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Characteristics of the Electrophysiological Activity of Muscles Attached to the Transverse Carpal Ligament in Carpal Tunnel Syndrome

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Abstract

The main cause of carpal tunnel syndrome (CTS) remains unknown. Stiffness of the subcutaneous area of the volar aspect of the carpal tunnel is present in many patients and suggests that the stiffness of muscles attached to the transverse carpal ligament is increased. We performed an electrophysiological study to investigate muscle activities and to clarify whether the stiffness of muscles attached to the transverse carpal ligament is involved in the pathogenesis of CTS. The subjects of this study included 16 patients with early CTS showing no motor dysfunction. Both thenar muscles (opponens pollicis, abductor pollicis brevis, and flexor pollicis brevis) and hypothenar muscles (opponens digiti minimi, abductor digiti minimi, flexor digiti minimi brevis) were investigated. Surface electrodes were placed on each muscle, and maximum voluntary contractions with the thumb and little finger in opposition were maintained for 3 seconds in all patients and in 7 control subjects. Electromyographs were subjected to fast Fourier transform analysis, and the root mean square (RMS) and the mean power frequency (MPF) were determined for each muscle. The RMS of the opponens pollicis was significantly less in hands affected by CTS (292.8 μV) than in healthy hands (405.9 μV). The RMS did not differ between affected hands and healthy hands for the other 2 thenar muscles but did differ significantly for the hypothenar muscles. The MPF did not differ between affected hands and healthy hands for any muscle. The results show that electrophysiological differences are present among muscles innervated by the median nerve and that hypothenar muscles originally unrelated to median nerve dysfunction are also affected in early CTS. These results suggest that modulation of muscles attached to the transverse carpal ligament is involved in the pathogenesis of CTS.

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Key words: carpal tunnel syndrome, root mean square, mean power frequency

Introduction

Carpal tunnel syndrome (CTS) is most the common entrapment neuropathy. Also called idiopathic CTS, it is, for reasons unknown, more common in females than in males. Synovitis of the flexor tendons running around the median nerve of

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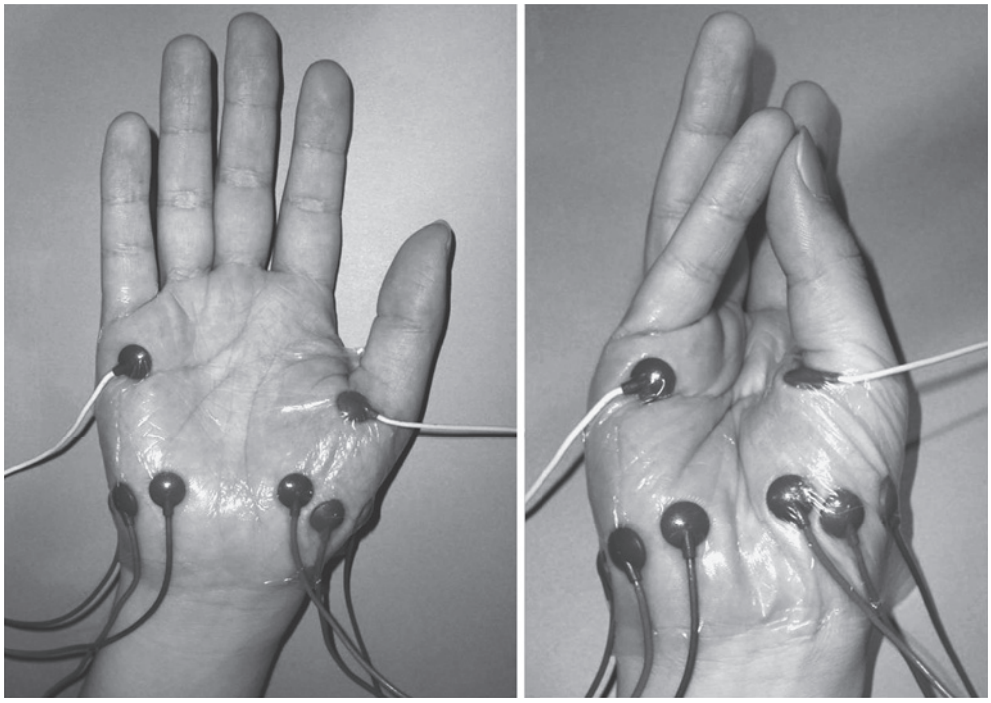

Fig. 1 A photograph of the electrodes placed on the thenar and hypothenar muscles (left). Electromyograms were acquired during 3 seconds of maximum voluntary contraction maintaining thumb-little finger opposition (right).

the wrist might develop, and, as the internal pressure of the carpal tunnel increases, chronic nerve compression occurs[1]. However, the mechanism of synovitis remains unclear. The state of the carpal tunnel in CTS has been extensively studied[2,3] but has not been clarified.

When the carpal tunnel area of patients with marked symptoms is palpated, the subcutaneous tissue is often stiff and lacks extensibility. These findings suggest decreased flexibility of the transverse carpal ligament supporting the carpal tunnel from the volar side. However, we have speculated that this decreased flexibility is not due to factors in the carpal tunnel but is associated with a decrease in the extensibility of the muscles attached to the transverse carpal ligament. To confirm this speculation, we performed an electrophysiological study of the activities of the muscles attached to this ligament.

Subjects and Methods

The subjects included patients with CTS whose symptoms were limited to sensory impairment, such as numbness and hypesthesia of the index and middle fingers innervated by the median nerve, and did not include motor dysfunction of the thumb. CTS generally begins with sensory impairment, and, subsequently, motor dysfunction develops. Because motor dysfunction is expected to markedly affect electrophysiological activities, the subjects of this study were limited to patients with early CTS. In addition, healthy adults without a history of finger numbness or hypesthesia were selected as control subjects. The subjects were 16 women with CTS (10 with unilateral symptoms and 6 with bilateral symptoms) aged 41 to 77 years (mean age, 59.1 years) and 7 control subjects (2 men and 5 women) aged 29 to 52 years (mean age, 36.4 years). All patients and control subjects gave informed consent before undergoing the clinical and electrophysiological examinations.

Round, silver surface electrodes (diameter, 1 cm) as different electrodes were placed on the venters of the thenar muscles (opponens pollicis [OP], abductor pollicis brevis [APB], and flexor pollicis brevis [FPB] muscles) and hypothenar muscles (opponens digiti minimi [OPM], flexor digiti minimi brevis [FDMB], and abductor digiti minimi [ADM] muscles), indifferent electrodes were placed in a belly-tendon

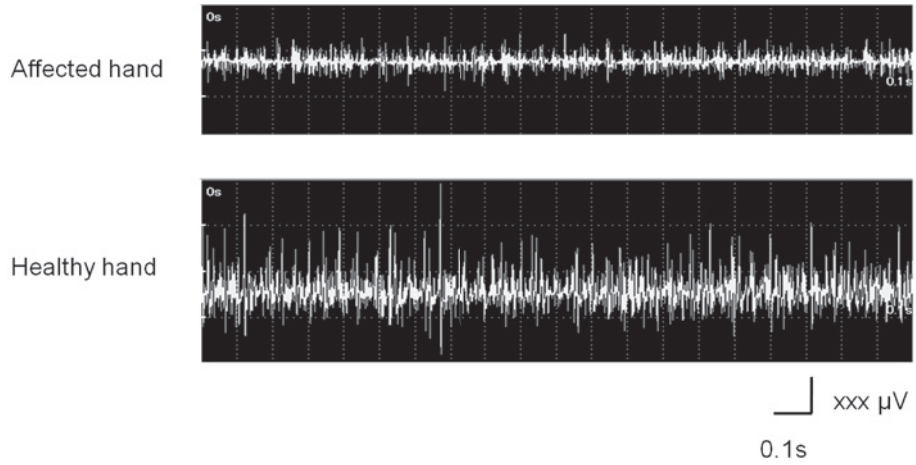

Fig. 2 Typical elctromyograms of the OP in a patient with CTS. The upper trace shows an electromyogram of an affected hand, and the lower trace shows an electromyogram of a healthy hand.

Table 1 RMS values in tested muscles

Muscles	Affected hands	Healthy hands
OP	292.8 (173.7)	405.9 (126.3)
APB	355.5 (155.1)	510.2 (161.2)
FPB	333.5 (126.1)	497.3 (135.3)
ODM	176.9 (111.7)	231.3 (115.9)
FDMB	171.4 (100.4)	230.0 (104.3)
ADM	177.7 (115.6)	227.9 (126.2)

n.s., *, *

mean (standard deviation) μV
*P<0.05

montage, and muscle activity potentials were recorded with the bipolar derivation method. The subjects maintained thumb-little finger opposition and performed maximum voluntary contraction for 3 seconds **(Fig. 1)**. The electromyograph used was the Neuropack 8 (Nihon Kohden Corp., Tokyo). The low-cut filter was set at 30 Hz, the high-cut filter at 3,000 Hz, and potentials were recorded at a sampling rate of 5,000 Hz **(Fig. 2)**. The obtained electromyographic waves were subjected to fast Fourier transform analysis using the frequency analysis program included with the electromyograph, and the effective value (root mean square [RMS]) and mean power frequency (MPF) were obtained.

Both hands were examined in all subjects. In the patients with unilateral CTS, the hand showing symptoms was regarded as the affected hand, and the other hand without symptoms was regarded as the healthy hand. In patients with bilateral CTS, both hands were regarded as affected hands. In the control group, both hands were regarded as healthy. Therefore, there were 22 affected hands (10 hands in 10 patients with unilateral CTS and 12 hands in 6 patients with bilateral CTS) and 24 healthy hands (10 hands without symptoms in 10 patients with unilateral CTS and 14 hands in 7 control subjects). The RMS and MPF were compared between affected and healthy hands, and statistical analysis was performed with the Mann-Whitney U-test.

Results

The RMS in affected hands was significantly less in the OP (405.9 μV) than in the FPB (497.3 μV) or APB (510.2 μV; **Table 1**), but in healthy hands no significant difference between the FPB and APB was observed. However, the RMS did not differ significantly between any pair of hypothenar muscles in healthy or affected hands **(Fig. 3, Table 1)**. The MPF did not differ among the thenar or hypothenar muscles **(Table 2)**.

These findings suggest that the characteristics of the OP may differ from those of the other 2 thenar muscles; on the other hand, the hypothenar muscles can be considered as a group for the comparison. Therefore, the OP was compared independently, and the APB and FPB were combined for comparisons in the following analyses.

The mean RMS in the OP was significantly lower in affected hands (292.8 μV) than in healthy hands

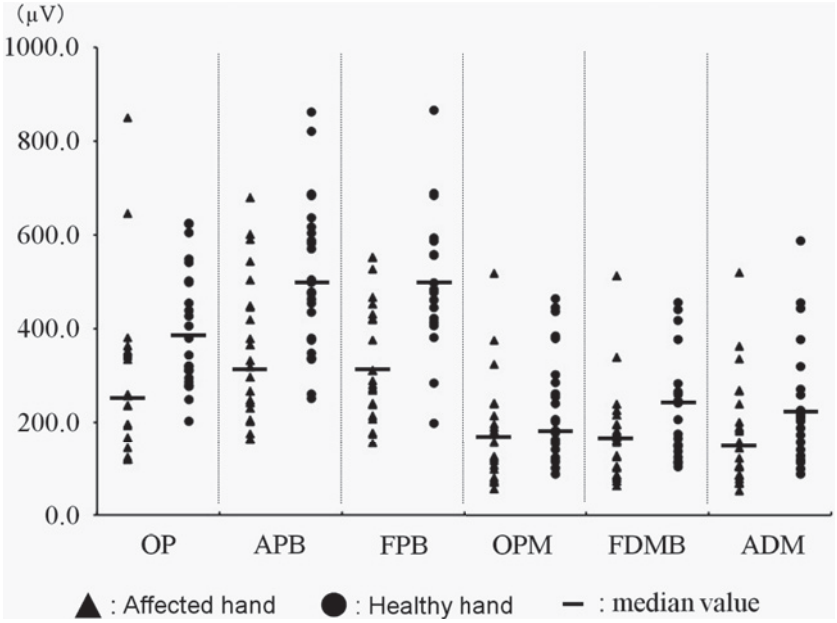

Fig. 3 Distribution of RMS values of each tested muscle. In each column that represents a tested muscle, the right plots show RMS values of an affected hand, and the left plots show RMS values of a healthy hand.

Table 2 MPF values in tested muscles

Muscles	Affected hands	Healthy hands
OP	201.6 (35.0)	187.3 (40.2)
APB	184.0 (27.9)	175.9 (35.8)
FPB	183.0 (21.7)	174.0 (29.4)
OPM	202.8 (51.0)	206.5 (42.5)
FDMB	203.4 (40.6)	204.9 (36.8)
ADM	204.4 (52.8)	211.9 (41.5)

(405.9 μV), but that in the APB and FPB did not differ significantly between affected hands (344.5 μV) and healthy hands (503.8 μV). The mean RMS in the hypothenar muscle group was significantly lower in affected hands (175.3 μV) than in healthy hands (229.7 μV; **Table 3**).

The mean MPF did not differ significantly between the thenar and hypothenar groups in affected hands or in healthy hands or between affected hands and healthy hands (**Table 4**).

Discussion

CTS is a representative entrapment neuropathy whose cause remains unclear. A suggested mechanism of symptom development is that synovitis of the flexor tendons running along the median nerve of the wrist is induced and increases the internal pressure of the carpal tunnel, which then causes chronic nerve compression. Therefore, pathological and biochemical evaluation of the carpal tunnel and evaluation of the nerve distribution of the transverse carpal ligament have been performed to clarify the cause of CTS[2–5]. Treatments for CTS include conservative treatment and, for severe CTS with motor dysfunction, carpal tunnel release. However, the persistent postoperative numbness and aggravation of palmar pain observed in some patients[6] suggest that decompression of the area around the median nerve does not, by itself, address the cause of CTS.

On the other hand, magnetic resonance in patients with CTS has shown volar bowing of the transverse carpal ligament[7–9] and has thus been considered a useful method for investigating the pathogenesis of CTS. The mechanism of bowing has been suggested to be a pushing-out phenomenon due to an increase in the internal pressure of the carpal tunnel. However, because the thenar and hypothenar muscles are attached to the transverse carpal ligament on the volar side of the carpal tunnel, an increase in the hardness of these muscles and their lifting of the transverse carpal ligament may also

Table 3 RMS values in affected hands and healthy hands

Muscle	Affected hands	Healthy hands	Difference between affected and healthy hands
OP	292.8 (173.7)	405.9 (126.3)	P<0.05
APB, FPB	344.5 (140.1)	503.8 (147.4)	Not significant
Hypothenars	175.3 (107.8)	229.7 (114.2)	P<0.05

Table 4 MPF values in affected hands and healthy hands

Muscle	Affected hands	Healthy hands	Difference between affected and healthy hands
OP	201.6 (35.0)	187.3 (40.2)	Not significant
APB, FPB	183.5 (24.7)	174.5 (32.4)	Not significant
Hypothenars	203.5 (47.7)	206.7 (39.9)	Not significant

induce bowing. We performed the present study with the belief that evaluation of muscle groups attached to the transverse carpal ligament, in addition to stiffness in the carpal tunnel area observed in patients with carpal tunnel syndrome, is important for clarifying the mechanism of CTS.

Evaluation of muscle activity potentials obtained from surface electrodes in the present study has shown that the RMS of both the OP and the hypothenar muscles was lower in affected hands than in healthy hands. Because all thenar muscles are innervated by the damaged median nerve, it is quite interesting that only the OP, and not the other 2 thenar muscles, showed a significant difference in the RMS between affected hands and healthy hands. Modulation of the hypothenar muscles originally unrelated to neuropathy is a surprising result. In contrast, the MPF, which is often used as a indicator of muscle fatigue[10,11], did not differ between affected hands and healthy hands. When neuropathy develops and affects innervated muscles, polyphasic potentials or long-lasting giant potentials are observed with needle electromyography, and the MPF is also considered to change. However, in the present study, patients without motor dysfunction performed only voluntary contraction for a short time. Therefore, the absence of changes in the MPF may be natural.

The relationship between the RMS and muscle hardness has also been studied. Gennisson et al. have reported that muscle hardness increases when the RMS increases during voluntary contraction of the biceps brachii muscle and that muscle hardness during voluntary contraction decreases when muscle hardness at rest is increased[12]. On the basis of these findings, we can speculate that the RMS decreases during the voluntary contraction of a muscle showing increased hardness at rest. Therefore, the decreased RMS in affected hands observed in the present study may have been due to the test muscle being harder in affected hands than in healthy hands. In patients with early CTS, such as the subjects of the present study, the hardness of the hypothenar muscles, as well as that of the OP, is increased and suggests changes outside the carpal tunnel.

Anatomical studies of the carpal tunnel have revealed flexibility on the central side of the carpal tunnel[13]. Sucher et al.[14–16] have reported that passive stretching of the transverse carpal ligament decreases the severity of symptoms, and they also observed the tension of the transverse carpal ligament due to thenar muscle contraction using ultrasonography. However, they did not address why the transverse carpal ligament becomes tense in patients with CTS. The results of the present study suggest that when muscle attachment sites harden owing to factors such as muscle fatigue and when the transverse carpal ligament is repeatedly subjected to contraction forces, hardening and shortening of the ligament itself may occur, and contraction of the thenar muscles may increase ligament tension and the internal pressure of the carpal tunnel. In the future, the developmental

mechanism of CTS should be further clarified through the observation of muscle attachment sites of the transverse carpal ligament using ultraprecise diagnostic imaging systems and the pathological evaluation of specimens obtained during carpal tunnel release.

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