Wrist, Elbow – Hand

M8

Surface Recording Technique, Study from Median *Thenar* (MT) Muscle

Original Settings Sensitivity, duration of pulse, sweep speed, low-frequency filter, high-frequency filter, and the machine used were not specified.

Position This study was performed in the supine position.

Recording The active electrode (A) was placed one half the distance between the metacarpophalangeal joint of the digit I (thumb) and the midpoint of the distal wrist crease, above the median *thenar* (MT) muscle (Fig. 1). The reference (R) was placed distally to the distal phalanx of the digit I (thumb). The ground (G) electrode position was not specified in the original text; it showed placed distally between the digit IV and digit V [1].

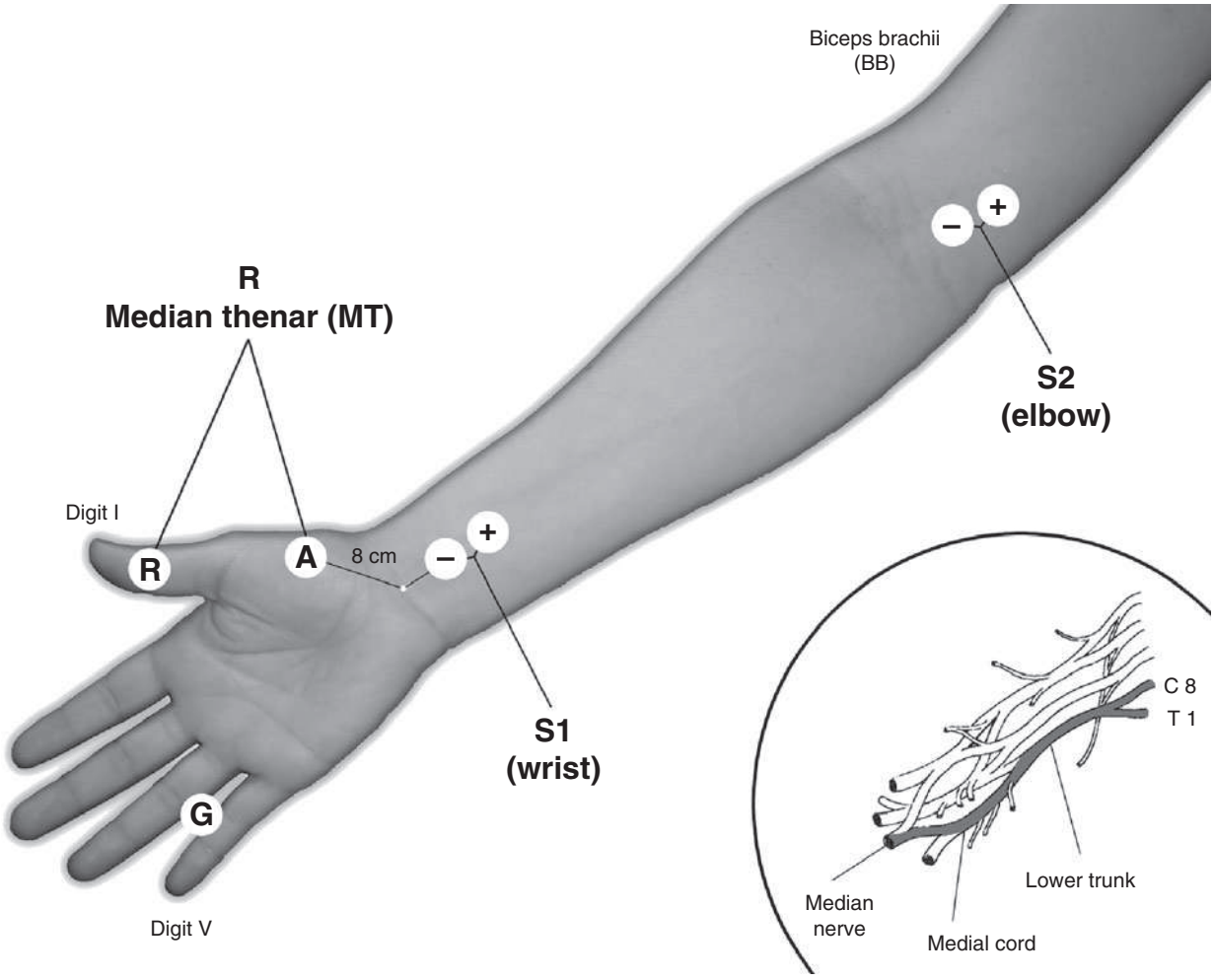
Stimulation The median nerve was stimulated at the wrist (S1) and at the elbow (S2). The first stimulation (S1) was performed at the wrist, with the cathode 8 cm proximal to the active recording electrode (A), on the median nerve (Fig. 2). The anode was proximal. Authors used a two-line method to measure the distance between the active and the recording electrodes (it was not specified in the text but showed clearly in article's original figure). The second stimulation (S2) was performed at the elbow, on the antecubital fossa, just lateral to the brachial artery. The anode was proximal. Authors emphasized the use of a standardized electrodiagnostic technique to minimize experimental errors, standardizing both the placement and the distance over which stimulation was performed. They used only supramaximal stimulations.

Measurements Distal latency (ms) of the compound muscle action potential (CMAP) was measured from the stimulus onset to the onset of the negative deflection of the CMAP; amplitude (mV) of the CMAP was measured from the baseline to the peak of the negative deflection. Motor nerve conduction velocity (MNCV) was calculated in the elbow–wrist (forearm) segment and measured in meter per second (m/s). Duration (ms) was measured from the onset to the end of the CMAP. No control of temperature was attempted. Normal values (Table 1) were obtained from 24 dominant wrists from 24 healthy volunteers. Pathological values (Table 2) of 17 patients with the carpal tunnel syndrome (CTS) were reported.

Kimura and Ayyar [2] evaluated MNCVs, distal latencies, and negative-to-peak amplitudes of CMAPs in 639 extremities from 438 patients with clinical signs and symptoms suggestive of CTS (284 women and 154 men, age range 18–85 years, mean age 51.4 years). Of 438 patients, 202 (46.1 %) had clinically bilateral involvement. They used a modified protocol placing the wrist stimulation (S1) at a 6 cm fixed distance from the recording electrode (A) to the motor point of the *abductor pollicis brevis* (APB) muscle (Fig. 3).

They evaluated MNCVs, distal latencies, and negative peak amplitudes of CMAPs in 175 extremities of 148 normal subjects and in a larger sample of patients with clinical signs of CTS. The MNCV of the forearm was calculated by dividing the distance between the two stimulating sites by the difference in latency measured from the stimulus artifact to the onset of the CMAPs. Authors determined F-wave latencies with nerve stimulation at the wrist and recording the response from the APB muscle. Authors used supramaximal stimulation; skin and room temperature were not reported. They studied 175 median nerves (Table 3) from 148 normal subjects (80 women and 68 men, age range 20–81 years, mean age 47.6 years) and 639 median nerves (Table 4) from 438 patients with CTS (284 women and 154 men, age range 18–85 years, mean age 51.4 years).

G. Gentili, M. Di Napoli, *The Median Nerve: Motor Conduction Studies*,
DOI 10.1007/978-3-319-10473-7_8, © Springer International Publishing Switzerland 2015



Typical waveform (wrist, elbow – MT muscle):

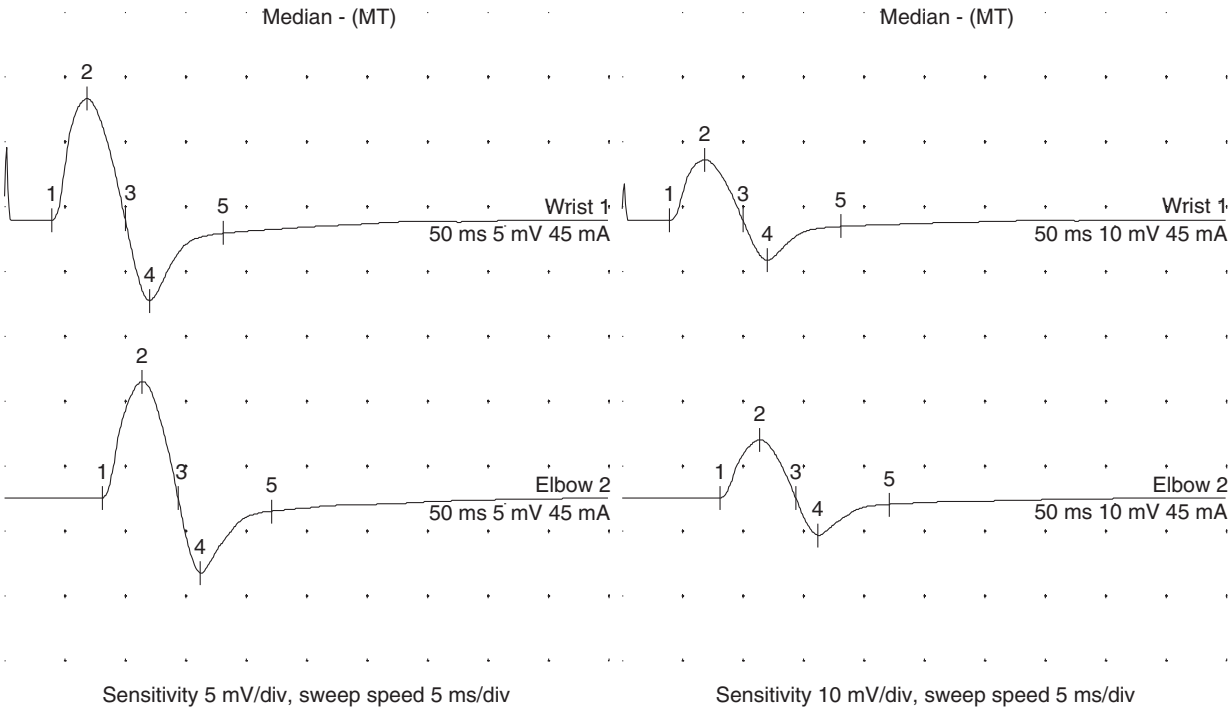


Fig. 1 Compound muscle action potentials (CMAPs) recorded at the hand from the MT muscle, stimulation of the wrist (*upper trace*) and of the elbow (*lower trace*)

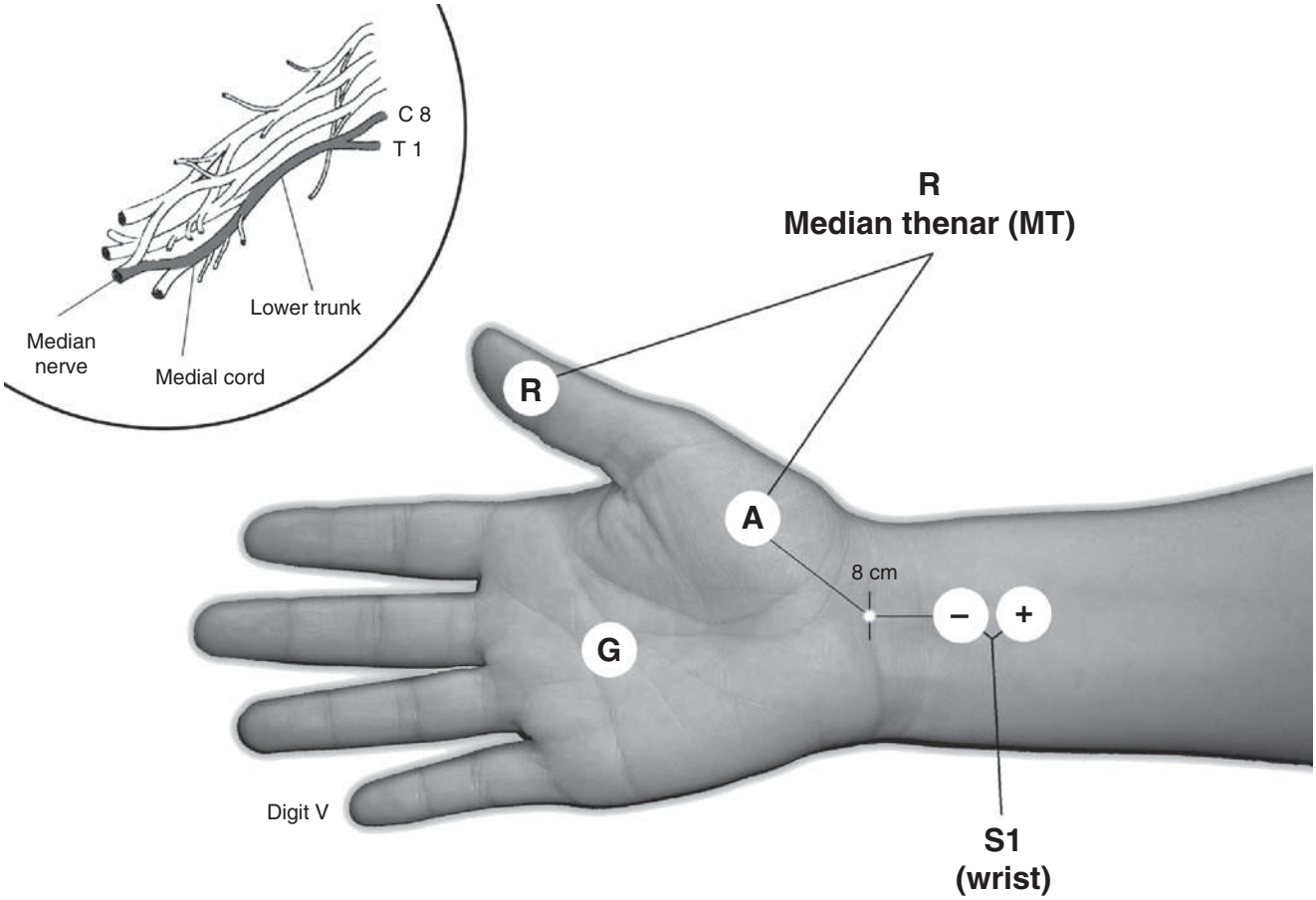


Fig. 2 Distal stimulation at the wrist, S1 placed at 8 cm fixed distance from the active recording (A) electrode on the MT muscle

Table 1 Reference values

Normal values [1]	Mean ± SD	Range
Wrist–APB, distal latency (ms)	3.7 ± 0.3	3.2–4.2
Wrist–elbow, MNCV (m/s)	56.7 ± 3.8	50.0–67.3
Wrist–APB, negative peak amplitude (mV)	13.2 ± 5.0	5.0–25.0
Wrist–elbow, negative peak amplitude (mV)	13.5 ± 4.1	5.0–23.0
Wrist–APB, duration (ms)	7.5 ± 1.5	5.0–10.2
Wrist–elbow, duration (ms)	7.5 ± 1.5	4.4–10.2

Table 2 Reference values

Pathological values [1]	Mean ± SD	Range
Wrist–APB, distal latency (ms)	5.3 ± 1.1	3.8–7.0
Wrist–elbow, MNCV (m/s)	52.8 ± 5.7	44.0–64.0
Wrist–APB, negative peak amplitude (mV)	9.4 ± 3.1	5.0–15.5
Wrist–elbow, negative peak amplitude (mV)	8.9 ± 2.9	5.6–15.0
Wrist–APB, duration (ms)	7.4 ± 1.7	5.4–11.8
Wrist–elbow, duration (ms)	7.5 ± 1.4	5.1–11.0

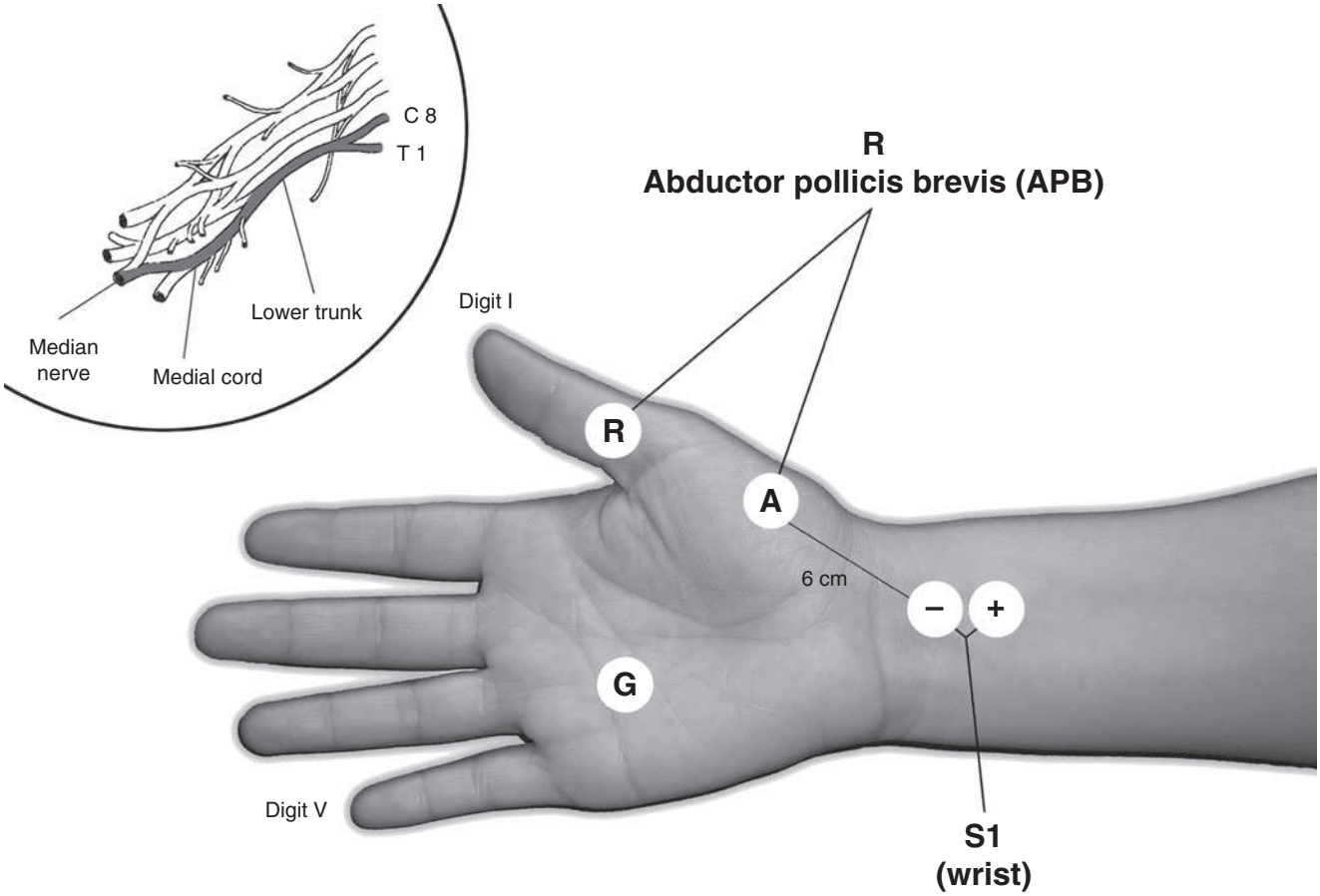


Fig. 3 Distal stimulation at the wrist, S1 placed at 6 cm fixed distance (straight line) from the active recording (A) electrode on the APB muscle

Table 3 Reference values

Normal values [2]	Mean ± SD
Wrist–APB, distal latency (ms)	3.31 ± 0.4
Wrist–APB, negative peak amplitude (mV)	8.47 ± 3.3

Table 4 Reference values

Pathological values [2]	Mean ± SD	Range
Wrist–APB, distal latency (ms)	5.41 ± 2.41	2.2–10.8
Wrist–APB, negative peak amplitude (mV)	6.38 ± 4.5	

Comment

In 12 symptomatic hands (1.9 %) of 639, Kimura and Ayyar [2] were not able to record the median CMAPs from the APB muscle after stimulation of the wrist. In 98.1 % of 639 hands (627 hands), CMAPs after stimulation at the wrist were recorded. In 54.3 % of the 627 hands, the distal motor latency (DML) was prolonged (4.7 ms or more). The mean negative peak amplitude was significantly decreased when compared to the normal value, and in 153 hands with no median sensory nerve action potential (SNAP) to the digit II the amplitude was 4.53 ± 3.7 mV. The MNCV of the forearm (wrist–elbow segment) was slowed in patients, with an observed value below 49 m/s in 22.6 % of 552 symptomatic hands with CTS investigated.

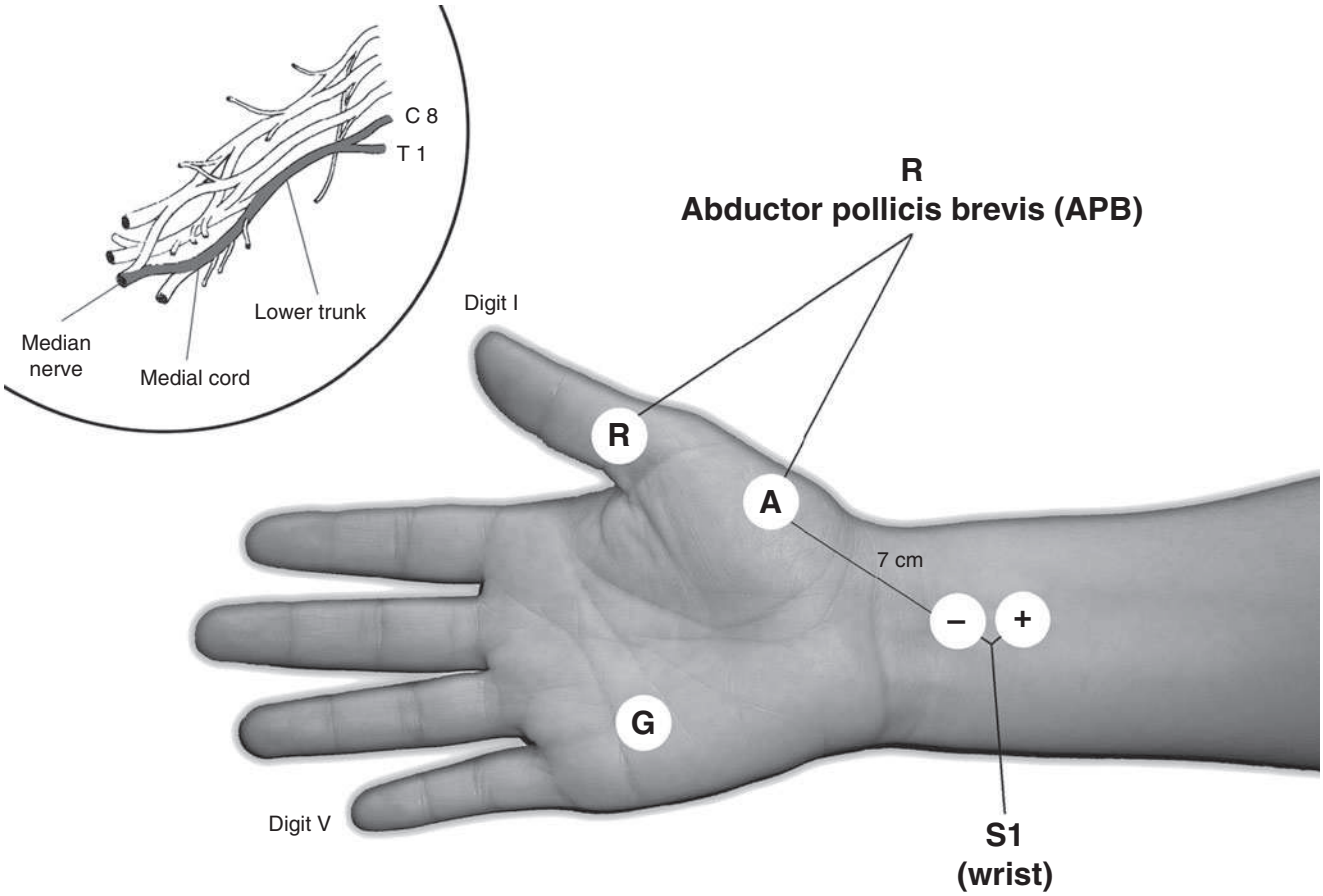


Fig. 4 Distal stimulation at the wrist, S1 placed at a 7 cm fixed distance (straight line) from the active recording (A) electrode on the APB muscle

Table 5 Reference values

Normal values [3]	Mean ± SD	Limit of normal
Wrist–APB, distal latency (ms)	3.36 ± 0.32	4.0

Table 6 Reference values

Pathological values [3]	Mean ± SD	Sensitivity
Wrist–APB, distal latency (ms)	5.24 ± 1.87	72 % (113 hands)

Table 7 Reference values

Normal values [4]	Mean	Range	Limit of normal
Wrist–APB, distal latency (ms)	3.30 ± 0.30	2.50–3.90	3.90

Table 8 Reference values

Pathological values [4]	Mean	Range
Wrist–APB, distal latency (ms)	4.64 ± 1.11	2.70–9.90

Recently, Kasius et al. [3] measured DML to the APB muscle in 47 healthy subjects (30 women – 63.8 %, 24 left hand – 51.1 % and 23 right hand – 48.9 %, mean age 41.04 ± 12.2 years) and in 157 patients with clinically defined CTS (122 women – 77.7 %, 71 left hand – 45.2 % and 86 right hand – 54.8 %, mean age 48.87 ± 13.7 years) using a 6 cm distance between recording and stimulating sites (Tables 5 and 6). Their values were consistent with those by Kimura and Ayyar [2], and comparing sensitivity of several sensory and motor conduction tests in the diagnosis of CTS, they found abnormal values in 113/157 hands (low sensitivity – 72 %).

Foresti et al. [4] using a 7 cm fixed distance (straight line) from the active recording electrode (Fig. 4) performed APB CMAP bilateral recordings in 25 healthy (Table 7) subjects (average age 42 years, age range 18–69 years, male/female ratio 2.5:1) and in 100 consecutive patients (Table 8) with suspected CTS (mean age 49 ± 11.9 years, age range 27–78 years, male/female ratio 3:1) (Tables 7 and 8). They used a five-channel Mystro-Plus electromyograph. Hand temperature was monitored and, if it was less than 32 °C, the limb was warmed. DML – onset latency was measured.

Comment

Foresti et al. [4] in a sample of 200 hands from 100 patients with suspected CTS found that 159 hands with a clinical suspicion of CTS and 149 hands of these were found to have electrophysiological signs of CTS (10 hands were normal); 61 patients had bilateral CTS. For the median APB DML, authors found low values of sensibility (78.19 and 73.70 %) and high values of specificity (>99 %, 90.20 %), on the base of an electrophysiological Gold Standard and using a clinical Gold Standard independent of the electrodiagnostic procedures, respectively.

In a retrospective analysis of all cases of CTS diagnosed in their laboratory over a 20-month period, Donahue et al. [5] investigated the presence of a superimposed process (i.e., axonal polyneuropathy, C8-T1 radiculopathy, or lower trunk/medial cord brachial plexopathy). Motor nerve conduction study to the APB muscle was performed using a Dantec Counterpoint electromyograph, surface 10 mm silver disk electrodes for recording, and stimulating median nerve 7 cm proximal to the active recording electrode (Fig. 4). They maintained temperature of the upper limb at 32–34 °C using hot packs. A total of 192 arms from 155 patients (111 women and 44 men, age range 19–94 years) were studied, 154 arms (80 %) had a normal (≥50 m/s) median motor forearm conduction velocity (MMFCV), whereas 38 arms (20 %) had slowed MMFCV. Authors found a superimposed process in only 2 (14 %) of the 14 arms with mild slowing of MMFCV (47–49.9 m/s), in 7 arms (46 %) of the 15 arms with moderate slowing of MMFCV (43.0–46.9 m/s), and in 4 (44 %) of the 9 arms with severe slowing of MMFCV (<43 m/s). They found that superimposed processes were common in the presence of a moderate and severe slowing of MMFCV. However, in patients with mild slowing of MMFCV (47–49.9 m/s) the incidence of a superimposed process was similar to that found in patients with a normal MMFCV.

The 8-cm standardization from the active recording electrode (Fig. 5) was first proposed by Melvin et al. [1] and it was used routinely in the EMG laboratories; the median motor conduction study to the APB muscle is actually one of the most commonly performed electrodiagnostic studies.

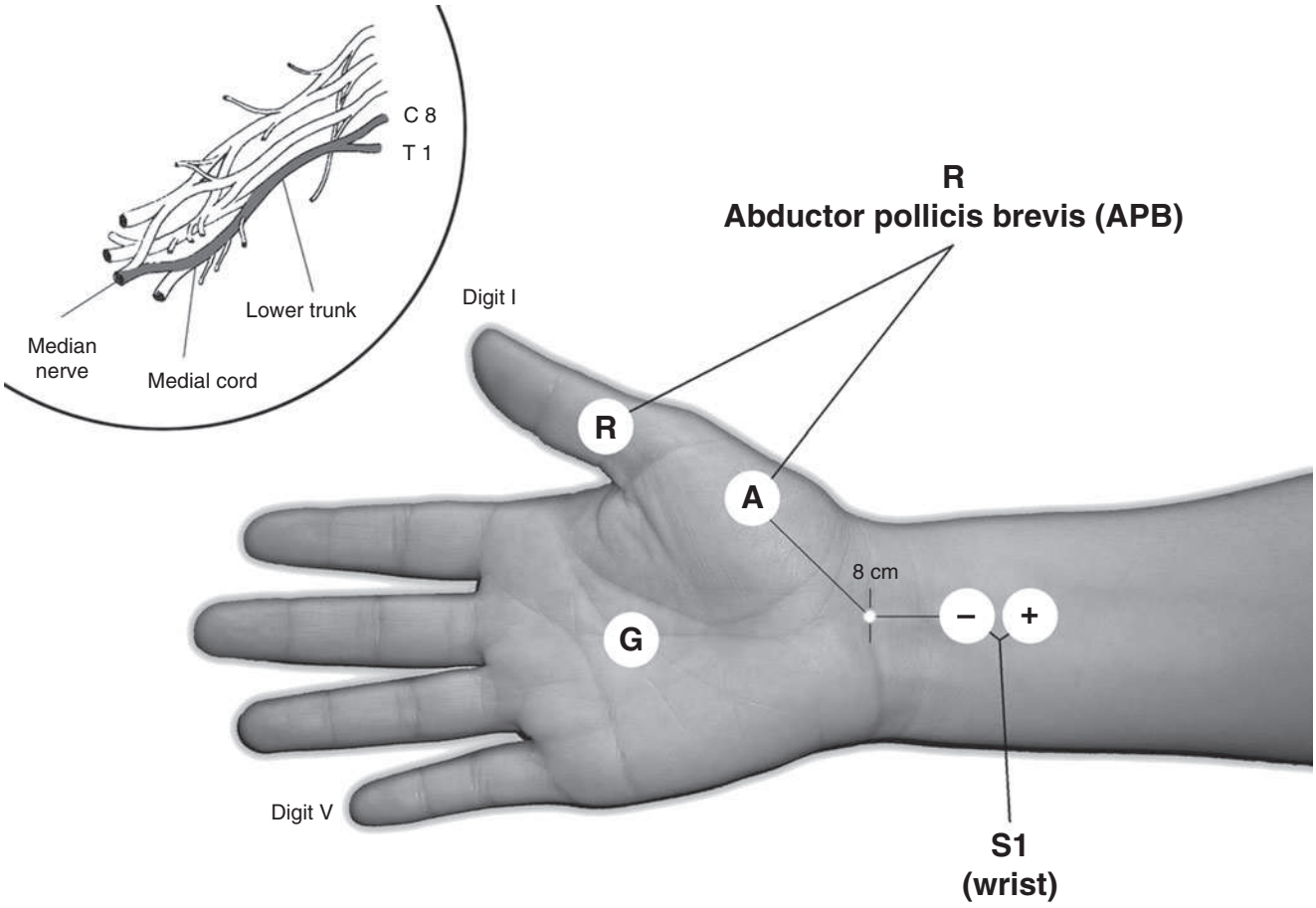


Fig. 5 Routine distal stimulation at the wrist, S1 placed at an 8 cm fixed distance (two lines), recording from the APB muscle

Table 9 Reference values

Normal values [6]	Mean ± SD	Range	Limit of normal
Wrist–APB, distal latency (ms)	3.7 ± 0.5	2.8–4.8	4.5
Wrist–APB, negative peak amplitude (mV)	10.2 ± 3.6	2.0–22.0	4.1
Wrist–APB, area (μVs)	33.7 ± 12.8	6.6–93.7	12.4
Wrist–APB, duration (ms)	5.9 ± 0.9	4.1–9.6	8.0
Males – latency (ms)	Mean ± SD	Range	Limit of normal
Age range 19–49	3.8 ± 0.4	3.0–4.6	4.6
Age range 50–79	4.0 ± 0.4	3.0–4.8	4.7
Females – latency (ms)	Mean ± SD	Range	Limit of normal
Age range 19–49	3.5 ± 0.4	2.8–4.8	4.4
Age range 50–79	3.8 ± 0.4	2.9–4.6	4.4
Amplitude (mV)	Mean ± SD	Range	Limit of normal
Age range 19–39	11.9 ± 3.6	2.2–22.0	5.9
Age range 40–59	9.8 ± 2.8	3.3–17.7	4.2
Age range 60–79	7.0 ± 2.6	2.0–14.3	3.8
Area *(μVs)*	Mean ± SD	Range	Limit of normal
Age range 19–49	37.4 ± 12.9	8.1–93.7	14.6
Age range 50–59	30.9 ± 8.6	14.1–45.6	15.3
Age range 60–79	23.7 ± 9.3	6.6–50.9	11.9
Males – MNCV (m/s)	Mean ± SD	Range	Limit of normal
Age range 19–39	58 ± 4	48–65	49
Age range 40–79	55 ± 5	40–78	47
Females – MNCV (m/s)	Mean ± SD	Range	Limit of normal
Age range 19–39	60 ± 3	50–66	53
Age range 40–79	57 ± 5	43–77	51

Many authors during past years have measured normal and pathological values on a larger population of normal subjects and patients, respectively. In 1999 Buschbacher [6] has recorded latency (ms), amplitude (mV), area (μVs), duration (ms), and MNCV (m/s) on a sample of 249 healthy subjects with age from 19 to 79 years (Table 9). He placed the active electrode halfway between the midpoint of the distal wrist crease and the volar surface of the first metacarpophalangeal joint, over the motor point of the APB muscle. The reference electrode was placed slightly distal to the joint. The ground electrode was placed on the dorsum of the hand (the figure shows the ground electrode placed on the palm). Wrist stimulation was performed with the cathode positioned 8 cm proximal to the active electrode on a line measured first to the midpoint of the distal wrist crease and then proximally to a point between the tendons of the *flexor carpi radialis* (FCR) and the *palmaris longus* (PL) muscles. In case of difficulty to identify the PL tendons, author suggested applying the stimulus slightly ulnar to the FCR tendon.

Comment

Buschbacher [6] found the upper limit of the normal increase in latency from one side to the other was 0.7 (±2 SD) ms; side-to-side upper limit of the normal decrease in amplitude was 6.9 (±2 SD) mV. Gender was found to be associated with different results for latency and MNCV. Age was found to be associated with different results for latency, amplitude, area, and MNCV.

Chang et al. [7], during a 1-year period, and a 2-year period [8], performed several sensory and motor conduction techniques to compare the sensitivities in the diagnosis of CTS. All studies were performed using a Nicolet Viking IV or Dantec Keypoint 4 electromyograph, and skin temperature at the hand was maintained at or above 32 °C. Conventional motor nerve conduction study to the APB muscle was performed in 100 control (Table 10) subjects (64 women and 36 men; age range 22–65 years, mean age 47.4 years) [7] and

in 150 control (Table 11) subjects (91 women and 69 men; age range 18–84 years, mean 53.9 years) [8].

Havton et al. [9] in 91 hands of 64 patients (54 women and 10 men; age range 26–82 years, mean age 49.5 ± 11.8 years) examined the correlation between the median forearm motor nerve conduction velocity (MNCV) and the markers of severity of the median neuropathy at the wrist (i.e., median distal motor latency and compound muscle action potential amplitude of the APB muscle). Skin temperature was monitored and cool hands (<32 °C) were warmed. All patients had a clinical history of CTS confirmed by electrodiagnosis (antidromic sensory conduction to the digit II <45 m/s, or 8 cm distance median distal motor latency >4.4 ms). The conduction velocity within the forearm segment of the median nerve was calculated from the difference between the proximal and the distal motor latency and the distance between the corresponding stimulating sites. In the CTS hands, the mean median distal motor latency (DML) was 5.2 ± 1.7 ms, the mean APB CMAP amplitude was 13.3 ± 5.2 mV, and the mean median MNCV was 52 ± 4 m/s. The median MNCV within the forearm segment was negatively correlated with the median nerve DML and positively correlated with the CMAP amplitude of the APB muscle. Authors found that increasing severity of CTS was associated with decreased median MNCV within the forearm as indicated by a prolonged DML or reduced CMAP amplitude. They suggested that a reduction in MNCV occurred after an acute injury to motor axons with partial denervation of the *thenar* muscle.

Recently, in a prospective study Lee et al. [10] measured DML to the APB muscle on 67 hands of 41 patients (Table 12) with electroclinically diagnosed CTS (53 hands from 32 women, 14 hands from 9 men; average age 56.2 ± 11.2 years) grouped according to the severity of the carpal tunnel syndrome (mild, moderate, and severe CTS) based on electrophysiological criteria by Lee and Kwon [11]. A Dantec Counterpoint Mk2 was used for the electrodiagnostic study.

Comment

For Lee et al. [10], among the median nerve motor branches, the recurrent branch to the APB muscle is in a position to be more vulnerable to carpal tunnel compression than branches to the 1st (1L) and to the 2nd (2L) lumbrical muscles. Frequencies of DML prolongation in the APB muscle recording were 60, 85, and 94 % in the mild, moderate, and severe CTS groups, respectively (Figs. 6, 7, and 8); frequency in the mild group was significantly lower.

Table 10 Reference values

Normal values [7]	Mean ± SD	Limit of normal (±2.5SD)
Wrist–APB, distal latency (ms)	3.59 ± 0.31	<4.37

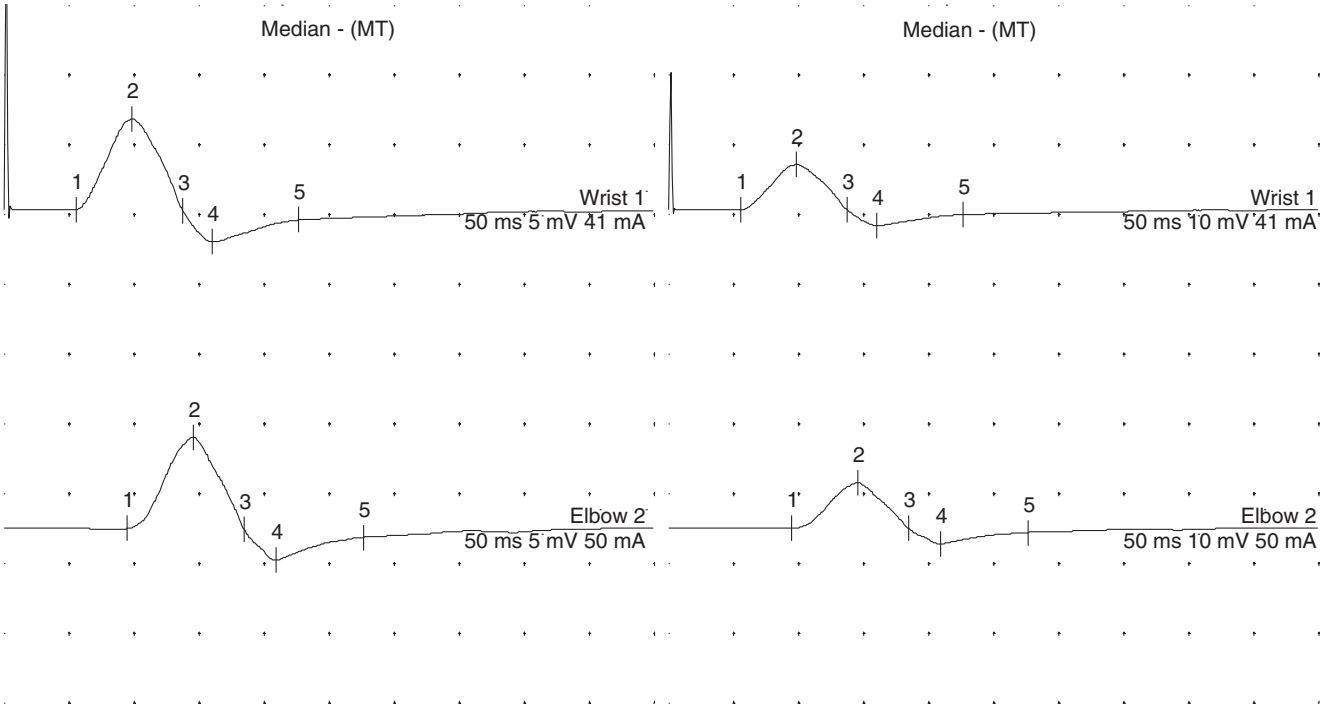
Table 11 Reference values

Normal values [8]	Mean ± SD	Limit of normal (±2.5SD)
Wrist–APB, distal latency (ms)	3.66 ± 0.31	<4.4

Table 12 Reference values

Pathological values [10] (all CTS patients – 67 hands)	Mean ± SD	Rate of abnormality (%_)
Wrist–APB, distal latency (ms)	5.47 ± 1.93	79
Pathological values [10] (mild CTS patients – 23 hands)	Mean ± SD	Rate of abnormality (%)
Wrist–APB, distal latency (ms)	4.34 ± 0.69	60
Pathological values [10] (moderate CTS patients – 27 hands)	Mean ± SD	Rate of abnormality (%)
Wrist–APB, distal latency (ms)	5.05 ± 0.68	85
Pathological values [10] (severe CTS patients – 17 hands)	Mean ± SD	Rate of abnormality (%)
Wrist–APB, distal latency (ms)	7.68 ± 2.57	94

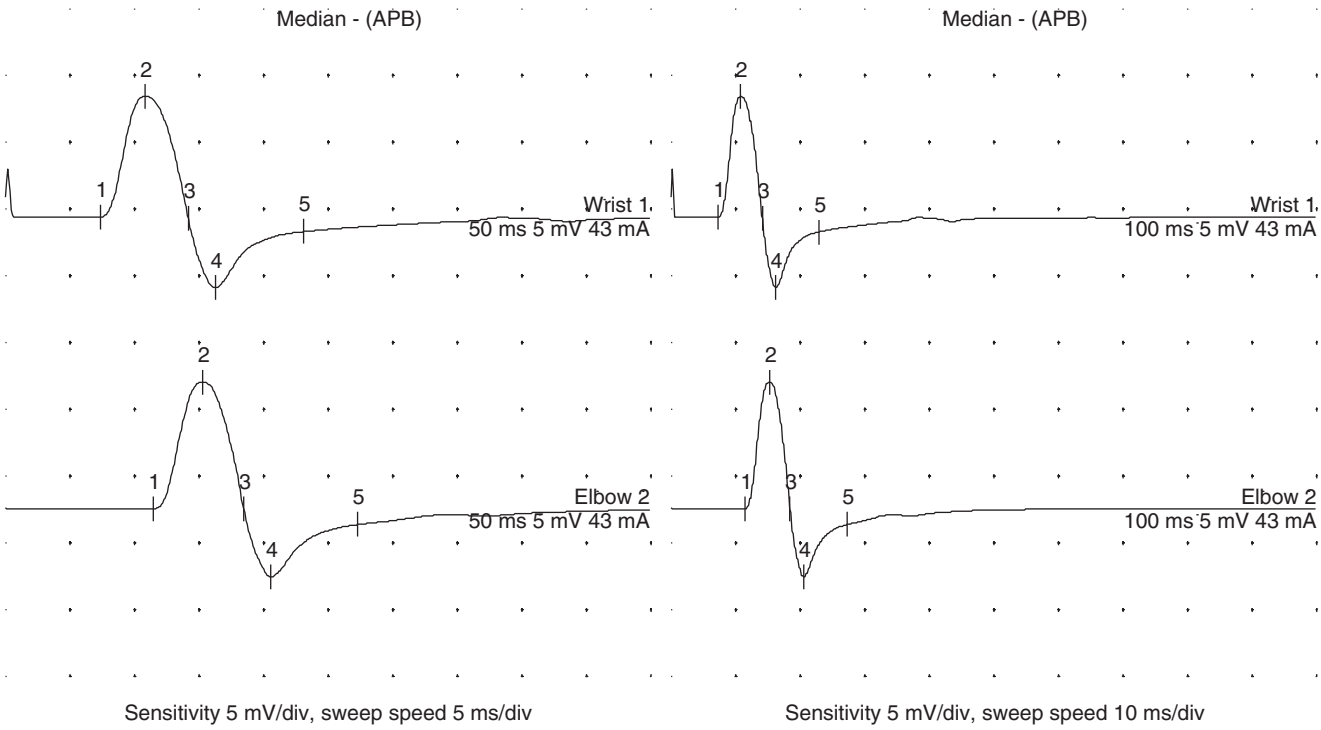
Pathological waveform (wrist, elbow – MT muscle):



Onset latency (wrist – MT): 5.55 ms; **Onset latency** (elbow – MT): 9.45 ms; **Peak latency** (wrist – MT): 9.95 ms; **Peak latency** (elbow – MT): 14.75 ms; **Onset to peak amplitude** (wrist – MT): 6.5 mV; **Peak to peak amplitude** (wrist – MT): 8.9 mV; **Onset to peak amplitude** (elbow – MT): 6.6 mV; **Peak to peak amplitude** (elbow – MT): 8.9 mV; **MNCV**(elbow – wrist): 59.0 m/s

Fig. 6 Compound muscle action potentials (CMAPs) recorded from the MT muscle in severe CTS – grade 4 by Bland's CTS classification scale [12], stimulation of the wrist (*upper trace*) and of the elbow (*lower trace*)

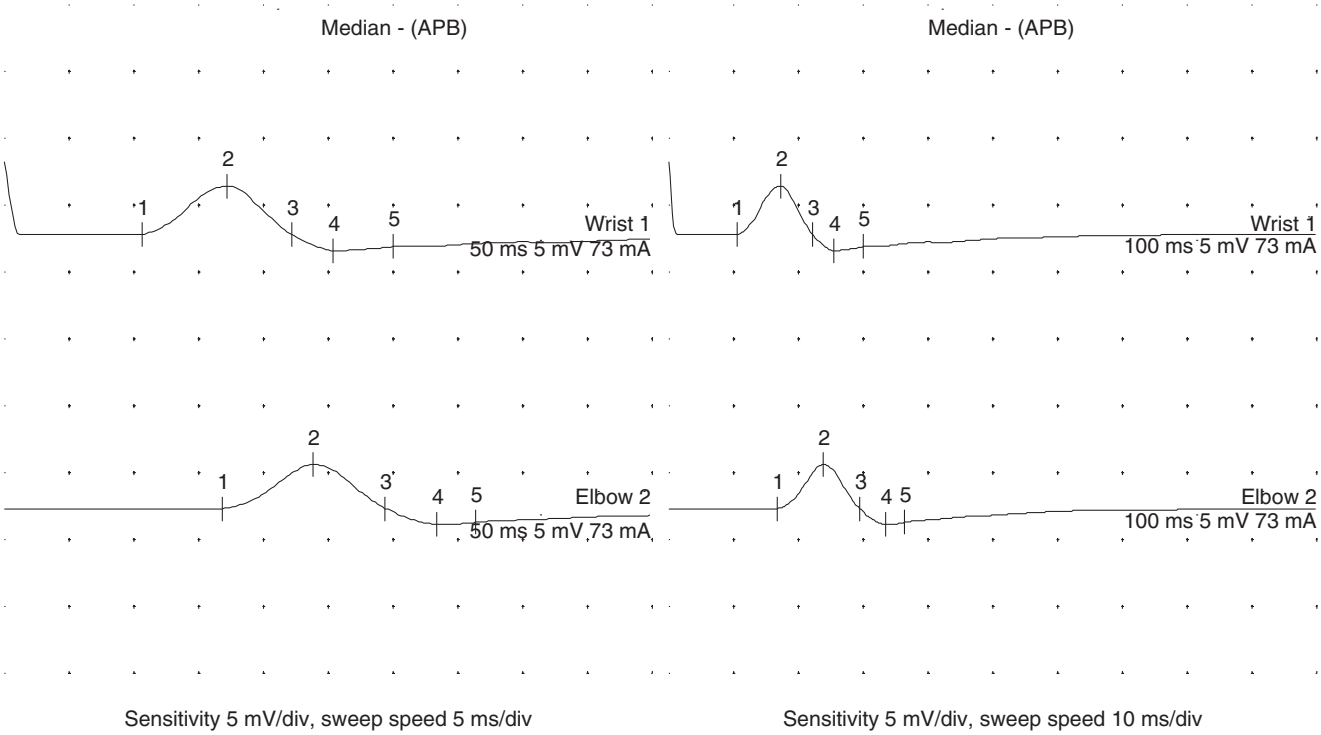
Pathological waveform (wrist, elbow – APB muscle):



Onset latency (wrist – APB): 7.35 ms; **Onset latency**(elbow – APB): 11.50 ms; **Peak latency**(wrist – APB): 11.30 ms; **Peak latency** (elbow – APB): 15.25 ms; **Onset to peak amplitude** (wrist – APB): 9.1 mV; **Onset to peak amplitude** (elbow – APB): 9.5 mV; **Peak to peak amplitude** (wrist – APB): 14.4 mV; **Peak to peak amplitude** (wrist – APB): 14.7 mV; **MNCV** (elbow – wrist): 53.0 m/s

Fig. 7 Compound muscle action potentials (CMAPs) recorded from the APB muscle in very severe CTS – grade 5 by Bland's CTS classification scale [12], stimulation of the wrist (*upper trace*) and of the elbow (*lower trace*)

Pathological waveform (wrist, elbow – APB muscle):



Onset latency (wrist – APB): 10.60 ms; **Onset latency** (elbow – APB): 16.80 ms; **Peak latency** (wrist – APB): 17.40 ms; **Peak latency** (elbow – APB): 23.15 ms; **Onset to peak amplitude** (wrist – APB): 3.6 mV; **Onset to peak amplitude** (elbow – APB): 3.3 mV**; Peak to peak amplitude** (wrist – APB): 5.0 mV; **Peak to peak amplitude** (wrist – APB): 4.6mV; **MNCV** (elbow – wrist): 38.7 m/s

Fig. 8 Compound muscle action potentials (CMAPs) recorded from the APB muscle in very severe CTS – grade 5 by Bland's CTS classification scale [12] and Guillain-Barré syndrome (2 weeks of onset of symptoms), stimulation of the wrist (*upper trace*) and of the elbow (*lower trace*)

References

1. Melvin JL, Schuchmann JA, Lanese RR (1973) Diagnostic specificity of motor and sensory nerve conduction variables in the carpal tunnel syndrome. Arch Phys Med Rehabil 54:69–74
2. Kimura I, Ayyar DR (1985) The carpal tunnel syndrome: electrophysiological aspects of 639 symptomatic extremities. Electromyogr Clin Neurophysiol 25:151–164
3. Kasius KM, Claes F, Verhagen WI et al (2012) The segmental palmar test in diagnosing carpal tunnel syndrome reassessed. Clin Neurophysiol 123:2291–2295
4. Foresti C, Quadri S, Rasella M et al (1996) Carpal tunnel syndrome: which electrodiagnostic path should we follow? A prospective study of 100 consecutive patients. Electromyogr Clin Neurophysiol 36:377–384
5. Donahue JE, Raynor EM, Rutkowe SB (1998) Forearm velocity in carpal tunnel syndrome: when is slow too slow? Arch Phys Med Rehabil 79:181–183
6. Buschbacher RM (1999) Median nerve motor conduction to the abductor pollicis brevis. Am J Phys Med Rehabil 78:S1–S8
7. Chang MH, Wei SJ, Chiang HL et al (2002) Comparison of motor conduction techniques in the diagnosis of carpal tunnel syndrome. Neurology 58:1603–1607
8. Chang MH, Liu LH, Lee YC et al (2006) Comparison of sensitivity of transcarpal median motor conduction velocity and conventional conduction techniques in electrodiagnosis of carpal tunnel syndrome. Clin Neurophysiol 117:984–991
9. Havton LA, Hotson JR, Kellerth JO (2007) Correlation of median forearm conduction velocity with carpal tunnel syndrome severity. Clin Neurophysiol 118:781–785
10. Lee HJ, Kwon HK, Kim DH et al (2013) Nerve conduction studies of median motor nerve and median sensory branches according to the severity of carpal tunnel syndrome. Ann Rehabil Med 37: 254–262
11. Lee HJ, Kwon HK (2004) Electrophysiologic classification of severity of carpal tunnel syndrome. J Korean Assoc EMG-Electrodiagn Med 6:1–3
12. Bland JDP (2000) A neurophysiological grading scale for carpal tunnel syndrome. Muscle Nerve 23:1280–1283