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RADIOANATOMICAL OVERVIEW OF CARPAL TUNNEL SYNDROME

Bahar Soylu[1], Burak Gülcen[1,*], Bahar Yanik[2]
[1]Balikesir University, Faculty of Medicine, Department of Anatomy, Balıkesir, Turkey - [2]Balikesir University, Faculty of Medicine, Department of Radiology, Balikesir, Turkey

ABSTRACT

Introduction: *This study aims to investigate the Carpal Tunnel Syndrome (CTS) levels of the patients predi-agnosed with CTS by electromyography (EMG) by using the scanning model.*

Materials and methods: *The study included thirty-two wrists of 22 patients with positive elec-tromyography examination with a preliminary CTS diagnosis. Cases with previous trauma, sur-gery, steroid injection involving the wrist region, and cases who reported systemic diseases such as uncontrolled diabetes, gout, and kidney failure were excluded from the study. In the study, ultrasound measurements of the control and patient groups were compared.*

Results: *Of the 22 patients aged 31-71 included in our study, 4 (18%) were male, and 18 (82%) were female. The analysis of the research data revealed significant differences between the patient and control groups in terms of the mean area of the median nerve in the carpal tunnel, the mean anteroposterior diameter, mean transverse diameter, the anteroposterior diameter of the median nerve in the distal forearm, and the mean anteroposterior diameter ratio at the level of the carpal tunnel.*

Conclusion: *The ultrasonography measurements in patients diagnosed with CTS by clinical examination and electrodiagnostic examination are significant in terms of revealing the findings related to the damage of the median nerve and the anatomical differences.*

Keywords: *Carpal tunnel syndrome, median nerve, ultrasonography.*

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Introduction

Carpal Tunnel Syndrome (CTS), which was first described by Sir James Paget in 1854, develops due to the compression of the median nerve in the carpal tunnel and is the most common entrapment neuropathy. In addition to sensory deficits such as loss of sensation, tingling, numbness, and pain that occur in the area innervated by the median nerve as a result of the compression of the median nerve, which has the motor and sensory fibers, at the level of the carpal tunnel, motor deficits such as loss of muscle strength and muscle atrophy also develop [1, 2].

Entrapment neuropathies may occur either acutely or chronically. Pressure on the nerve can be acute, intermittent, repetitive, or continuous. Trap neuropathies may develop acutely when the nerve is compressed from the outside in places where it is superficial. A regional compression that lasts 2 to 12 hours may be sufficient to produce such an effect. In chronic compressions, the nerve is subject to continuous microtrauma and distortion as it passes through a fibrous or bony, anatomically narrow tunnel[3, 4]. Canalis carpi is a fibro-osseous tunnel bounded by fibrous structures on the palmar side and osseous structures on the dorsal side at the level of the wrist[5]. The borders of the canalis carpi, which provide the connection between the distal forearm and the deep palm, are proximally the distal skin wrist fold and distally the hamulus ossis hamati. The prevalence of CTS in the general population has been reported between 0.1% and 0.5% in the literature[6-8]. It has been reported that CTS is most common in the 30 to 50 age group and is 3 times more common in females than in males[6]. Additionally, it has been reported that the dominant hand is involved first, with symptoms occurring in both hands after a while[9].

Peripheral nerve compression may develop due to reasons such as pressure, strain, and friction. On the other hand, the presence of an underlying systemic disease or age factors may also predispose to the formation of compression[10]. In CTS, complaints related to motor and sensory disorders are seen in the wrist, hand, and fingers (1st, 2nd, and 3rd fingers and the radial half of 4th finger) innervated by the median nerve[3]. Symptoms related to the involvement of the sensory branches of the median nerve are observed in the early stage, whereas motor symptoms are observed in the advanced stage[11]. The diagnosis of CTS is a clinical diagnosis that is made based on the patient's medical history, physical examination, electrophysiological findings, and results of the special tests[11-13]. Electrophysiological examination is the most reliable diagnostic method in diagnosing CTS.

Ultrasonography (US) provides information on anatomical variations of the median nerve and surrounding structures that may be a causative factor in CTS. On US imaging at the wrist, the median nerve is easily visualized in transverse view as hypoechoic nerve fibres with hyperechoic rims immediately superficial to the flexor tendons, with the hyperechoic fleksor retinaculum overlying it within the carpal tunnel demonstrates the probe position for examination of the median nerve and US images of the median nerve in CTS[14].

Materials and methods

This research was designed as a survey study. The study population comprised the patients who applied to Orthopedics Clinic with complaints of numbness, tingling, and pain in hand between January 2012 and December 2014 and were prediagnosed with CTS by EMG. This study was approved by the ethics committee of the hospital, and all patients agreed to participate in this study. The individual agreed and signed an informed consent form. Only patients with idiopathic CTS were included in the patient group, whereas patients with previous trauma, surgery, and steroid injection involving the wrist region and cases with systemic diseases such as uncontrolled diabetes, gout, and kidney failure were excluded from the patient group. Consequentially, the patient group consisted of the 32 wrists of 22 idiopathic CTS patients. Of the 22 patients aged 31-71 included in the patient group, 4 (18%) were male, and 18 (82%) were female. Additionally, a control group was formed from the 25 wrists of the 25 individuals aged between 35-75 who did not have a known systemic disease or wrist trauma, no history of surgery and no symptoms related to the wrist. Of the 25 individuals included in the control group, 3 (12%) were male, and 22 (88%) were female.

The independent variables of the ultrasound measurements made on the median nerve in the carpal tunnel both in the control group and the patient group were the mean area of the median nerve, the mean anteroposterior diameter, and the mean transverse diameter in the distal section, the anteroposterior diameter of the median nerve in the distal forearm, and the mean ratio of the anterior-posterior diameter of the median nerve in the distal forearm and the ratio of the anterior-posterior diameter at the level of the carpal tunnel.

US examination was used as the data collection tool in the study. Before the US examination, the patients were placed on their backs, their wrists were placed in the neutral (supine) position, and support materials were used as necessary.

All examinations were performed on a Toshiba Aplio MX (SSA-780 Toshiba Medical Systems, Tokyo Japan) US instrument using a 6-15 MHz board band linear probe. The examination was started from the median nerve at the wrist level in the axial plane. Space-occupying lesions and variations such as bifid median nerve, ganglion cyst, etc., and fluid accumulation in the tendons adjacent to the nerve (tenosynovitis and tendinitis) that may cause compression on the median nerve of the wrist were sought, and 10 patients who were found to have these features were excluded from the study. The median nerve was followed along its trace from the distal 1/3 of the forearm to the most distal level, where it could be traced in the palm of the hand. After observing the nerve and its adjacent anatomical structures, the median nerve contours, the structure, and internal echogenicity thereof were examined along the trace. The median nerve was detected under the flexor retinaculum in the wrist, and the distal section of the carpal tunnel was used for measurements. Anteroposterior and transverse diameters and median nerve areas of the median nerve were measured at the determined level. In addition, the anterior-posterior diameter of the median nerve in the distal forearm was determined, and its ratio with the anterior-posterior diameter at the level of the carpal tunnel was calculated. Area measurements were made using the manual trace method available on the US device.

The hyperechoic sheath was excluded from the area measurements. In all measurements, "square millimeter (mm2)" and "millimeter (mm)" were used as the units to express the areas and lengths, respectively. Care was taken to make sure that the median nerve entered the examination plane exactly in the axial plane during the measurement. SPSS 23.0 (Statistical Package for Social Sciences for Windows version 23.0, Armonk, NY: IBM Corp., 2015) software package was used for the statistical analyses of the research data. The variables investigated in the study were expressed as numbers, mean ($\bar{x}$), standard deviation (sd), and/or percentage (%) values. In comparisons between the groups, the "Kolmogorov Smirnov" test was used to check whether the variables conformed to the normal distribution.The "Independent Samples T-Test" and the "Mann Whitney U Test" were used to determine whether there was a difference between groups.

The "Pearson's Correlation" test was used to assess the relationship between the variables. Probability values of ≤0.05 were deemed to indicate statistical significance.

Results

The US examination of the patients diagnosed with CTS by EMG revealed a hypoechoic appearance due to compression-related edema in the median nerve and loss of fine reticular echogenicities formed by the epineurium layers covering the outside of the neural fascicles that form the median nerve's structure. See Figure 1.

On the other hand, the US examination of the control subjects revealed a typical reticular echo pattern in the median nerve. In the measurements made in the control group, the mean area of the median nerve in the distal part of the carpal tunnel was found as 5.84±1.28 mm^2, the mean anteroposterior diameter was 1.68±0.30 mm, the mean transverse diameter was 5.03±0.85 mm, the anteroposterior diameter of the median nerve in the distal forearm was 1.75±0.31 mm, and the mean ratio of the anteriorposterior diameter of the median nerve in the distal forearm to the mean anteriorposterior diameter at the level of the carpal tunnel was 0.96±0.11 mm.

On the other hand, in the measurements made in the patient group, the mean area of the median nerve in the distal part of the carpal tunnel was found as 14.69±1,97 mm^2, the mean anteroposterior diameter was 3.02±0,76 mm, the mean transverse diameter was 6.68±1.97 mm, the anteroposterior diameter of the median nerve in the distal forearm was 2.04±0.25 mm, and the mean ratio of the anteriorposterior diameter of the median nerve in the distal forearm to the mean anteriorposterior diameter at the level of the carpal tunnel was 1.49±0.36 mm (Table 1).

A significant difference was found between the patient and the control groups in the mean area of the median nerve in the distal part of the carpal tunnel, the mean anteroposterior diameter, the mean transverse diameter, the anteriorposterior diameter of the median nerve in the distal forearm, the mean ratio of the anteriorposterior diameter of the median nerve in the distal forearm, and the mean ratio of the anteriorposterior diameter at the level of the carpal tunnel.

Figure 1: US image of the median nerve in the axial plane.

	Control			Patient			Difference
	n	x̄	±SD	n	x̄	±SD	(P)
Mnarea	25	5.84	1.28	32	14.69	1.97	8.85 (p<0.001)
Mnapd	25	1.68	0.3	32	3.02	0.76	1.34 (p<0.001)
Mntransd	25	1.75	0.31	32	2.04	0.25	0.29 (p<0.001)
Mnapdprox	25	5.03	0.85	32	6.68	1.97	1.65 (p<0.001)
Dist/prox	25	0.96	0.11	32	1.49	0.36	0.53 (p<0.001)

Table 1: Comparison of study groups (x̄±SD, Independent Samples T Test, Mann-Whitney U Test).

Note: Mnarea: median nerve area distal to the carpal tunnel, Mnapd: median nerve anteroposte-rior diameter distal to carpal tunnel, Mntransd: median nerve transverse diameter distal to carpal tunnel, Mnapdprox: median nerve anteroposterior diameter in the distal forearm, Dist/prox: the ratio of the mean anteroposterior diameter of the median nerve in the distal part of the carpal tunnel to the mean anteroposterior diameter of the median nerve in the distal forearm. SD: Standard deviation.

Discussion

CTS is the most common peripheral entrapment neuropathy caused by the compression of the median nerve in the carpal tunnel at the wrist level(15). The medical history and the physical and electrodiagnostic examination findings of the patient are usually sufficient for the diagnosis of CTS. The most important symptoms are paresthesia and pain(16). Burning sensation, pain, and numbness in the hand, which match the distribution of the median nerve (on the radial side of the 1st, 2nd, 3rd, and 4th finger), are typical. In addition, symptoms typically become more frequent at night and during sleep. In advanced cases, weakness and denervation of the thenar muscles are accompanied by secondary muscle atrophy(17). In this period, in addition to focal demyelination in the wrist, axonal degeneration is deemed to occur in the distal motor and sensory fibers(18). Depending on the degree of nerve compression and other factors, standard sensory examination findings may appear normal in 20% to 50% of the patients with CTS(9). CTS is more common in individuals over the age of 30 and in females. Eighteen (82%) of the 22 patients included in the patient group were female, and their ages ranged from 31 to 71. Thus, the demographic characteristics of the patient group included in this study matched the relevant data reported in the similar studies available in the literature(12).

Direct radiography can be used to visualize the carpal tunnel as it helps demonstrate transverse carpal ligament calcifications and carpal bone lesions. Additionally, computed tomography (CT) can be used to demonstrate carpal bone lesions in more detail. Carpal tunnel width and cross-sectional area measurements have been performed using CT in the past. CT is insufficient in revealing the etiology of CTS because of its limited soft-tissue resolution despite having a cross-sectional imaging feature(19, 20). Magnetic resonance imaging (MRI) is a much more superior imaging technique compared to other methods, as it can be used to identify both the median nerve and the adjacent soft tissue lesions, given its superior soft-tissue resolution(21, 22). However, its use is limited due to its high cost and limited accessibility.

Wong et al. emphasized that the decrease in median nerve echogenicity, the loss of the reticular appearance pattern observed in the median nerve, and nerve echogenicity are all subjective criteria that can be evaluated differently by different examiners(23). Accordingly, the decrease in nerve echogenicity and the loss of reticular pattern were not included among the diagnostic criteria in this study.

In most of the studies, it has been reported that the best sonographic data for the diagnosis of CTS is the increase in the cross-sectional area of the median nerve(2, 17, 23-26). In order for the nerves to function normally, their metabolic functions and the fluidity of the substance in the tube must be right. In the event of compression, the disruption of axoplasmic flow, endoneural edema, inflammation, demyelination, remyelination, and thereby, the perineural thickening, occur, causing the median nerve to swell as demonstrated by sonographic cross-sectional area measurements(27). In most of the studies conducted to date, it has been reported that the cross-sectional area of the median nerve increases at the level of the psiform bone, the flattening rate increases at the level of the hamatum notch, as well as the palmar arch of the flexor retinaculum and the swelling rate of the nerve in patients with CTS(28, 29).

According to Duncan et al., a cross-sectional area of the median nerve greater than 9 mm^2 is considered abnormal(30). On the other hand, according to Cobb et al., Snell et al., and Buchberger et al., a cross-sectional area of the median nerve greater than 6±10 mm^2 at the distal radioulnar joint level, greater than 6±11 mm^2 at the hamate bone level and greater than 10mm^2 at the capitatum bone level is considered abnormal(17, 31-33). According to Mohammadi et al., the cross-sectional area of the median nerve at the hamate bone level was measured as 9.9±1 mm^2 in patients with CTS and 4.5±0.8

mm^2 in healthy individuals, indicating a significant difference between the patient and control groups[34]. In the study conducted by Kim et al., the mean cross-sectional area of the median nerve in the distal carpal tunnel was found as 9.9±3.42 mm^2 in men and 8.46±1.84 mm^2 in women[35]. Additionally, Lu et al. found that the cross-sectional area of the median nerve in the transverse plane at the level of the hamate bone hook was higher in the patient group than in the control group[36]. According to Fu et al., the mean cross-sectional area of the median nerve at the level of the hamate bone hook in the transverse plane was 9.2±2.8 mm^2 in the patient group and 8.8±1.3 mm^2 in the control group[37]. In the study performed by Azman et al., the mean cross-sectional area of the median nerve at the level of the hamate bone hook in the transverse plane was measured as 15.4±5.37 mm2 in the patient group and 8.8±1.74 mm^2 in the control group[38]. According to Paliwal et al., a cross-sectional area of the median nerve in the transverse plane at the level of the hamate bone hook and the level of the trapezium bone hook greater than 11 mm^2 in patients with CTS are considered abnormal (39). Inui et al. measured the cross-sectional area of the median nerve at the level of the hamate bone hook as 12.4±5.9 mm^2 in patients with CTS[40]. In comparison, in this study, the mean median nerve area at the level of the hamate hook in the axial plane was measured as 14.69±1.97 mm^2 in the patient group and 5.84±1.28 mm^2 in the control group, indicating a statistically significant difference between the groups. These findings are consistent with the relevant findings reported in the literature.

One of the sonographic data in US studies performed in cases diagnosed with CTS is the mean transverse diameter. In a study, Köroğlu measured the median nerve transverse diameter at the level of the hamatum notch as 5.17±0.97 mm in patients with CTS and 4.55±0.40 mm in healthy individuals[5]. According to Duncan et al., the median nerve transverse diameter at the level of the hamatum notch as 6,90±1,3 mm in patients with CTS and 4.7±0.0 mm in healthy individuals[30]. In comparison, in this study, the mean transverse diameter was measured as 6.68±1.97mm in the patient group and 5.03±0.85mm in the control group, indicating a statistically significant difference between the groups.

Conclusion

In this study, the ratio of the anterior-posterior diameter of the median nerve in the distal forearm to the anterior-posterior diameter at the carpal tunnel level was measured in patients diagnosed with CTS by EMG. Accordingly, the mean anterior-posterior diameter of the median nerve in the distal forearm was found as 2.04±0.25 mm in the patient groupand 1.75±0.31 mm in the control group. The mean ratio of the anterior-posterior diameter of the median nerve in the distal forearm to the mean anterior-posterior diameter at the distal level of the carpal tunnel was 1.49±0.36 in the patient group and 0.96±0.11 in the control group, indicating a statistically significant difference between the groups.

In the US measurements made in the distal part of the carpal tunnel in both the patient and control groups, the anteroposterior and transverse diameters of the median nerve, median nerve areas, the anteroposterior diameter of the median nerve in the distal forearm, and the ratio of the anterior-posterior diameter at the level of the carpal tunnel were measured. The findings obtained in our study were found to be statistically significant in accordance with the literature.

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Corresponding Author:
Burak Gülcen
Balıkesir University, Faculty of Medicine, Department of Anatomy, Çağış Campus, Bigadiç 17.km. Balıkesir/Turkey
Email: guotianming2208@163.com
(Turkey)