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The Changes of the Sectional Surface Area Of The Median Nerve Compartment In Hands With Symptomatic Carpal Tunnel Syndrome And Normal Hands

Cengiz ÇOKLUK
Kerametttin AYDIN
Ömer İYİGÜN
Cemil RAKUNT
Fahrettin ÇELİK

Ondokuz Mayıs University, Medical Faculty Samsun, Turkey

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Correspondence address:
Cengiz ÇOKLUK
Ondokuzmayıs Üniversitesi Tıp Fakültesi, Nöroşirürji Anabilim Dalı, Samsun, Türkey

ABSTRACT

OBJECTIVE: The aim of this study was to describe subjective and objective criteria for ultrasonographic diagnosis of the carpal tunnel syndrome (CTS).

METHODS: The study population consisted of 165 hands of 114 cases with idiopathic CTS while the remaining 291 hands were asymptomatic. All hands were examined by using an ultrasound scanner with a 5-75 MHz linear transducer. All hands were examined for subjective and objective findings of CTS. To facilitate objective estimation, the carpal tunnel was divided into two anatomical compartments as the median nerve compartment (MNC) and the compartment of flexor digitorum tendons (FDTC). ?

RESULTS: In the hands with idiopathic CTS, it was estimated that the entrapped median nerve made up 85% of MNC. The ratio of MNC to FDTC was found to be 0.07 ± 0.02. In normal hands, the median nerve made up 33% of MNC. The ratio of MNC FDTC was 0.23 ± 0.03. In idiopathic CTS the mean cross-sectional surface area of the whole tunnel decreased at a rate of 20% in comparison with normal hands. The decreasing ratio of MNC was 71% at the level of the hook of the hamate. The cross-sectional surface area of the median nerve only lost its caliber at a rate of 24% in comparison with normal hands. The cross-sectional surface area of MNC and FDTC tendons seems to be a sensitive finding for the neuroradiological diagnosing of idiopathic CTS. ?

CONCLUSION: In conclusion, this study revealed that ultrasonographic neuroexamination may be used for the neuroradiological diagnosis of idiopathic CTS.

KEY WORDS: Median nerve, carpal tunnel syndrome, entrapment neuropathy, ultrasonography, ultrasonographic neuroexamination.

INTRODUCTION

Entrapment of the median nerve between the transverse carpal ligament and the flexor tendons at the wrist is named carpal tunnel syndrome (CTS). It is the most common entrapment neuropathy encountered in clinical practice. The median nerve originates from the brachial plexus, travels down the arm and enters the forearm between the two heads of the pronator teres. In the wrist, the median nerve lies deep to the palmaris longus and slightly to its ulnar side. It passes through the flexor retinaculum tunnel lying closer to the transverse carpal ligament than the flexor tendons of the hand. The median nerve divides into its terminal motor and sensory branches when leaving the flexor retinaculum. Carpal tunnel syndrome usually occurs in patients between 36 and 60 years old and is two to five times more common in women. It affects 1% of the general population but is more frequently seen in persons whose work requires repetitive wrist motion (1, 2, 3, 4). The diagnosis can be basically made from the history, physical examination, electromyographic studies and nerve conduction velocities (1, 5, 6).

There are two significant factors in the pathogenesis of CTS: ischemia and direct pressure. The transverse carpal ligament is responsible for producing direct pressure and mechanical compression to the median nerve within the tunnel. These effects can change the caliber of the nerve. The pathophysiological changes following mechanical compression of the nerve depend upon two factors: the degree and duration of compression. The median nerve entrapment neuropathy may be basically graded into two forms according to the severity of these two factors. In the mild form, there are no major structural changes in the nerve but the axoplasmic flow is interrupted because of extrinsic pressure. In the severe form, segmental demyelization may occur in the compressed segment. Ischemia appears to be another significant factor in the pathogenesis of median nerve entrapment neuropathy. It is a result of impediment to the microvascular blood flow. Swelling of the median nerve within the tunnel may lead to further compression. Ultrasonography evaluation of the musculoskeletal system is used for the diagnosis of many disorders. Examination of the median nerve within the tunnel is a simple example of this use (7, 8, 9, 10). Median nerve enlargement immediately proximal to the carpal tunnel and bowing of the flexor retinaculum has been described as sonographic findings in patients with CTS.

This clinical study was conducted to describe subjective findings and to estimate objective criteria for the neuroradiological diagnosis of idiopathic CTS by using real-time ultrasonography.

PATIENTS AND METHODS

The study population consisted of 228 females aged between 34 and 55 years old. The hands were divided into two groups according to the presence or absence of carpal tunnel syndrome. Group I included the hands with median nerve entrapment neuropathy at the wrist. The diagnosis of CTS in these patients was made using the patient's history, physical examination, the results of electromyographic studies and nerve conduction velocities. The following electrodiagnostic criteria qualified for the diagnosis of CTS: median digit II and ulnar digit V sensory latency difference greater than 0.5 ms, median sensory velocity less than 40 ms, median distal motor latency greater than 4.0 ms. Normal hands were included in Group II. They did not have any symptom attributed to the median nerve entrapment neuropathy at the wrist.

Ultrasonography Technique:

All hands were examined with a Tosbee ultrasound scanner (Tosbee Toshiba Inc. Japan). A 5-75 MHz linear transducer was used. Before the examination, the tip and surrounding area of the transducer head were plastered with sterile gel to maximize sonographic images. The tip of the transducer was touched gently to the palmar surface of the hand and moved in the superior to inferior direction in the axial and longitudinal planes. The distal flexion crease was accepted as the surface landmark for the entrance area of the median nerve to the tunnel. The line drawn to the distal end of the fully extended thumb was accepted as the inferior border of the transverse carpal ligament. The line drawn between these two landmarks was accepted as the level of the hook of the hamate. Ultrasonographic axial images were obtained at two different levels for stereological estimation. The first level was the tunnel segment of the median nerve at the midlevel between the line of the distal flexion crease and the line with the distal border of the fully extended thumb. The second level was the segment just before the median nerve entered the tunnel. This level is located just superior to the distal flexion crease. Longitudinal images were obtained at the line running from the midpoint of the distal flexion crease to the midpoint between the III and IV fingers. Selected images were paused on the monitor screen and printed on paper.

Compartmentalization of the Carpal Tunnel:

The carpal tunnel was divided into two anatomical compartments according to the contents and their localization within the tunnel. The first compartment was named the median nerve compartment and included the median nerve blood vessels and perineural fat tissue. This compartment was located just under the transverse carpal ligament. The embryologic origin of median nerve within this compartment is ectoderm. The second was named the compartment of flexor digitorum tendons and included the flexor tendons of the digits and their vagina tendinea. This compartment was located under the median nerve compartment. The embryologic origin of its content (flexor digitorum tendons with their vagina tendinea) is mesoderm. The aim of this division was to facilitate the objective estimation of the carpal tunnel and its contents in terms of neuroradiological definition of idiopathic CTS.

The anatomical borders of these compartments were as follows: The transverse carpal ligament was the roof of the median nerve compartment. The lateral and medial borders of the compartment were created by the carpal bones. Vagina communis tendinum musculorum flexorum and vagina tendinis musculi flexum pollicis longi were located on the floor of the median nerve compartment. The floor and lateral and medial border of the compartment of the flexor digitorum tendons were created by the rigid carpal bones. The roof of the compartment was restricted by the connective membrane of the median nerve compartment.

Estimation of Cross-Sectional Surface Area of the Median Nerve:

We used the sonographic (Tosbee Toshiba Inc. Tokyo) area estimation tool in the calculation of cross-sectional surface areas of the wrist.

Statistical Analysis:

Student's t-test was used for statistical analysis. Statistical significance was established at a p value < 0.05.

RESULTS

This study included 228 females ranging in age from 34 to 55 years. One hundred and sixty-five hands of 114 cases had idiopathic CTS and the remaining 291 hands were asymptomatic.

General Sonographic Findings in Normal Individuals:

Skin and subcutaneous tissues were seen as relatively hypoechogenic in comparison with the transverse carpal ligament. The transverse carpal ligament, median nerve, flexor digitorum tendons and carpal bones had a specific appearance on ultrasonographic examination of the hand. The transverse carpal ligament was seen as a hyperechogenic area. The middle part of the ligament was more hyperechogenic than other parts of the ligament. The bony structure of the hands was hypoechogenic. The area between the carpal bones and the transverse carpal ligament (carpal tunnel) was practically divided into two different compartments by their contents as MNC and FDTC. Abnormal states constricting the MNC may lead to over-pressure to the median nerve, resulting in CTS. The shape of MNC was ellipsoid. The lateral and medial edge was seen as a triangular shape. The opening of the angular corners was towards the median nerve. The superior and inferior borders were straight. The tendons of digits were seen as hyperechogenic ellipsoid structures as four superior and four inferior separate studs. The spaces among these tendons appeared hypoechogenic. The median nerve had a characteristic appearance that differentiated it from the fibrillary hyperechogenic tendons. The nerve was hypoechogenic with a hyperechogenic border and showed multiple bright reflections in the transverse imaging plane. The median nerve was round/oval in the proximal wrist and flattened progressively as it coursed through the carpal tunnel.

General ultrasonographic findings in idiopathic CTS:

In normal hands, the mean cross-sectional surface area of the carpal tunnel was 145.6 ± 9.2 mm^2 (ranging between 130-171 mm2) at the midlevel of the tunnel. The sectional surface area of MNC within the carpal tunnel was estimated as 27.2 ± 3.5 mm^2 (ranging between 23-39 mm2) at the level of the hook of the hamate. The area of the median nerve only was 8.8 ± 1.2 mm^2 (ranging between 6-10 mm^2) in its compartment. It was found that the median nerve made up 33% of the compartment, ranging between 26% and 43% in this group. The nerve area was 11.11 ± 1.6 mm^2 at the level proximal to the distal flexion crease before it entered the tunnel. According to our estimation, the cross-sectional surface area of the median nerve in the midlevel of the tunnel was 21% smaller than the calibration of the nerve before it entered the tunnel. It was calculated that FDTC was 118.2 ± 8.7 mm^2 at the same level. It was estimated that MNC made up 19% of the tunnel while FDTC made up the remaining 81%. The mean ratio of MNC to FDTC was 0.23 ± 0.03 (ranging between 0.17 and 0.31) in normal hands.

In hands with idiopathic CTS, the mean cross-sectional surface area of the tunnel was 117.4 ± 7.3

mm^2 (ranging between 105 and 141 mm^2) at the level of the hook of the hamate (at the midlevel of the tunnel). Sectional surface area of MNC was 7.9 ± 2.4 mm^2 (ranging between 5 and 11 mm2) at the midlevel of the tunnel. The area of the median nerve only was 6.7 ± 1.2 mm^2 (ranging between 4 and 9 mm^2) within its compartment. It was estimated that the compressed median nerve made up 84% of the compartment, ranging between 56% and 100% in this group. The mean cross-sectional surface area of the nerve was estimated as 12.66 ± 0.86 mm^2 before it entered the tunnel. According to our estimation, the cross-sectional surface area of the median nerve in the middle part of the tunnel was 47% smaller than the proximal part of the nerve. FDTC was 108.9 ± 6.8 mm^2 at the same level. It was estimated that MNC made up 6.8% of the whole tunnel in this group while FDTC made up the remaining 93.2%. The mean ratio of MNC to FDTC was 0.07 ± 0.02 (ranging between 0.04 and 0.11). The sectional surface area of MNC in hands with idiopathic CTS was smaller than those of normal hands at a ratio of 71%. A statistically significant difference was noted between the two groups in all of the parameters.

The evaluation parameters and estimations are shown in (Table I).

DISCUSSION

The diagnosis of median nerve entrapment in the carpal tunnel can be done basically from the history, physical examination, electromyographic studies and nerve conduction velocities (1, 5). The concept of neuroradiological investigation for idiopathic CTS include CT, MRI and ultrasonographic examination of the wrist (1, 3, 5, 9, 10). Ultrasonographic neuroexamination has been used for the diagnosis of the peripheral nerve lesions such as entrapment neuropathy and nerve palsy after bone fractures and postoperative peripheral nerve lesions (7, 8, 9, 10, 11 12). It has also been used during the surgical repair of peripheral nerve injury to describe and localize the lesions (13). Ultrasonography seems to be a reliable, simple, cheap, safe, practical and readily available neuroradiological diagnostic tool to examine the content of the carpal tunnel and diagnose median nerve entrapment neuropathy. The main disadvantage of this method is the possibility of it being influenced by the examiner's ability and technique. We hypothesized that ultrasonographic neuroexamination of the wrist may be used to obtain specific subjective and objective criteria and findings in the diagnosis of idiopathic CTS. In previously published articles, it has been reported that ultrasonographic findings in CTS included flattening of the nerve especially at the level of the hamate bone, volar bulging of the flexor retinaculum, enlargement of the median nerve as it enters the carpal tunnel and decreased mobility of the median nerve on flexion and extension of the fingers, hand and wrist. In addition to these subjective criteria it was noted that the objective criteria for idiopathic CTS included the mean cross-sectional area of the median nerve greater than 10 mm squared at the pisiform bone level, the flattening ratio of the nerve (transverse diameter divided by AP diameter)

Table I. The evaluation parameters and estimations in normal and idiopatic CTS.

Evaluation parameters	*Normal hands (n = 291)*	*Hands with idiopatic CTS (n = 165)*
Cross-sectional surface area of whole carpal tunnel (Mid-tunnel) (mm^2)	145.6 ± 9.2	*117.4 ± 7.3
Cross-sectional surface area of MNC (Mid-tunnel) (mm^2)	27.1 ± 3.2	*7.9 ± 2.4
Cross-sectional surface area of the median nerve (Mid-tunnel) (mm^2)	8.8 ± 1.2	*6.6 ± 1.2
Cross sectional surface area of the median nerve (Before entering the tunnel) (mm^2)	11.1 ± 1.6	**12.6 ± 0.8
Cross sectional surface area of FDTC (Mid-tunnel) (mm^2)	118.2 ± 8.7	*108.9 ± 6.8
The percentage filled by the median nerve in the MNC (Mid-tunnel)	33%	*85%
MNC/FDTC	0.23 ± 0.03	*0.07 ± 0.02

greater than 41 at the level of the hamate bone and volar bulging of the flexor retinaculum greater than 31 mm (5, 8, 9, 10, 11, 12). To make clear the neuroradiological diagnosis of idiopathic CTS it is necessary to estimate some anatomical parts of the carpal tunnel. In this clinical study we used 6 objective parameters to estimate the changes in patients with idiopathic CTS. These parameters included the cross-sectional surface area of MNC, the median nerve FDTC and whole carpal tunnel and the mass of median nerve within its compartment together with the ratio of MNC to FDTC. Mean cross-sectional surface area of the carpal tunnel in cases with idiopathic CTS decreased at a ratio of 20% in comparison with normal asymptomatic individuals. Our data revealed that the cross-sectional surface area of MNC at the level of the hook of the hamate lost 71% of its calibration in patients with idiopathic CTS. The decreasing of the sectional surface area of FDTC was very small. It was found to be 8% in comparison with normal individuals. Stenosis was mainly seen in MNC. In the other hand the calibration of FDTC does not mainly derive from the disease in idiopathic CTS. The cross-sectional surface area of the median nerve decreased at a ratio of 24% in idiopathic CTS. In the control group it was found that the median nerve did not cover all the tunnel and only filled 19% of it. Although median nerve caliber decreases in idiopathic CTS, 84% of the tunnel was filled by the compressed median nerve. The ratio of MNC to FDTC was 0.23 ± 0.03 in normal individuals and 0.07 ± 0.02 in the case with idiopathic CTS. Our study revealed that subjective findings for idiopathic CTS include enlargement of the median nerve caliber before it enters to the tunnel, flattening and compression of the nerve at the level of the hook of the hamate bone, increasing of the volume and volar bulging of the flexor retinaculum and more hyperechogenic appearance of the flexor retinaculum and the median nerve in the sonographic images.

In this study we described six objective findings for the ultrasonographic diagnosis of idiopathic CTS. Five of these showed specific changes in idiopathic CTS in comparison with normal individuals. These findings include decreasing of the cross-sectional surface area of the carpal tunnel (ranging between 105-141 mm^2, mean area 117. 4 ± 7. 3 mm^2), decreasing of the cross-sectional surface area

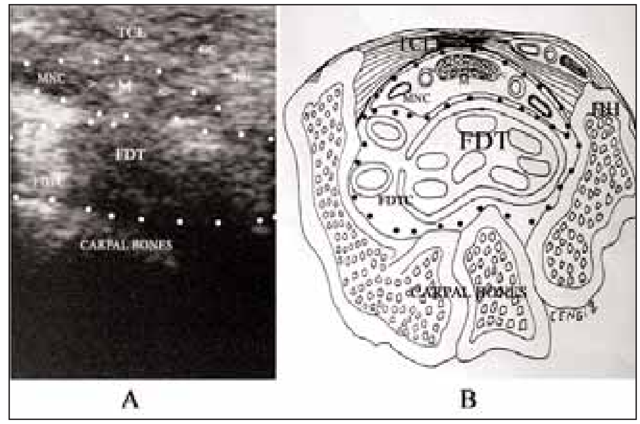

Figure 1: A. Ultrasonographic appearance of carpal tunnel in a normal subject (TCL: Transverse carpal ligament, GC: Guyon canal, HH: Hook of the hamate, MNC: Median nerve compartment, FTD: Flexor digitorum tendons, FDTC: Flexor digitorum tendons compartment, d

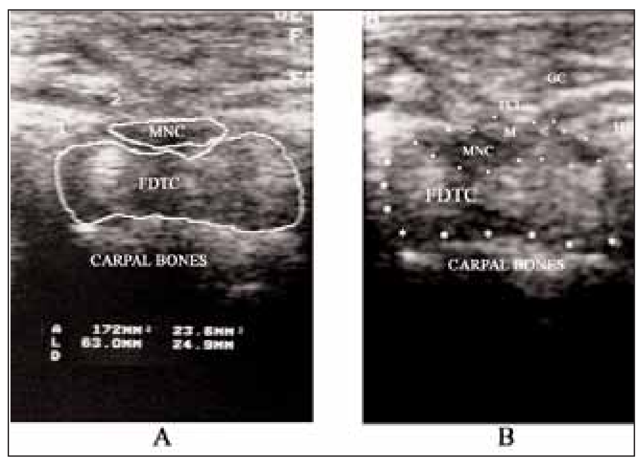

Figure 2: A. Estimation of sectional surface area of MNC and FDTC by using ultrasonography in a normal subject (MNC: Median nerve compartment, FDTC: Flexor digitorum tendons compartment). **B.** Normal ultrasonographic anatomy was shown in a normal subject.

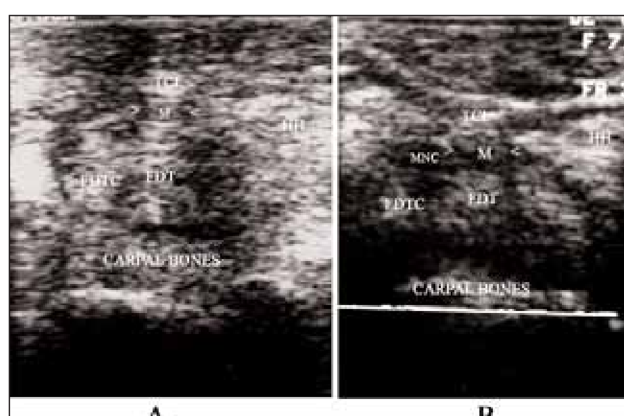

Figure 3: A. Ultrasonographic appearance of carpal tunnel contents in a CTS case (TCL: Transverse carpal ligament, HH: Hook of the hamate, MNC: Median nerve compartment, M: Median nerve, FTD: Flexor digitorum tendons, FDTC: Flexor digitorum tendons compartment.

of MNC (ranging between 5-14 mm^2, mean area 7, 9 ± 2, 4 mm^2) and the median nerve (at the level of the hook of the hamate, ranging between 4-9 mm^2 and mean area 6.6 ± 1.2 and at the level before its entering to the tunnel ranging between 12-14 mm^2 and mean area 12.6 ± 0.8 mm^2), increasing of the median nerve filling of the compartment (ranging between 56-100%, mean 85%) and decreasing of the ratio of MNC to FDTC (range 0.04 -0.11, mean 0.07 ± 0.02). According to our data from this study, the ratio of the cross-sectional surface area of MNC to the cross-sectional surface area of FDTC seem to be a sensitive criteria in the neuroradiological diagnosing of idiopathic CTS. In normal individuals this value ranged between 0.17 and 0.31 (mean 0.23 ± 0.03) but in cases with idiopathic CTS this value ranged between 0.04 and 0.11 (mean 0.07 ± 0.02). The percentage the median nerve occupies in the MNC is also another important finding to diagnose an idiopathic CTS by ultrasonographic neuroexamination. In normal individuals, 26-43% of the compartment was made up by the median nerve. The remaining part of the compartment (57-74%) was a potential space filled by fat and other connective tissues. In the sonographic examination, this area was seen as a hypoechogenic area located around the nerve. This space biomechanically facilitates mobilization of the nerve during hand movement and grasping of objects. In cases with idiopathic CTS, 56-100% of the compartment was made up by the median nerve. For ultrasonographic diagnosis of idiopathic CTS, the ratio of the cross-sectional surface area of MNC to the cross-sectional surface area of FDTC should be less than 0.11. In the same hand, the median nerve should make up more than 56% of MNC.

CONCLUSION

This study revealed that ultrasonographic neuroexamination may be used for the neuroradiological diagnosis of idiopathic median nerve entrapment neuropathy at the wrist in a physical medicine and rehabilitation practice. In the first stage, symptomatic cases should be examined for subjective criteria such as enlargement of the median nerve caliber before it enters the tunnel, flattening and compression of the nerve at the level of the hook of the hamate, increase in the volume and volar bulging of the flexor retinaculum and more hyperechogenic appearance of the flexor retinaculum and the median nerve. In the second stage, cases having subjective findings should be evaluated for objective criteria.

The ratio of the cross-sectional surface area of MNC to the cross-sectional surface area of FDTC is an especially important finding. This ratio should be less than 0.11 in idiopathic CTS. This finding should supported by the median nerve filling in a higher percentage of the MNC. The median nerve should make up more than 56% of MNC in idiopathic CTS. The cross-sectional surface area of the median nerve compartment, median nerve only, FDTC and the whole carpal tunnel should be estimated in the examined hands.

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