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Diagnostic Value of Ultrasound Compared to Electro Diagnosis in Carpal Tunnel Syndrome

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ABSTRACT

Introduction: Carpal Tunnel Syndrome (CTS) is one of the main causes of disability. The diagnosis of CTS confirm by electrodiagnostic tests. Sonography is an alternative method for diagnosis of CTS that can investigate anatomy and probable pathology. The aim of this study is to investigate the multiple sonographic diagnostic criteria and compare its diagnostic value with electrodiagnosis.

Materials and Methods: In this descriptive-cross sectional study, 84 wrists (42 patients with CTS and 42 individuals without any clinical signs in upper limb) were investigated. Symptomatic patients underwent clinical examination, standard electrodiagnostic evaluation of upper limb and sonographic investigation of median nerve in forearm and wrist. The control group underwent sonographic investigation.

Results: Cross Sectional Area (CSA) of Median nerve at distal wrist crease, at the level of Hamate hook and Trapezium, the amount of flexor retinaculum bowing, ratio of CSA at the forearm to distal wrist crease and ratio of CSA at the Pisiform level to distal wrist crease had significant difference in the case group compared to the control group (P-value<0.05). Among these criterion, the most sensitivity, NPV and accuracy was for CSA at distal wrist crease (73.8%, 72.5%, 71.4% respectively), the most specificity, PPV was at the level of Hamate hook and Trapezium (85.3%, 80% respectively).

Conclusion: Our study reveals that sonography is a somehow sensitive and specific method in diagnosis of CTS and can be used as an adjuvant method in diagnosis of CTS but cannot substitute electrodiagnosis.

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Introduction

Carpal Tunnel Syndrome (CTS) is the most common compressive neuropathy with the prevalence of three-ten percent (1). CTS is a clinical syndrome that occurs due to the compression of the Median nerve in the wrist and is a major cause of occupational disability. The diagnosis of this syndrome is primarily based on the patient's complain and physical examination and can be confirmed by Electro Diagnostic test (EDX) (2, 3).

Sensitivity and specificity of EDX for the diagnosis of CTS were reportedly (85%) and (95%), respectively (4, 5). Despite wide usage of electro diagnostic test as diagnostic method of CTS, it may still give some false positive and negative results (6, 7). EDX is operator dependent and requires enough experience. Besides, this technique is often uncomfortable for patients.

Advances in high resolution ultrasound during recent years, have motivated the researchers to investigate its efficacy in diagnosis of CTS. Ultrasound is a noninvasive between and less time consuming method.

This procedure is not uncomfortable for the patient and also has ability to detect possible underlying pathology (space occupying lesions, flexor

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tenosynovitis, etc.). In recent years, numerous studies with different methods have been done in this field, and the reported sensitivity and specificity of ultrasound varies 65 and (100%) and from 72 between (98%), respectively (8). Yet, there is an anecdotal bias toward the preferential use of ultrasound over EDX to confirm clinical findings in the diagnosis of CTS. Neither the appropriate US probe position nor ultrasound diagnostic criteria have been fully determined for CTS.

In this study, we sought to investigate different ultrasound diagnostic criteria and to compare diagnostic value of ultrasound to EDX in CTS diagnosis.

Materials and Methods

In this cross-sectional study, we evaluated referred patients to electro diagnosis clinic of Shohada Tajrish, Tehran, Iran, who were suffering from clinical symptoms of CTS for at least three months, were selected. These, patients underwent EDX. EDX was performed by an experienced specialist with cooperation of a senior assistant under standard condition by “Medelec Synergy” electromyography system.

EDX included Median and ulnar nerves examination by standard technique with supramaximal and surface electrodes (according to AANEM standard criteria).

Device settings order included 20 microV/Div sensitivity and two ms/Div sweep speed to check the SNAP and 4000 microV/Div sensitivity and five ms/Div sweep speed for CMAP. CTS diagnosis was confirmed if Median peak latency in distance of 14 cm to D-3 was more than (3.5) ms, distal motor onset latency of Median nerve with eight cm distance with thenar area was above (4.1) cm, and subtraction of peak latency of SNAP of Median and ulnar nerve to D-4 was more than (0.5) ms.

Wrist ultrasonography was done by an experienced physical medicine specialist with special interest in musculoskeletal imaging and a senior assistant. In this study, a Philips HD6 ultrasound machine with linear probe (Linear) MHz 12-3 was used.

Patient was seated facing the examiner while their forearm in extended supination position, their wrist in neutral position and their fingers placed on the table in semi extended position. To find the nerve, the probe was put on the wrist without any pressure longitudinally and in perpendicular position. Then, the patient was asked to move her fingers make the tendons and Median nerve’s motion possible; but, since median nerve moves less, freely the probe was rotated 90 degrees to check the cross-sectional image distal wrist crease level.

Cross Sectional Area (CSA) of Median nerve was evaluated at four areas: 1) in forearm zone, seven centimeters above distal wrist crease, 2) in distal wrist crease zone, 3) distal to the Pisiform and Scaphoid bones, 4) tunnel outlet after Hamate hook and Trapezium in each area. Median nerve CSA was measured in mm two by placing electronic calipers of the ultrasound machine around the margin of the nerve (direct method). Perineurium between neural fascicles was considered hypoechoic and Median nerve sheath was hyperechoic.

Also, bowing of the flexor retinaculum was measured in mm at the maximum distance of retinaculum from the line that connects Trapezium bone and Hamate hook in transverse section.

Each measurement was performed three times and average values were calculated and recorded as final data. For comparison, control group was consisted of individuals who were referred to electro-diagnostic clinic due to other reasons and did not have any previous medical signs and symptoms any previous surgeries in upper limbs. Ultrasound was performed for the control group, as well.

Finally, gathered data were analyzed using Data SPSS version $_{16}$ software (statistical package for social sciences, Chicago, IL). Quantitative data were described as mean ± SD. Qualitative data were shown as frequency and percentage. Shapiro-Wilk test was used to evaluate the normality of data.

T-test, Mann-Whitney and also ANOVA were used for qualitative data and Chi-Square test was used for qualitative data.

ROC curve was used to find out cutoff points, sensitivity, specificity, as well as positive and negative predictive values. The cutoff points accuracies were determined, as well. Cutoff point in ROC curve is chosen based on the optimum point with the most sensitivity and specificity.

From an ethical viewpoint, all the procedures carried out in our study (i.e. NCV and ultrasound) were non-invasive methods. Patients did not charge for ultrasound. The study was approved by the Medical Ethics Committee and Research Council of Shahid Beheshti University of Medical Sciences, Tehran, Iran and a written informed consent was obtained from all the patients, regarding any of the personal data of patients do not independently present to any center.

Results

In our study, 84 wrists including 42 CTS patients and 42 controls did not have any clinical sign and symptom in upper limbs, were examined. Of this number, 72 were women and 12 were men. In CTS group, 39 subjects were women (92.9%) and three persons were men (7.1%).

In the control group, 33 were women (78.6%) and nine were men (21.4%). Using Chi-square test, no significant differences between the two groups were found in terms of gender (p=0.061).

Mean age in was 52 ± 9 years and 48 ± 9 years for the CTS and the control groups, which did not show any significant difference between the two groups (P=0.055).

Mean values of Cross Sectional Area of Median nerve (CSA) in different levels are shown in table 1.

Table1: Mean values of cross-sectional area of Median nerve (CSA) in different

Sonographic findings	Control group	CTS group	P-Value
Mean CSA 7cm proximal to distal wrist crease(mm^2)	6.6±1.2	6.3±1.1	0.420
Mean CSA at distal wrist crease (mm^2)	11.4±2.7	15.4±5	<0.001
Mean CSA at Pisiform and Scaphoid level (mm^2)	10 ± 1.6	10.4±2.9	0.792
Mean CSA in tunnel outlet at the level of Hamate hook and Trapezium (mm^2)	10.6±2.1	14.3± 5.2	<0.001
Mean CSA ratio of forearm to distal wrist crease	0.5 ±0.1	0.4 ± 0.1	<0.001
Mean CSA ratio of Pisiform to distal wrist crease	0.9 ±0.2	0.7 ± 0.1	<0.001
Mean bowing of flexor retinaculum	3 ± 0.8	3.6 ± 0.8	0.002

Mean CSA of Median nerve in distal wrist crease, in tunnel outlet at Hamate hook and Trapezium, bowing rate of the flexor retinaculum, mean CSA in forearm to CSA in distal wrist crease ratio, and mean CSA at trapezium to CSA in distal wrist crease ratio (swelling ratio) were significantly different between the two groups. Mean CSA of the Median nerve at Pisiform and Scaphoid levels and seven cm above distal wrist crease did not have any significant difference between the cases and the controls.

Among the patients with mild, moderate and severe CTS, mean CSA was higher in severe group compared to moderate group and in moderate group compared to the mild group, in all the sections.

All differences, except the ones at Pisiform level, were found to be statistically significant.

Using ROC curve, optimal threshold (cutoff) was determined. Cutoff and the sensitivity, specificity, positive predictive value, negative predictive value and accuracy of different levels are presented in Table 2.

Table2: Diagnostic value of sonography in different levels

	Cutoff	Accuracy	NPV	PPV	Spe	Sen
At distal wrist crease level	12.65	71.42	72.50	70.45	69.05	73.81
In tunnel outlet at the level of Hamate hook and Trapezium	13.15	63.09	66.04	80	85.37	57.14
Bowing of flexor retinaculum	3.15	63.09	64.86	61.70	57.14	69.05

The highest sensitivity, negative predictive value and accuracy were related to CSA in distal wrist crease.

The most specificity and positive predictive value were recorded in tunnel outlet at Hamate hook and Trapezium level.

Discussion

In initial studies, anatomic landmarks such as Pisiform bone or Hamate hook were determined to measure CSA of Median nerve (7, 8). However, recent studies have shown that maximum CSA of the Median nerve is obtained at locations proximal to carpal tunnel inlet and measurement in this area is more sensitive and specific; in fact, it could be said that just one measurement of CSA in this area is enough to obtain needed information for CTS diagnosis (9).

Swen's WA reported Median nerve CSA of (11.3) mm^2 and (6.1) mm^2 in study and control group, respectively (10). In Wiesler study, mean CSA value was nine mm^2 in the control group, and 14 mm^2 in the study group. So he resulted that higher CSA in ultrasound has associations with abnormal results in EDX (8). In our study, the most CSA was reported in distal wrist crease level.

Dalili Concluded that Median nerve CSAs at inlet and outlet of the carpal tunnel have a significant association with CTS diagnosis. The highest sensitivity was observed for CSA at tunnel inlet (11). In our study, Median nerve CSA at distal wrist crease and tunnel outlet levels had significant difference between the two groups and the highest sensitivity belonged to distal wrist crease level.

In Shawn's study, bowing of the flexor retinaculum, CSA at Pisiform level, and forearm to Pisiform CSA ratio had moderate to strong correlation with EDX results (12). In a study conducted by Hobson wrist to forearm median nerve ration was reported to be an accurate diagnostic method and in ratios above ¼ the sensitivity nears (100%) (13).

Wong mentioned Median nerve cross-sectional method to be sensitive and specific. The same authors mentioned flexor retinaculum bulging rate as an insensitive method for CTS diagnosis (14).

In a review article, Beckman mentioned that increase in Median nerve CSA at Pisiform and Hamate levels were reliable diagnostic criteria for CTS (15). In our study Median nerve CSA at Pisiform level did not show any significant difference between the two groups. However, bowing of the flexor retinaculum, forearm to distal wrist crease CSA ratio, and Pisiform to distal wrist crease CSA ratio (swelling fold) showed significant difference between the two groups.

In Moghtaderi's study, mean CSA value in moderate CTS subjects was significantly higher than severe cases, in locations proximal and distal to carpal tunnel (16). Despite this, in our study CSA was significantly higher in severe cases than moderate cases in all sites of measurement.

In our study, cutoff value of (12.65) in distal wrist crease level resulted in sensitivity, specify and accuracy of (73.81%, 69.05%) and (71.42%), respectively. For the same cutoff value, positive and negative predictive values were calculated as (70.45 %) and (72.50%), respectively. With a cutoff of (13.15) at tunnel outlet level, sensitivity, specificity and accuracy were about (57.14%, 85.37%) and (63.09%), respectively. Positive and negative predictive values were recorded as (80%) and (66.04%), respectively.

Lower sensitivity reported in our study compared to others' is probably due to higher cutoffs used in ours.

In Nakamachi study with Median nerve CSA cutoff value of 12 mm^2, sensitivity, specificity and accuracy were reported as (67%, 97%) and (82%), respectively (17). With the same CSA cutoff for Median nerve, Klauser reported (83%) sensitivity as well as (50%) specificity and (82%) accuracy (18). With a (11.5) mm^2 cutoff at proximal to carpal tunnel, Moghtaderi reported (83%, 90.7%, 65.5%) and (55.7%) for sensitivity, specificity, positive predictive value and negative predictive value, respectively. A cutoff of (13.5) mm^2 at distal to carpal tunnel, (36.1%, 93%, 81.2%) and (63.4%) values were reported for sensitivity, specificity, positive predictive value and negative predictive value, respectively (16).

Samadzadeh found sensitivity, specificity and accuracy values of (58%, 99%) and (83%), respectively in gray scale ultrasound with a 11 mm^2 CSA cutoff and concluded that the Doppler sonography sensitivity in initial phases of CTS was higher than gray scale ultrasound. However, EDX was still mentioned the best choice for CTS diagnosis (19). Median nerve CSA cutoffs of ten mm^2 proximal to the carpal tunnel and 12 mm^2 at tunnel outlet level resulted in (82.8%, 72%) and (79.3%) values for sensitivity, specificity and accuracy, respectively for Wong (20). In a study by Ziswiler Median nerve CSA cutoff of ten mm^2 resulted in a (82%) sensitivity, a (87%) specificity, and a (83/4%) accuracy (21). Mohammadi obtained sensitivity, specificity and accuracy of (97%, 98%) and (97.2%), respectively with an (8.5) mm^2 cutoff (22).

Yesildong, considered CSA of (10.5) cm^2 at Pisiform level for CTS diagnosis (23). In Altinok's study with a cutoff of nine mm^2 cutoff at Pisiform level, a (65%) sensitivity, a (92.5%) specificity and a (78.9%) accuracy were reported in ultrasound (24). In our study, CSA at distal wrist crease level showed highest sensitivity (73.8%), negative predictive value (72.5%), and accuracy (71.4%). The highest specificity and positive predictive value were recorded for CSA in the tunnel outlet at Hamate hook and Trapezium level (85.3% and 80%, respectively).

In Swen's WA study, ultrasound showed less sensitivity but higher specificity in comparison with EDX. It was concluded that ultrasound is comparable to EDX in CTS diagnosis and should be considered an initial diagnostic procedure in subjects suspicious for CTS (10). Samadzade reported higher sensitivity for Doppler ultrasound than gray scale ultrasound; but still, EDX was mentioned as the best diagnostic choice (19).

In AANEM paper, Nerve Conduction Study (NCS) sensitivity and specificity in CTS diagnosis were reported (85%) and (95%), respectively (2, 3).

According to study, ultrasound was reported to have lower sensitivity and specificity compared to EDX (10). However, a couple of previous studies have reported no significant difference between the two modalities accuracies in CTS diagnosis (25-27).

According to our observations, sensitivity and specificity of the ultrasound was lower than EDX.

Probably the differences in reported diagnostic threshold, sensitivity and specificity in different studies are due to demographic differences, different standard diagnostic criteria used (NCS or clinical signs), and lack of a standard method and measurement condition.

Limitations, recommendations and offers

According to the current study results, further studies with larger population sizes are recommended, in order to gain more accurate findings in future. Also, designing blind studies (in which ultrasound operator are blinded to EDX results) can provide us with valuable information. This could not be arranged in our study due to the lack of experienced specialists.

Our findings can only be applied to Idiopathic CTS and further studies are recommended to account for other forms of CTS.

Other criteria in wrist ultrasound such as Median nerve mobility, the nerve hypervascularity, flatting ratio, CSA correlation with the severity of signs and symptoms, CSA correlation with wrist dimensions, and ulnar nerve CSA are recommended to be investigated in future studies.

Conclusion

According to the current study, Median nerve CSA at distal wrist crease level, at the tunnel outlet at the Hamate hook and Trapezium level, bowing of flexor retinaculum, forearm to distal wrist crease CSA ratio, and Pisiform to distal wrist crease CSA ratio showed significant difference between the case and the control groups. Hamate hook in our study, CSA at distal wrist crease level showed the highest sensitivity (73.8%), negative predictive value (72.5%), and accuracy (71.4%). The highest specificity and positive predictive value were recorded for CSA in tunnel outlet at Hamate hook and Trapezium level (85.3%) and (80%), respectively.

According to our findings, it seems that ultrasound is sensitive and specific (especially CSA at distal wrist crease and carpal tunnel outlet levels) enough for CTS diagnosis. This procedure can be used as an adjuvant approach in CTS diagnosis, but cannot replace EDX entirely.

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References

1- Bongers FJ, Schellevis FG, van den Bosch WJ, van der Zee J. Carpal tunnel syndrome in general practice (1987 and 2001): incidence and the role of occupational and non-occupational factors. The British journal of general practice: the journal of the Royal College of General Practitioners. 2007 Jan;57(534):36-9.

2- Jablecki CK, Andary MT, Floeter MK, Miller RG, Quartly CA, Vennix MJ, et al. WITHDRAWN: Second AAEM literature review of the usefulness of nerve conduction studies and needle electromyography for the evaluation of patients with carpal tunnel syndrome. Muscle & nerve. 2002Jun 11.

3- Jablecki CK, Andary MT, So YT, Wilkins DE, Williams FH. Literature review of the usefulness of nerve conduction studies and electromyography for the evaluation of patients with carpal tunnel syndrome. AAEM Quality Assurance Committee. Muscle & nerve. 1993 Dec;16(12):1392-414.

4- Atroshi I, Gummesson C, Johnsson R, Ornstein E, Ranstam J, Rosen I. Prevalence of carpal tunnel syndrome in a general population. JAMA: the journal of the American Medical Association. 1999 Jul 14;282(2):153-8.

5- Atroshi I, Gummesson C, Johnsson R, Ornstein E. Diagnostic properties of nerve conduction tests in population-based carpal tunnel syndrome. BMC musculoskeletal disorders. 2003 May 7;4:9.

6- Cartwright MS, Hobson-Webb LD, Boon AJ, Alter KE, Hunt CH, Flores VH, et al. Evidence-based guideline: neuromuscular ultrasound for the diagnosis of carpal tunnel syndrome. Muscle & nerve. 2012 Aug;46(2):287-93.

7- Buchberger W, Judmaier W, Birbamer G, Lener M, Schmidauer C. Carpal tunnel syndrome: diagnosis with high-resolution sonography. AJR American journal of roentgenology. 1992;159(4):793-8.

8- Wiesler ER, Chloros GD, Cartwright MS, Smith BP, Rushing J, Walker FO. The use of diagnostic ultrasound in carpal tunnel syndrome. The Journal of hand surgery. 2006 May-Jun;31(5):726-32.

9- Nakamichi KI, Tachibana S. Enlarged median nerve in idiopathic carpal tunnel syndrome. Muscle & nerve. 2000 Nov;23(11):1713-8.

10- Swen WA, Jacobs JW, Bussemaker FE, de Waard JW, Bijlsma JW. Carpal tunnel sonography by the rheumatologist versus nerve conduction study by the neurologist. The Journal of rheumatology. 2001 Jan;28(1):62-9.

11- Dalili A-r, Mardani-kivi M, Alizadeh A, Hatamian H-r, Hoseininejad M, Peyrazm H, et al. Comparison between Sonography and Electrodiagnostic Testing in the Diagnosis of Carpal Tunnel Syndrome Anesthesiology and Pain. 2011;2(5):43-51. [In Persian].

12- Roll SC, Evans KD, Li X, Freimer M, Sommerich CM. Screening for carpal tunnel syndrome using sonography. Journal of ultrasound in medicine: official journal of the American Institute of Ultrasound in Medicine. 2011 Dec;30(12):1657-67.

13- Hobson-Webb LD, Massey JM, Juel VC, Sanders DB. The ultrasonographic wrist-to-forearm median nerve area ratio in carpal tunnel syndrome. Clinical neurophysiology: official journal of the International Federation of Clinical Neurophysiology. 2008 Jun;119(6):1353-7.

14- Wong SM, Griffith JF, Hui AC, Tang A, Wong KS. Discriminatory sonographic criteria for the diagnosis of carpal tunnel syndrome. Arthritis and rheumatism. 2002 Jul;46(7):1914-21.

15- Beekman R, Visser LH. Sonography in the diagnosis of carpal tunnel syndrome: a critical review of the literature. Muscle & nerve. 2003Jan;27(1): 26-33.

16- Ashraf AR, Jali R, Moghtaderi AR, Yazdani AH. The diagnostic value of ultrasonography in patients with electrophysiologicaly confirmed carpal tunnel syndrome. Electromyography and clinical neurophysiology. 2009 Jan-Feb;49(1):3-8.

17- Nakamichi K, Tachibana S. Ultrasonographic measurement of median nerve cross-sectional area in idiopathic carpal tunnel syndrome: Diagnostic accuracy. Muscle & nerve. 2002 Dec;26(6):798-803.

18- Klauser AS, Halpern EJ, Faschingbauer R, Guerra F, Martinoli C, Gabl MF, et al. Bifid median nerve in carpal tunnel syndrome: assessment with US cross-sectional area measurement. Radiology. 2011 Jun;259(3):808-15.

19- Samadzadeh S, Motameni M, Rezaei M, Rezaei C, Faroukhi J. The comparison between ultrasonography and electrodiagnosis value in diagnosing carpal tunnel syndrome. Journal of Kermanshah University of Medical Sciences. 2013;17(4):244-51. [In Persian].

20- Wong SM, Griffith JF, Hui AC, Lo SK, Fu M, Wong KS. Carpal tunnel syndrome: diagnostic usefulness of sonography. Radiology. 2004 Jul;232(1):93-9.

21- Ziswiler HR, Reichenbach S, Vogelin E, Bachmann LM, Villiger PM, Juni P. Diagnostic value of sonography in patients with suspected carpal tunnel syndrome: a prospective study. Arthritis and rheumatism. 2005 Jan;52(1):304-11.

22- Mohammadi A, Afshar A, Etemadi A, Masoudi S, Baghizadeh A. Diagnostic value of cross-sectional area of median nerve in grading severity of carpal tunnel syndrome. Archives of Iranian medicine. 2010 Nov;13(6):516-21.

23- Yesildag A, Kutluhan S, Sengul N, Koyuncuoglu HR, Oyar O, Guler K, et al. The role of ultrasonographic measurements of the median nerve in the diagnosis of carpal tunnel syndrome. Clinical radiology. 2004 Oct;59(10):910-5.

24- Altinok MT, Baysal O, Karakas HM, Firat AK. Sonographic evaluation of the carpal tunnel after provocative exercises. Journal of ultrasound in medicine: official journal of the American Institute of Ultrasound in Medicine. 2004 Oct;23(10):1301-6.
25- El Miedany Y, Aty S, Ashour S. Ultrasonography versus nerve conduction study in patients with carpal tunnel syndrome: substantive or complementary tests? Rheumatology. 2004;43(7):887-95.
26- Visser LH, Smidt MH, Lee ML. High-resolution sonography versus EMG in the diagnosis of carpal tunnel syndrome. Journal of neurology, neurosurgery, and psychiatry. 2008 Jan;79(1):63-7.
27- Kele H, Verheggen R, Bittermann HJ, Reimers CD. The potential value of ultrasonography in the evaluation of carpal tunnel syndrome. Neurology. 2003 Aug 12;61(3):389-91.