A. Mohammadi MD[1]
A.R. Afshar MD[2]
S. Masudi MSc[3]
A, Etemadi MD[4]

Comparison of High Resolution Ultrasonography and Nerve Conduction Study in the Diagnosis of Carpal Tunnel Syndrome: Diagnostic Value of Median Nerve Cross-Sectional Area

Background/Objective: Carpal tunnel syndrome (CTS) is a common peripheral entrapment neuropathy. This study was performed to evaluate whether high-resolution ultrasonography may be an alternative diagnostic method for nerve conduction study (NCS) in the diagnosis of carpal tunnel syndrome.

Patients and Methods: 132 wrists of 82 patients and 152 wrists of controls were enrolled in the study. The cross sectional area of the median nerve was measured at the carpal tunnel inlet and outlet in all patients and controls. All patients had a nerve conduction study. Then comparison between ultrasonography and NCS was performed. Combination of clinical diagnosis and NCS was used as the gold standard.

Results: The mean cross-sectional area (CSA) of the median nerve at the tunnel inlet was 11.4±1.7 mm^2 for the patient group and 5.78 ±0.9 mm^2 for the control group ($P<0.001$). The mean cross-sectional area at the tunnel outlet was 9.9±1.2 mm^2 for the patient group and 4.7±0.7 mm^2 for the control group ($P<0.001$). The best cut-off value of CSA at the tunnel inlet and the outlet was 7.5 mm^2.

Conclusion: In patients with clinical diagnosis of CTS we confirmed that the diagnostic value of ultrasonography is similar to NCS and sonography may be used in primary evaluation of CTS.

Keywords: Ultrasonography, Carpal Tunnel Syndrome, Nerve Conduction Study

1. Assistant Professor, Department of Radiology, Urmia University of Medical Sciences, Urmia, Iran.
2. Assistant Professor, Department of Orthopedics and Hand Surgery, Imam Khomeini Hospital, Urmia University of Medical Sciences, Urmia, Iran.
3. Faculty of Health, Department of Epidemiology, Urmia University of Medical Sciences, Urmia, Iran.
4. Department of Physical Medicine and Rehabilitation, Imam Khomeini Hospital, Urmia University of Medical Sciences, Urmia, Iran.

Corresponding Author:
Afshin Mohammadi
Address: Department of Radiology, Imam Khomeini Hospital, Ershad Blvd., Modaress St., Urmia, Iran.
Tel: +98441-344-7113
Fax: +98441-346-9935
Email: mohamadi_afshin@yahoo.com

Received February 27, 2009;
Accepted after revision August 23, 2009.

Iran J Radiol 2009;6(3):147-152

Introduction

Carpal tunnel syndrome (CTS), which is the most common entrapment neuropathy, is recognized as one of the most important causes of workplace morbidity.[1] There is an estimated 9% prevalence of carpal tunnel syndrome among adult women and a 0.6% prevalence among adult men.[2] The diagnosis of CTS is usually made on a combination of clinical signs such as the Tinel sign and the Phalen sign and electroneurophysiological examination.[2]

Although nerve conduction studies provide important information, it has 95% specificity and a sensitivity ranging from 49% to 86%.[3] Nevertheless, an electrodiagnostic study remains an expensive and time-consuming procedure not easily accessible for many physicians.

Advances in ultrasound (US) technology have made it possible to achieve a good spatial resolution for clear evaluation of the peripheral nerves. Wide availability, lower cost, noninvasiveness and shorter examination time are the advantages of sonography for primary evaluation of CTS. The fact that ultrasonography may be useful in the diagnosis of carpal tunnel syndrome has been mentioned before in certain studies.[4-8]

The objective of this prospective study was to evaluate the accuracy of sonography for the diagnosis of CTS.

This study was performed to determine whether sonography might be an alternative method to nerve conduction study in the diagnosis of carpal tunnel syndrome. Many authors believe that confirmation of suggestive clinical findings by the electrophysiological study may be used as the gold standard for the diagnosis of CTS.[1] A combination of clinical findings and the electrophysiological study were used as the gold standard reference in this study.

Patients and Methods

From March to January 2008, 82 patients with clinical signs and symptoms and electrophysiologically confirmed CTS, and 76 asymptomatic control subjects were examined with high-resolution sonography for determination of the median nerve cross-sectional area at the carpal tunnel inlet and outlet and the anteroposterior diameter of the median nerve at the carpal tunnel inlet and outlet.

Eighty-two patients (74 women, 8 men) with 132 affected nerves (132 wrists) underwent high-resolution sonography within 10 days after their-nerve conduction study.

Thirty-two patients had unilateral CTS of which 20 cases were right handed and 12 cases were left handed, and 50 patients had bilateral CTS.

Patients with coexistent neurological diseases such as polyneuropathy, proximal median neuropathy, cervical radiculopathy, diabetes mellitus, patients with a space-occupying lesion in the wrist and previous wrist surgery were excluded from the study.

The control group consisted of 152 wrists in 76 randomly selected asymptomatic healthy subjects (69 women and 7 men) from our hospital coworkers. These subjects did not have clinical symptoms of CTS and had a normal physical examination, which was carried out by a hand surgeon. If subjects of the control group were suspicious of CTS after the clinical examination by the hand surgeon, they were excluded from the study. The healthy group agreed to undergo US examination.

The nerve conduction studies were performed with the guidance of an electrodiagnostician who had a special interest in nerve conduction studies. Sonographic examination was performed after nerve conduction study by a radiologist experienced in musculoskeletal sonography. All examinations were performed with a high-frequency 11 MHz linear array transducer (Toshiba, Nemio 30 and Japan).

The radiologist and electrodiagnostician were blinded to each other's study results and to the case/control status of each wrist at the time of examination.

After physical examination by a hand surgeon as the primary evaluation, all patients were referred for ultrasonographic and electrophysiologic examination.

Subjects were seated facing the examiner. The arms were extended, the wrists were rested on a hard flat surface, the forearms were supinated and the fingers

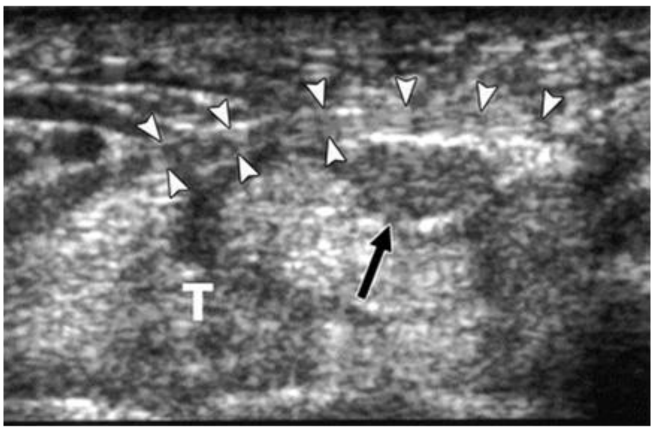

Fig. 1. Axial sonogram of the cross-section of the median nerve at the carpal tunnel inlet. Arrowhead shows the flexor retinaculum and the arrow shows the median nerve.

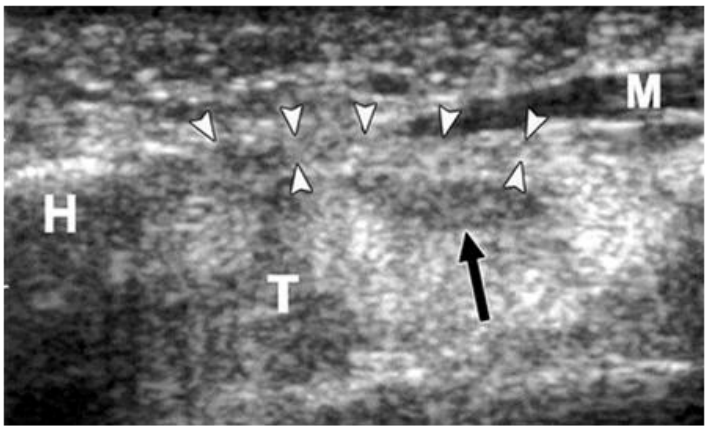

Fig. 2. Axial sonogram of the cross-section of the median nerve at the carpal tunnel outlet. The arrowhead shows the flexor retinaculum and the arrow shows the median nerve.

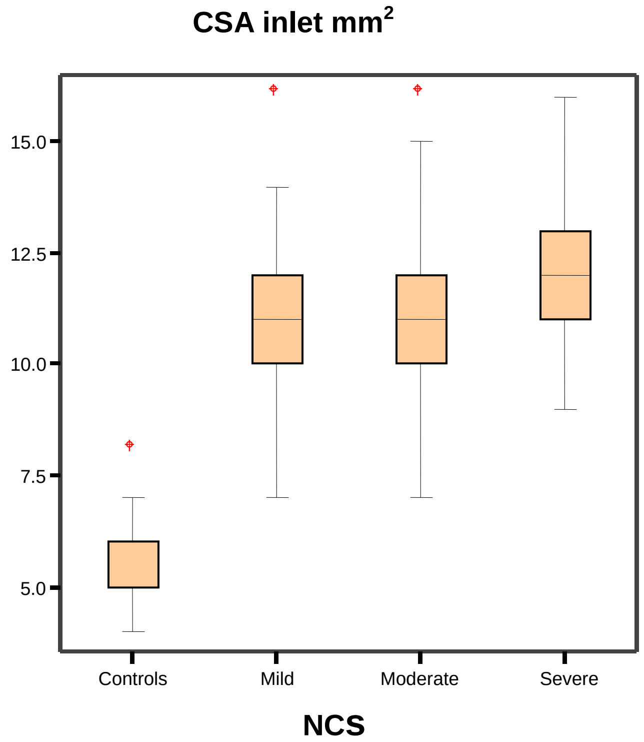

Fig. 3. Interactive graph shows the difference between mean cross-sectional area of controls and mild, moderate and severe forms of CTS at the carpal tunnel inlet.

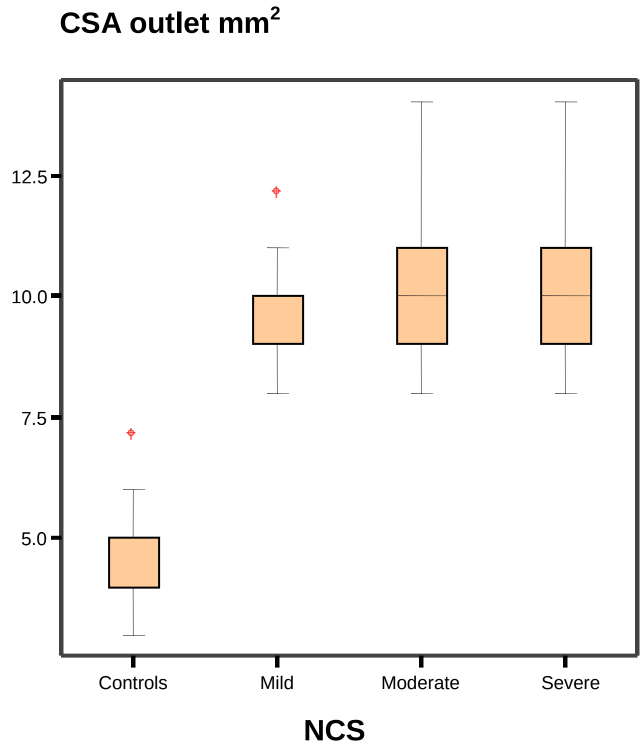

Fig. 4. Interactive graph shows the difference between the mean cross-sectional area of controls and mild, moderate and severe forms of CTS at the carpal tunnel outlet.

were semi-flexed.

Axial ultrasonograms of the median nerve were performed at two anatomical levels and at each level the cross-sectional area of the median nerve was measured. The levels mentioned above are as follows: (1) At the carpal tunnel inlet at the level of pisiform and scaphoid bones (Fig. 1). (2) At the carpal tunnel outlet at the level of the hook of the hamate and trapezium bones (Fig. 2). By means of direct tracing with electronic calipers around the margin of the nerve on sonogram, particular attention was paid to maintaining adequate probe orientation, to keep the US beam perpendicular to the nerve.

The university research ethics committee approved the study protocol; written informed consent was obtained in all patients.

Descriptive statistics were presented as mean±SD. Statistical analysis was carried out using one way ANOVA models. The significance level was considered as 0.05. The area under the ROC curve was determined to investigate the accuracy of the measurement of the median nerve cross sectional area.

Results

Of 132 symptomatic wrists, 34 had mild, 53 had moderate and 45 had severe CTS. Of 132 affected wrists, 30 wrists were related to patients with right hand CTS and 16 wrists were related to patients with left hand CTS and 86 patients` had bilateral CTS.

The patients had a mean±SD age of 43.6± 9 years and the controls had a mean± SD of 43.8 ±8 years.

Table 1. Results of Median Nerve Cross-Sectional Area at the Carpal Tunnel Inlet and Outlet in Controls and Cases (Mild, Moderate and Severe Groups)

	Patients			Control (n=152)	P Value
	Mild (n=34)	Moderate (n=53)	Severe (n=45)		
CSA Inlet	10.8±1.9	11.4±1.8	12±1.5	5.8±0.9	<0.001
CSA Outlet	9.7±0.9	10.1±1.2	10±1.4	4.7±0.7	<0.001

CSA: Cross-Sectional Area; mm^2

Table 2. Accuracy of Sonography According to Different Cut-off Values at the Carpal Tunnel Inlet

Cutpoint	Sensitivity	Specificity
3	1	0
4.5	1	0.118
5.5	1	0.329
6.5	1	0.789
7.5	0.977	0.980
8.5	0.962	1
9.5	0.886	1
10.5	0.720	1
11.5	0.455	1
12.5	0.250	1
13.5	0.114	1
14.5	0.053	1
15.5	0.023	1
17	0	1

Table 3. Accuracy of Sonography According to Different Cut-off Values at the Carpal Tunnel Outlet

Cutpoint	Sensitivity	Specificity
2	1	0
3.5	1	0.007
4.5	1	0.467
5.5	1	0.882
6.5	1	0.987
7.5	1	1
8.5	0.912	1
9.5	0.559	1
10.5	0.176	1
11.5	0.029	1
13	0	1

When results of nerve conduction studies were positive, the patients were classified as CTS.

The mean cross-sectional area of the median nerve at the tunnel inlet was 10.8±1.9 mm^2 in patients with mild CTS, 11.4±1.8 mm^2 in patients with moderate CTS and 12.0±1.5 mm^2 in patients with severe CTS, while this was 5.8±0.9 mm^2 for the control group. This difference was statistically significant ($P<0.001$) (Table 1). The difference between these three patient subgroups was not statistically significant ($p>0.05$) (Fig. 3).

The mean cross-sectional area of the median nerve at the tunnel outlet was 9.7±0.9 mm^2 ,10.1±1.2 mm^2 and 10.00±1.4 mm^2 in mild, moderate and severe CTS, respectively and 4.7±0.7 mm^2 for the control group, mentioning the statistically significant difference ($P<0.001$) (Table 1).

The difference between these three patient subgroups was not significant statistically ($P>0.05$) (Fig. 4). The measurements were similar in the right and left hand.

Receiver Operating Characteristics (ROC) Curve

We used ROC curves to explore the relationship between the sensitivity and specificity of the different US measurements of the median nerve and the optimal cut-off value of the median nerve cross-sectional area. The under the curve area for the CSA of the median nerve at the tunnel inlet was 0.99 (CI 95%: 0.98-1.00) (Fig. 5).

In this study, the cut-off value of 7.5mm^2 yielded a sensitivity of 97% and a specificity of 98% for the diagnosis of CTS in the carpal tunnel inlet (Table 2).

The area under the ROC curve for the cross-sectional area of the median nerve at the tunnel outlet was 1.00 (CI 95%: 0.99-1.00) (Fig. 6). This study showed a cut-off value of 7.5 mm^2 yielding a sensitivity and specificity of 100 % at the carpal tunnel outlet (Table 3). A cut-off of 7.5 mm^2 had excellent accuracy to rule out CTS; the fitted negative likelihood ratio was 0.03 for CSA lower than 7.5 mm^2. Conversely, a cut-off of 7.5 mm^2 had excellent accuracy to rule in CTS, with a positive likelihood ratio of 48.5 for areas higher than 7.5 mm^2 at the carpal tunnel inlet. For a cut-off of 7.5 mm^2, which yielded equal sensitivity and specificity of 100%, negative and positive likelihood ratios were conclusive at the tunnel outlet.

A cut-off of 7.5 mm^2 at the tunnel outlet had excellent accuracy to rule out CTS; the negative LR was zero for CSA lower than 7.5 mm^2 and had excellent accuracy to rule in CTS with the positive LR of 100 for CSA higher than 7.5 mm^2 at the carpal tunnel outlet.

Discussion

Accurate diagnosis of carpal tunnel syndrome is essential, especially, if the patient is candidated for surgery. Magnetic resonance imaging (MRI) clearly shows the anatomy of the carpal tunnel and the median nerve.[9-11] MRI is not routinely used to screen patients with suspected CTS because it is time-consuming, expensive and may not be available.

Many authors have reported the accuracy of sonographic criteria for the diagnosis of CTS[4-8,12] and several studies have addressed the quantification of the cross-sectional area of the median nerve and its roles in diagnosing CTS.[6,11,13] Ultrasonography does not show the function of the median nerve but it may show alteration of anatomy and enlargement of the median nerve.[13]

The advantages of ultrasonography include easy accessibility, low cost, rapid performance and non-invasiveness. The most reliable finding in previous studies is the increase of the cross-sectional area of the median nerve at the carpal tunnel inlet, yielding sensitivities ranging from 67% to 94% and specificities from 57% to 97% with a cut-off value varying between 8.5 and 15mm^2 in different reports.[4-6,12,14]

Other authors, however, found swelling of the median nerve at the distal carpal tunnel yielding sensitivities ranging from 57% to 75% and specificities ranging from 51% to 92% with threshold values ranging from 11 to 13 mm^2,[15] while Keles et al. found the optimal cut-off value of 9.3mm^2 for the cross sectional area of the median nerve at the middle level of the carpal tunnel (Se 80%, Sp 77%).[16]

The benefit of a single cut-off point is obvious in daily practice. We measured a single cut-off point for both left and right hands in this study.

It is generally accepted that approximately 10% of the patients with classic symptoms of CTS have a normal NCS result.[17] NCS shows failure of conduction in unmyelinated sensory fibers as a change in physiologic function.

Sonography measures a different parameter (anatomic defects) compared to NCS (physiological abnormalities). It is possible that some patients who have detectable CTS at sonography may have swelling of the median nerve which is not severe enough to cause impairment in conduction.

In all patients studied, the median nerve demonstrated a consistent and statistically significant increase in the cross-sectional area. The cut-off point of 7.5 mm^2 for the mean cross-sectional area of the median nerve to distinguish patients from controls, corresponds with the previously reported findings in the literature.[4-7, 12-15.]

In a recent study by Klauser et al., the authors reported choosing a cross-sectional area of 16.8 mm^2 as a reliable criterion for CTS and made the diagnostic

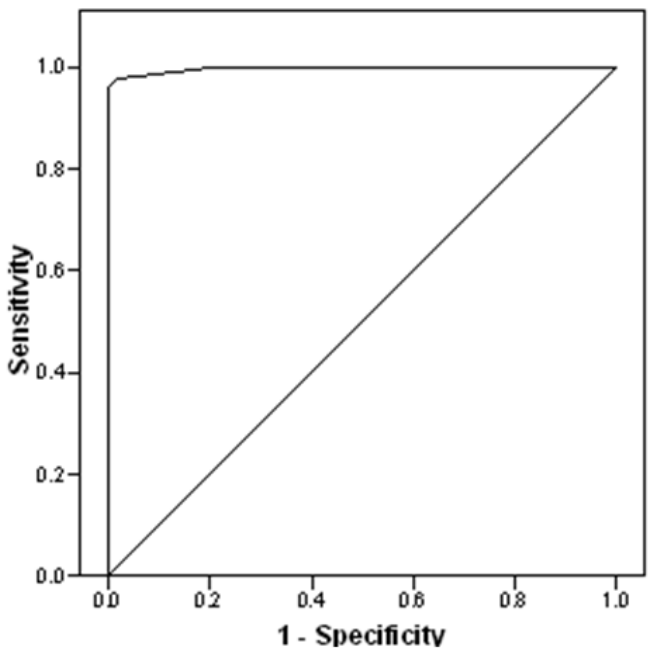

Fig. 5. Graph showing ROC curve for the cross-sectional area of the median nerve at the carpal tunnel inlet**.**

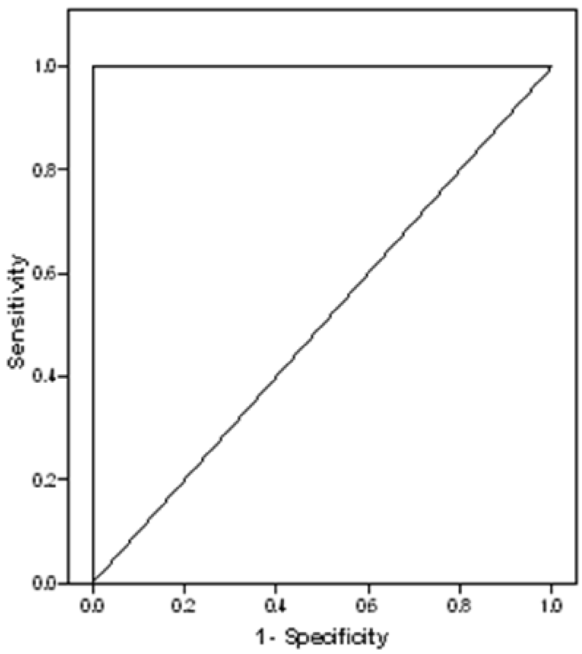

Fig. 6. Graph showing ROC curve for the cross-sectional area of the median nerve at the carpal tunnel outlet.

value of sonography approach that of the electrophysiological study.[7] Some authors reported that ultrasonography is not accurate enough to replace NCS in the diagnosis of CTS.[18]

The cut-off point of 7.5 mm^2 is less than most of the previous studies,[4-6,12-19] because many other studies were performed in the tertiary referral centers and selection bias is inherent in these type of hospital–based studies because the represented patients had severe enough symptoms to be candidated for surgery in the first place. However, in this study, patients with mild, moderate and severe symptoms were enrolled in the study and there was no selection bias.

In this study, measurements of the cross-sectional area of the median nerve at the carpal tunnel inlet and outlet have equal diagnostic values in the diagnosis of carpal tunnel syndrome.

Although the data in this study suggest that sonography is effective in the diagnosis of CTS, electrodiagnostic study results may be used to identify other conditions mimicing CTS, such as cervical radiculopathy, polyneuropathy, or other median nerve entrapment syndromes.

This study had limitations; sonography is an operator-dependent test, and enough experience is mandatory to ensure reliability and reproducibility. Therefore, the results of this study, may only be generalized to appropriately trained examiners.

In conclusion, high-frequency US examination of the median nerve and measurement of its cross-sectional area should be strongly considered as a new, alternative diagnostic modality for the primary evaluation of CTS. It shows high correlation with the present standard NCS in the diagnosis of CTS. However, further studies are necessary to determine the diagnostic value and to confirm the best cut-off point for the diagnosis of CTS in order to establish the appropriate practical algorithm in the daily clinical setting.

References

1. Moran L, Perez M, Esteban A, Bellon J, Ar-ranz B, del Cerro M. Sonographic measurement of cross-sectional area of the median nerve in the diagnosis of carpal tunnel syndrome: correlation with nerve conduction studies. J Clin Ultrasound 2009 Mar-Apr;37(3):125-31.
2. de Krom MC, de Krom CJ, Spaans F. Carpal tunnel syndrome: diagnosis, treatment, prevention and its relevance to dentistry. Ned Tijdschr Tandheelkd 2009 Feb;116(2):97-101.
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. Wang LY, Leong CP, Huang YC, Hung JW, Cheung SM, Pong YP. Best diagnostic criterion in high-resolution ultrasonography for carpal tunnel syndrome. Chang Gung Med J 2008 Sep-Oct;31(5):469-76.
5. Mondelli M, Filippou G, Gallo A, Frediani B. Diagnostic utility of ultrasonography versus nerve conduction studies in mild carpal tunnel syndrome. Arthritis Rheum 2008 Mar 15;59(3):357-66.
6. Padua L, Pazzaglia C, Caliandro P, Granata G, Foschini M, Briani C et al. Carpal tunnel syndrome: ultrasound, neurophysiology, clinical and patient-oriented assessment. Clin Neurophysiol 2008 Sep;119(9):2064-9.
7. Klauser AS, Halpern EJ, De Zordo T, Feuch-tner GM, Arora R, Gruber J et al. Carpal tunnel syndrome assessment with US: value of additional cross-sectional area measurements of the median nerve in patients versus healthy volunteers. Radiology 2009 Jan;250(1):171-7.
8. Sernik RA, Abicalaf CA, Pimentel BF, Braga-Baiak A, Braga L, Cerri GG. Ultrasound features of carpal tunnel syndrome: a prospective case-control study. Skeletal Radiol 2008 Jan;37(1):49-53.
9. Stein D, Neufeld A, Pasternak O, Graif M, Patish H, Schwimmer E et al. Diffusion tensor imaging of the median nerve in healthy and carpal tunnel syndrome subjects. J Magn Reson Imaging 2009 Mar;29(3):657-62.
10. Yao L, Gai N. Median nerve cross-sectional area and MRI diffusion characteristics: normative values at the carpal tunnel. Skeletal Radiol 2009 Apr;38(4):355-61.
11. Kobayashi S, Hayakawa K, Nakane T, Meir A, Mwaka ES, Yayama T et al. Visualization of intraneural edema using gadolinium-enhanced magnetic resonance imaging of carpal tunnel syndrome. J Orthop Sci 2009 Jan;14(1):24-34.
12. Polykandriotis E, Premm W, Horch RE. Carpal tunnel syndrome in young adults-an ultrasonographic and neurophysiological study. Minim Invasive Neurosurg 2007 Dec;50(6):328-34.
13. Iannicelli E, Almberger M, Chianta GA, Salvini V, Rossi G, Monacelli G et al. High resolution ultrasonography in the diagnosis of the carpal tunnel syndrome. Radiol Med 2005 Nov-Dec;110(5-6):623-9.
14. Hobson-Webb LD, Massey JM, Juel VC, Sanders DB. The ultrasonographic wrist-to-forearm median nerve area ratio in carpal tunnel syndrome. Clin Neurophysiol 2008 Jun;119(6):1353-7.
15. 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.
16. Keleş I, Karagülle Kendi AT, Aydin G, Zöğ SG, Orkun S. Diagnostic precision of ultrasonography in patients with carpal tunnel syndrome. Am J Phys Med Rehabil 2005 Jun;84(6):443-50.
17. 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.
18. Kwon BC, Jung KI, Baek GH. Comparison of sonography and electrodiagnostic testing in the diagnosis of carpal tunnel syndrome. J Hand Surg Am 2008 Jan;33(1):65-71.
19. Kaymak B, Ozçakar L, Cetin A, Candan Ce-tin M, Akinci A, Hasçelik Z. A comparison of the benefits of sonography and electrophysiologic measurements as predictors of symptom severity and functional status in patients with carpal tunnel syndrome. Arch Phys Med Rehabil 2008 Apr;89(4):743-8.