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Correlation of Ultrasound Measurement of Median Nerve with Elctrodiagnostic Study in Carpal Tunnel Syndrome

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Abstract: **Background**: Carpal tunnel syndrome (CTS) is the commonest entrapment neuropathy of upper extremity in pain medicine clinic . Different ways used to evaluate median nerve entrapment . this indices like NCS which is invasive way and ultrasound measurement of CSA of median nerve which is non-invasive way to diagnosis of CTS. **Aim of the study:** Study the correlation of ultrasound with NCS in symptomatic patient. Threshold values for the calculated sonographic parameters to distinguish mild and moderate from severe CTS compared to NCS. **Patients and Methods:** This prospective cross-sectional study was conducted 42 patients were diagnosed clinically to have CTS that were confirmed by neurophysiologic studies. Median nerve was measured of CSA at distal crease of wrist and at level of pronator quaderatus with ultrasound to calculate Delta CSA and correlate with NCS. **Results**: According to electrodiagnostic study, 38%(Elnady, B. *et al*., 2019) of patients had mild, 31%(Koyuncuoglu, H. R. *et al*., 2005) of patients had moderate and 31%(Koyuncuoglu, H. R. *et al*., 2005) of patients had severe carpal tunnel syndrome. there was a significant correlation between distal CSA and delta CSA of median nerve with NCS. **Conclusion**: This study found that there is a significant correlation between Nerve conduction study and cross section area of median nerve so that The assessment of carpal tunnel syndrome by the measurement of delta CSA and cross section area of median nerve at wrist with a sonographic device may be a useful non-invasive alternative for electrodiagnostic study.

Keywords: Carpal Tunnel Syndrome , Median Nerve , Nerve Conductive Study.

INTRODUCTION

Carpal tunnel syndrome (CTS) is a collection of characteristic symptoms and signs that occurs following compression of the median nerve within the carpal tunnel.

Usual symptoms include numbness, paresthesia, and pain in the median nerve distribution. These symptoms may or may not be accompanied by objective changes in sensation and strength of median-innervated structures in the hand. (Chammas, M. *et al*., 2014)

An estimated 4% and 5% of people suffer from CTS worldwide, with the most susceptible population being elderly individuals aged between 40 and 60 years. (Chammas, M. *et al*., 2014)

CTS is also more prevalent amongst women as compared to men.
For instance, the UK General Practice Research Database in 2000 evaluated that CTS prevalence was 88 per 100,000 in males, while in women, the incidence was 193 per 100,000(Chaynes, P. *et al*., 2004). More frequent evaluations of the incidence of CTS notes its occurrence to be higher for women aged between 45 and 54 years, while the risk is higher for men aged between 75 and 84 years. (Chammas, M. *et al*., 2014)

The diagnosis of CTS patients requires the respective medical professional to develop a case history associated with the characteristic signs of CTS. The patient should be questioned on the frequency of occurrence of these symptoms, whether they happen at night or during the day, or whether certain positions or repeated movements provoke the symptoms. (Ghasemi-Rad, M. *et al*., 2014) The initial medical tests for carpal tunnel syndrome are Tinel's sign and Phalen's maneuver. Tinel's sign elicits a positive result when tapping over the carpal tunnel produces symptoms in the median nerve distribution. On the other hand, during Phalen's maneuver, a patient flexes the wrist to 90 degrees, and the test is positive if the flexing produces symptoms along with the distribution of the median nerve. Additionally, monofilament testing, vibration, as well as two-point discrimination, could elicit sensory effects in carpal tunnel syndrome. (Wipperman, J., & Goerl, K. 2016) Using the patient's medical history and physiological assessment may produce limited results and have less specific areas of symptom occurrence. Patients may, therefore, be required to complete a self-diagnosis questionnaire, described as the Katz Hand Diagram. This enables the patient to specify the parts of their hand that

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experience the symptoms and classify the symptoms like numbness, pain, tingling, or hypoesthesia. (Ghasemi-Rad, M. *et al*., 2014)

Ultrasonography potentially can identify space-occupying lesions in and around the median nerve, confirm abnormalities in the median nerve (e.g., increased cross-sectional area) that can be diagnostic of CTS, and help to guide steroid injections into the carpal tunnel. (Chaynes, P. *et al*., 2004) A median nerve area of less than 6 mm^2 usually excludes and an area greater than 12 mm^2 indicates carpal tunnel syndrome. (Peetrons, P. A. & Derbali, W. 2013)

Distal CSA of the median nerve of normal and mild, moderate and severe CTS was 9.4, 12, 13, and 16 mm^2, respectively. (Phongamwong, C. *et al*., 2017)

A more accurate assessment of carpal tunnel syndrome assesses a change in median nerve cross-sectional area; an increase in size greater than 2 mm^2 comparing proximal (at proximal pronator quadratus) with distal (maximal nerve enlargement at the wrist crease) can diagnose carpal tunnel syndrome with 99% accuracy. (Klauser, A. S. *et al*., 2015)

In addition, a change in median nerve area of 5 mm^2 indicates moderate and 9 mm^2 severe carpal tunnel syndrome.19 Of note, the circumferential trace method of measuring area is preferred, given variations in the shape of the median nerve, and measurement is made inside the echogenic epineurium. Normal values of the median nerve cross-sectional area using ultrasonography in healthy individuals at pronator quadratus level found a CSA up to 9.62 mm^2. (Ng, A. J. T. *et al*., 2022)

Other findings of carpal tunnel syndrome include volar bowing of the retinaculum in the transverse plane and flattening of the median nerve within the carpal tunnel best seen in long axis, where the abrupt transition in size has been termed the notch sign.20 Also, imaging of the carpal tunnel during movement of the digits has shown decreased transverse sliding of the median nerve in carpal tunnel syndrome. (Nakamichi, K., & Tachibana, S. 1995)

Demonstration of blood flow on color Doppler imaging has also been shown to be an accurate indicator of carpal tunnel syndrome. (Ghasemi-Esfe, A. R. *et al*., 2011) Magnetic resonance imaging (MRI) of the carpal tunnel is particularly useful preoperatively if a space-occupying lesion in the carpal tunnel is suggested.

Aim of study

- To study the correlation of ultrasound measurement of median nerve with NCS in symptomatic patient.
- Threshold values for the calculated sonographic parameters to distinguish mild and moderate from severe CTS compared to NCS.

PATIENT AND METHODS

The prospective cross-sectional study was performed in pain subspecialty of Gazi-AlHariri teaching hospital, and included forty two patients from March 2024 to March 2025.

After obtaining approval of the scientific committee of Pain medical subspecialty of The Iraqi Board for medical specialist informed written patient or relatives consent with adequate information about the study was obtained for all patients before enrolling them.

All patients were included in our study if their age was between 20-70 years, diagnosed as CTS by NCS and weight between 40-90 kg.
Exclusion criteria:

- Refusal of patient.
- Known cervical spine trauma
- Cervical radicular symptom.
- Thoracic outlet syndrome.
- History CTS surgery.
- Tumor Lipoma or ganglion at wrist
- Flexor tendon tenosynovitis.

All patients received standard median motor and sensory nerve conduction studies. Keypoint (Medtronic functional Diagnostic A/S -DK-2740 Skovlunde, Denmark) electromyography machine was used throughout the study. Using disposable bipolar surface recording electrode (H690 NM-317Y3, DK-2740 Skovlunde, Denmark), motor median nerve recording abductor pollicis brevis stimulating the wrist. The SNC of the median was performed by using ring electrode in the index and stimulation at the wrist Carpal tunnel syndrome was diagnosed according to the delayed sensory and/or motor nerve conduction.

Sonographic assessments were performed by B-mode ultrasound view with linear probe.

- Position the patient is placed in the sitting position with the elbow flexed to about 100 degrees and the forearm resting comfortably palm up on a padded bedside table with the

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fingers slightly flexed which will relax the flexor tendons.
- The distal crease of the wrist is identified.
- By using Samsung ultrasound machine. Place ultrasound transducer 10 MHz linear probe over the distal crease of the wrist at the level of the pisiform in a transverse plane.
- The median nerve will appear as a bundle of hyperechoic nerve fibers surrounded by a slightly more hyperechoic neural sheath lying beneath the flexor retinaculum and above the superficial flexor tendons (Fig. 1).
- At Forearm About 8 cm proximal to wrist crease at level of pronator quadratus median nerve located between FDS and FDP.

(CSA of median nerve were calculated dCSA (wrist) of (10-12) mm 2 indicates mild, (13-15) moderate and =>16 mm2 severe carpal tunnel syndrome. , pCSA (forearm) normal value <9.65 mm2 and ΔCSA of (2-4) mm2 indicates mild, (5-8) moderate and 9 mm2 severe carpal tunnel syndrome).

With following formula:

ΔCSA = CSA (wrist) – CSA (forearm).

Statistical analysis was performed with the IBM-SPSS 23 statistical software program. Univariate data were summarized using standard descriptive statistics, tabulation of categorical variables and histograms of numerical variables.

Associations between categorical variables were assessed via cross-tabulation and chi-square test. Mann Whitney Test (a non-parametric equivalent of the independent samples t-test), and Kruskal-Wallis test (a non-parametric equivalent to one-way ANOVA) were used to compare means of continuous variables. Exact tests were used to calculate the p-value. In all statistical analyses, a p-value < 0.05 was considered significant.

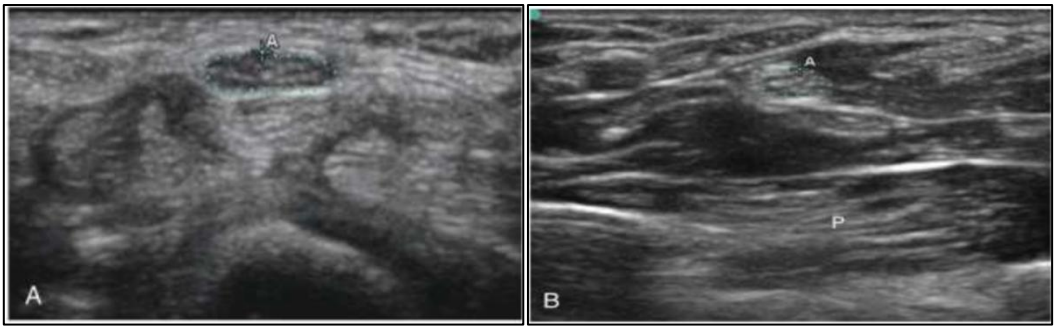

Figure 1: Carpal Tunnel Syndrome: Measurement Technique. Ultrasound images in short axis to the median nerve at the level of (A) carpal tunnel and (B) pronator quadratus (P) show the circumferential trace method of calculating median nerve area (see caliper markings).

RESULTS

A total of 42 patients with CTS were enrolled in this study, the mean age of patients was 44.5 years ranging between 20-70 years with female to male ratio was 2.5:1, the mean weight of patients was 74.98. The distribution of age, sex and weight are shown in table 1.

Table 1: Age, sex and weight distribution in study group.

Variables		**Number**	**Percent**
Age (years)	20 – 29	3	7.1%
	30 – 39	11	26.2%
	40 – 49	14	33.3%
	50 – 59	7	16.7%
	60 – 69	5	11.9%
	> 70	2	4.8%
	Mean ± SD	44.5 ± 12.3	
Sex	Male	12	28.6%
	Female	30	71.4%
Weight (kg)	60 – 69	12	28.6%
	70 – 79	17	40.4%
	80 - 89	13	31%
	Mean ± SD	74.98 ± 7.86	

The mild CTS was 16(38%), the moderate CTS was 13(31%), the sever CTS was 13(31%).

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Table 2: Distribution of CTS severity by NCS categories of median nerve patients with CTS were enrolled in this study.

CTS by NCS	No.	Percent
Mild	16	38%
Moderate	13	31%
severe	13	31%

Mean of Proximal CTS was 7.25, Distal CTS was 14.42, Delta CTS was 7.16.

Table 3: Comparison of median nerve CSA values patients with CTS were enrolled in this study.

	Mean ± SD	Range	Median
Proximal Median nerve CSA (mm^2)	7.25±1.42	4.7-10.2	7.0
Distal Median nerve CSA (mm^2)	14.42±4.56	7.0-24.0	14.5
Delta Median nerve CSA (mm^2)	7.16±4.29	1.0-17.0	7.1

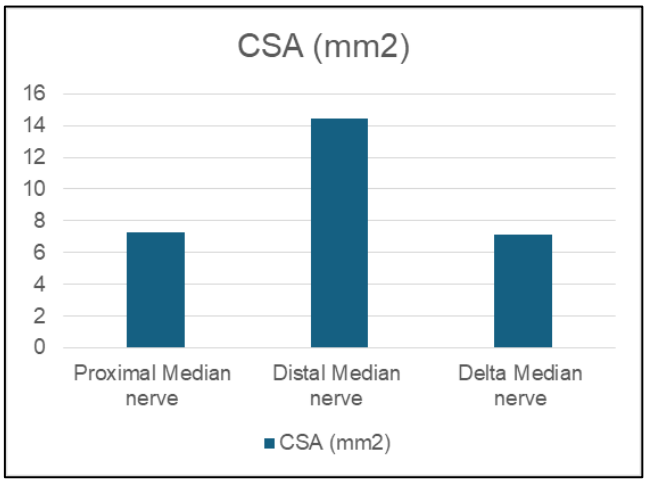

Figure 2: comparison of median nerve CSA values.

Table 4: Distribution of proximal median nerve CSA (mm2) categories.

Proximal Median nerve CSA (mm^2)	No.	Percent
Normal (≤ 9.6)	39	92.9%
Abnormal (>9.6)	3	7.1%

Table 5: Distribution of distal median nerve CSA (mm2) severity categories.

Distal Median nerve CSA (mm^2)	No.	Percent
Mild (10-12)	18	42.8%
Moderate (13-15)	7	16.7%
Severe (≥ 16)	17	40.5%

Table 6: Distribution of delta median nerve CSA (mm2) severity categories.

Delta Median nerve CSA (mm^2)	No.	Percent
Normal (<2.0)	5	11.9%
Mild (2-4)	9	21.4%
Moderate (5-8)	12	28.6%
Severe (≥ 9)	16	38.1%

Table 7: correlation of proximal CSA with NCS based on severity patients with CTS were enrolled in this study.

Proximal Median nerve CSA	NCS						p-Value
	Mild		Moderate		Severe		
	No.	%	No.	%	No.	%	
Normal (≤9.6)	16	100	13	100	10	76.9	0.027*
Abnormal (>9.6)	-	-	-	-	3	23.1	

*: Significant difference between percentages using Pearson Chi-square test (χ^2-test) at 0.05 level.

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Table 8: correlation of distal CSA with NCS based on severity CSA of CTS were enrolled in this study.

Distal Median nerve CSA	**NCS**						**p-Value**
	Mild		**Moderate**		**Severe**		
	No.	%	No.	%	No.	%	
Mild (10-12)	13	81.3	4	30.8	1	7.7	0.0001*
Moderate (13-15)	2	12.4	4	38.4	-	-	
Severe ((≥16)	1	6.3	4	30.8	12	92.4	

*: Significant difference between percentages using Pearson Chi-square test (χ^2-test) at 0.05 level.

Table 9: correlation of delta CSA of median nerve with NCS based on severity delta CSA of CTS were enrolled in this study.

Delta Median nerve CSA	**NCS**						**p-Value**
	Mild		**Moderate**		**Severe**		
	No.	%	No.	%	No.	%	
Normal (<2.0)	3	18.8	1	7.7	1	7.7	0.0001*
Mild 2-4)	9	56.4	-	-	-	-	
Moderate (4-8)	3	18.8	9	69.2	-	-	
Severe (≥ 9)	1	6.3	3	23.1	12	92.4	

*: Significant difference between percentages using Pearson Chi-square test (χ2-test) at 0.05 level.

Table 10: strength agreement between two method shows delta CSA substantial agreement while distal CSA moderate agreement.

		NCS severity				**Kappa coefficient**
		Mild		**Moderate-Severe**		
		No.	**%**	**No.**	**%**	
Distal Median nerve CSA	**Mild**	13	81.2	5	19.2	0.606
	Moderate-severe	3	18.8	21	80.8	
	p-Value	0.0001*				
Delta Median nerve CSA	**Normal**	3	18.8	2	7.7	0.690
	Mild	9	56.2	-	-	
	Moderate-severe	4	25	24	92.3	
	p-Value	0.0001*				

*: Significant difference between percentages using Pearson Chi-square test (χ^2-test) at 0.05 level.

Table 11: comparison of median nerve CSA measurement among NCS severity groups.

		No.	**Proximal Median nerve CSA**			**Distal Median nerve CSA**			**Delta Median nerve CSA**		
			Mean±SD	**Range**	**median**	**Mean±SD**	**Range**	**median**	**Mean±SD**	**Range**	**median**
NCS	**mild**	16	6.66±1.23	4.7-8.5	6.5	10.51±2.99	7-19	9	3.86±2.6	1-11	3
	moderate	13	7.42±1.09	6-9.6	7	14.7±2.63	11-19	15	7.32±2.98	1.4-13	7.2
	Severe	13	7.82±1.73	6-10.2	8	18.8±3.29	11.3-24	19.3	11.07±3.81	1.3-17	10.4
	p-Value		0.078			0.0001*			0.0001*		

*: Significant difference among more than two independent means using ANOVA-test at 0.05 level.

DISCUSSION

Median nerve entrapment in the wrist joint is the most frequent entrapment neuropathy. (Möller, I. *et al*., 2018) Neurophysiologic study is accurate in diagnosis of CTS. (Ibrahim, I. *et al*., 2012) NCS is used as an invasive method to diagnosis of CTS. in addition to being invasive, technically demanding and operator dependant, that motivate the researcher to investigate CSA of median nerve as an alternative method. negative electrophysiologic studies may occur in up to 30% of CTS patients. (Koyuncuoglu, H. R. *et al*., 2005)

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US is advantageous in that it is noninvasive, less painful (and therefore more acceptable to patients), more readily available and less expensive.

This study includes 42 patients investigated the use of US for CSA measurements of the median nerve in patients with electrophysiological confirmed CTS.

Regarding the demographic data in this study, the age distribution Mean±SD (Range) 44.5±12.3 (20-70) , this results gives idea that most affected patients were age group (40-49 years old was 33.3% and 30-39 was 26.2%).

In our study shows female patients predominance as compared with male patients (71.4% in females patients versus 28.6% male) was agree with khan *et al*24 2012 was high prevalence in females, so female gender could considered to be a risk factor for developing CTS This may attributed to the hormonal changes in women, particularly in pregnancy and menopause. (Padua, L. *et al*., 1999)

In our study, there were strong correlation between delta CSA of median nerve associated with electrodiagnostic study. This was comparable to result of Klauser *et al*.19 2015 are useful delta CSA in predicting CTS severity compared to NCS with value 7.2 mm^2 to distinguish between mild and moderate and 10.4 mm^2 distinguish between moderate and severe CTS.

In our study demonstrated substantial agreement between ultrasonographic measurements and NCS severity, with kappa coefficients of 0.606 for distal CSA and 0.690 for delta CSA. This substantial to almost perfect agreement aligns with findings from Wang *et al*. (Koyuncuoglu, H. R. *et al*., 2005), who emphasized the reliability of ultrasonographic measurements, particularly delta CSA, in assessing CTS severity.

In our study that was using proximal CSA of median nerve not for diagnosis CTS. The proximal CSA at forearm is used as a reference or control for comparison, which accounts for inter-individual variability such as body size, age or nerve anatomy. Proximal CSA remained unchanged or mild thickening in systemic disease. (Tagliafico, A. *et al*., 2010)

Elnady *et al* (Elnady, B. *et al*., 2019) and Klauser *et al*. (Klauser, A. S. *et al*., 2009) also stated that ΔCSA is correlated with neurophysiologic CTS severity, which agreed with our findings related to ΔCSA.

Mhoon *et al*. (Mhoon, J. T. *et al*., 2012) did not find a significant correlation between distal CSA and electrophysiologic severity assessment In our study, the dCSA was statistically correlated to the severity of CTS with neurophysiologic assessment, the higher the value the more severe the CTS, which were concordant with other studies. (Baiee, R. H. *et al*., 2015)

Another study that was conduct by Aloi *et al*. (Aloi, N. F. *et al*., 2023) reported that the distal CSA of median nerve at wrist could predict the CTS and discriminate between normal and abnormal EDS, and between mild CTS and moderate to severe CTS showed, this result agree with our study in mild 81.3% and severe 92.3% but moderate CTS 38.4%.

The limitations of our study were the small sample size, the unequal distribution between gender, the large discrepancy of the patients aged, the sub analysis of US measurements in relation to variable etiologies and BMI. The assessment of US measurements in cases with bifid median was not done on our group of patients.

CONCLUSIONS

Assessment of median nerve CSA with a sonography appears to correlate well with NCS and can guide to non-invasive CTS assessment.

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