Med. J. Cairo Univ., Vol. 86, No. 2, March: 1009-1018, 2018
www.medicaljournalofcairouniversity.net

Role of Conventional MR Imaging of the Median Nerve in Carpal Tunnel Syndrome: A Case Control Comparative Study with Electrophysiological Tests and Clinical Assessment

AHMAD M. WAFAIE, M.D.*; KAREEM M. MOUSSA, M.D.*; HODA M. ABBAAS, M.Sc.*; LAMIA M. AFIFI, M.D.** and AYMAN M. MANSOUR, M.D.***

The Departments of Radiology, Neurophysiology** and Musculoskeletal Surgery***, Faculty of Medicine, Cairo University, Egypt*

Abstract

Background: Carpal Tunnel Syndrome (CTS) is the most common peripheral neuropathy of an upper extremity. The diagnosis of CTS is commonly based on findings from the medical history, physical examination, provocative tests and Electrophysiological Studies (EPS) as the reference standard, but in some cases the results may be equivocal due to discrepancies in the different measured clinical parameters. Imaging has the potential to resolve these discrepancies. Fat-saturated, T2-weighted Magnetic Resonance Imaging (MRI) can reveal morphological changes in CTS patients, such as nerve enlargement, nerve flattening, increased nerve signal intensity, and bowing of the flexor retinaculum.

Aim of Work: The aim of this study is to study the role of conventional MRI in the diagnosis of Carpal Tunnel Syndrome (CTS).

Patients and Methods: Twenty-three wrists in 15 healthy subjects and 47 wrists in 31 CTS patients were evaluated with MRI and Electrophysiological Studies (EPS). The qualitative and quantitative analysis of MRI include: (1) The high signal intensity of the Median Nerve (MN) on the T2W and PD fat suppressed weighted images, (2) Flexor Retinaculum (FR) bowing and measurements of its height and area, (3) Flattening ratio of the MN, (4) MN CSA. EPS; including nerve conduction velocity was also performed for comparison with clinical assessment as a standard of reference.

Results: There was a significant difference between healthy individuals and patients with CTS for all qualitative and quantitative MRI interpretation. This includes, the higher SI of the MN on both T2 and PD WIs, the greater FR bowing area and height, the higher flattening ratio of the MN at CT and the greater value of MN CSA. As regards the MRI results, the sensitivity, specificity, negative predictive value, positive predictive value and accuracy were 97.8%, 95.6%, 95.6%, 97.8% and 97.1% respectively.

Conclusion: MRI can contribute to carpal tunnel syndrome diagnosis on the basis of its qualitative and quantitative measurements.

Key Words: *MRI imaging – Electrophysiological studies – Carpal tunnel syndrome.*

Correspondence to: Dr. Ahmad M. Wafaie,
The Department of Radiology, Faculty of Medicine,
Cairo University, Egypt

Introduction

THE commonest peripheral neuropathy of the upper extremity is CTS. It is caused by Median Nerve (MN) entrapment inside the Carpal Tunnel (CT) [1]. CTS patients present with pain and paresthesia of the hand with impaired pinch and grip activities [2,3]. CTS is more common among women between 40 and 60 years of age. The dominant hand is usually affected first and produces the most severe symptoms. CTS usually occur only in adults with an estimated prevalence of 2.1% [4].

Most cases of CTS are of unknown cause. However, there is notable fibrous hypertrophy consequent upon chronic edema with minimal inflammation. Space occupying lesions in the CT as ganglion cyst, hamartoma, neuroma, hemangioma and lipoma can also compress the MN. Also, systemic factors either raise the interstitial tissue pressure or lead to deposition of pathological material that constricts the space in CT as diabetes and thyroid disorders [5].

CTS is commonly diagnosed based on history taking, physical examination and provocative tests. Some clinician uses Electrophysiological Studies (EPS) to further confirm the diagnosis, but in some patients the results may be equivocal. Imaging has the potential to resolve these inconsistencies [3].

MRI allows good imaging of soft tissue. This makes it the optimal choice when studying CT in detail. MRI can be used to determine the exact point of MN entrapment [6]. MRI is excellent for picking up rare pathological causes of CTS such as ganglion, haemangioma or bony deformity by whom the presence of which may alter surgical intervention [7].

Aim of the work: The aim of this work is to investigate the role of MRI in the diagnosis of CTS and correlate between its results and electrophysiological indicators for detecting their sensitivity and specificity in diagnosis of CTS using clinical assessment as standard of reference.

Patients and Methods

This prospective study was performed between July 2014 and September 2015. This study included 46 subjects distributed in patient and control groups. In the patient group, we evaluated 47 wrists in 31 CTS patients while in the control group; we evaluated 23 wrists in 15 healthy subjects. This study was approved by our local institutional review board and ethics committee, and also all participants gave written informed consent.

Inclusion criteria:

- Patients were clinically evident CTS by an expert orthopedic surgeon, and they were presented with typical clinical history, symptoms, and signs of CTS; e.g. intermittent (nightly) numbness, tingling, or burning sensations in the thumb, index finger, middle finger, and the lateral half of the ring finger; atrophy of the thenar muscle.
- Positive Phalen's, Tinel's and Durkan's test results.
- For the control group, they were completely asymptomatic and had no CTS symptoms as well as negative Phalen's, Tinel's and Durkan's test results. There was no previous history of any neurological, musculoskeletal, neuromuscular, endocrinal, metabolic, autoimmune diseases and did not receive any drugs that could affect the nerve conduction as NSAIDs.

Exclusion criteria:

Our exclusion criteria were any contraindications for MRI ora previous surgery on the MN at the wrist.

Methods:

Patients were subjected to the following:

1- Clinical assessment.

2- EPS.

3- Conventional MRI.

1- *Clinical assessment:*

• All participants were subjected to full clinical history taking including: name, age, sex, dominant wrist, work, history of present illness (onset of time, duration, etc.) and full medical record including: history of neurological, musculoskeletal, neuromuscular, endocrinal, metabolic, autoimmune diseases and drug intake could affect the nerve conduction as NSAIDs.

• Clinical assessment of CTS by Phalen's, Tinel's and Durkan's tests was done for all subjects in the patients and controls groups. In Phalen's test, the patient is asked to hold their wrists in complete and forced flexion for 30-60 seconds. If the patient develops symptoms such as burning, tingling or numb sensation over the thumb, index, middle and ring fingers the test is considered positive and suggests CTS. Tinel's test is performed by lightly percussing over the MN and is considered positive when it causes tingling in the thumb, index, middle finger and the lateral half of the ring fingers. Durkan's test is done by pressing the examiner thumb over CT and holds pressure for 30 seconds. An onset of pain or paresthesia in the MN distribution within 30 seconds is a positive result of the test.

• Also clinical assessment of CTS severity by Boston Carpal Tunnel Questionnaire (BCTQ), Historical-Objective (Hi-Ob) scale system, Active and Passive Range of Motion (A/PROM) and strength testing for the abductor pollicis brevis muscle was done for all subjects in the patients and control groups. Details of BCTQ and Hi-Ob scale system in this study is described in Tables (1,2). In A/PROM, the distal bilateral upper limbs (elbow, forearm, wrist and digits) motion range were measured actively and passively with noting if there are any limitations to its motion range were present. In strength testing for the abductor pollicis brevis muscle, the examiner palpates the muscle while performing palmar abduction.

2- *Electrophysiological study:*

All patients and controls had EPS within maximum two weeks of their MR examinations. The EPS adopted in this study included: Motor Nerve Distal Latency (MNDL), Sensory Nerve Distal Latency (SNDL), Motor Nerve Amplitude (MNA), Sensory Nerve Amplitude (SNA) and Electromyography (EMG).

Measurements performed and cut-off points or normal values used in this study were done in reference to Jablecki et al., **[10]** as follows:

- The normative MN Sensory Nerve Conduction studies (SNCs) over digit 2 are distal latency less than 3.6ms, amplitude greater than 15 μv, and conduction velocity greater than 56m/s.
- The normative MN Motor Nerve Conduction studies (MNCs) recorded over APB muscle are distal latency less than 4.4ms, amplitude greater than 4mv, and conduction velocity greater than 48m/s.

3- *Magnetic resonance imaging:*

• *MR imaging technique:*

- MRI and DTI were performed by using Gyroscan Interna 1.5T Magnet (Philips Medical Systems, Best, Netherlands). The patients were scanned in the prone position with the examined hand extended over the head (superman position). The dorsum of the examined hand lies parallel to the coronal plane of the magnet. The used circular coil was placed over the wrist joint, and was rapped and fixed by rubber bands.
- Details of the pulse sequences used in our study are shown in (Table 3).

Table (1): BCTQ application in this study according to Meirelles et al., **[8]** with minor modifications.

Grade 0	• No hand or wrist pain, weakness or tingling sensation during day and night, and no difficulty in performing fine activities.
Grade 1	• Little/mild hand or wrist pain, tingling sensation during day and night. This daytime pain occurred once or twice and it lasts for less than 10 minutes in at least for 2 weeks, and the night pain occurred once in at least for 2 weeks. With little/mild dormancy on the affected hand. • Little difficulty in performing fine activities (functional questionnaire; writing, buttoning clothes, housekeeping and opening a glass vial cap).
Grade 2	• Moderate pain or tingling sensation during day and night in at least for 2 weeks. This pain occurred twice or three times during night while three to five times during day and it lasts for 10-60 minutes. With moderate dormancy on the affected hand. • Moderate difficulty in performing fine activities (functional questionnaire).
Grade 3	• Intense pain or tingling sensation during day and night for at least 2 weeks. This pain occurred four to five times during night while more than five times during day and it lasts for more than 60 minutes. With intense dormancy on the affected hand. • Intense difficulty in performing fine activities (functional questionnaire).
Grade 4	• Severe pain or tingling sensation during day and night for at least 2 weeks. The daytime pain is constant while the night pain occurred more than five times. With severe dormancy on the affected hand. • Complete disability in performing fine activities due to the severity of hand symptoms (functional questionnaire).

Table (2): Hi-Ob scale system application in our study according to Pazzaglia et al., **[9]**.

Grade 0	• No typical CTS symptoms were present.
Grade 1	• Nocturnal hand paresthesia only for at least 2 weeks, and its disappearance is rapid.
Grade 2	• Nocturnal and diurnal hand paresthesia after repetitive movements or pronged posture for at least 2 weeks. • Grade 2P: An associated hand pain along MN distribution for at least 2 weeks with its analysis {site, intensifiers, nullifiers, effect on hand function and description (sharp, dull aching, throbbing ...etc)}.
Grade 3	• Sensory deficit by using a cotton wool to compare the sensation of the palmer aspect of index or middle fingers (MN innervated fingers) vs. the little one. • Grade 3P: An associated hand pain for at least 2 weeks.
Grade 4	• Selective hypotrophy or motor deficit of the thenar muscle compared to the other hand muscles by performing resistance to the patient thumb abduction at a right angle to the palm. • Grade 4P: An associated hand pain for at least 2 weeks.
Grade 5	• Thenar atrophy; defined by a concavity of thenar eminence with respect to the plane of the palm or thenar muscle paralysis which is defined as; inability to abduct the thumb ventrally from the palm.

Table (3): Details of different pulse sequences used.

Pulse sequence	FOV (mm)	Slice thickness (mm)	Gap (mm)	TE (msec)	TR (msec)	Matrix	Flip angle	Total sequence duration	Number of signals averaged
Axial TIWI	140	3	0.5	20	382	128 X 128	90º	2m 55s	2
Axial T2WI	80	2.5	0.5	100	1000	160 X 120	90º	2m 24s	1
Axial PD with fat suppression	80	2.5	0.5	30	2300	228 X 197	90º	3m 27s	1
Axial DWI	100 X 100	3	0.5	4600	90	64 X 62	90º	4m	4

TR: Time of Repetition. TE: Time of Echo. FOV: Field of View.

Image analysis:

All data were transferred to the manufacturer-supplied workstation with Extended MR Workspace software, Version 2.5.3.0 (Philips Medical Systems, Best, Netherland) to perform fiber tracking.

1- The presence of high signal intensity on the T2W and PD fat suppressed WIs in comparison to thenar muscle signal intensity, and determining its degree (mild or marked).

2- The presence of Flexor Retinaculum (FR) bowing and measurements of its height and area (on T1WIs) above the carpal line at both CT inlet (at the level of scaphoid and pisiform) and exit (at the level of trapezium and hook of hamate bones). FR bowing height is calculated by the distance between a line lying tangentially between the identified carpal bones and the apex of the FR. Whereas retinacular bowing area is calculated by drawing an ellipse between the apex of the FR bowing and a tangential line joining the identified carpal bones, and the ellipse area was automatically calculated.

3- Flattening ratio of the MN calculation (on T1WIs) by dividing its longitudinal by transverse dimensions at the level of hook of hamate bone.

4- MN Cross Sectional Area (CSA) calculation was performed (on DWIs correlated with the anatomical reference T 1 WIs) at the level of maximum expansion.

5- Presence of any abnormalities or space occupying lesions that might be the cause of MN entrapment inside the CT.

Results

1- *Clinical assessment results:*

Thirty-one CTS patients were included in this study, 26 females (83.87%) and 5 males (16.12%). Fifteen healthy controls were also included, 8 females (53.33%) and 7 males (46.66%). In the patient group, the age ranged between 19 and 84 years with mean age of 46 years, median age of 48 years and Standard Deviation (SD) of 13.65. In the control group, the age ranged between 29 and 71 years with mean age of 44 years, median age of 38 years and SD of 14.31. This study evaluated 47 wrists in 31 CTS patients and 23 wrists in 15 healthy individuals. Regarding patient group, 16 patients had bilateral and 15 patients had unilateral wrist involvement.

In the patient group, the BCTQ scale system results were; two patients (6.45%) had grade 1, twenty-five patients (80.64%) had grade 2 and four patients (12.90%) had grade 3. While by Hi-Ob scale system; one patient (3.22%) had grade 1, twenty patients (64.51 %) had grade 2, seven patients (22.58%) had grade 3 and three patents (9.68%) had grade 4. In A/PROM of the upper extremity examination; fifteen (31.9%) wrists experienced limitation in their motion range, while thirty-two (68.1%) show no limitation. Whilein strength testing for the abductor pollicis brevis muscle; six (12.8%) wrists experienced weakness and while forty-one (87.2%) show no affection.

2- Electrophysiological results:

In the patient group, 45 wrists (95.74%) had positive EPS results and 2wrists (4.25%) showed negative EPS results. In the controls group, 21 wrists (95.65%) wrists had negative EPS results and one wrist (4.34%) showed positive EPS results. EPS parameters results are shown in (Table 4). As regards the EPS results in this study, there were 45 true positive, 22 true negative, 1 false positive and 2 false negative result. The sensitivity, specificity, Negative Predictive Value (NPV), Positive Predictive Value (PPV) and accuracy were 95.7%, 95.7%, and 91.7%, 97.8% and 95.7% respectively.

3- Conventional MRI results:

Most of the total examined 47 wrists in our case group showed no obvious causes for MN entrapment. One patient (2.12%) showed small ganglion cyst inside the CT and two patients (4.24%) showed bifid median nerve. The signal intensity of the MN in T2WIs and PD with fat suppression weighted imagesis shown in (Table 5). The FR bowing height was 1.5 and 5.6mm in

the control and patient groups respectively at the CT inlet with a p-value of <0.01. While at the carpal tunnel outlet, the FR bowing height was 1.08 and 2.89mm in the control and patient groups respectively with a p-value of <0.05. The FR bowing area was 20 and 46.8mm^2 in the control and patient groups respectively at the CT inlet with a p-value of <0.01. At the carpal tunnel outlet, the FR bowing area was 9.88 and 15.6mm^2 in the control and patient groups respectively with a p-value of <0.01. The MN flattening ratio was 1.34 and 3.07 in the control and patient groups respectively with a p-value of <0.01. The CSA of the MN in both groups is shown in (Table 6).

- ROC curve was performed to determine MN CSA cut-off value in this study; a cut-off value 10.9mm^2 between the control and patient groups has a maximum sensitivity of 100% and a specificity of 91.3% with 95% confidence interval. As regards the MRI results in this study, there were 46 true positive, 22 true negative, 1 false positive and 1 false negative result. The sensitivity, specificity, NPV, PPV and accuracy were 97.8%, 95.6%, 95.6%, 97.8% and 97.1% respectively.

- Significant difference was found between the CSA values in the case group with the grading scale of BCTQ (p<0.05) and Hi-Ob system (p< 0.05). CSA value was significantly higher in CTS patients with affected abductor pollicis brevismotor power than those had normal abductor pollicis brevismuscle power (p<.05).

Table (4): EPS values distribution of the total examined wrists in our study.

Study group	Value	MNDL (ms)	SNDL (ms)	MNA (mv)	SNA (μv)
Control group	Mean	3.4	2.8	8.2	40.6
	Standard deviation	0.7	0.6	3.2	15
	Median	3.4	2.7	7.8	43.00
Patient group	Mean	5.17	3.97	5.77	16.17
	Standard deviation	1.49	1.41	4.59	12.97
	Median	5.10	3.90	5	12.80
p-value		_.01	_.01	_.01	_.01

MNDL : Motor Nerve Distal Latency. MNA : Motor Nerve Amplitude.
SNDL : Sensory Nerve Distal Latency. SNA : Sensory Nerve Amplitude.

Table (5): Distribution of MN signal intensity in T2WIs and PD with fat suppression WIs in our study.

Degree of MN signal intensity	Pulse sequence	Control group	Patient group	p-value
No increased signal intensity	T2WIs	16 (69.56%)	2 (4.3%)	_.01
	PD with fat suppression	12 (52.17%)	1 (2.1%)	
Mild increased signal intensity	T2WIs	7 (30.43%)	24 (51.1%)	_.01
	PD with fat suppression	11 (47.82%)	25 (53.2%)	
Marked increased signal intensity	T2WIs	0	21 (44.7%)	_.01
	PD with fat suppression	0	21 (44.7%)	

Table (6): Distribution of MN CSA values between both groups in our study.

Study group	Value	CSA (mm^2)
Control group	Mean	9.62
	Standard deviation	2.24
	Median	10
Patient group	Mean	30.84
	Standard deviation	12.28
	Median	30
p-value		_.01

Figures:

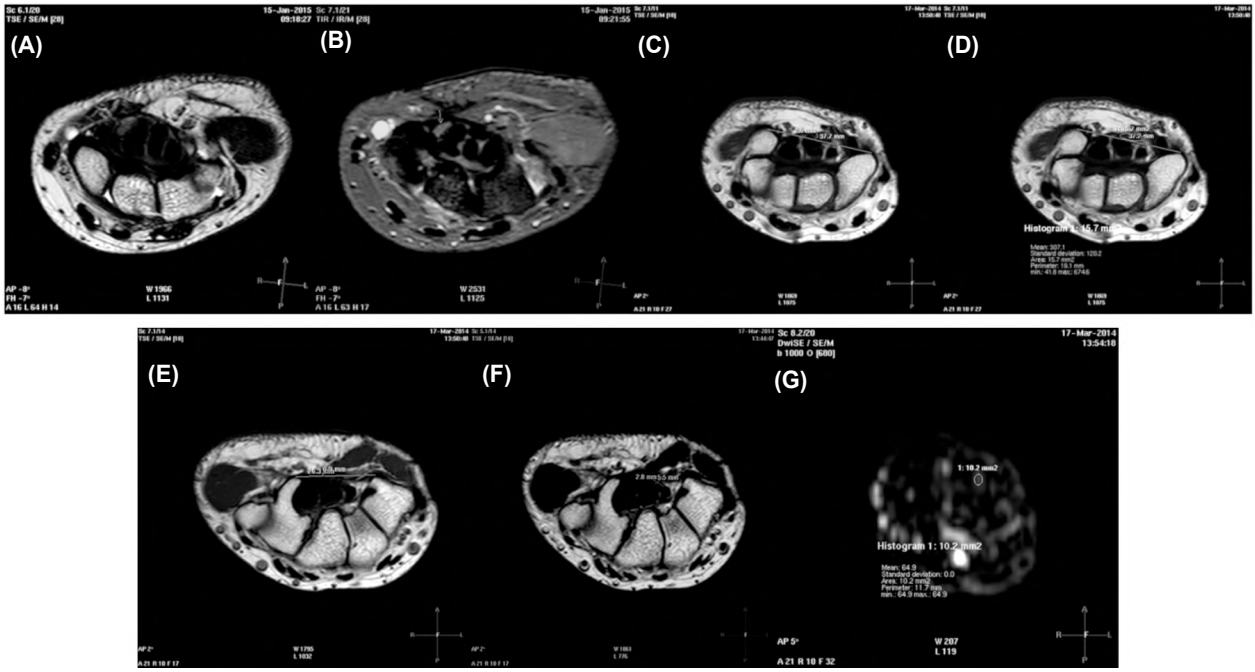

Fig. (1): A 34-year-old male subject with no history of hand parasthesia or pain. He had negative Phalen, Tinel and Durkan's tests as well as negative EPS results. (A,B) Axial T2 and PD with fat suppression WIs show MN signal intensity was similar to the thenar muscles (C,D) Axial T 1 WIs at the level of CT inlet shows FR bowing height was 2mm and bowing area of 15.7mm^2 (E) Axial T 1 WIs at the level of CT outlet shows FR bowing height was 0.9mm (F) Axial T 1 WI shows MN flattening ratio at the level of hook of hamate was 1.96 (G) Axial DWI shows CSA of the MN at the level of pisiform bone was 10.2mm^2.

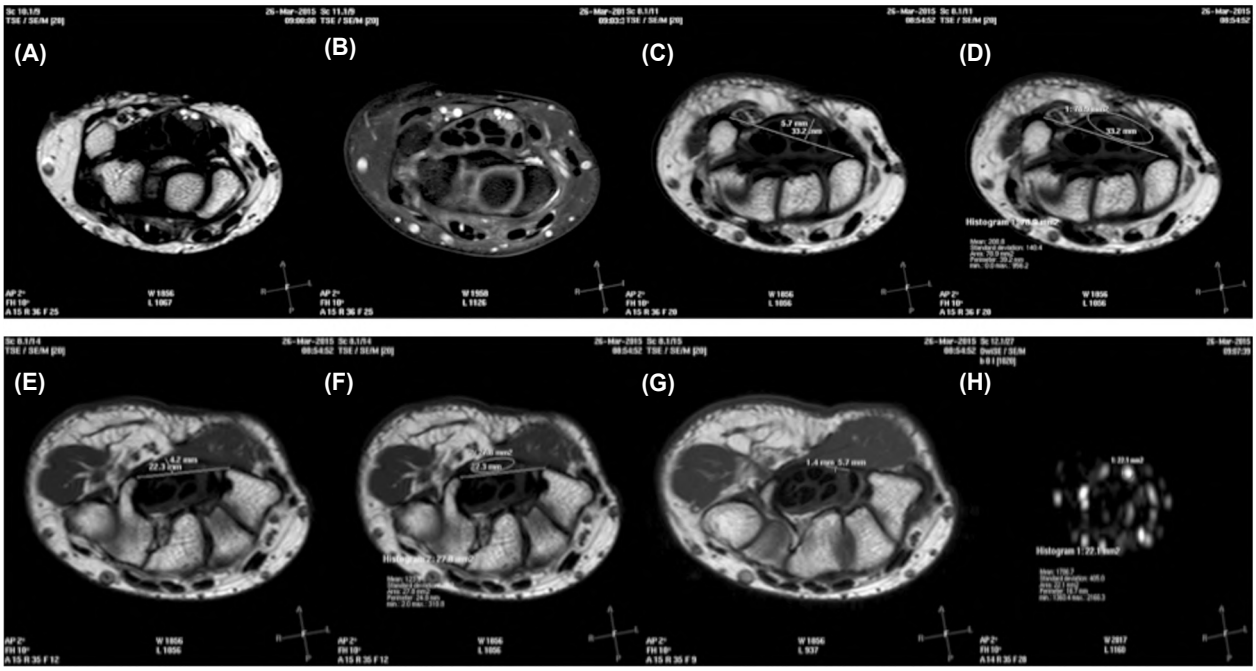

Fig. (2): A 41-year-old female patient with history of right hand parasthesia and pain along MN distribution. She had positive Phalen, Tinel and Durkan's tests. On EPS results, she had mild entrapment on MN at the level of CT. (A,B) Axial T2 and PD with fat suppression WIs shows multiple small ganglion cysts were noted at the ulnar side of the MN causing compression on it; the MN was markedly hyperintense compared to the thenar muscle (C,D) Axial T1WIs at the level of CT inlet shows FR bowing height was 5.7mm and bowing area of 78.9mm ^{2} (E,F) Axial T1 WIs at the level of CT outlet shows FR bowing height was 4.2mm and bowing area of 27.8mm ^{2} (G) Axial T 1 WI shows MN flattening ratio at the level of hook of hamate was 4.07 (H) Axial DWI shows CSA of the MN at the level of pisiform bone was 22.1mm2.

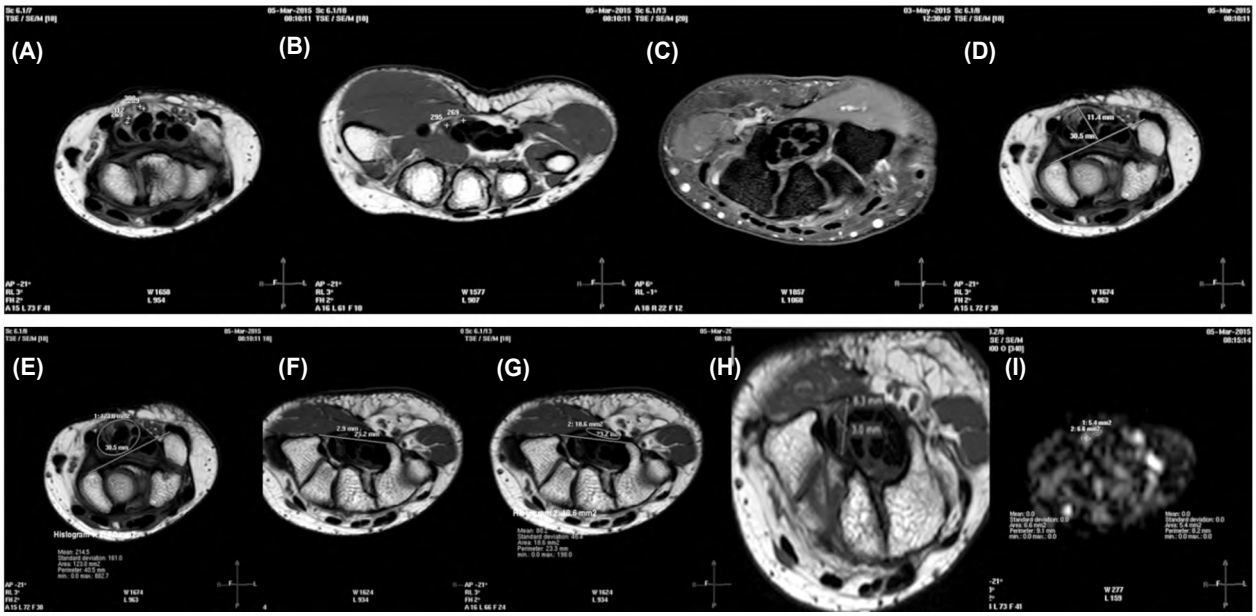

Fig. (3): A 43-year-old female patient with history of left hand parasthesia and pain along MN distribution. She had positive Phalen, Tinel and Durkan's tests. On EPS results, she had mild entrapment on MN. (A,B,C) Axial T2 WI & PD with fat suppression WIs show bifid MN along its whole pathway throughout CT from its inlet to its exit; the MN was markedly hyperintense compared to the thenar muscle (D,E) Axial T 1 WIs at the level of CT inlet shows FR bowing height was 11.4mm and bowing area of 123mm^2 (F,G) Axial T1WIs at the level of CT outlet shows FR bowing height was 2.9mm and bowing area of 18.6mm^2 (H) Axial T1WI shows MN flattening ratio at the level of hook of hamate was 2.7 (I) Axial DWI at the level of pisiform bone show bifid MN with CSA of the top one was 5.4mm^2 and the caudal one was 6.6mm^2.

Statistical analysis:

All statistical calculations were done using computer program: Statistical Package for the Social Science (SPSS, Chicago, IL, USA) Version 15 for Microsoft Windows. We described quantitative variables as mean, SD and median and qualitative variables as number and percentage.

The following tests were done:

- Paired student's *t*-test, ANOVA, Mann-Whitney, Wilcoxon, Post Hoc, Kruskal-Wallis and Chi-Square tests were used to compare quantitative as well as qualitative variables between both groups.
- The sensitivity, specificity, accuracy, positive predictive value, negative predictive value and accuracy were also calculated.
- Probability (*p*-value):
  - *p*-value <0.05 was considered significant.
  - *p*-value <0.001 was considered as highly significant.
  - *p*-value >0.05 was considered insignificant.

Discussion

CTS is the most common peripheral neuropathy of the upper limb, and it is caused by an entrapment of the MN within the CT. Although EPS are considered the single most accurate test that can confirm the diagnosis of CTS, their false negative and false positive rates have been well documented **[11,12]**. Also EPS have the main disadvantage of being painful. Therefore, more accurate and painless diagnostic techniques are desirable **[13]**. MRI provides a great diagnostic tool to investigate CTSpatients **[14,15]**.

A high significant difference was found in comparing the EPS values in-between both groups (p<0.01) in this work. Mean MNDL and SNDL values were found higher in patients group than controls group. While MNA and SNA were found lower in patients group than controls group. MNDL greater than 4.4ms is used as a cut-off value for diagnosing CTS in our work. These findings were also noted by Wang et al., **[16]** who also stated that; the most commonly adopted EPS diagnostic parameter for defining CTS is the MNDL. Larger MNDL indicates more severe CTS, and MNDL greaterthan 4ms was used as a cut-off value for diagnosing CTS. The EPS results in this study showed one false positive case in controls group (clinically proved not having nerve entrapment) and two false negative cases in clinically diagnosed CTS patients. The overall accuracy of our EPS

results was 95.7%. While the MRI results in this work showed a sensitivity of 97.8% and specificity of 95.6% with a total accuracy of 97.14%.

In this study, more patients showed increased signal intensity of the MN in T2WIs & PD with fat suppression weighted images than the control group and the difference was highly significant with a p-value less than 0.01. These findings were also reported by Karabulut et al., [17] whose study stated that the signal intensity evaluation showed hyperintensity on T2WIs in 28 of 36 wrists while 8 were isointense of the patient group. On the other hand, 7 of 34 wrists displayed hyperintense MN on T2WIs, and 27 were isointense in the control group, with a p-value less than 0.05. In the study by Samanci et al., [18] which was conducted on 23 CTS patients and 24 healthy volunteers, the MN T2 signal was statistically higher in CTS patients compared to controls.

In quantitative MR results performed in this work, FR bowing heights and areas were statistically different between the between patient and control groups (p<0.01). The patients had higher values than control group. The mean value of FR bowing height at the CT inlet was 1.5mm with bowing area of 20mm^2, and at the CT outlet it was 1.08mm with bowing area of 9.88mm^2 in control group. On the other hand, the CT inlet FR bowing height in the patient group was 5.6mm with bowing area of 46.8mm^2, and at CT$_2$ outlet it was 2.8mm with bowing area of 15 .6mm^2. These findings were close to a study by Uchiyama et al., [19] who found that the mean values of the FR bowing height and area at the CT inlet were 2.14mm and 21.25mm^2 respectively and at the CT outlet were 1.29mm and 9.6mm^2 respectively in healthy individuals. In the patients the CT inlet values were 4.71 and 64.05mm^2, while the CT outlet values were 2.78mm and 21.8mm^2 in CTS patients. Nearly similar results were achieved by Oge et al., [20] who found that the mean values of FR bowing height at the CT exit were 1.12 and 2.3 1mm in normal and CTS subjects respectively.

There have been inconsistencies in results regarding the flattening ratio of the MN among investigators. In a study done by Karabulut and co-workers [17]; the MN at the level of the hook of hamate bone was significantly flattened in CTS patients than normal subjects (p 0.01) with mean values of MN flattening ratio were 1.83 and 2.45 in normal and CTS subjects respectively. On the other hand, Uchiyama et al., [19] found a significant different at the pisiform bone but no statistically significant difference at the hamate hook. In this study, the flattening ratio of the MN at the CT outlet was highly significant different between the patients and controls with a P value less than 0.01. The mean value of MN flattening ratio was 1.34 in control group and 3.07 in patient group.

In this work, a high significant difference was found between both groups (p_0.01) as CTS patients had higher MN CSA than control group. Mean ± SD MN CSA values were 9.62±2.24mm^2 in control group and 30.84±12.24mm^2 in patient group. Similar observations were also reported by previous studies, who stated that there was a statistically significant difference between healthy subjects and CTS patients in MN CSA, and CTS patients had greater CSA values than healthy group [17,19,21] . In the study by Uchiyama et al., [19]; the CSA values were 9.1±2.3mm^2 and 14.8±5.5 mm^2 in healthy individuals and CTS patients respectively. While Karabulut et al., [17] found that CSA values were 13.45±4.23mm^2 and 15.94±3.05 mm^2 in healthy individuals and CTS patients respectively. Recently, Guggenberger et al., [21] observed that MN CSA values were 11.99 ±2.9mm^2 and 14.89±3.5mm^2 in healthy individuals and CTS patients respectively. Also Oge et al., [20] found that MN swelling at the CT is one of the major defined MR findings of CTS. The CSA of MN was found to be 9.8±0.29mm^2 in the control group, and it was 15.5±0.8mm^2 in the patient group, and the difference was statistically high significant (p<0.01). In the study by Ikeda and co-workers, the MN CSA was found to be significantly higher in CTS patients compared to normal subject. Ikeda et al., also found that the CSA at was positively correlated with distal motor latency in CTS patients [22].

According to the performed ROC curve for CSA to determine its cut-off value for the discrimination between the normative and pathological values for CTS diagnosis in this study; it was <10.9mm^2 with AUC was 99.4%, sensitivity and specificity were 100% and 91.3% respectively. This finding was also noted very close to publicans of Ahmad et al., [23] who stated that; the shape and dimension of the MN are important radiological features to diagnose CTS, and the upper 95% confidence surface area of the MN was found to be 11.13mm^2.

Significant difference was found between the CSA values in the case group with the grading scale of BCTQ (p<.05) and Hi-Ob system (p<.05). This finding was also issued by Guggenberger et al., [21].

MR imaging is useful for revealing the cause of nerve compression, and it can be used to determine the exact point of nerve entrapment, and to identify space occupying lesions. EPS cannot detect lesions inside the CT that can compress the MN. In this study, one patient with a ganglion cyst inside the CT was detected as the cause of MN compression. Those associated MR findings were also reported by Özden et al., **[24]** who found that two cases out of twelve CTS patients had ganglion cysts as obvious intracarpal causes for MN entrapment.

Two cases with a bifid MN was accidently observed in our study, and this finding was also noted by a literature of Granec et al., **[25]** who studied a case of young patient with symptoms of MN compression in CT without known risk factors. Ultrasonography and MRI showed bifurcation of the MN. Bifid MN is not uncommon nerve variation in the CT but it may aggravate CTS symptoms. No clinical or EPS finding that could detect anatomical nerve variation in CTS. The knowledge of morphological changes of the MN is certainly a considerable fact in therapeutic approach, especially operative. In case of bifid MN, the surgeons must consider the possibility of coexisting persistent median artery to avoid intraoperative vascular damage. They also have to consider the possibility of two nerve compartments and perform epineurectomy besides decompression of each nerve branch, and also it may raise the possibility of early postoperative recurrence of CTS symptoms.

This study enabled us to diagnose CTS based on conventional MRI. As in most previous studies, we noticed significant differences in MRI results between CTS patients and healthy groups where increased T2-signal intensity in the MN, marked bowing of the FR, increases in CSA area and flattening of the MN seem to be sensitive MR signs of CTS diagnosis. Also this study enabled to determine the severity of CTS based on MRI results. As the higher grades of CTS severity were significantly matched with a higher CSA values.

Conclusion:

MRI enables visualization and characterization of the MN in healthy subjects and CTS patients and its indices show clear-cut discrimination between the two groups and in fact enable the use of it in thediagnosis of CTS.

References

1- VANHEES M., MORIZAKI Y., THORESON A.R., LARSON D., ZHAO C., AN K.N. and AMADIO P.C.: The effect of displacement on the mechanical properties of human cadaver subsynovial connective tissue. J. Orthop. Res., 30 (11): 1732-7, 2012.

2- KATZ J.N. and SIMMONS B.P.: Clinical practice. Carpal tunnel syndrome. N. Engl. J. Med., 346 (23): 1807-12, 2002.

3- GRAHAM B.: The value added by electrodiagnostic testing in the diagnosis of carpal tunnel syndrome. J. Bone Joint Surg. Am., 90 (12): 2587-93, 2008.

4- WERNER R., FRANZBLAU A. and GELL N.: Randomized controlled trial of nocturnal splinting for active workers with symptoms of carpal tunnel syndrome. Arch. Phys. Med. Rehabil., 86 (1): 1-7, 2005.

5- PRAKASH P.K. and MANISH K.V.: Carpal Tunnel Syndrome: Current Concepts. J.I.M.S.A.; 24 (1); 21-5, 2011.

6- GHASEMI-RAD M., NOSAIR E., VEGH A., MOHAMMADI A., AKKAD A., LESHA E., MOHAMMADI M.H., SAYED D., DAVARIAN A., MALEKI-MIYANDOAB T. and HASAN A.: A handy review of carpal tunnel syndrome: From anatomy to diagnosis and treatment. World J. Radiol., 6 (6): 284-300, 2014.

7- SCHMELZER R.E., DELLA ROCCA G.J. and CAPLIN D.A.: Endoscopic carpal tunnel release a review of 753 cases in 486 patients. Plast. Reconstr. Surg., 117 (1): 177-85, 2006.

8- MEIRELLES L.M., GOMES DOS SANTOS J.B., LEONEL DOS SANTOS L., BRANCO M.A., FALOPPA F., LEITE V.M. and FERNANDES C.H.: Evaluation of Boston Questionnaire applied at late post-operative period of carpal tunnel syndrome operated with the paineretinaculatome through palmar port. Acta. Ortop. Bras., 14 (3): 126-32, 2006.

9- PAZZAGLIA C., CALIANDRO P., APRILE I., MONDELLI M., FOSCHINI M., TONALI P.A. and PADUA L.: Multicentric study on carpal tunnel syndrome and pregnancy incidence and natural course. Acta. Neurochir., 92 (6): 35-9, 2005.

10- JABLECKI C.K., ANDARY M.T., FLOETER M.K., MILLER R.G., QUARTLY C.A., VENNIX M.J. and WILSON J.R.: American Association of Electrodiagnostic Medicine; American Academy of Neurology; American Academy of Physical Medicine and Rehabilitation. Electrodiagnostic studies in carpal tunnel syndrome. Report of the American Association of Electrodiagnostic Medicine, American Academy of Neurology, and the American Academy of Physical Medicine and Rehabilitation. Neurology, 58 (11): 1589-92, 2002.

11- LeBLANC K.E. and CESTIA W.: Carpal tunnel syndrome. Am. Fam. Physician., 83 (8): 952-8, 2011.

12- IBRAHIM I., KHAN W.S., GODDARD N. and SMITHAM P.: Carpal tunnel syndrome: A review of the recent literature. Open. Orthop. J., 6 (1): 69-76, 2012.

13- KHALIL C., HANCART C., Le THUC V., CHANTELOT C., CHECHIN D. and COTTEN A.: Diffusion tensor imaging and tractography of the median nerve in carpal tunnel syndrome: Preliminary results. Eur. Radiol., 18 (10): 2283-91, 2008.

14- JARVIK J.G., YUEN E., HAYNOR D.R., BRADLEY C.M., FULTON-KEHOE D., SMITH-WELLER T., WU R., KLIOT M., KRAFT G., WANG L., ERLICH V., HEAGERTY P.J. and FRANKLIN G.M.: MR nerve im-

aging in a prospective cohort of patients with suspected carpal tunnel syndrome. Neurology, 58 (11): 1597-602, 2002.

15- PASTERNACK I.I., MALMIVAARA A., TERVAHARTIALA P., FORSBERG H. and VEHMAS T.: Magnetic resonance imaging findings in respect to carpal tunnel syndrome. Scand J. Work Environ Health, 29 (3): 189-96, 2003.

16- WANG C.K., JOU I.M., HUANG H.W., CHEN P.Y., TSAI H.M., LIU Y.S. and LIN C.C.: Carpal tunnel syndrome assessed with diffusion tensor imaging: Comparison with electrophysiological studies of patients and healthy volunteers. Eur. J. Radiol., 81 (11): 3378-83, 2012.

17- KARABULUT Ö., TUNCER M.C., KARABULUT Z. and GÜZE E.: Analysis of MR imaging of wrists in female patients with carpal tunnel syndrome and healthy controls. Int. J. Morphol., 27 (3): 791-800, 2009.

18- SAMANCI Y., KARAGÖZ Y., YAMAN M., ATÇı I.B., EMRE U., KıLıÇKESMEZ N.Ö. and ÇELIK S.E.: Evaluation of median nerve T2 signal changes in patients with surgically treated carpal tunnel syndrome. Clin. Neurol-Neurosurg., 150: 152-8, 2016.

19- UCHIYAMA S., ITSUBO T., YASUTOMI T., NAKAGAWA H., KAMIMURA M. and KATO H.: Quantitative MRI of the wrist and nerve conduction studies in patients with idiopathic carpal tunnel syndrome. J. Neurol. Neurosurg Psychiatry, 76 (8): 1103-8, 2005.

20- OGE H.K., ACU B., GUCER T., YANIK T., SAVLARLI S., FIRAT M.M.: Quantitative MRI Analysis of Idiopathic Carpal Tunnel Syndrome. Turk. Neurosurg., 22 (6): 763-8, 2012.

21- GUGGENBERGER R., MARKOVIC D., EPPENBERGER P., CHHABRA A., SCHILLER A., NANZ D., PRÜSSMANN K. and ANDREISEK G.: Assessment of Median Nerve with MR Neurography by Using Diffusion-Tensor Imaging: Normative and Pathologic Diffusion Values. Radiology, 265 (1): 194-203, 2012.

22- IKEDA M., OKADA M., TOYAMA M., UEMURA T., TAKAMATSU K. and NAKAMURA H.: Comparison of Median Nerve Cross-sectional Area on 3-T MRI in Patients With Carpal Tunnel Syndrome. Orthopedics, 40 (1): e77-e81, 2017.

23- AHMAD R., HAMED O. and ALZAHRANI F.: Normative values of the median nerve MRI CSA at the carpal tunnel in the normal populations. ECR 2015/C-0497. Doi: 10.1594/ecr2015/C-0497.

24- ÖZDEN R., DUMAN G.A. and YıLDıZ S.O.: Space-Occupying Lesions: Rare Causes of Carpal Tunnel Syndrome. International Journal of Clinical Research, 2 (1): 12-7, 2014.

25- GRANEC D., BI´CANIC´ G., BORIC´ I. and DELIMAR D.: Bifid median nerve in a patient with carpal tunnel syndrome-correlation of clinical, diagnostic and intraoperative findings: Case report and review of the literature. Acta Clin. Croat., 51 (4): 667-71, 2012.

دور الرنين المغناطيسى للعصب الرسغى المتوسط فى متلازمة النفق الرسغى؛ ودراسة مقارنة الحالات بالإختبارات الكهروفسيولوجية والتقييم الإكلينيكى

تعتبر متلازمة النفق الرسغى أشهر إعتلال عصبى، والذى يؤثر بدوره على العصب المتوسط فى النفق الرسغى. وعلى الرغم من أن دراسات التوصيل العصبى تعتبر هى الأكثر دقة، فهى مؤلمة جدا وكذلك هناك بعض من الحالات السلبية الكاذبة والإيجابية الكاذبة الموثقة قد تعوق هذا الإختبار. ومع ذلك، فإن الجمع بين إستخدام نتائج الإختبارات الكهروفسيولوجية وخصائص الأعراض توفر تشخيص أكثر دقة، ولكن هذه الدقة ليست المثلى. وبالتالى، هناك حاجة إلى تقنيات تشخيصية أكثر دقة.

وقد مكنتنا هذه الدراسة لتشخيص متلازمة النفق الرسغى على أساس التصوير بالرنين المغناطيسى التقليدى بملاحظة فروق ذات دلالة إحصائية فى قيم الرنين المغناطيسى بين مرضى متلازمة النفق الرسغى والمجموعات الصحية، حيث وجد قيم كل من شدة الإشارة العصبية للعصب الرسغى المتوسط، إرتفاع ومساحة إنبعاج الغشاء المبطن للنفق الرسغى، ومعدل إنبساط العصب الرسغى المتوسط فى النفق الرسغى، ومتوسط المساحة المقطعية العرضية للعصب الرسغى مرتفعة جدا لدى المرضى الذين يعانون من متلازمة النفق الرسغى عن الأفراد الأصحاء.

وقد وجدت العلاقة والمقارنة بين قيم الرنين المغناطيسى ودرجات الإختبارات الكهروفسيولوجية لمتلازمة النفق الرسغى غير مختلفة إحصائيا بشكل كبير. لذلك تمكن إستخدام هذا الفحص فى تشخيص متلازمة النفق الرسغى إلى حد كبير عن طريق تصوير وتوصيف العصب المتوسط فى الأشخاص الأصحاء ومرضى متلازمة النفق الرسغى.