. The shape of the CMAP

was split-up in one patient and was normal in the oth-
ers. Motor conduction velocity in the forearm was

slightly reduced in one patient, normal in 19 patients.

DML from wrist to ADM, the amplitude and the shape

of the ulnar CMAP were normal in all patients (Table

2).

Sensory Conduction Studies (Table 3)

A SAP was obtained by stimulation of D1 and D3

in all patients and maximum sensory conduction veloc-
y along the median nerve to the wrist was decreased

in 20 and 19 patients, respectively. The amplitude of

SAP at wrist was reduced in 8 patients by D1 and 12

patients by D3 stimulation of D3 was also reduced.

So, SAP amplitude was reduced in 60% of the patience

by stimulation of at least one of these two fingers.

The shape of the SAP was abnormal in 13 of 20

patients (Polyphasic in 8 and split-up in 2 for D1; pol-
yphasic in 11 and split-up in 2 for D3 stimulation).

Sensory conduction velocity along the forearm was

normal in all. Ulnar sensory conduction velocity by D5

stimulation, the amplitude and shape of the SAP at

the wrist were normal in all patients. In the median

nerve study, mean velocity was 31.5±5.5 m/s from
>D1 and 34.5±8.2 m/s from D3 to the wrist. The

amplitude of the SAP at the wrist was 12.7±12.9 µv

for D1 and 8.0±8.9 µv for D3 stimulation. Median

SAP was absent in one patient by stimulation of D4.

The mean conduction velocity and the amplitude of

the SAP for the remaining 19 patients were 30.6±6.8

m/s and 3.9±4.8 µv, respectively. The shape of the

potentials were polyphasic in 14 and normal in 5

patients. The mean median sensory conduction veloc-
y along the forearm and amplitude of the SAP at the

elbow were 61.2±7.6 m/s and 5.9±5.6 µv for

D1; 61.4±4.9 m/s and 3.5±2.2 µv for D3; 64.7±9.0

m/s and 1.4±0.5 µv for D4 stimulation, respectively.

Ulnar nerve study showed a mean sensory velocity of

52.8±6.6 m/s from D5 to wrist and the mean SAP

amplitude of 16.8±7.0 µv at the wrist. These values

were 54.4±4.4 m/s and 11.2±6.0 µv for D4 stimula-
tion. The shape of the SAPs were normal in all

patients (The results of the ulnar nerve study of the

patient in whom the median D4 potential was absent

were excluded). There was no statistical difference

between the mean median sensory conduction veloc-
ties from the fingers to the wrist and along the fore-
arm by stimulation of D1, D3 and D4 (P>0.05 for

each couple). The mean amplitude of the SAP at the

wrist by stimulation of D4 was significantly smaller

compared to D1 (P<0.01). The mean amplitude of the

potential at the elbow by stimulation of D4 was sig-

nificantly smaller than D1 and D3 studies. (P<0.01 for

each) (Figures 1,2). The mean SCV from D4 to the

wrist was reduced and the mean amplitude at te wrist

was decreased significantly compared to that of the ulnar

(p<0.01 for both). There was no significant dif-

ference between ulnar SCVs by stimulation of D4 and

D5. The mean amplitude of ulnar SAP at wrist by

stimulation of D4 was significantly smaller than that of

D5 (P<0.02). There was no difference between the

mean amplitude of D4 ulnar SAP and D1 or D3

median SAPs. The mean amplitude of D5 ulnar SAP

was not different from that of D1, but was larger than

those of D3 (P<0.01), median D4 (P<0.01) and

ulnar D4 (P<0.02).

Discussion

Median nerve sensory conduction study is the most

reliable method in the electrophysiological diagnosis of

CTS. The most valuable parameters are sensory con-
duction velocity across the wrist and the amplitude of

sensory potential at the wrist (2,3). Buchtal and co-
Table 1. Normal values for median and ulnar nerve conduction in our laboratory

### Median nerve

<table>
<thead>
<tr>
<th>Age Range</th>
<th>Sensory Velocity (m/s)</th>
<th>Amplitude (µV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>95% limits</td>
</tr>
<tr>
<td></td>
<td>lower</td>
<td>upper</td>
</tr>
<tr>
<td>D1</td>
<td>55</td>
<td>46</td>
</tr>
<tr>
<td>to wrist</td>
<td>54</td>
<td>44</td>
</tr>
<tr>
<td>70</td>
<td>62</td>
<td>46</td>
</tr>
<tr>
<td>to wrist</td>
<td>68</td>
<td>59</td>
</tr>
<tr>
<td>61</td>
<td>53</td>
<td>48</td>
</tr>
<tr>
<td>64</td>
<td>55</td>
<td>47</td>
</tr>
<tr>
<td>61</td>
<td>53</td>
<td>47</td>
</tr>
<tr>
<td>64</td>
<td>54</td>
<td>46</td>
</tr>
<tr>
<td>to wrist</td>
<td>60</td>
<td>51</td>
</tr>
<tr>
<td>64</td>
<td>55</td>
<td>47</td>
</tr>
<tr>
<td>62</td>
<td>53</td>
<td>47</td>
</tr>
<tr>
<td>64</td>
<td>59</td>
<td>48</td>
</tr>
<tr>
<td>to wrist</td>
<td>68</td>
<td>60</td>
</tr>
<tr>
<td>66</td>
<td>57</td>
<td>68</td>
</tr>
</tbody>
</table>

### Ulnar nerve

<table>
<thead>
<tr>
<th>Age Range</th>
<th>Sensory Velocity (m/s)</th>
<th>Amplitude (µV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>95% limits</td>
</tr>
<tr>
<td></td>
<td>lower</td>
<td>upper</td>
</tr>
<tr>
<td>D5</td>
<td>59</td>
<td>48</td>
</tr>
<tr>
<td>to wrist</td>
<td>57</td>
<td>46</td>
</tr>
<tr>
<td>64</td>
<td>55</td>
<td>44</td>
</tr>
<tr>
<td>56</td>
<td>47</td>
<td>47</td>
</tr>
</tbody>
</table>

### Median nerve

<table>
<thead>
<tr>
<th>Age Range</th>
<th>Distal Motor Latency (ms)</th>
<th>Amplitude (µV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>lower</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(years)</td>
</tr>
<tr>
<td>to 2.7</td>
<td>3.3</td>
<td>2.0</td>
</tr>
<tr>
<td>to APB</td>
<td>3.0</td>
<td>3.6</td>
</tr>
<tr>
<td>to 3.1</td>
<td>3.7</td>
<td>2.4</td>
</tr>
</tbody>
</table>

### Motor velocity (m/s)

<table>
<thead>
<tr>
<th>Age Range</th>
<th>Motor Velocity (m/s)</th>
<th>Amplitude (µV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>lower</td>
</tr>
<tr>
<td></td>
<td>(years)</td>
<td></td>
</tr>
<tr>
<td>61</td>
<td>51</td>
<td>50</td>
</tr>
<tr>
<td>62</td>
<td>52</td>
<td>51</td>
</tr>
<tr>
<td>63</td>
<td>54</td>
<td>53</td>
</tr>
<tr>
<td>64</td>
<td>55</td>
<td>54</td>
</tr>
</tbody>
</table>

81
workers found a decreased sensory conduction velocity from finger to wrist in 75% of 117 patients with CTS (1). Together with a palm to wrist conduction study, only six patients remained normal electrophysiologically. In the same study D1 study was abnormal in 10% of the patients with a normal D3 study and vice versa. That is, studying two fingers instead of one increases the diagnostic sensitivity. Kimura suggests that motor conduction is as abnormal as sensory conduction in CTS (4). In our study, sensory conduction velocity was affected in all patients and in at least one finger. The DML was abnormal in 19 out of 20. Variability of the amplitude of SAP obtained using a needle electrode occurs as often as using surface electrode (a decrement of 30-50% of normal can be accepted normal) (1). This means that the amplitude change is not as reliable as the velocity. However, the advantage of a needle is to be able to record a potential even if it is very small. We obtained potentials in all patients at D1 and D3 studies with this method. In 60% of patients there was a decreased amplitude of SAP by at least one of the D1 and D3 studies. Buchtal et al. found this ratio to be 78% (1). Amplitude diminution occurs less often than slowing of conduction. This is characteristic for all entrapment neuropathies. First, the conduction slowing occurs at the site of compression, and then the amplitude of the action potential decreases because of axonal injury (5). In electrophysiologic studies using conventional techniques, ulnar nerve study is also needed for the diagnosis of CTS. One of the reasons for this is to eliminate a polyneuropathy in which slowing of distal conduction occurs. If ulnar sensory conduction is also slow there are two possibilities: 1- An accompanied ulnar neuropathy; this was present in 15% of patients in Buchtal and co-workers' study and 6.4% in the Rochester study (1,6). 2- A possibility of polyneuropathy. To exclude this, sural (7) or radial (8) sensory conduction study should be performed. The second reason for an ulnar nerve study in patients with a suspicion of a CTS is as a direct aid to the diagnosis. Median nerve study sometimes gives results within normal range. Although the ratio between the amplitudes of median and ulnar SAPs is at least one in the normal population, this is less than one in patients with a CTS (9). In our study ulnar nerve motor and sensory studies were normal in all patients.

On the other hand, the ratio of the amplitude of the median SAP to ulnar's (D5) was less than one for D1 in 14 patients and for D3 in 16 patients. Compression of the median nerve at the wrist is the most common entrapment neuropathy (10). The ideal method for electrodagnosis is comparison of median and ulnar sensory latencies according to some authors (11,12), because this gives a control value in the patient himself/herself. Pure median and ulnar innervated fingers are usually chosen (1). D4 has both median and ulnar nerve fibers. So using only this finger, one can record SAPs over median and ulnar nerves simultaneously. Various parameters of this recording can be used for the diagnosis of a CTS. In an antidromic study from the wrist to D4 along
nerves. Johnson and co-workers found a latency difference of 0.3 ms or less between the ulnar and median nerves in healthy control subjects, while this difference is 1.0-2.1 ms in patients with a CTS (12). The authors suggest that this technique is easily applicable and time saving (less than 10 minutes for the whole examination). The study of Uncini and co-workers gave more interesting results (13). In that study, there was no difference between the latencies from D4 and D2 to the wrist in healthy subjects; but the latency from D4 to the wrist was significantly longer than that from D2 in patients with a CTS. Comparing the latency difference between the ulnar and median nerves, the authors suggest that D4 study shows the most significant deviation from normal, and because of this, it is the most sensitive technique for the diagnosis. The cause of the high vulnerability of the median nerve fibers of D4 in carpal tunnel is the location of the bundle from the D4 on the ulnar margin of the nerve (13).

Valls and Llanas determined double peaked potentials in almost all patients with a CTS by D4 study (61 out of 70 cases). The first potential belongs to the ulnar, while the second represents the median fibers (14). This abnormality did not appear in the control group. That is, this technique is highly specific. Lauritzen and co-workers compared the D4 study with D1 and D3 studies (15). They found no difference between the mean conduction velocities along the three fingers either in patients with a CTS or in healthy subjects. On the other hand a SAP was recorded in all of 38 patients by stimulation of D1 and D3, when 5 patients showed lack of a potential by stimulation of D4. This leads to a comment that D4 study is less sensitive than D1 and D3 studies. In the same work, in 9 patients with clinically suspected CTS, but with normal routine electrophysiologic studies, the D4 study was also normal. By stimulation of D4 (30.6±6.8 m/s), in our study, the mean sensory conduction velocity was not significantly different from that of D1 (31.5±5.5 m/s) or D3 (34.5±8.2m/s). The amplitude of SAP at wrist by D4 stimulation 3.9±4.8 µv) was not significantly different from that of D3 (8.0±8.9 µv). The only abnormality we found was the significant difference between the amplitudes of SAPs.
by stimulation of D1 (12.7±12.8 µv). This significantly small amplitude may provide superiority of the D4 study over the D1 study. On the other hand it is very important to record a potential even if it is very small. Thus conduction velocity can be determined. We could not record a SAP by D4 stimulation in a case in this study in whom D1 and D3 studies showed a potential. Thus, in severe cases it may be difficult to distinguish a potential from the isoelectric line and the superiority of D4 study may turn to a disadvantage.

Digit 4 has fibers from two different nerves. So, this finger may have less median nerve fibers than the purely median innervated fingers. If it is so, there may be an amplitude difference between the D4 study and the others in normal population. This needs further investigation.

Conclusion

Using the ring finger seems at least as sensitive as thumb or third finger in the diagnosis of a CTS. By using the ring finger both median and ulnar nerve can be tested simultaneously and this may save time. Patients clinically suspected as having a CTS, but with normal routine electrophysiologic studies, can be examined by D4 to see whether it is more sensitive than conventional examination.

Correspondence author
H. Özden ŞENER
İbni Sina Hastanesi
Nöroloji Bölümü
Ankara-Turkey

References