Cukurova Medical Journal
ÇUKUROVA ÜNİVERSİTESİ TIP FAKÜLTESİ

Cukurova Med J 2020;45(4):1276-1282
DOI: 10.17826/cumj.745698

ARAŞTIRMA / RESEARCH

Assessment of diagnostic efficiency of real-time strain elastography by using the median nerve stiffness at females with carpal tunnel syndrome

Karpal tünel sendromunda median sinir sertliği ölçümlerini kullanarak real-time strain elastografinin tanısal etkinliğinin değerlendirilmesi

Emrah Karatay[1], Özlem Türkoğlu[2], Başak Mansız Kaplan[3]

[1]Health Science University Kartal Lütfi Kirdar Educational Research Hospital, Department of Radiology, Istanbul, Turkey.
[2]Health Science University Sultan Abdulhamid Han Educational Research Hospital, Department of Radiology, Istanbul, Turkey.
[3]University of Health Sciences, Ankara Training and Research Hospital, Department of Physical Medicine and Rehabilitation, Ankara, Turkey.

Cukurova Medical Journal 2020;45 (4):1276-1282

Abstract

Purpose: We aimed to show the diagnostic value of strain elastography in relation to carpal tunnel syndrome (CTS) and to show the relationship between electromyography (EMG) and sonographic cross-sectional area measurements.
Materials and Methods: The patients with paresthesia of the median nerve distrubition lasting at least for 3 months were included. A total of 23 female patients's of CTS and 25 healthy female volunteers' wrist in which one median nerve existed included that of 36 CTS and 46 healthy wrists. The patients had clinical signs and their EMG test confirmed the diagnosis. The patients median nerve along its course on the wrist was applied strain elastography at three points of the radioulnar joint, scaphoidpsiform junction and hamate bone.
Results: The EMG findings, strain elastogragraphy ratios and the CSA of the median nerve were found to be correlated significantly. The median nerve strain ratio in elastography was significantly increased in the CTS patients compared to the control group.
Conclusion: Sonoelastography promises to be a useful method for the diagnosis of CTS.
Keywords:. electromyography, Carpal tunnel syndrome, Strain Elastography, elasticity

Öz

Amaç: Krpal tünel sendromu(KTS) tanılı olgularda real - time strain elastografisinin tanısal değerini ve median sinire yönelik EMG (elektromiyografi) bulguları ile sonografik parametrelerin (sinir kesit alanı ölçümü) arasındaki korelasyonu göstermeyi amaçladık.
Gereç ve Yöntem: Çalışmaya median sinirin trasesinde en az 3 ay süren parestezisi olan hastalar dahil edildi. KTS tespit edilen toplam 23 kadın hasta ve 25 sağlıklı kadın kontrol gruplarının el bileği incelenirken bifid median sinir ekarte edilerek toplamda 36 KTS ve 46 sağlıklı median sinire el bileği trasesinde 3 farklı noktada; radyoulnar eklem, skafoidpsiform bileşke ve hamat kemik olmak üzere real time strain elastografisi uygulandı. Hastaların klinik belirtileri vardı ve EMG testleri tanıyı doğruladı
Bulgular: KTS mevcut olgularda EMG bulguları ile sonografik median sinir kesit alanı ölçümü ve strain elastografi oran değerleri korele olarak tespit edildi. KTS olgularında median sinir elastografi strain oran değeri kontrol grubuna göre anlamlı olarak artmıştı ($p < 0.001$).
Sonuç: Sonoelastografi KTS tanısı için yararlı bir yöntem olarak umut verici sonuçlar vermektedir.

Anahtar kelimeler: Elektromiyografi, karpal tünel sendromu, strain elastografi, elastisiti

Yazışma Adresi/Address for Correspondence: Dr. Özlem Türkoğlu, Health Science University Sultan Abdulhamid Han Educational Research Hospital, Department of Radiology, Istanbul, Turkey. E-mail: ozlemkolcak@hotmail.com
Geliş tarihi/Received: 31.05.2020 Kabul tarihi/Accepted: 22.09.2020 Çevrimiçi yayın/Published online: 23.10.2020

INTRODUCTION

Carpal tunnel syndrome (CTS), similar to other entrapment neuropathies, is a common disorder that can cause serious problems in daily life. CTS is the most common entrapment neuropathy of upper extremity as the median nerve travels through the wrist at the carpal tunnel[1-3]. The main indicators of the CTS are the pain on the median nerve distribution area, numbness, tingling and late atrophy in tenar muscles of the arm. The diagnosis of the syndrome is based on these clinical signs and additional electromyography (EMG) test. However, EMG is an invasive, and often the uncomfortable procedure for patients. Moreover, a few studies observed that EMG has false-negative results in the diagnoses of the CTS[4-6]. As another diagnostic approach, the magnetic resonance imaging (MRI) may be beneficial but inadequate and overpriced for a certain diagnosis.

The elasticity of a substance is defined as the tendency of that substance to recover its original shape and size after exposure to a force or stress. Elastography is based on strain on the final tissue to be applied to the tissue and is expressed in a ratio. The strain in the tissue is formed by mechanical compressions made with an US probe[5]. The Real-Time Strain Elastography (RTSE) is a new non-invasive method which is an ultrasound (USG) technique in which images are obtained by evaluating the tissue response to localized mechanical stimuli generated by an ultrasonography probe. The strain in the tissue is formed by mechanical compressions made with an US probe. In addition, the Real Time Elastography images to be obtained are directed simultaneously by the high-resolution B-mode images obtained simultaneously, resulting in optimal images[5-7]. The US elastography have been performed on a variety of diseases, mostly in the breast, hepatic fibrosis and thyroid[8,9].

Some studies have reported that musculoskeletal application of USG elastography is valuable in detecting muscle and tendon abnormalities[10,16]. However, there are a few studies for peripheral nerve tissue and traumatic neuropathies[17-22]. In this study, we aimed to show the diagnostic value of strain elastography with CTS and to show the relationship between EMG and USG cross-sectional area measurements. In addition, we evaluated the relationship with entrapment by measuring the median nerve cross sectional area at multiple levels at the wrist level.

MATERIALS AND METHODS

This prospective study was approved by the Marmara University Faculty of Medicine ethics committee (decision date; 09.2014, 70737436-1400057149 approval number). The study adhered to all ethical principles for the good conduct of research with humans outlined by the Declaration of Helsinki. Firstly, written informed consent was obtained from participants, patient and control group, who voluntarily participated after they were given the information sheet and verbally informed about the study's objectives, benefits and risks, and the recruitment procedure. The control group consisted of healthy volunteers without CTS symptomatology. The patients with paresthesia of the median nerve distribution, lasting for at least three months and whose EMG test showing coherence with mild to moderate CTS were included to the study group. The exclusion criteria were as following; thenar atrophy (heavy CTS), escherichia colitis in aetiology, pregnancy, patients previously treated with CTS, the presence of cervical radiculopathy, and endocrinological disease, connective tissue disease. This study was conducted prospectively between June 2015 and January 2016. Throughout the study, 89 patients with a pre-diagnosis of CTS were evaluated, 66 patients who did not meet the inclusion criteria were excluded from the study. A total of 23 female patients' of CTS and 25 healthy female volunteers' wrists in which one median nerve existed were evaluated in this study. The age of patients ranged from 25-61; control group ranged from 21-53. The wrists containing bifid median nerve excluded so that 36 CTS wrists and 46 healthy wrists were applied. The clinical signs and EMG had been evaluated to diagnose the CTS. Then the patients with the CTS diagnoses were applied sonographic strain elastography. Both wrists of the healthy volunteers in the control group were assessed as well.

Clinical evaluation

The CTS patients who met the necessary criteria applying the policlinics of Physical Medicine and Rehabilitation Department of Marmara University Hospital were chosen. Patients were evaluated for the upper extremity muscle strength, sensory examination, deep tendon reflexes, Tinel and Phallen tests, presence of tenor atrophy, flick test, KATZ hand diagram scores. Clinical evaluation was performed by an physical medicine and rehabilitation physician.

EMG

The EMG was performed by an electrophysiologist in the Electrophysiology Laboratory of Physical Medicine and Rehabilitation Department of Marmara University Hospital. These reviews were done by the Medtronic-Keypoint Portable device (Denmark, 2007) with the following settings. The sensory and motor nerve conduction studies were performed for the median and ulnar nerves. The EMG device motor settings were as follows: the sensitivity: 55 μV, the filters: 20 Hz to 10 kHz, the warning duration: 0.1 milliseconds, the warning frequency:1Hz. The sensory settings were as follows: the sensitivity: 120 μV, the Filters: 20 Hz to 2 kHz, the warning duration: 0.1 milliseconds, the warning frequency: 1 Hz. The needle settings were as follows: spontaneous activity: 50 μH amplitude, 0.1 ms duration, MUP analysis: 1 mV amplitude, 30 msec duration, Recruitment: 1 mV amplitude, 200 msec duration (Table 1).

Table 1. Comparison of EMG, ultrasound and elastography values between CTS and control group

	CTS (n= 36)	Control (n= 46)	*p* value
EMG parameters			
Motor latency	3.9±0.55	3.00±0.50	p<0.001
Sensory rate	43.8±6.03	53.8±6.40	p<0.001
Motor amplitude	9.85±5.65	11.8±2.42	p<0.05
Sensory amplitude	23.92±8.31	43.73±1.05	p<0.001
Ultrasound measurements			
RUJ CSA (cm^2)	0.10±0.03	0.07±0.01	p<0.001
SCP-CSA (cm^2)	0.11±0.04	0.07±0.02	p<0.001
H-CSA (cm^2)	0.11±0.03	0.07±0.01	p<0.001
Elastography values			
RUJ-elastography	2.94±3.58	0.76±0.75	p<0.001
SCP-elastography	6.11±4.23	0.88±0.61	p<0.001
H-elastography	6.24±5.98	1.09±1.06	p<0.001

CTS, carpal tunnel syndrome; EMG, electromyography; RUJ, radioulnar joint; SCP, scaphoid-psiform; H, hamate; CSA, cross-sectional area

Sonographic evaluation and ultrasonic elastography

Ultrasound and elastography procedures were evaluated by one of the two radiologists (O.K or E.K) dealing with musculoskeletal ultrasonography. Ultrasound examination for median nerve was performed before Strain Elastography, and B-mode imaging guidance was used during RTSE. We used 18-7 Mhz linear array probe with RTSE (Toshiba Medical Systems Tochigi, Japan). No medication was applied to the patient for imaging purposes. The patient was sitting against the radiologist in the elbow flexed, the forearm lying on the knee on the same side, the wrist in the supine position, and the fingers relatively relaxed slightly open The B-mode imaging and RTSE procedures were performed by placing the linear probe transversely on the wrist volar face, on the carpal tunnel level. In order to view the median nerve, first, the B-mode imaging was performed. During the B-mode ultrasound imaging, median nerve length and cross-sectional area (CSA) measurements were performed at the level of the distal radioulnar joint (RUJ), scaphoid-psiform (SCP)level and os hamate (H), respectively (Figure 1).

Then, the elastography mode was switched in synchronism with the B-mode imaging. The strain elastography was performed by applying periodical pressure by a linear probe to the median nerve. Excessive pressure was avoided on the wrist to avoid sampling errors during measurements. During this process, vertical compression was carefully applied so as not to cause the underlying tissue replacement.

When symmetric sinusoidal waves were obtained on the screen, the image was stopped, and the strain elastography measurements were made. In the view of the sinusoidal wave, the part that remains on the baseline represents compression, while the rest represents the decompression phase. Measurements were made in the decompression phase since there was less and more stable pressure.

During the elastography process, the median nerve, which contains the areas of the healthy median nerve was observed in blue, while it displayed in red colour on the colour scale in case of increased hardness and fibrosis.

Figure 1. Distal measurement (entrance of the carpal tunnel): width and height (white), ss-sectional area (CSA) of the median nerve (green).

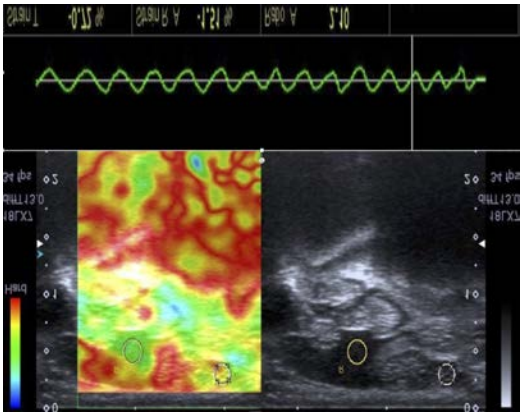

Figure 2. The first regio of interest (ROI) was placed in the muscle of flexor digitorum superficialis and the subsequent ROI was placed in the median nerve.

Similar to B-mode imaging, RTSE measurements were made from 3 levels of medial nerve swelling at the carpal tunnel entrance: at the level of the distal radioulnar joint (RUJ), scaphoid-psiform (SCP) level and os hamate (H), respectively. The first region of interest (ROI) was placed in the muscle of flexor digitorum superficialis (Profundus was not preferred due to its deep location), and the subsequent ROI was placed in the median nerve (Figure 2). During all measurements, the ROI diameter was fixed at 2 mm. In order to measure correctly, the ROI points were placed in different areas, with no projections on each other. During the procedure, ROI points were placed at the centre of the muscle and median nerve to be examined, and measurements were made. From two points, Q analysis and ratio parameters were obtained, and the elastography process was terminated.

Statistical analysis

Data were collected and analyzed by SPSS version 18 (SPSS, Chicago, IL, USA). Descriptive statistical methods (median, frequency, percent, minimum, and maximum) were used to evaluate the study data. In our study, the effect size was accepted as an 80% confidence interval with an error rate of 0,625 and 0.05, the power of the test was calculated as 80% with an error rate of 0.05. Kolmogorov-Smirnov test assessed normality of quantitative data distribution. The chi-square test for nominal data and the Mann-Whitney U test for numerical data were used. McNemar test were used to evaluate interpersonal correlation. Correlation between parameters was tested by Spearman correlation test. In this study, p value <0.05 was considered significant.

RESULTS

There was no relationship between age and elastography parameters. However, the median nerve CSA at the os hamatum level was slightly increased with increasing age ($p = 0.04$). There was a significant correlation between motor latency and CSA at the level of RU joint, SCP and hamatum. (P all <0.001) $r = 0.692$ for RUJ, $r = 0.710$ for SCP, $r = 0.790$ for H. There is also a significant correlation between motor latency and elastography (p all <0.001) $r = 0.501$ for distal RUE, $r = 0.702$ for SCP, $r = 0.602$ for H. Significant correlation was found with CSA measurements in terms of sensory conduction velocity (negative correlation) (p all <0.001) $r = -0.678$ for distal RUE, $r = -0.674$ for SCP, $r = -0.760$ for H. As the CSA measurements increased, the message speed decreased. There was a negative correlation between sensory speed and elastography

parameters. (p all <0.001) r = -0.544 for distal RUE, r = -0.713 for SCP, r = -0.612 for H.

The CSA measurement made on the RU joint and a measurement of the same level of elastography were found to be significantly correlated $p < 0.001$ r = 0.527. The CSA measurement made on the SCP joint level and a measurement of the same level of elastography were found to be significantly correlated p <0.001 r = 0.663. The CSA measurement made on the Hook of the hamatum and a measurement of the same level of elastography were found to be significantly correlated $p < 0.001$ r = 0.508.

When the two groups were compared, significant differences were found in distal median motor latency, sensory conduction velocity, median motor nerve combined muscle action potential amplitude, CSA measurements of the median nerve on os hamate, distal radioulnar joint, SCP level and elastography parameters from the same levels (p <0.05) (Table 1).

The results of the EMG and the CSA of the median nerve were found to be correlated significantly. The results confirmed that the CSA measurement could be performed for the CTS diagnosis as well. The median nerve strain ratio was significantly increased in the CTS patients compared to the control group. Sonoelastography (RTSE) promises to be a useful method for the diagnosis of CTS.

DISCUSSION

In this study, the median nerve elasticity was evaluated along its trace on 3 points of wrist joint; at the level of os hamate, scaphoid, psiform level and radioulnar joint using semi-quantitative (strain rate) technique as in studies of Miyamoto H, Gunes, Emara et al[11-13]. The elastography proved strain ratios and the median nerve stiffness that was associated with increased pressure on the median nerve and its circulation were strongly related. Through the carpal tunnel, CSA of the median nerve at the level of os hamate was found high different from other two points in older age groups that could be related with more oedema formation and contribution of age at this point. It was already explained in literature the causes fibrosis and scar tissue formation in the median nerve had been related with oedema[14-17]. Focusing our finding, we found the literature mentioning the nerve release operation, which was performed on the os hamate level caused a meaningful difference in pain and symptom reduction[18]. The literature contains studies about oedema of the median nerve such as the oxidative stress and disruption of antioxidant defence may be associated with fibrosis of the median nerve or the median stiffness after the steroid injection was decreased[19-22]. There is also a study to evaluate the effectiveness of low-level laser therapy on median nerve stiffness using strain elastography in carpal tunnel syndrome[23]. It is thought that ischemic injury of the median nerve coexisted with increased intracarpal tunnel pressure results in axonal degeneration and focal demyelination with a fibrotic response. The incorrect diagnosis was identified as one of the most common causes of inadequate treatment in CTS. Researchers found results in favour of the development of CTS with increased BMI and obesity in several studies[24-27].

CTS is now diagnosed by clinical findings and the EMG of the median nerve. In our study, RTSE proved to be a valuable tool for CTS. The EMG and the RTSE findings were showing a significant correlation. The strain ratio value was increased in patients diagnosed as the CTS compared to the healthy control group. Usually, ultrasonographic evaluations are standard for musculoskeletal since the tendons are comfortable to see and superficially located than the other soft tissues. In the literature, it has not been encountered the multiple points of the median nerve on the wrist to be evaluated by means of strain elastography. By doing this, we tried to explore topographic details of fibrosis and find additional data maybe for surgical strategy.

Similarly, since the median nerve is superficial and distinctive, it can be easily assessed by both ultrasonography. In environments where EMG is not available or used, it seems to be very reliable in the diagnosis of CTS to use sonographic elastography.

In our study relatively small sample group and the absence of BMI (body mass index) values was a limitation of our study. Ultrasonography is becoming increasingly important because of its non-invasiveness in the diagnosis of CTS[28-31]. There is a lot of discussion with the diagnostic site of ultrasonography.

In this study, we looked for three wrist points according to the motor and sensory nerve conduction velocities and fibrosis with EMG and strain elastography. The strain elastography findings were found correlated with the EMG tests. The strain

ultrasound elastography, which is a non-invasive painless measure that is a promising method to detect the CTS advantage. With studies to be conducted with larger patient samples, strain elastography technique will become more common in the diagnosis of CTS patient. The radioulnar joint, scaphoid-psiform level and os hamate level were three points on the median nerve that we looked significant difference of CSA measurements. The os hamate level CSA was found slightly increased with increasing age that can be a further subject to be evaluated for treatment strategies.

Yazar Katkıları: Çalışma konsepti/Tasarımı: EK, ÖT, BMK; Veri toplama: EK, ÖT, BMK; Veri analizi ve yorumlama: EK, ÖT, BMK; Yazı taslağı: EK, ÖT; İçeriğin eleştirel incelenmesi: EK, ÖT, BMK; Son onay ve sorumluluk: EK, ÖT, BMK; Teknik ve malzeme desteği: EK, BMK; Süpervizyon: EK, ÖT, BMK; Fon sağlama (mevcut ise): yok.
Etik Onay: Bu çalışma için Marmara Üniversitesi Tıp Fakültesi Klinik Araştırmalar Etik Kurulundan 07,03.2014 tarih ve 09.2014.0002/70737436-050.06.04.1400057149 protokol kodu ile etik onay alınmıştır.
Hakem Değerlendirmesi: Dış bağımsız.
Çıkar Çatışması: Yazarlar çıkar çatışması beyan etmemişlerdir.
Finansal Destek: Yazarlar finansal destek beyan etmemişlerdir.
Author Contributions: Concept/Design : EK, ÖT, BMK; Data acquisition: EK, ÖT, BMK; Data analysis and interpretation: EK, ÖT, BMK; Drafting manuscript: EK, ÖT; Critical revision of manuscript: EK, ÖT, BMK; Final approval and accountability: EK, ÖT, BMK; Technical or material support: EK, BMK; Supervision: EK, ÖT, BMK; Securing funding (if available): n/a.
Ethical Approval: Ethical approval for this study was obtained from Marmara University Faculty of Medicine Clinical Research Ethics Committee with the protocol code of 09.2014.0002 / 70737436-050.06.1400057149, dated 07.03.2014.
Peer-review: Externally peer-reviewed.
Conflict of Interest: Authors declared no conflict of interest.
Financial Disclosure: Authors declared no financial support

REFERENCES

1. Martyn CN, Hughes RA. Epidemiology of peripheral neuropathy. J Neurol Neurosurg Psychiatry. 1997;62:310–18.
2. Moran L, Perez M, Esteban A, Bellon J, Arranz 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;37:125–31.
3. Ozben S, Acar H, Gunaydin S, Genc F, Ozer F, Ozben H. The second lumbrical–interosseous latency comparison in carpal tunnel syndrome. J Clin Neurophysiol. 2012;29:263–67.
4. Atroshi I, Gummesson C, Johnsson R, Ornstein E. Diagnostic properties of nerve conduction tests in population based carpal tunnel syndrome. BMC Musculoskelet Disord. 2003;4:9.
5. Gomes I, Becker J, Ehlers JA, Nora DB. Prediction of the neurophysiological diagnosis of carpal tunnel syndrome from the demographic and clinical data. Clin Neurophysiol. 2006;117:964–71.
6. Witt JC, Hentz JG, Stevens JC. Carpal tunnel syndrome with normal nerve conduction studies. Muscle Nerve. 2004;29:515–22.
7. Mathew RP, Venkatesh SK. Imaging of hepatic fibrosis. Curr Gastroenterol Rep. 2018;20:45.
8. Hari S, Paul SB, Vidyasagar R, Dhamija E, Adarsh AD, Thulkar S et al. Breast mass characterization using shear wave elastography and ultrasound. Diagn Interv Imaging. 2018;99:699-707.
9. Tyloch DJ, Tyloch JF, Adamowicz J, Juszczak K, Ostrowski A, Warsiński P et al. Elastography in prostate gland imaging and prostate cancer detection. Med Ultrason. 2018;20:515-23.
10. Feng YN, Li YP, Liu CL, Zhang ZJ. Assessing the elastic properties of skeletal muscle and tendon using shearwave ultrasound elastography and MyotonPRO. Sci Rep. 2018;8:17064.
11. Miyamoto H, Halpern EJ, Kastlunger M, Gabl M, Arora R, Bellmann-Weiler et al. Carpal tunnel syndrome: diagnosis by means of median nerve elasticity--improved diagnostic accuracy of US with sonoelastography. Radiology. 2014;270:481-86.
12. Gunes O, Serkan O, Nergiz H, Mahmut D, Keziban G. Ultrasound elastographic evaluation in the diagnosis of carpal tunnel syndrome: initial findings. Ultrasound Med Biol. 2013;39: 1184–189.
13. Emara DM, El Shafei MM, Naby HMA. Utility of ultrasound elastography in a cohort of patients with idiopathic carpal tunnel syndrome. The Egypt J of Radiol Nucl Med. 2018; 49:408-14.
14. de Krom MC, Knipschild PG, Kester AD, Thijs CT, Boekkooi PF, Spaans F. Carpal tunnel syndrome: Prevalence in the general population. J Clin Epidemiol. 1992;45:373–76.
15. Szabo RM, Chidgey LK. Stress carpal tunnel pressures in patients with carpal tunnel syndrome and normal patients. J Hand Surg Am. 1989;14:624-27.
16. Mackinnon SE, Dellon AL, Hudson AR, Hunter DA. A primate model for chronic nerve compression. J Reconstr Microsurg. 1985;1:185–95.
17. Rempel D, Evanoff B, Amadio PC, De Krom M, Franklin G, Franzblau A et al. Consensus criteria for the classification of carpal tunnel syndrome in epidemiologic studies. Am J Public Health. 1998;88:1447–451.
18. Dinarvand V, Abdollahi I, Ahmad SR, Bandpei MAM, Babaee M, Talimkhani A. The effect of scaphoid and hamate mobilization on treatment of patients with carpal tunnel syndrome. Anesth Pain Med. 2017;7.e14621.
19. Demirkol A, Uludag M, Soran N, Aksoy N, Gun K, Incebıyık S et al. Total oxidative stress and antioxidant status in patients with carpal tunnel syndrome. Redox Rep. 2012;7:234-38.
20. Kim JK, Koh YD, Kim JS, Hann HJ, Kim MJ. Oxidative stress in subsynovial connective tissue of idiopathic carpal tunnel syndrome. J Orthop Res. 2010;28:1463-468.

21. Asadov R, Erdal A, Buğdaycı O, Gündüz OH, Ekinci G. The effectiveness of ultrasonography and ultrasonographic elastography in the diagnosis of carpal tunnel syndrome and evaluation of treatment response after steroid injection. Eur J Radiol. 2018;108:172-76.
22. Dehghan F, Haghighat S, Ramezanian H, Karami M, Rezaei MR. Ultrasonography predictive factors of response to local steroid injection in patients with carpal tunnel syndrome. Adv Biomed Res. 2018;7:22.
23. Tezcan S, Ulu Ozturk F, Uslu N, Nalbant M, Umit Yemisci O. Carpal tunnel syndrome: evaluation of the effects of low-level laser therapy with ultrasound strain imaging. J Ultrasound Med. 2019;38:113-122.
24. Shiri R, Pourmemari MH, Falah-Hassani K, Viikari-Juntura E. The effect of excess body mass on the risk of carpal tunnel syndrome: a metaanalysis of 58 studies. Obes Rev. 2015;16:1094–1104.
25. Mansoor S, Siddiqui M, Mateen F, Saadat S, Khan ZH, Zahid M et al. Prevalence of obesity in carpal tunnel syndrome patients: A cross-sectional survey. Cureus. 2017;9:e1519.
26. Uzar E, İlhan A, Ersoy A. Association between carpal tunnel syndrome and abdominal obesity. Turk J Neurol. 2010;16:187-92.
27. Kurt S, Kisacik B, Kaplan Y, Yildirim B, Etikan I, Karaer H. Obesity and carpal tunnel syndrome: is there a causal relationship? Eur Neurol. 2008;59:253-57.
28. Martin MJ, Cartwright MS. A pilot study of strain elastography in the diagnosis of carpal Tunnel Syndrome. J Clin Neurophysiol. 2017;34:114–18.
29. Miyamoto H, Morizaki Y, Kashiyama T, Tanaka S. Grey-scale sonography and sonoelastography for diagnosing carpal tunnel syndrome. World J Radiol. 2016;8:281–87.
30. Liao YY, Lee WN, Lee MR, Chen WS, Chiou HJ, Kuo TT et al. Carpal tunnel syndrome: US strain imaging for diagnosis. Radiology. 2015;75:205-14.
31. Lin CP, Chen IJ, Chang KV, Wu WT, Özçakar L. Utility of ultrasound elastography in evaluation of carpal tunnel syndrome: A systematic review and meta-analysis. Ultrasound Med Biol. 2019;45:2855-865.