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H. Özden ŞENER

Nezih YÜCEMEN

Nermin MUTLUER

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Nermin MUTLUER

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Department of Neurology, Faculty of Medicine, Ankara University, Ankara-Turkey

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 velcocity 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.

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

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 paraesthesis 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 hipoesthesis. None of the patients had syptoms 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 Buctal 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 (SAP) 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

obtain a SAP. A surface electrode referred to the finger 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 stimulation; 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 compared 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; denervation 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 laboratory 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 others. 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 velocity 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 patiens 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; polyphasic 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 velocity 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 stimulation. 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 velocities from the fingers to the wrist and along the forearm 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 singificantly smaller compared to D1 ($P<0.01$). The mean amplitude of the potential at the elbow by stimulation of D4 was significantly 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 difference 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 fom 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 conduction 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

	Sensory velocity (m/s)				Amplitude (μV)			
	mean	95% limits		age	mean	95% limits		
		lower	upper	(years)		lower	upper	
	57	47	66	15-24	43	17	106	
D1	55	46	64	25-34	37	15	94	stim. D1
to	54	44	63	35-44	33	13	82	rec. wrist
wrist	52	43	61	45-54	29	12	70	
	51	41	60	55-64	25	10	62	
	70	62	79	15-24	12	5	31	
wrist	68	59	77	25-34	10	4	26	stim. D1
to	66	57	74	35-44	9	3.5	22	rec. elbow
elbow	64	55	72	45-54	7.5	3	19	
	61	53	70	55-64	6.5	2.5	16	
	64	55	73	15-24	16	7	35	
D3	62	53	71	25-34	14	6.5	31	stim. D3
to	60	51	69	35-44	13	6	27	rec. wrist
wrist	58	49	67	45-54	11	5	25	
	57	48	66	55-64	10	4.5	22	
	71	62	79	15-24	7.5	3	19	
wrist	68	60	77	25,34	7	2.5	17	stim. D3
to	66	57	75	25,34	6	2.5	15	rec. Elbow
elbow	64	55	73	45-54	5	2	13	
	62	53	71	55-64	4.5	2	12	

ulnar nerve

	Sensory velocity (m/s)				Amplitude (μV)			
	mean	95% limits		age	mean	95% limits		
		lower	upper	(years)		lower	upper	
	59	48	70	15-24	17	7	43	
D5	58	47	69	25-34	16	6	40	stim. D5
to	57	46	68	35-44	14	5.5	36	rec. wrist
wrist	55	44	66	45-54	13	5	33	
	56	47	65	55-64	10	4	26	

Median nerve

	Distal motor latency (ms) 95% limits				Amplitude (μV) 95% limits			
	mean	lower	upper	age (years)	mean	lower	upper	
	2.7	3.3	2.0	15-24	16	7	38	
to	2.8	3.4	2.1	25,34	15	7	37	
APB	2.9	3.5	2.2	35-44	15	6	36	stim. wrist
	3.0	3.6	2.3	45-54	14	6	35	
	3.1	3.7	2.4	55-64	14	6	34	

	Motor velocity (m/s)				Amplitude (μV)			
		95% limits		age		95% limits		
	mean	lower	upper	(years)	mean	lower	upper	
	65	56	75	15-24	18	8	44	
elbow	64	55	74	25-34	17	7	41	
to	63	54	73	35-44	16	7	38	stim. elbow
wrist	62	52	72	45,54	15	6	35	
	61	51	70	55-64	14	6	32	

Table 1 . (Continued)

Ulnar nerve

	Distal motor latency (ms) 95% limits				Amplitude (μV) 95% limits			
	mean	lower	upper	age (years)	mean (17-69 years)	lower	upper	
	2.2	2.7	1.6	15-24	16	8	30	stim. Wrist
to	2.2	2.8	1.7	25-34				
ADM	2.3	2.9	1.7	35-44				
	2.4	2.9	1.8	45-54				
	2.4	3.0	1.9	55-64				

Table 2. Motor conduction along median and ulnar nerves in patients (mean±SD).

	Median nerve (range)	Ulnar nerve (range)
DML (ms)	5.1±1.3(3.7-8.5)	2.6±0.4 (2.2-3.0)
CMAP (mv)	8.6±4.5 (0.4-15.4)	16.7±4.9 (8.3-22.8)
Distance (mm)	66.6±6.2 (50.0-75.0)	67.3±0.6 (50.0-75.0)

Table 3. Sensory conduction along median and ulnar nerves in patients (mean±SD).

	wrist		elbow	
	v (m/s) (range)	amplitude (MV) (range)	v (m/s)	amplitude (μv)
D1	31.5±5.5 (21.0-42.9)	12.7±12.9 (1.4-42.4)	61.2±7.6	5.9±5.6
D3	34.5±8.2 (21.0-50.0)	8.0±8.9 (1.2-34.4)	61.4±4.9	3.5±2.2
D4 (median)	30.6±6.8 (18.3-41.6)	3.9±4.8 (0.6-17.4)	64.7±9.0	1.4±0.5
D4 (ulnar)	54.4±4.4 (48.0-65.0)	11.2±6.0 (7.4-25.6)	54.4±4.4	11.2±6.0
D5	52.8±6.6 (45.6-66.6)	16.8±7.0) (5.2-28.4)	52.8±6.6	16.8±7.0

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 electcrode (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 Buhctal 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 electrodiagnosis is comparison of median and ulnar sensory latencies according to some authors (11,12), because this gives a control value in the patient himself/herfself. 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 and antidromic study from the wrist to D4 along

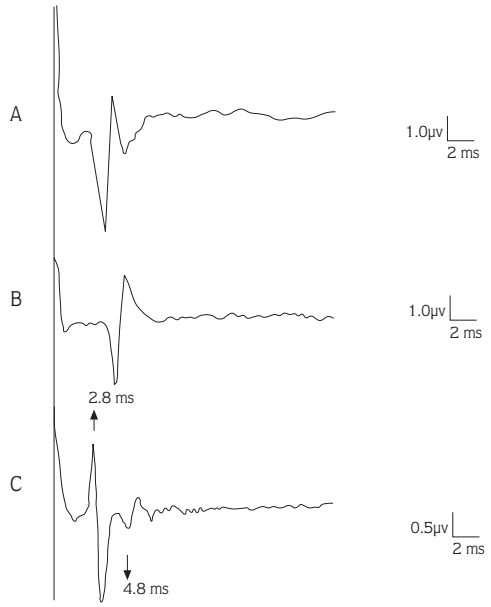

Figure 1. Median SAP at wrist by stimulation of D1 (A), D3 (B) and D4 (C) in a patient with carpal tunnel syndrome . Latency, distance and velocity: 3.5 ms, 10.5 cm and 30.0 m/s for D1; 3.9 ms, 16.5 cm and 42.3 m/s for D3; and 4.8 ms, 16.0 cm and 33.3 m/s for D4, respectively. (The upside-down potential with a latency of 2.8 ms at C represents contamination from ulnar nerve when using a medial reference. Reference electrode was placed lateraly to avoid such a misinterpretation). Sensitivity is 1.0 µv/div. At A and B, 0.5 µv/div at C.

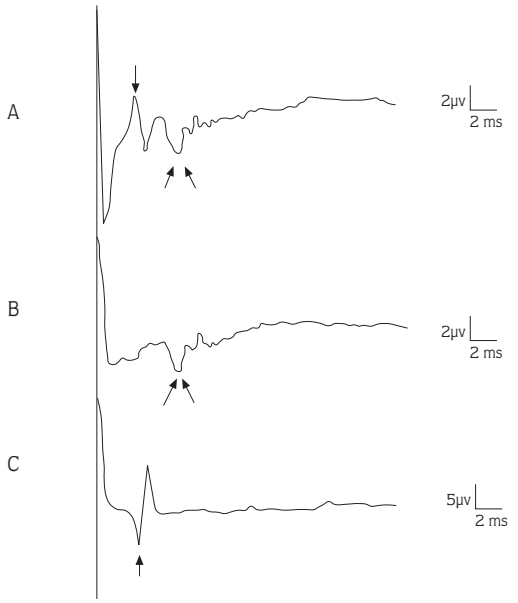

Figure 2. By stimulation of D4 in a patient with a carpal tunnel syndrome: A. Medially referred median SAP; B. Laterally referred median SAP; C. Laterally referred ulnar SAP. Ulnar SAP marked with single arrow at A and C; polyphasic median SAP marked with double arrow at A and B. Sensitivity is 2 µv/div. At A and B, 5 µv/div. At C.

nerves, Johnson and co-workers found a latency diffrence of 0.3 ms or less between the ulnar and median nerves in healthy control subjects, while this differences 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 singificantly 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 disvantage.

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

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