



Assessment of Carpal Tunnel Syndrome Severity by Ultrasound and Electrodiagnosis Study

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Abstract

Carpal tunnel syndrome (CTS) is the upper limb neuropathic entrapment. Electrodiagnostic study (EDX) is the gold standard for diagnosis. However, EDX is not always abnormal in CTS beside its relatively high cost which requires the search for alternative modalities.

Objectives: To investigate ultrasound (US) has a function in the evaluation of CTS as well as determination disease severity.

Subjects and Methods: A case-control experiment which involve 50 CTS patients (65 wrists) and 30 healthy subjects (30 wrists). Electrodiagnostic study involve nerve conduction test (NCS) were performed for all included wrists, with ultrasound measure the cross-sectional area (CSA) of the median nerve.

Results: The result of 65 affected wrists with CTS is classified for 40 (61.15%) wrist mild disease, 19 wrists (29.23%) demonstrated a moderate disease and 6 wrists (9.23%) had severe disease. The mean in mild, moderate, and severe cases, median nerve CSA was determined $11.21 \pm 1.22 \text{ mm}^2$, $15.09 \pm 0.1.14 \text{ mm}^2$ and $17.88 \pm 0.2.1 \text{ mm}^2$, respectively with highly significant differences between the three categories. Furthermore, all three categories had higher CSA than control ($8.73 \pm 0.45 \text{ mm}^2$) with highly significant differences. In patients, CSA demonstrated a significant linked with median distal sensory latency ($r = 0.718$, $p < 0.001$), median motor distal latency ($r = 0.818$, $p < 0.001$) and age ($r = 0.316$, $p = 0.01$) and a negative significant with median nerve conduction velocity ($r = -0.837$, $p < 0.001$). US demonstrated excellent diagnostic values. The sensitivity and specificity of US in the context of discriminate patients and controls at cut off value of CSA = 10 mm^2 were 92% and 100%, respectively. Furthermore, US can effectively discriminate between mild, moderate and severe cases CTS with sensitivity levels ranging from 83%- 100% and 94%-100% specificity. The optimal cut off values ranges between 13.2 - 16.2 mm^2 .

Conclusions: The CSA of the median nerve is increased and the degree of enlargement significantly correlates with the parameters of disease severity. However, the CSA of the nerve does not associate with the gender of patients or the side of the affected wrist. Ultrasound of CST of median nerve has an excellent diagnostic value in the distinguish between patients and controls, with 92 percent sensitivity and 99 percent specificity, respectively. The optimum cut off value is 10 mm^2 . Also, US can effectively distinguish mild, moderate and severe cases CTS with Sensitivity levels ranging from 83%- 100% and 94%-100% Specificity. The optimal values cut off ranges between 13.2 - 16.2 mm^2 .

Key Words: Carpal Tunnel Syndrome, Ultrasound, Median Cross-sectional Area, Nerve Conduction Study, Electrodiagnostic Study.

DOI Number: 10.14704/nq.2022.20.1.NQ22005

NeuroQuantology 2022; 20(1):34-40

Introduction

Is the neuropathic lesion of the nerve at the region of wrist that travels during canal along with nine flexor tendons. It is also is known as the most

prevalent neuropathy of entrapment affecting upper extremities described by numbness and tingling, and discomfort or pain in the hand.

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Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Received: 02 November 2021 **Accepted:** 05 December 2021



It is considered and is remembered as one of the most significant causes of morbidity in the workplace (Coraci, 2014). Trauma, pressure increase in the canal, ischemia lesion to median nerve in the carpal tunnel are all factors lead to CTS, the normal pressure ranged from 2 and 10 mm Hg. Carpal tunnel pressure changes during wrist extension and flexion leading to an increase 8 to 10 folds. Therefore, recurrent hand movement is the main risk factor of carpal tunnel syndrome (Ibrahim et al, 2012). It can be detected by taking a medical history and performing physical examinations depend on American Academy of Neurology practice.

1. Discomfort, pain, paresthesia, especially at night.
2. Sensory fiber involvement.
3. Motor involvement, weakness of the thumb abduction and hypotrophy of abductor pollicis brevis.
4. Positive Phalen's maneuver and/or Tinel's sign (Chen 2011).

Electrodiagnosis is the most useful tool for diagnosing CTS and determining its severity, however it is considered intrusive, another diagnostic noninvasive, feasible, simple like high resolution ultrasonography. (Kang 2012) The etiology of carpal tunnel is demyelination and accompanied by axonal loss due to severity. In a nerve electrodiagnosis, a demyelination lesion in the median nerve reflected in a slowing of the sensory median nerve's distal latency, If very tiny discrepancies between the median and ulnar latencies (usually 0.4–0.5 ms) are discovered in these sensitive median-versus-ulnar comparison investigations, they are regarded abnormal. (Preston, D., C. & Shapiro, B., E. 2021).

Over the last few years, neuromuscular ultrasonography has become more widely employed in conjunction with EDX in the evaluation of patients with neuromuscular illnesses. (Preston, D., C. & Shapiro, B., E. (2021). used of ultrasound growing for many factors simple, accurate, rapid, non-invasive method low cost, feasible, (Coraci 2014). The prevalent criterion in CTS is increase diameter of nerve (cross-sectional area >10 mm² which has a high sensitivity as 97.9%. (Cara McDonagh, 2015).

When examining nerve, there are a number of factors to consider. The cross-sectional area (CSA) above 10mm is significant, and it is the most important and well-validated parameter. The ultrasound image of median compression at the

wrist is an enlarged and hypoechoic nerve next to the entrapment site with loss of the usual fascicular architecture, which is evaluated using a tracing method immediately inside the hyperechoic epineurium. (Descatha, A., L. Huard 2012).

Materials and Methods

A case - control experiment which conducted in Al-Shaheed Ghazi Al-Hariri teaching hospital, Iraq, Baghdad in from 2021/1/20 to 2021/7/23 Which included a total of 50 patients with carpal tunnel syndrome and 30 normal subjects As control, they referred from neurosurgery department, orthopaedic department, electrodiagnosis study cover NCS (nerve conduction test) perform for all hands and ultrasound measure median cross-sectional area, Data were collected via direct interface with the patients and examination using a data collecting sheet including; age, gender, date of examination, RT or LT hand affected or Both.

Exclusion Criteria Were

Patient with diabetic mellitus, Patient with wrist trauma, Patient with cervical radiculopathy, Patient connective tissue diseases, Patient with rheumatoid arthritis, Thyroid disease Natus electroneuromyography was used, which involved assessing bilateral motor with sensory fibers of the ulnar and median nerves and recording abnormal parameters in the median nerve. The results classified into mild (sensory fibers affected), moderate (sensory and motor fibers affected) and severe (severe motor fiber affected) according to the neurophysiological reference values' local severity scale (J.D. Bland, 2000). During examination during the test procedures, the room temperature was kept between (25C°-28C°) and the skin temperature was kept between (36C°-37C°) with a mean of 36.7C° using a skin thermometer.

The following parameters were studied in sensory nerve: Amplitude, conduction velocity, distal latency. When stimulating sensory fiber the current of Supramaximal stimulation was used to elicit the maximum potential of the sensory nerve. The following parameters were studied in motor nerve: Amplitude, velocity, latency, duration the motor nerve is stimulated at two sites along its path (proximal and distal), and the muscle supplied by the same nerve is recorded. The stimulus intensity must be high enough to activate all motor nerve fibers (Preston and Shapiro, 2013). The HD11XE Philips 2009 was used for the US evaluation, and



the US model was equipped with linear probe of (7.5 MHz frequency) at the same time with nerve conduction study, the setting position is apply to examine the patient, with his hand open and flat on the coach, examination done with transverse direction. We used the upper normal CS area limit for the median nerve (<10 mm²) (Preston, D., C. & Shapiro, B., E. (2021) (Cara McDonagh, Michael Alexander, David Kane, 2015).

Statistic analyse conducted by S P S S software (S P S S, Chicago). Data were offered as mean and root mean square deviation, and analysed with unpaired Student t - test. Relative operating characteristic curve (ROC) estimated value diagnostic of cross - sectional area (CSA) of the median nerve in the context of discrimination between patients and controls. Pearson's r to explore possible correlation CSA with other variable in patients and controls. P - value < 0.05 significant difference.

Result

Demographic data of population study, mean patients age 46.1±11.27 years significantly different from that of controls group (35.35±8.49 years), no significant distinction in gender distribution between the two groups. Likewise, patient group and control group had comparable weight, height and BMI with no significant differences There were 65 affected wrists in patients, of which 38 (58.46%) were right wrist and 27(41.54%) were left wrists. On the other wrist, there were 13 right wrists (56.52%) and 10 left wrists (43.48 %) in control group with no significant distinction (Table 1).

Table 1. Demographic data of population study

variables	Patients (N= 50)	Controls (N=30)	P value
Age, years Mean±SD Range	46.1±11.27 21-64	35.35±8.49 20-52	<0.001
Gender Male Female	20(40%) 30(60%)	12(52.17%) 11(47.83%)	0.330
Height, cm Mean±SD Range	75.82±10.17 57-110	75.39±8.13 59-90	0.860
Weight, kg Mean±SD Range	164.97±9.23 150-179	167.35±7.44 157-180	0.281
BMI, kg/m ² Mean±SD Range	27.85±2.88 20.76-38.06	26.89±2.05 23.89-23.25	0.156
Side Right Left	38(58.46%) 27(41.54%)	13(56.52%) 10(43.48%)	0.871

Electrophysiological Parameters and Ultrasonography

The mean time for median sensory latency, median motor latency and conduction velocity in CTS patients was 4.18±0.63 ms, 4.0±1.41 ms and 49.62±9.79 m/s, respectively compared with 2.8±0.3 ms, 2.92±0.34 ms and 61.32±4.75 m/s, respectively in controls with highly significant differences. However, there was no significant differentiation between them patients group and controls group in ulnar nerve sensory distal latency (2.61±0.29 ms versus 2.57±3.66 ms). According to the result of ultrasound, mean median CSA in CTS patients 13.11±2.57 mm² (range= 8.5-19.9 mm²) which was much higher than that of controls (mean = 8.73±0.45 mm², range= 7.5-9.0 mm²) as shown in table 2.

Table 2. Electrophysiological parameters and sonography

Variables	CTS (65 wrists)	Controls (30 wrists)	P-value
Median N. sensory distal latency, ms Mean±SD Range	4.18±0.63 3.5-6.0	2.8±0.3 2.3-3.3	<0.00
Median N. motor distal latency, ms Mean±SD Range	4.0±1.41 2.0-8.09	2.92±0.34 2.2-3.5	0.001
Median N. conduction velocity, m/s Mean±SD Range	49.62±9.79 25.0-60.0	61.32±4.75 52.0-68.0	<0.001
Ulna N. sensory distal latency, ms Mean±SD Range	2.61±0.29 2.06-3.34	2.57±3.66 2.1-3.32	0.644
Median N. cross sectional area, mm ² Mean±SD Range	13.11±2.57 8.5-19.9	8.73±0.45 7.5-9.0	<0.001

36

Disease Severity

The result of 65 affected wrists with CTS is classified for, 40 (61.15%) had mild disease, 19 wrists (29.23%) demonstrated a moderate disease and 6 wrist (9.23%) had severe disease (Figure 1).



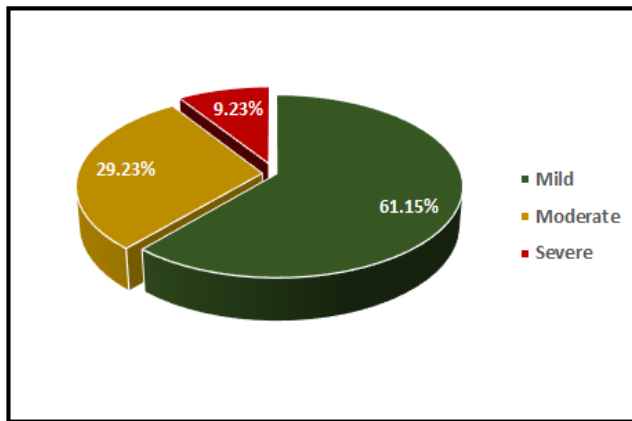


Figure 1. CTS disease severity

Association of MN CSA (median nerve cross-sectional area) with Disease Severity: The mean CSA of median nerve in mild, moderate, severe cases was $11.21 \pm 1.22 \text{ mm}^2$, $15.09 \pm 0.114 \text{ mm}^2$ and $17.88 \pm 0.2.1 \text{ mm}^2$, respectively with highly significant differences between the three categories. Furthermore, all three categories had higher CSA than control ($8.73 \pm 0.45 \text{ mm}^2$) with highly significant differences (Figure 2).

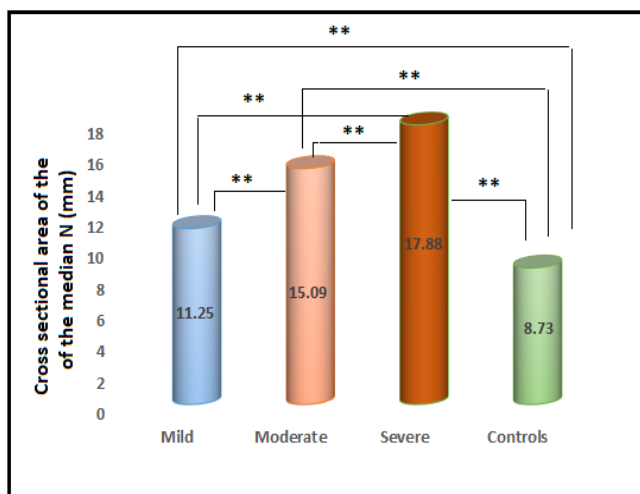


Figure 2. Association of CSA of median Nerve with Disease Severity
 **Highly significant difference. Analysis of test variance was to analyse data

Diagnostic Performance of Ultrasound

Value diagnostic investigated by a Relative Operating Characteristic (ROC) curve median CSA (calculated through US) in detection and differentiation of CTS. Generally, US demonstrated excellent diagnostic values. In the context distinguish between CTS patients group and control group, area under the curve (AUC) was 0.950 and 95% CI = 0.903 - 0.996, $p < 0.001$. Sensitivity,

Specificity of US at value cut off of CSA = 10 mm^2 were 92% and 100 %, respectively (Figure 3).

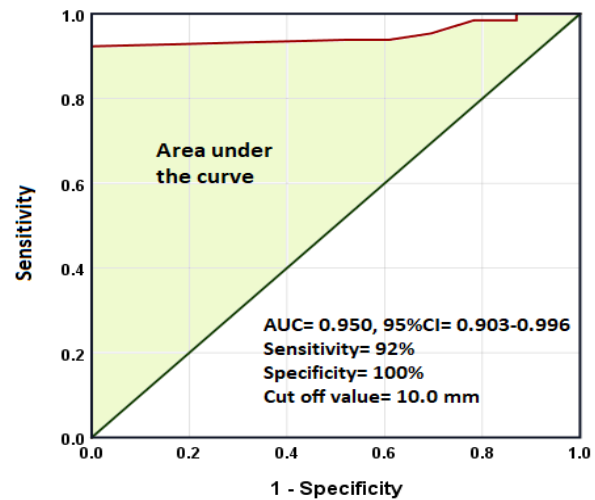


Figure 3. Relative operating characteristic curve for Ultrasound context of discriminate between CTS patients and controls

In the context of discriminate between mild and moderate CTS, the AUC was 0.974, 95 % CI = 0.925-1.00, $\Theta < 0.001$. Sensitivity, Specificity of the Ultrasound at value cut-off of CSA = 13.1 mm^2 were 95% and 97.5%, respectively (Figure 4).

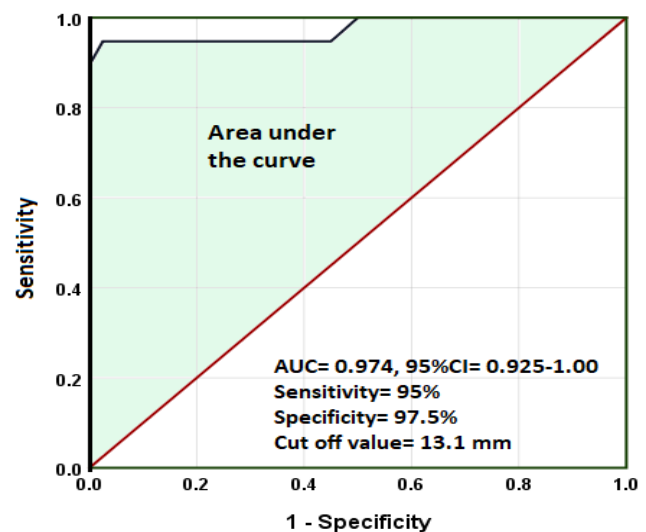


Figure 4. Relative operating characteristic curve for US in context of discrimination between mild and moderate CTS

In the context of discrimination mild and severe CTS, AUC was 1.00, 95 % CI = 1.00 - 1.00, $\Theta < 0.001$. Sensitivity and Specificity of US at cut off value of CSA = 14.0 mm^2 100% for both (Figure 5).

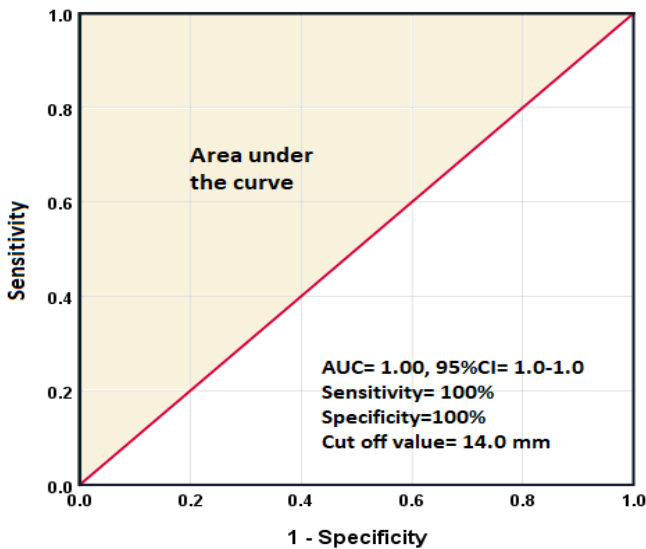


Figure 5. Relative operating characteristic curve for US in context of discriminate between mild and severe CTS

In the context of discriminate between moderate and severe CTS, AUC 0.868, 95 % CI = 0.645-1.00, p = 0.008. Sensitivity, Specificity of US at cut off value of CSA = 16.2 mm² 83% and 94%, respectively (Figure 6).

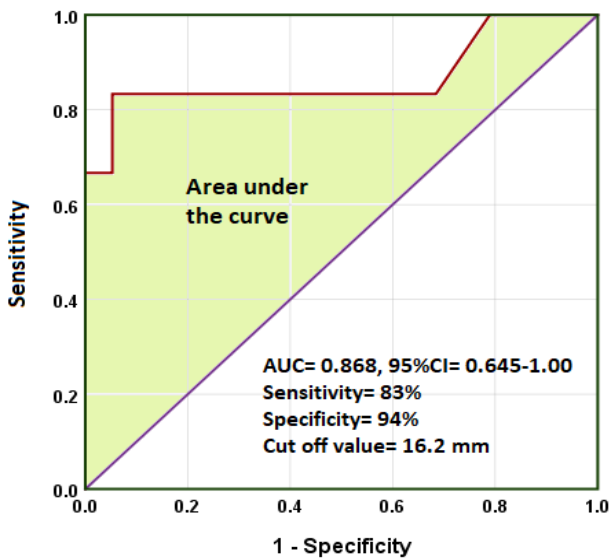


Figure 6. Relative operating characteristic curve for US in context of discriminate between moderate and severe CTS

Discussion

In the present study, patients were older than controls with a significant difference. This result corroborates with many previous studies. In A Turkish study including 547 patients with CTS, wrists were categorized into four groups normal, mild, moderate, sever.

After adjusting for BMI, the CTS development risk raised by a factor of 1.86 for ages thirty–sixty years and by 4.17 for ages sixty when the age group eighteen–thirty-five years was used as the control group. Almost similar result regarding the risk of older age in development of CTS were reported by two other studies (Kouyoumdjian, 2002; Kouyoumdjian, 1999). The precise reasons beyond this association are not precisely known. However, it was assumed axon loss, development of nerve conduction, vessels abnormalities increase with age (Kommalage, 2011). In the present study, motor and sensory latency of the median nerve increased significantly in CTS, while the conduction velocity of this nerve significantly decreased compared with the controls. These electrophysiological changes are the basic for gold standard diagnosis of CTS. The median nerve is always affected with different degree of damage. Several mechanisms have been proposed that results in median nerve injury with an eventual increase sensory and motor latency and decrease conduction velocity (Arrori and Spence, 2008). An interesting finding in this study was median cross-sectional area was significantly different on CTS patients than controls, and the CSA of median was significantly linked with severity disease. Such results were frequently reported by a plethora of previous studies (Mohammadi 2012; Ajeena, 2013; El-Shintenawy 2019). (Tsai 2013) and (Chan 2011) identified a strong link between median nerve conduction anomalies detected by electro diagnostic testing and CSA measured by ultrasound. In the same context, there was correlating between CSA median at the tunnel inlet, median motor distal latency (DML). As prolonged median DML is a marker of focal nerve demyelination across the carpal tunnel, this provides a biological basis for the US finding in CTS (Chan 2011). The most important finding in the present study were that the US had excellent diagnostic values either discrimination between control and patients with CTS in the context of CTS or in the context of discrimination between different severities of the CTS. In accordance with these results are many studies worldwide. In many of these studies the CSA of the median nerve yielded sensitivities range from sixty-seven to ninety four percent, and from fifty-seven to ninety seven percent to specificities, with value cut off 8.5 to 9.5 percent 15mm² (Wang 2008; Mondelli 2008; Padua 2008; Polykandriotis, 2007; Hobson-Webb, 2008). Also, in agreement with the present result is the result by (Karadag 2010) who claimed that



ultrasound was helpful in determining the severity of CTS. They came to the conclusion that ultrasound measurements of CSA could provide information regarding the severity of median involvement, it established value cutoff in the US to differentiate between different levels of CTS severity as follows: >thirteen mm² for mild, thirteen to fifteen mm² for moderate, and < fifteen mm² for severe symptoms. In a Turkish study, (Kaymak 2008) conducted a cross-sectional study to clarification whether US or electrophysiologic testing is a preferable foreteller of grading severity and to estimated value diagnostic US in CTS patients. The median CSA at the tunnel entrance and proximal tunnel were 12.5 ± 2.6 and 10.6 ± 2.6, respectively in patients versus 15.6 ± 4.2 and 11.5 ± 3.2, respectively in control group, with highly significant differences. The optimum value cut off for median CSA was 11.2mm² at the entrance tunnel and 11.9mm² at the proximal carpal tunnel. Sensitivity and specificity at the proximal tunnel (eighty-eight%, sixty-six%, respectively) were higher than those at the carpal tunnel entrance (sixty-eight% and sixty-two%, respectively).

The differences cut off value is mainly related to the severity of disease. However, these values are variable and not universally applicable as there are differences in study population, demographic differences and the "gold standard" used in the diagnosis of CTS.

NCS is not always abnormal in CTS (Chan 2011), and in two studies, US revealed abnormal findings in CTS patients who had normal NCS (Altinok 2004; Koyuncuoglu 2005). On the other hand, US appear to be relatively quite specific for CTS (Pastare 2009). Furthermore, US may be useful in severe CTS, where NCS may be unrecordable (Chan 2011). Lower cost, non-invasive - test and shorter time for test are additional advantages of sonography over Electrodiagnostic for appraisal of CTS (Mohammadi 2013).

Conclusions

1. The majority of CTS patients in the study had a mild to moderate disease.
2. The CSA median is largest in patients with CTS and degree of enlargement significantly correlates with the parameters of disease severity. However, the CSA of the nerve not associated with the gender of patients or the side of the affected wrist.
3. Ultrasound of CST of median nerve has an excellent diagnostic value in the

discrimination between patients and controls, with Sensitivity, Specificity of 92%, 99%. The optimum value cut off is ten mm².

4. Also, US can effectively discriminate between mild, moderate and severe cases of CTS with sensitivity ranges 83%- 100% and 94%-100% specificity. The optimal cut off values ranges between 13.2-16.2 mm².

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