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DIAGNOSTIC VALUES OF ULTRASOUND MEASUREMENTS OF THE MEDIAN NERVE IN PATIENTS WITH CARPAL TUNNEL SYNDROME

Grujoska-Veta Dushanka,[1] Dzoleva –Toleska R, [1] Velkovski V[1], Osmani B,[2] Guchev F,[2] Bogdanska J [3]

[1]PHI University Clinic for Traumatology, Orthopedic Diseases, Anesthesiology, Reanimation and Intensive Care Medicine and Emergency Department, Clinical Center „Mother Theresa", Skopje, RNM, University Clinic for Orthopedic Diseases -Skopje

[2]University clinic of rheumatology- Skopje, Clinical Center "Mother Theresa", Skopje, RNM

[3]Institute of Medical and Experimental Biochemistry, Faculty of Medicine in Skopje, University „Ss. Cyril and Methodius" Skopje, RN Macedonia

Abstract

Carpal tunnel syndrome (CTS) is the most common peripheral neuropathy of the upper extremity, caused by chronic compression of the median nerve in the area of the carpal tunnel with prevalence in females. The diagnosis is based on characteristic symptoms and signs, clinical findings, electroneuromyographic examination (ENMG) and diagnostic imaging.

The aim of our study is to determine the role of ultrasound examination (US) of the median nerve in patients with CTS.

A prospective clinical study included 116 patients with clinical diagnosis of CTS and positive findings of ENMG examination who were admitted for surgical procedure of open carpal tunnel release. US examination of carpal tunnel and the median nerve were done in all patients on transverse and longitudinal axis of wrists.

Measurements of the cross-sectional area (CSA) of the median nerve at inlet level revealed various grades of severity: mild, moderate and severe with CSA values of 10,9 -12,1 mm^2; 12,2 -15,3 mm^2 ;15,9-20,3mm^2 respectively. Correlation of severity grading of US measurements and ENMG findings was positive and statistically significant ($p=0.000003$, $p=0.00006$, and $p<0.0001$).

Neuromuscular ultrasound examination provides valuable information on morphology of carpal tunnel content and possible etiology of CTS. Although dynamic imaging is used during US examination, measurements are done only on static scanning. It is used as additional tool in clinical practice of orthopedic surgeons and is very useful in early diagnosis, treatment planning and outcome follow-up.

Keywords: carpal tunnel syndrome, ultrasound measurements, severity grading

Introduction

Carpal tunnel syndrome (CTS) is one of the most common peripheral neuropathies caused by chronic compression of the median nerve in the area of the carpal tunnel. The diagnosis of the syndrome is mainly based on the history of the disease, clinical findings, positive findings of provocative tests and electroneuromyographic examination (ENMG) of the median nerve [1-3]. False-negative results of ENMG studies might vary from 10-20% [4].

With the technological advancement of visualization methods and equipment, ultrasonography and magnetic resonance imaging were introduced as additional diagnostic tests for carpal tunnel syndrome 20 years ago. Fornage first described peripheral nerves including the median nerve by ultrasound examination in 1989. [5,6].

Later in 1992, Buchberger et al. reported on US parameters for the diagnosis of CTS with comparable accuracy with MRI. [7] Those parameters are increased flattening ratio of the median nerve

measured at the level of the hamate, increased cross sectional area (CSA) at the level of the pisiforme bone, significantly increased CSA at the level of the pisiforme bone compared with CSA at the level of the distal radius and significant bowing of the flexor retinaculum. Since then, many researchers agreed that enlargement of the median nerve presented as increased cross-sectional area (CSA) at the level of scaphoid-pisiforme bone –inlet of carpal tunnel, has optimal diagnostic accuracy [8].

Other diagnostic parameters and methods for the existence of the syndrome are: increased volume of the median nerve before the entrance and after the exit from the tunnel with the so-called "Notch sign" and "inverted Notch sign", hourglass sign, flattening of the median nerve and increased intra neural vascularity. From the data in the literature, values of 4-9 mm^2 of CSA of median nerve at the scaphoid-pisiforme level are found in healthy individuals, and values from 9-15mm^2 of CSA are diagnostic for CTS [9].

Many different methods are used to improve measuring accuracy for diagnosis of CTS compared to ENMG testing as current reference standard, but the most appropriate median nerve CSA cutoff value is not yet determined [10-12].

Neuromuscular ultrasound examination (US) provides valuable information on morphology of carpal tunnel content and possible etiology of CTS. It is used as additional tool in clinical practice and research studies by orthopedic surgeons, rheumatologist, neurologist and others dealing with musculoskeletal system [13].

Aim: The aim of our study is to determine the role of ultrasound measurements of the median nerve in patients with CTS

Material and methods

Our study is a prospective clinical study conducted at the University Clinic for Traumatology, Orthopedic Diseases, Anesthesiology, Reanimation and Intensive Care Medicine and Emergency Department, Clinical Center Mother Theresa, Skopje, RNM, during a 3-year period. One hundred and sixteen patients included in the study were with clinical diagnosis of CTS and positive findings of ENMG examination and were admitted for surgical procedure of open carpal tunnel release (CTR), at the University Clinic for Orthopedic Diseases in Skopje. Preoperative ultrasound examination of the median nerves was done in all patients at least 7 days prior to surgery.

Medical history of the disease and previous injuries and treatments were recorded. Findings of patient's physical examination of hands (muscle strength, range of motions of wrist and metacarpophalangeal joints), signs of thenar hypotrophy as well as findings of provocative tests (Phalen, Durkan and hand elevation test) were noted.

All patients were asked to fulfill questionnaires concerning their perception of his/her symptoms and hand function, dominant hand, level of education, profession, weight, height, cigarette smoking, consumption of alcohol and associated diseases. Weight and height were measured in all CTS patients and healthy individuals in order to calculate their body mass index (BMI).

CTS severity was classified on the basis of ENMG reports according to the Canterbury Severity Scale [14]. According to this scale, grades are: normal (grade 0); very mild (grade 1), mild (grade 2), moderate (grade 3), severe (grade 4), very severe (grade 5) and extremely severe (grade 6).

Inclusion criteria for the group of participants:

- persons aged 25-75 years
- anamnestic data on tingling and/or pain in the thumb, second, third and radial part of the fourth finger, nocturnal paresthesia, clumsiness with the fingers of the affected hand
- positive provocative tests
- confirmed diagnosis of CTS by ENMG

Exclusion criteria for the group of participants:

- persons under 25 years of age and older than 75 years
- pregnant women
- people with reduced cognitive abilities
- detainees and prisoners
- previous hand surgery
- soft-tissue injuries or fractures of the bones of the forearm and wrist
- polyneuropathy, hereditary neuropathy

Control group consisted of 54 healthy individuals (HI), 39 female, 15 male, mean age 54 years. Inclusion criteria: without symptoms and signs for CTS, negative provocative tests and the same exclusion criteria. Control participants were recruited from the hospital staff, accompanying persons of patients or patients who were screened for osteoporosis. ENMG examination was not done in control group.

Ultrasound examination (US) was performed by senior orthopedic surgeon, with experience of more than 20 years in ultrasound examination of musculoskeletal system. A real–time machine SONOLINE Versa Pro Ultrasound Imaging System (Siemens AG, Erlangen, Germany) equipped with a 7, 5 MHz linear array transducer or Esaote MyLab 9 (Italy) were used.

Patients were sitting during examination with their forearms in a supinated position on a table facing the examiner. Wrists were in neutral position and the fingers in semi-extended position. Care was taken to avoid applying additional forces on the transducer to prevent further nerve deformation.

The standardized protocol for median nerve examination in distal forearm and carpal tunnel included scanning in both transverse and longitudinal planes. The volar wrist crease was used as an initial external reference point. The transducer was placed perpendicular to the nerve under examination using a transverse scanning technique.

On transverse plane, cross sectional area (CSA inlet) of the median nerve was measured at the entrance (inlet) of the carpal tunnel (proximal margin of flexor retinaculum between the pisiforme bone and scaphoid tubercule). The median nerve was identified as an oval structure surrounded by the hyperechoic epineurium at the pisiform level of the carpal tunnel, lying inferior to the flexor retinaculum (thin hyperechoic line). The flexor pollicis longus tendon, the 4 flexor digitorum superficialis tendons and the 4 flexor digitorum profundus tendons are situated in carpal tunnel with the median nerve above the flexor tendons of the index and middle finger.

Measurements were taken at the inner border of the hyperechoic rim of the nerve by direct tracing as seen on Figure 1. As seen on figure 2, on longitudinal plane, the median nerve was visualized as darker, hypoechoic linear structure bordered by a thin hyperechoic rim (epineurium). Anteroposterior diameter of the median nerve was measured at the inlet level (where the nerve was largest) and in the carpal tunnel where the nerve was flattened. The flexor tendons were visualized as brighter, hyperechoic linear structures with fibrillar pattern just below the median nerve **(**Figure 1 and Figure 2).

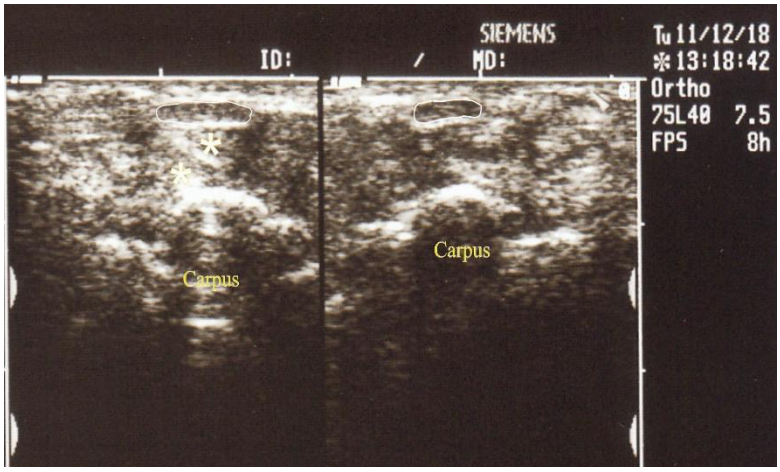

Figure 1. Transverse ultrasound image of the median nerve (outlined) in healthy individual at inlet level; left side on sonogram: CSA right: 6,42mm^2; right side on sonogram CSA left: 5,3mm$^{2.}$ Normal "honeycomb" appearance of the median nerve. The flexor tendons were normal

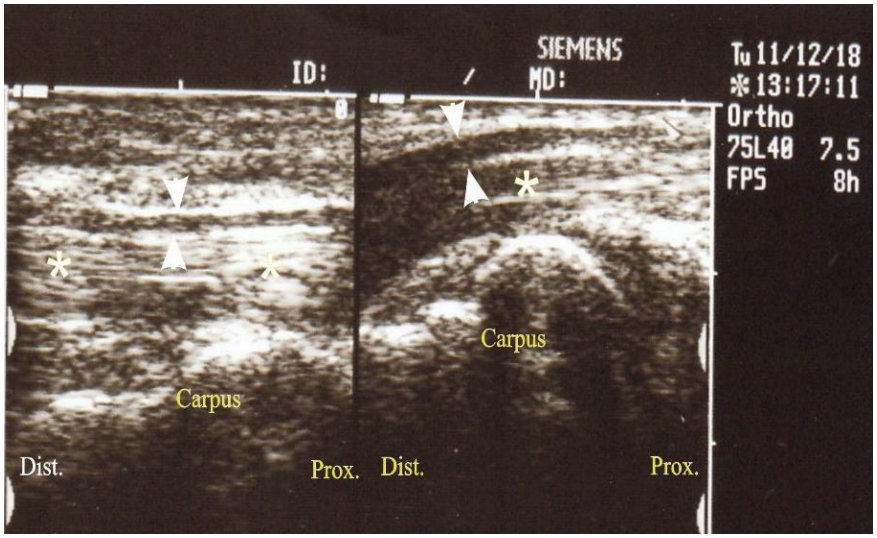

Figure 2. Longitudinal ultrasound image of the median nerve in healthy individual. Thickness (between arrowheads) Left side on sonogram: Inlet thickness d: 1,42 mm; right side on sonogram: tunnel thickness d: 0,9mm. The flexor tendons were normal.

Statistical analysis

A descriptive-analytical statistical method was used for the statistical processing of the obtained results from the clinical study. Statistical analysis was carried out by using the software SPSS, version 22.0. Descriptive data are presented as mean± standard deviation (SD), or as median. Percentages are given for categorical variables. The threshold for statistical significance was set at $p<0.05$.

The clinical study was approved by the Ethics Committee for Human Research at the Faculty of Medicine in Skopje," Ss. Cyril and Methodius" University in Skopje, R N Macedonia (Approval No. 03-2895/7). All participants gave their written consent.

Results

One hundred and sixteen patients were enrolled in this study according to the inclusion criteria. They were examined by ENMG examination prior to admittance for surgical procedure of open carpal tunnel release (OCTR) at the University Clinic for Orthopedic Diseases-Skopje. Eighty-seven patients were female and twenty-nine male, with a mean age of 55.41±10.7 years (age range 27-75). In the distribution according to the level of education, most of the patients with CTS had completed secondary education - 62.9% (73), compared to 44,44% (24) of healthy individuals. 86.2% (100) of CTS patients and 85,2% (46) of healthy individuals, were of Macedonian ethnicity, followed by patients of Albanian ethnicity - 6% (7) and 11,1% (6) respectively.

According to the classification of BMI scores, patients with CTS, as well as healthy individuals, were overweight. Right hand was dominant hand in both group of participants.

Female patients with CTS were younger than male patients, but the mean age was not statistically significant ($p=0.16$). The mean age of female patients was 54.6±10.4 and of male patients 57.83 ± 10.9

Table 1 presents the most common symptoms and duration of symptoms. Results obtained showed that all patients complained on paresthesia and numbness. Twenty (17.2%) CTS patients had pain during daytime. Nocturnal pains were predominant symptoms in this group of patients - 47.4% (55), 35.35% (41), respectively. Sleep disturbance and clumsiness with the hands were positive in 41 (35.35%) patient, who also had hypotrophy of thenar and muscle weakness. Duration of characteristic symptoms of more than 2 years was noted in 50.9% (59) of CTS patients (Table 1**)**.

Table 1. Symptoms, duration of symptoms, symptomatic hand

Variable	
Symptoms	**n (%)**
Numbness, paresthesia	116 (100)
Numbness, paresthesia, pain	20 (17.24)
Numbness, paresthesia, nocturnal pains,	55 (47.41)
Numbness, paresthesia, nocturnal pains, sleep disturbance, weakness	41 (35.35)
Duration of symptoms	**n (%)**
6 – 12 months	15 (12.93)
12 – 24 months	42 (36.21)
> 24 months	59 (50.86)
Symptomatic hand	**n (%)**
Right hand	38 (32.76)
Left hand	26 (22.41)
Both hands	51 (43.96)

According to ENMG examination, 38 patients presented with bilateral CTS, 45 patients were with right hand CTS and 33 with left hand CTS. Although 38 patients had bilateral CTS, only findings of the first surgically treated hands, were used for statistical analysis. 66 (56.9%) patients were treated surgically on the right hand, and 50 (43.1%) on the left hand. (Table 2).

Table 2. Diagnosis of CTS according to ENMG and Carpal tunnel release

Diagnosis	**n (%)**
CTS dext	45 (38.79)
CTS sin	33 (28.45)
CTS bill	38 (32.76)
Carpal tunnel release	**n (%)**
Right hand	66 (56.9)
Left hand	50 (43.1)

According to Canterbury Severity scale for severity grading of ENMG examination, 50% of the patients were in group with moderate severity and 39,65% in groups from severe to extremely severe. (Table 3).

Table 3. Canterbury Severity scale for CTS patients

CTS severity (ENMG)	**N (%)**
normal	1 (0.86)
very mild	2 (1.72)
mild	9 (7.76)
moderate	58 (50)
severe	17 (14.65)
very severe	10 (8.62)
extremely severe	19 (16.38)
Total	116 (100)

Statistical analysis showed that according to the measurements of the mean cross-sectional area of the median nerve at inlet level and compared to ENMG findings as reference testing for severity of CTS, patients were divided in 3 groups. 10,9 -12,1 mm^2 values of CSA inlet were measured in patients with mild CTS, 12,2 -15,3 mm^2 in moderate CTS and 15,9-20,3mm^2 in severe CTS.

Ultrasound images of the median nerve in a 54 years old patient with signs of severe CTS on transverse and longitudinal view are presented on Figure 3 and Figure 4.

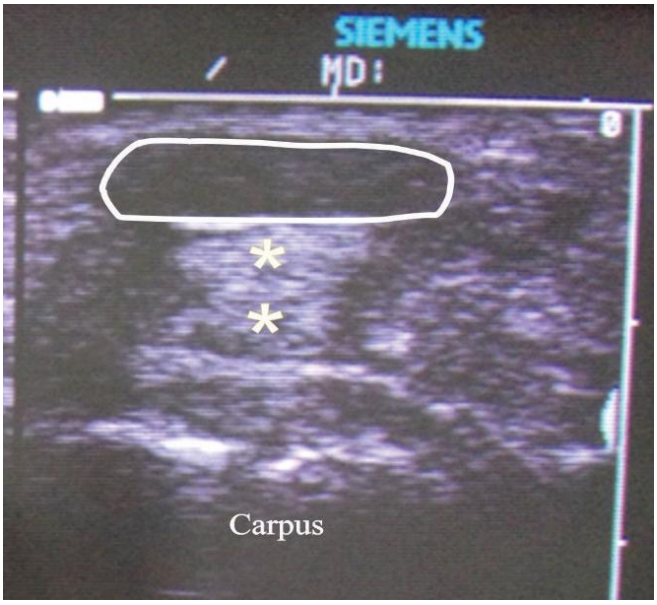

Figure 3. Transverse ultrasound image of the median nerve (outlined, hypoechoic) in severe CTS. CSA inlet: 24,5 mm^2. The flexor tendons were normal. (Female patient, 54y, duration of symptoms >24months)

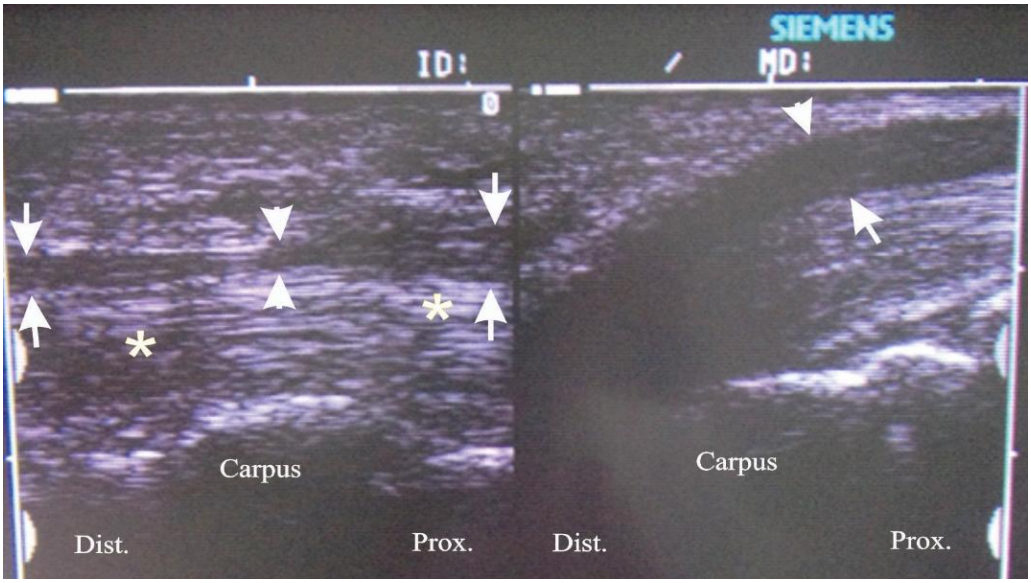

Figure 4. Longitudinal ultrasound image of the median nerve in severe CTS right hand (the same patient from Figure 3); Thickness (between arrows) Left side on sonogram: Flattening of the median nerve, smallest tunnel thickness: 0,7 mm; (arrowheads); enlargement of the median nerve ("Notch" sign) at inlet (prox.) and "inverted Notch" sign at the outlet (dist.). Right side on sonogram: Inlet thickness: 3,42 mm. The flexor tendons were normal.

There was no statistically significant difference in US findings of preoperative thicknesses of the median nerve between right and left wrists, measured on longitudinal view (Table 4).

Table 4. Preoperative ultrasound findings of thicknesses of the median nerve measured on longitudinal view in patients with CTS

Thickness of the median nerve	**mean ± SD**	**median (IQR)**
thickness inlet (mm) / right hand	2.95 ± 0.8	2.9 (2.3 – 3.4)
thickness tunnel (mm) / right hand	1.18 ± 0.4	1.2 (0.9 – 1.4)
thickness inlet (mm) / left hand	2.92 ± 0.7	2.8 (2.3 – 3.5)
thickness tunnel (mm) / right hand	1.18 ± 0.3	1.1 (0.9 –1.45)

Flattening of the median nerve at compression site and proximal enlargement of the nerve ("Notch sign"), was found positive in 64.71% right wrists and in 54,17% left wrists.

According to the results in the tables 5 and 6, the ultrasound measurements of CSA inlet of the median nerve, differed significantly depending on ENMG measurements, on the right and left hand ($p = 0.0001$, $p = 0.0002$, respectively).

In the group of right hand - surgically treated patients, 3 patients (15.5%) with severe findings on ENMG measurements, had CSA inlet from 12.2 to 15.3 mm^2 and 6 patients (20,6%) had CSA inlet above 15.9 mm^2. Extremely severe findings on ENMG measurements had 1 patient with CSA inlet < 10.9 mm^2, 1 patient with CSA inlet from 12.2 to 15.3 mm^2 and 11 patients (32.35%) with CSA inlet above 15.9 mm^2. (Table 5)

Table 5. Correlation between severity of CTS according to preoperative ENMG and US findings of the right hand in patients with CTS

ENMG	**CSA inlet (mm^2) / right hand**				**Total**
	<10.9 n (%)	**10.9 – 12.1 mild n(%)**	**12.2 – 15.3 moderate n(%)**	**15.9 – 20.3 severe n(%)**	
normal	1(25)	0	0	0	1
very mild	0	0	1(3.85)	0	1
mild	1(25)	0	2(11.54)	0	3
moderate	1(25)	6(100)	17(65.38)	11(32.35)	35
severe	0	0	3(15.38)	6(20.59)	9
very severe	0	0	0	4(14.71)	4
extremely severe	1(25)	0	1(3.85)	11(32.35)	13
Total	**4**	**6**	**24**	**32**	**66**
p-level	**H = 21.4 p = 0.0001 sig**				

H (Kruskal-Wallis test)

In the group of left hand - surgically treated patients, 1 patient (5.26%) with very severe findings on ENMG measurements, had CSA inlet from 12.2 to 15.3 mm^2 and 5 patients (20%) had CSA inlet above 15.9 mm^2. 6 patients (24%) with CSA inlet above 15.9 mm^2 had extremely severe findings on ENMG measurements. (Table 6)

Table 6. Correlation between severity of CTS according to preoperative ENMG and US findings of the left hand in patients with CTS

ENMG	**CSA inlet (mm^2) / left hand**			Total
	10.9 – 12.1 mild n (%)	**12.2 – 15.3 moderate n (%)**	**15.9 – 20.3 severe n (%)**	
normal	0	0	0	0
very mild	0	1 (5.26)	0	1
mild	3 (60)	2 (10.53)	1 (4)	6
moderate	2 (40)	13 (68.42)	8 (32)	23
severe	0	3 (10.53)	5 (20)	8
very severe	0	1 (5.26)	5 (20)	6
extremely severe	0	0	6 (24)	6
Total	**5**	**20**	**25**	**50**
p-level	**H = 16.8 p=0.0002 sig**			

H (Kruskal-Wallis test)

US measurements and ENMG findings showed high concordance in defining CTS diagnosis and severity. Values of Spearman's coefficient R=0.533 showed positive correlation of ENMG finding and US thickness- inlet of right hand, R=0.544 showed positive correlation of ENMG finding and US thickness- inlet of left hand, R=0.566 showed positive correlation of ENMG finding and CSA- inlet of right hand and R=0.683 showed positive correlation of ENMG finding and CSA- inlet of left hand.

All four correlations are statistically significant ((p=0.000003, p=0.00006, and p<0.0001).

These statistical results lead to conclusion that findings of US and ENMG examinations are with positive correlation. It means that patients with CTS and greater values of CSA-inlet, have higher degrees of severity of the median nerve impairment, and vice versa.

Comparative ultrasound findings of thickness of the median nerve on longitudinal view (LV) and CSA on transversal view (TV) in healthy individuals (HI), without symtoms and signs of CTS and) are presented in table 7.

All analyzed characteristics were with higher values in patients with CTS compared to healthy individuals and were statistically significant (p<0.0001, p=0.0002, p<0.0001, p=0.0023, p<0.0001, и, p<0.0001, respectively). (Table 7).

Table 7. Comparative ultrasound findings in healthy individuals (HI) and patients with CTS (CTSP) on longitudinal view (LV) and transversal view (TV**)**

US measurements	patients	Descriptive Statistics		p-level
		mean ± SD	median (IQR)	
thickness inlet (mm) / right hand (LV)	HI	2.05 ± 0.5	1.96 (1.6 – 2.31)	Z=6.4
	CTSP	2.95 ± 0.8	2.9 (2.3 – 3.4)	p=0.0000 sig
thickness inlet (mm) / left hand (LV)	HI	1.97 ± 0.4	1.84 (1.61 – 2.31)	Z=6.1
	CTSP	2.92 ± 0.7	2.8 (2.3 – 3.5)	p=0.00000 sig
thickness/tunnel (mm) right hand (LV)	HI	1.41 ± 0.3	1.54 (1.21 – 1.60)	Z=3.7
	CTSP	1.18 ± 0.4	1.2 (0.9 – 1.4)	p=0.00024 sig
thickness/tunnel (mm) left hand (LV)	HI	1.39 ± 0.3	1.45 (1.17 – 1.54)	Z=3.05
	CTSP	1.19 ± 0.35	1.1 (0.9 – 1.45)	p=0.0023 sig
CSA- inlet (mm^2) / right hand (TV)	HI	8.39 ± 2.3	8.35 (6.5 – 9.71)	Z=8.9
	CTSP	17.51 ± 5.8	16 (13.34 – 21)	p=0.00000 sig
CSA - inlet (mm^2) / left hand (TV)	HI	7.91 ± 2.2	7.89 (6.67 – 9.45)	Z=8.6
	CTSP	17.84 ± 5.7	16.4 (13.7 – 20.45)	p=0.00000 sig

p (Mann-Whitney U Test)

Discussion

Carpal tunnel syndrome is the most common neurocompressive disease, with multifactorial etiology and prevalence in women. The diagnosis of CTS is mainly based on characteristic symptoms, clinical signs, electroneuromyographic findings (ENMG) and on US examination in the last 20 years.

Hormonal variations in reproductive and menopausal period, as well as many other risk factors (occupational and non-occupational) in both females and males, are associated with different metabolic (dyslipidemia, hypercholesterolemia) or microvascular changes which might lead to the onset of tissue edema or reduction of nutrients and oxygen to the nerves and development of ischemia[15,16].

Such alterations are more expressed in nerves placed in narrow osteofibrous tunnels like the median nerve. [17,18].

The clinical picture depends on the duration and intensity of pressure on the median nerve, which is a mixed type of nerve with sensitive and motor nerve fibers. At the beginning, the discomfort is in the form of sensory disturbances (numbness, paraesthesia and /or pain in the fingers - from the thumb to the radial side of the ring finger, tingling and burning pain even radiating to the elbow or shoulder, nocturnal pains).

Later, in more severe cases, when motor component of the median nerve is involved, decreased muscle power, gripping or dropping objects and clumsiness during everyday activities are observed Characteristic clinical finding are usually absent in milder cases with CTS.

The results obtained in our study have shown that majority of participants were of female gender at the mean age of 54.61 ± 10.4 years. This is in correlation with most of the epidemiological studies which have reported a higher risk of CTS among women than among men [19,20].

The sensory component of the median nerve is affected much earlier than the motor component and there is usually a delay in the sensory nerve conduction velocity in early stages of CTS. These symptoms (numbness, paraesthesia and /or pain in the fingers - from the thumb to the radial side of the ring finger, tingling and burning pain even radiating to the elbow or shoulder), were reported in the majority of our patients.

As shown in the study, duration of the symptoms was over 12 months in 36,21% and over 24 months in 50,86% of patients which explains more severe clinical stage with typical nocturnal pains and

sleep disturbance as predominant symptoms in 82,75% of patients. Nocturnal pains and paraesthesia of gradual onset are reported to be 51-96% sensitive and 27-68% specific for CTS [21].

Clumsiness with the hands were positive in 41 (35.35%) patient, who also had hypotrophy of thenar and muscle weakness (abductor pollicis brevis and opponens pollicis muscle). Hypotrophy of thenar muscles, as a significant sign of serious functional loss, is reported in many studies too [22].

Our study revealed a mean normal CSA at inlet level of 8.39 mm2 ± 2.3 for right hand and 7.91 mm2 ± 2.2 for left hand in 54 healthy individuals. These results of CSA- inlet in healthy individuals are significantly smaller than the mean CSA- inlet in the patients with CTS (17.51 ± 5.8 for right hand and 17.84 ± 5.7 for left hand). We also observed significantly smaller mean values for thickness inlet and thickness tunnel of the median nerve on longitudinal images in healthy individuals compared to patients with CTS.

Bathala et al. examined 100 healthy Asian subjects and found mean median nerve CSA of 7,2 mm2 ±1. [23]. In study by Mani et al., conducted in 75 asymptomatic adults (150 writs), the normal range at two SDs of the CSA of the median nerve was 5,2 - 9,6mm2 [24]. Similar values for CSA inlet (6,1-10,4 mm2) in healthy controls were found in other studies too [25,26].

The ultrasonographical CTS criteria used to diagnose the CSA inlet of the median nerve was larger than 10.9 mm2 according to our study. Our results of measuring CSA inlet: 10,9 -12,1 mm2 values of CSA inlet for mild CTS, 12,2 -15,3 mm2 for moderate CTS and 15,9-20,3mm2 for severe CTS were similar to the report of El Miedany[27].

All the patients with CTS included in our study underwent ENMG examination. 70 (60,34%) patients were graded in mild to moderate group, and 46 (39.66%) were graded in severe to extremely severe group according to Canterbury severity scale by Bland.

Results from our study showed positive correlation between severity of functional impairment (by ENMG) and morphological changes (by US) of the median nerve. Patients with greater values of the median nerve CSA-inlet, have higher degrees of severity of the median nerve impairment, and vice versa. This is confirmed in other researches too [28,29].

A prospective study by Ziswiler et al. showed a cutoff of <8mm2 had satisfactory power to rule out CTS, and CSA >12mm2 had excellent power to rule in CTS. They suggested using the largest CSA as a single diagnostic indicator in clinical practice. Also, their results showed a positive correlation of sonographic findings with the distal motor latency (p=0,50, P<0,0001) with an average increase in latency of 0,23msec per mm2 increase in CSA. [30]. Peetrons et al. also supported this idea in their study. [31].
In studies by Moran et al. and Mhoon et al., significant correlation between the values of the median nerve CSA and electrodiagnostic severity scales was not found[32,33].

The results of US measurements of the right hand in patients with CTS in our study, revealed wrist with CSA of >10,9 mm2 which is classified as normal according to ENMG severity. This could represent early disease stage that resulted in swelling of the median nerve and paresthesia as dominant symptom, but not yet resulting in pathologic nerve conduction. A study by Koyuncuoglu et al. also showed positive US findings with negative ENMG findings in 30,5% of patients. [34,35].

These results support the usefulness of US in early detection of CTS and "custom-made" plan of treatment for each patient.

Our study had several limitations. In this study, we didn't collect any data on reasons for long duration of symptoms before diagnosis and treatment. A high number of patients with CTS who underwent open carpal tunnel release procedure (56- right hand, 45-left hand), were in moderate and severe groups. It means that those patients suffered until they gained serious functional loss and were disabled for months. Although few statistically significant correlations were found, we didn't calculate specificity and sensitivity of US imaging with ENMG as reference standard.

The present study had several strengths. First it was a part of prospective clinical study that determined the role of US examination of the median nerve in correlation to clinical and ENMG examination in patients with CTS. US examiner was blinded of the results of ENMG examinations which were done not more than a month before US investigation.

A strength of our study, despite relatively small number of participants in the control group, showed mean values of CSA of the median nerve at inlet level and mean values of the median nerve on longitudinal view in healthy individuals in our country. Also, our results revealed that US of the carpal tunnel and the median nerve might detect early stages of CTS. Morphological changes of the median nerve, its shape and caliber, are the result of pathophysiological factors and disease duration so early diagnosis of CTS and appropriate treatment are necessary in order to avoid permanent nerve impairment.

Conclusion

Neuromuscular ultrasound examination (US) provides valuable information on morphology of carpal tunnel content and possible etiology of CTS.

Although dynamic imaging is used during US examination, measurements are done only on static scanning. It is used as additional tool in clinical practice of orthopedic surgeons experienced in US examination of musculoskeletal system. It is very useful in early diagnosis, treatment planning and outcome follow-up.

US is as accurate as ENMG examination, reproducible, noninvasive, less time consuming, not expensive and more comfortable for the patients. It is very important that state of the art technical equipment is used and it should be used as first line imaging technique in order to improve patient care.

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