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ORIGINAL ARTICLE

Value of cross-sectional area of median nerve by MRI in carpal tunnel syndrome

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Summary *Background:* Carpal tunnel syndrome is diagnosed based on history, physical examination, and nerve conduction testing; however, there are no clear criteria for the diagnosis of carpal tunnel syndrome. Recently, studies have aimed to diagnose carpal tunnel syndrome through ultrasound or MRI. The purpose of this study was to compare and analyze the cross-sectional area of the median nerve between patients with carpal tunnel syndrome and a control group.
Methods: From July 2015 to August 2017, we retrospectively analyzed fishery and white-collar workers (164 people, 37 men, 127 women). Carpal tunnel syndrome was diagnosed on the basis of both physical examination and nerve conduction testing. A negative result in either test led to exclusion from the study.
Results: In total, 164 wrist MRI were retrieved, with 67 patients diagnosed with carpal tunnel syndrome and 97 patients allocated to the control group. The mean value of cross-sectional area at the pisiform was 18.8 mm^2 in the MRI of the carpal tunnel syndrome patients and 12.1 mm^2 (p-value <0.05) in the control group. The mean value of cross-sectional area at the hook of hamate was 11.70 mm^2 and that at the control group was 11.67 mm^2 (p-value 0.055).
Conclusion: Cross-sectional area at pisiform in MRI is a valuable factor in the diagnosis of carpal tunnel syndrome and in predicting the duration of pain.

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1. Introduction

Carpal tunnel syndrome (CTS) is one of the most common compressive neuropathies in the hand clinic with is caused by compression of the median nerve in the carpal tunnel. The most common symptoms are radiating pain, numbness, tingling sensations, paresthesia in the thumb, index, middle and ring finger.[1] Weakness of thumb, and thenar muscle atrophy can appear after long periods of time.[2,3] CTS is diagnosed on history, physical examinations, and nerve conduction tests, but there are no clear criteria for the diagnosis. Recently, there have been studies to diagnose CTS through ultrasound or MRI measuring nerve enlargement on the cross-sectional area (CSA) of the carpal tunnel.[4,5] Recent studies suggest that using ultrasonography to measure carpal tunnel CSA can be a diagnostic tool of CTS. Many of the previous studies used ultrasound[6–9] but there have not been many studies regarding MRI findings of CTS. We hypothesized that there would be significant differences of CSA of carpal tunnel and median nerve between CTS patients and a control group on MRI findings. Therefore, the purpose of this study was to compare the CSA of median nerve between patients with carpal tunnel syndrome and a control group using MRI. In addition, using receiver operating characteristic (ROC) curve to analyze the result of the cut-off value of CSA may be helpful in diagnosing CTS.

2. Methods

2.1. Participants

In this cross-sectional study, all participants were referred for the evaluation of CTS to our hospital from July 2015 to August 2017. We retrospectively analyzed total of 164 people (37 men, 127 women). The following criteria were used to diagnose CTS[6]: (1) patients with CTS symptoms, (2) positive findings of any of the following physical examinations: Phalen's test, Tinel's sign, and direct compression test and (3) evidence of median neuropathy in EMG-NCV. Patients meeting any of the following criteria were excluded from the study: (1) previous operation history around the wrist, (2) no evidence of median neuropathy in EMG-NCV, and (3) vague symptoms or physical examination results. Finally, 67 wrists were diagnosed with CTS and the control group consisted of 97 healthy wrists.

2.2. Health examination survey

The one-on-one survey was conducted by nurses who were informed of the objective of this study and who were trained in data collection procedures. The survey included information on socio-demographic variables (age, gender, weight and height, body mass index (BMI), and waist circumference).

2.3. Radiologic examination

MRI evaluation was performed on all participants. All of the patients were placed in the supine position with their arms by their side. The forearms were placed in the neutral position and were placed in a small flex coil and immobilized with cushions. The laser beam was localized over the wrist joint. One orthopedic doctor interpreted all of the MRI images and measured each value while blind to the clinical and electrophysiological findings using a picture archiving and communication system (PACS). CSA of carpal tunnel was measured by tracing the margin of the carpal tunnel at hook of hamate. CSA of median nerve was measured by tracing the margins of the nerves at level of pisiform and hamate hook, this was defined as carpal tunnel inlet (CTI) and carpal tunnel outlet (CTO). Additionally, the widths and heights of the median nerves were measured at the CTI and CTO. After obtaining each value, we measured the unit area ratio of CTI and CTO, the width/height ratio of CTI and CTO.[10] (Fig. 1).

2.4. Nerve conduction studies

All patients underwent nerve conduction test. All studies were conducted by one physiatrist using surface and needle electrodes. The skin was adjusted above 32 °C and examination underwent on room temperature at 25 °C. CTS patients were divided into three groups on the basis of electrophysiological severity[11,12]: 1) Mild: prolonged sensory distal latency ± SNAP (sensory nerve action potential) amplitude reduction; 2) Moderate: prolongation of both median motor and sensory distal latencies; 3) Severe: moderate type of CTS, with either an absence of SNAP, or low amplitude or absent thenar CMAP (compound muscle action potential), or findings compatible with axonal injury in electromyography.

2.5. Statistical analysis

SPSS for windows (version 23.0) was used for statistical analysis. Continuous variables were expressed as means and standard deviations, and nominal variables were expressed as numbers and percentages. Pearson correlation tests were used to evaluate the relationships with pain duration and MRI values in CTS. The mean values of parameters according to the presence or absence of CTS were compared and analyzed. ROC analysis was used to evaluate the cut-off value of CTS predicting the prognosis of CTS. In all analyses, p-values <0.05 were considered to be significant.

3. Results

3.1. Baseline characteristics of subjects

In total, 164 wrist MRI were retrieved with a mean age of 61.8 years (range: 42—78 years). Sixty-seven patients were diagnosed with CTS (7 men and 60 women). The control group consisted of 97 patients (31 men and 66 women). BMI shows significantly low (p-value < 0.01) in non-CTS group with 23.46 (SD 2.40). Demographic data of the CTS and control groups are outlined in Table 1.

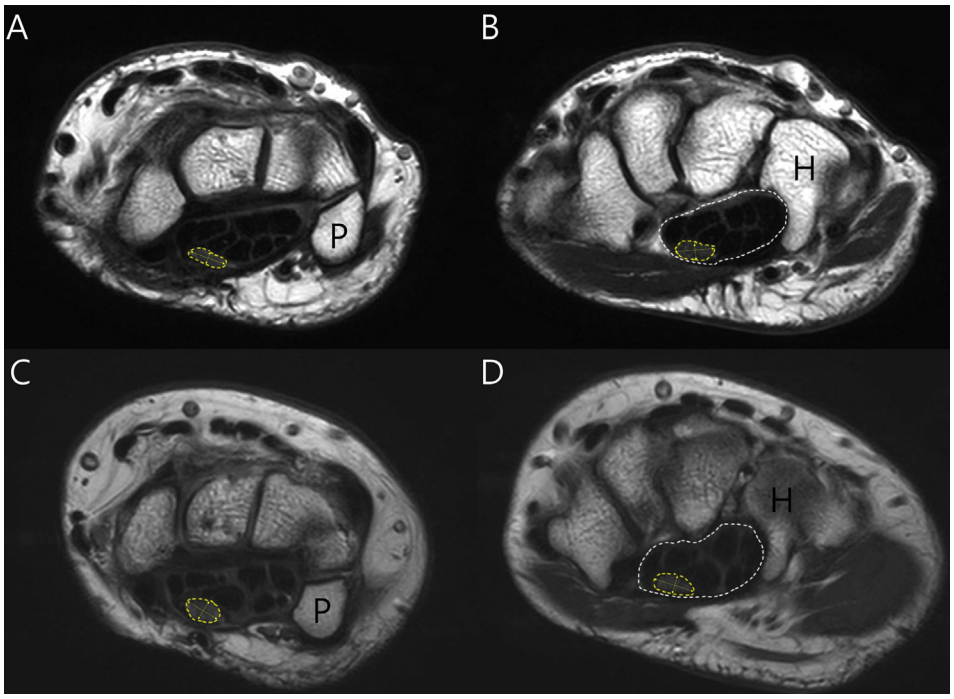

Figure 1 MRI axial section of the wrist (T2-weighted sequence); CTI (A), CTO (B) of control patient and CTI (C), CTO(D) of patient with carpal tunnel syndrome. The area of margination with white dotted line indicates the CSA of the entire carpal tunnel. The area of margination with yellow dotted line indicates the CSA of the median nerve. P: pisiform, H: hamate bone.

3.2. MRI values by presence of CTS

Table 2 shows the MRI values of CTS and control groups. The CSA of the carpal tunnel was larger in the CTS group of 214.48 (SD 25.28) mm^2 than in the control group of 199.37 (SD 20.51) mm^2 ($p < 0.01$). CSA of the median nerve of 18.77 (SD 4.53) mm^2, width of 8.19 (SD 1.35) mm, and height of 2.97 (SD 0.41) mm in CTI were significantly larger in the CTS group than in the control group ($p < 0.01$). The CSA of the median nerve ratio between CTI and CTO was high in the CTS group with 1.64 (SD 0.42) comparing to non-CTS group with 1.04 (SD 0.18) ($p < 0.01$). Furthermore, the median nerve width and height ratio was significantly high in the CTS group with 2.80 (SD 0.57) comparing to non-CTS group with 2.19 (SD 0.56) ($p < 0.01$).

In addition, the ratio of CSA between median nerve and carpal tunnel was significantly high in the CTS group with 19.25 (SD 4.92) comparing to non-CTS group with 17.73 (SD 3.86) ($p < 0.01$).

Table 1 Demographic data of CTS and control groups.

Variable	CTS	Non-CTS	*p*-value
Age (year)	61.58 ± 8.69	60.82 ± 7.75	0.56
Weight (kg)	60.84 ± 10.48	60.46 ± 8.75	0.80
Height (cm)	155.15 ± 6.16	160.36 ± 7.11	<0.01
BMI	25.21 ± 3.48	23.46 ± 2.40	<0.01
Waist (cm)	85.22 ± 8.20	82.27 ± 7.50	0.02

CTS: carpal tunnel syndrome, BMI: body mass index.

Table 3 shows the mean CSA at different levels of the median nerve in patients with CTS. As the severity of NCV test in patients with CTS increased, CSA of carpal tunnel at CTO and CSA of median nerve at CTI were significantly increased, respectively ($p < 0.01$). However, CSA of median nerve at CTO level was not significant according to the severity of NCV test.

3.3. Association between duration of pain and MRI variables in CTS

In addition, we have investigated the relationship between the duration of pain and MRI variables. A total of 88 patients replied that their pain was maintained for more than one month. The coefficient of correlation in the nerve at CTI was 0.35 (p-value <0.01). The area of the nerve at CTI is highly significant (p-value <0.05) (Table 4).

3.4. ROC analysis for diagnosis of CTS using median nerve at CTI

Using ROC curve, we evaluated the cut-off value of median nerve CTA in CTI to diagnose CTS (Fig.2). The area under the ROM curve of 164 wrists (positive group 67, negative group 97) was shown to be 0.907. The ROC curve showed a sensitivity of 83.6% and a specificity of 84.5% when the CSA of the median nerve was 15.1 mm^2 or larger in CTI (p-value <0.01).[13]

Table 2 MRI values of CTS and control groups.

Variable	CTS	Non-CTS	p-value
CSA of carpal tunnel at CTO (mm^2)	214.48 ± 25.28	199.37 ± 20.51	<0.01
CSA of median nerve at CTI (mm^2)	18.77 ± 4.53	12.09 ± 2.82	<0.01
CSA of median nerve at CTO (mm^2)	11.70 ± 2.69	11.67 ± 2.43	0.94
Ratio of nerve (P/H)	1.64 ± 0.42	1.04 ± 0.18	<0.01
Width at CTI (mm)	8.19 ± 1.35	5.80 ± 1.12	<0.01
Height at CTI (mm)	2.97 ± 0.41	2.73 ± 0.54	<0.01
Ratio at CTI(W/H)	2.80 ± 0.57	2.19 ± 0.56	<0.01
Width at CTO (mm)	6.04 ± 1.13	5.82 ± 1.08	0.20
Height at CTO (mm)	2.75 ± 0.62	2.75 ± 0.69	0.99
Ratio at CTO(W/H)	2.32 ± 0.71	2.26 ± 0.71	0.55
Ratio of CSA between median nerve and carpal tunnel	19.25 ± 4.92	17.73 ± 3.86	<0.01

CSA: cross-sectional area, CTI: carpal tunnel inlet, CTO: carpal tunnel outlet, W: width, H: height.

Table 3 Mean MRI measurements of CSA with different severity CTS.

	NO CTS	Mild CTS	Moderate CTS	Severe CTS	*p*-value
CSA of carpal tunnel at CTO (mm^2)	199.37 ± 20.40	208.60 ± 26.78	217.30 ± 22.29	224.90 ± 28.09	<0.01
CSA of median nerve at CTI (mm^2)	12.10 ± 2.80	17.23 ± 3.18	19.59 ± 4.98	20.34 ± 4.27	<0.01
CSA of median nerve at CTO (mm^2)	11.67 ± 2.42	11.28 ± 2.13	12.01 ± 2.90	11.58 ± 3.20	>0.01

CTI: carpal tunnel inlet, CTO: carpal tunnel outlet, CTS: carpal tunnel syndrome, CSA: cross-sectional area, N.S: not significant.

4. Discussion

The diagnosis of CTS is based on clinical signs and symptoms, and the nerve conduction test can be helpful as well. In recent years, ultrasonography has been used to measure CSA of median nerve. Compared to ultrasonography, MRI has the major advantage of achieving detailed imaging of bone and soft tissue, which can differentiate from other diseases in the wrist.[5,14] It is the most accurate non-invasive technique to measure CSA of the wrist.

Recent studies[14] suggest that measuring the nerve at the carpal tunnel inlet (CTI) which is bony landmark of pisiform shows the highest rates of sensitivity with 84% in diagnosing CTS when compared to the carpal tunnel outlet (CTO) which is bony landmark of hamate hook.[15]

Similar to our study, the largest CSA was measured at the level of the carpal tunnel inlet.[16] Mean CSA and perimeter significantly differed between the patient and control groups. The CSA group showed 14.02 (SD 4.5) mm^2 of CSA and the control group showed 8.2 (SD 2.1) mm^2. The median nerve CSA at the carpal tunnel inlet can be used as a diagnostic criterion for CTS. Previously, in other studies[17] also described that median nerve width and carpal tunnel diameter at the pisiform bone level were found on MRI to

Table 4 Association between duration of pain and MRI variables in CTS.

	Person-Correlation coefficient	*p*-value
CSA of carpal tunnel at CTO (mm^2)	0.11	0.29
CSA of median nerve at CTI (mm^2)	0.35	<0.01
CSA of median nerve at CTO (mm^2)	0.18	0.09
Ratio of nerve (P/H)	0.21	0.05
Width at CTI (mm)	0.31	<0.01
Height at CTI (mm)	0.13	0.23
Ratio at CTI(W/H)	0.16	0.13
Width at CTO (mm)	0.17	0.12
Height at CTO (mm)	0.06	0.56
Ratio at CTO(W/H)	0.05	0.65

CSA: cross-sectional area, CTI: carpal tunnel inlet, CTO: carpal tunnel outlet, W: width, H: height.

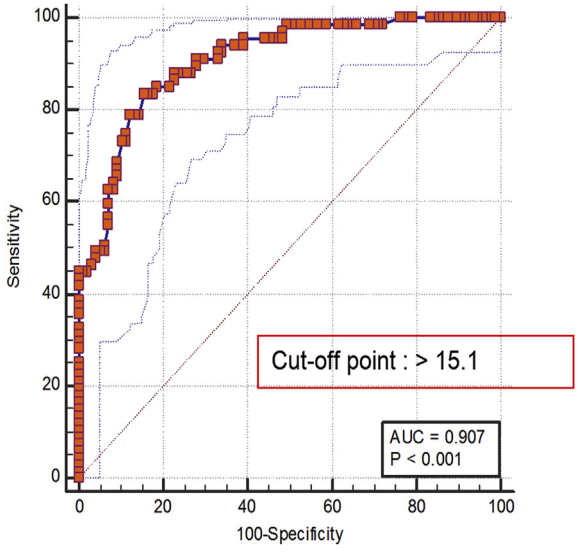

Figure 2 ROC analysis for the diagnosis of CTS using the nerve at CTI.

be significantly increased, whereas median nerve diameter at the hamate bone level and pressure angle of the median nerve were significantly lower in the CTS group.

Recent studies[11] performed whether sonography can be an alternative method to nerve conduction study (NCS) in the diagnosis of CTS. They found that the CSA at various levels of the median nerve were significantly greater in the CTS diseased hands than the non-diseased hands ($P = 0.001$). In present study, CSA of the median nerve at CTI was increased according to the severity of NCV test.

Another study[18] described the diagnostic value of ultrasonography in CTS patients. The mean CSA was 13.7 (SD 4.2) mm^2 in symptomatic hands and 7.9 (SD 1.3) mm^2 in asymptomatic hands. The cut-off value of 10 mm^2 for the mean CSA was found to be the upper limit for normal values. However, the accuracy of the exam significantly depends on the capacity of the examiner, and it is hard to evaluate anatomical structures over certain depth, so the result may very on ultrasonography. We have the strong advantage that using MRI to measure carpal tunnel CSA is more accurate than ultrasonography. Additionally, there was a relationship between the duration of pain and CSA of median nerve at CTI. It could probably explain that if the median nerve has been compressed more, the symptoms last for long period because the nerve had been injured much more.

Our results demonstrated that patients who were diagnosed with CTS in the whole study group showed a significant increase of CSA of median nerve in CTO. In addition, CSA of median nerve, width, and height were also significantly increased in CTI in the CTS group. (p-value <0.05). The best cut-off value of median nerve CSA for diagnosing CTS is 15.1 mm^2.

There are several limitations of this study. First, this study was a cross-sectional study. Because it was not a longitudinal study, we cannot determine anything about causal relationships. However, our fishery and white-collar workers cohort study is collecting longitudinal data; this will be used in a new study. Second, we did not analyze severity of symptoms and could not verify intra-operative pathology. However, this study is remarkable such that MRI was taken for every patient, which used to be barely accessible for the diagnosis of CTS, and it may serve as a reference study. Third, this study involves specific cohort data, and there might be selection bias as it collected data exclusively from those in the fishery. Future studies need to involve groups from fields beyond fishery. Fourth, there is a possibility of measuring error. Fifth, only static parameters using MRI were measured in this study. Finally, Magnetic resonance imaging (MRI) performed in this study did not evaluate the quantitative value of edematous change.

In conclusion, the values of CSA of the median nerve were statistically significantly different between patients with CTS and the control group ($p < 0.05$). In addition, ROC curve shows that when the area of the nerve in CTI is greater than 15.1 mm^2, it is a significant diagnostic value of CTS, which indicates that the patient is prone to suffer from pain.

Measuring CSA of the median nerve in CTI using MRI can serve as a tool for diagnosing CTS. The surgeons may consider taking MRI for the detailed evaluation of CTS if the patients have symptoms but no evidence on a nerve conduction test.

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None.

Conflicts of interest

All authors declare that they have no conflict of interest.

IRB status

All participants were required to provide written informed consent. The study was approved by the Institutional Review Board of the Gyeongsang National University Hospital (GNUH 2018-10-009-001).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.asjsur.2019.08.001.

References

1. Kim WL, Kim JS, Lee JB, Kim SH, Min DU, Park HY. Survey of preferences in patients scheduled for carpal tunnel release using conjoint analysis. *Clin Orthop Surg*. 2017;9:96–100.
2. Jegal M, Woo SJ, Lee HI, Shim JW, Shin WJ, Park MJ. Anatomical relationships between muscles overlying distal transverse carpal ligament and thenar motor branch of the median nerve. *Clin Orthop Surg*. 2018;10:89–93.
3. Atroshi I, Gummesson C, Johnsson R, Ornstein E, Ranstam J, Rosen I. Prevalence of carpal tunnel syndrome in a general population. *JAMA*. 1999;282:153–158.
4. Nakamichi KI, Tachibana S. Enlarged median nerve in idiopathic carpal tunnel syndrome. *Muscle Nerve*. 2000;23:1713–1718.
5. Fu T, Cao M, Liu F, et al. Carpal tunnel syndrome assessment with ultrasonography: value of inlet-to-outlet median nerve area ratio in patients versus healthy volunteers. *PLoS One*. 2015;10, e0116777.
6. 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. *Arch Iran Med*. 2010;13:516–521.
7. 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;37:125–131.
8. Pastare D, Therimadasamy AK, Lee E, Wilder-Smith EP. Sonography versus nerve conduction studies in patients referred with a clinical diagnosis of carpal tunnel syndrome. *J Clin Ultrasound*. 2009;37:389–393.

9. 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 Rheum*. 2005;52:304—311.
10. Martins RS, Siqueira MG, Simplicio H, Agapito D, Medeiros M. Magnetic resonance imaging of idiopathic carpal tunnel syndrome: correlation with clinical findings and electrophysiological investigation. *Clin Neurol Neurosurg*. 2008;110:38—45.
11. Azami A, Maleki N, Anari H, Iranparvar Alamdari M, Kalantarhormozi M, Tavosi Z. The diagnostic value of ultrasound compared with nerve conduction velocity in carpal tunnel syndrome. *Int J Rheum Dis*. 2014;17:612—620.
12. Yu G, Chen Q, Wang D, et al. Diagnosis of carpal tunnel syndrome assessed using high-frequency ultrasonography: cross-section areas of 8-site median nerve. *Clin Rheumatol*. 2016; 35:2557—2564.
13. Ghasemi M, Masoumi S, Ansari B, Fereidan-Esfahani M, Mousavi SM. Determination of cut-off point of cross-sectional area of median nerve at the wrist for diagnosing carpal tunnel syndrome. *Iran J Neurol*. 2017;16:164—167.
14. Paliwal PR, Therimadasamy AK, Chan YC, Wilder-Smith EP. Does measuring the median nerve at the carpal tunnel outlet improve ultrasound CTS diagnosis? *J Neurol Sci*. 2014;339: 47—51.
15. Ulasli AM, Duymus M, Nacir B, Rana EH, Kosar U. Reasons for using swelling ratio in sonographic diagnosis of carpal tunnel syndrome and a reliable method for its calculation. *Muscle Nerve*. 2013;47:396—402.
16. Sarraf P, Malek M, Ghajarzadeh M, Miri S, Parhizgar E, Emami-Razavi SZ. The best cutoff point for median nerve cross sectional area at the level of carpal tunnel inlet. *Acta Med Iran*. 2014;52:613—618.
17. Somay G, Somay H, Cevik D, Sungur F, Berkman Z. The pressure angle of the median nerve as a new magnetic resonance imaging parameter for the evaluation of carpal tunnel. *Clin Neurol Neurosurg*. 2009;111:28—33.
18. Kim MK, Jeon HJ, Park SH, Park DS, Nam HS. Value of ultrasonography in the diagnosis of carpal tunnel syndrome: correlation with electrophysiological abnormalities and clinical severity. *J Korean Neurosurg Soc*. 2014;55:78—82.