

T2 relaxometry and cross-sectional area of the median nerve as quantitative MRI biomarkers in carpal tunnel syndrome

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ABSTRACT

Introduction: T2 relaxometry and cross-sectional area (CSA) values of the median nerve, assessed by magnetic resonance imaging (MRI) at various levels of the carpal tunnel have not been sufficiently evaluated in patients with carpal tunnel syndrome (CTS). This study aimed to assess the CSA and T2 relaxometry values of the median nerve at the proximal and distal levels of the carpal tunnel using MRI in Mexican patients with CTS. **Material and methods:** This case series included patients clinically diagnosed with CTS. Wrist 3.0T MRI scans were performed, and CSA and T2 relaxometry maps of the median nerve were obtained at the proximal (pisiform bone) and distal (hook of hamate bone) levels of the carpal tunnel. Age, weight, height, body mass index (BMI), and clinical severity and functional scores of CTS were recorded. **Results:** Twelve wrists from 10 patients with CTS were included. The mean CSA of the median nerve at the proximal level ($12.7 \pm 2.1 \text{ mm}^2$) was significantly higher than at the distal level ($9.7 \pm 1.9 \text{ mm}^2$; $p < 0.001$), with a large effect size (Cohen's $d = 1.43$). The mean T2 relaxation time was higher at the proximal level ($64.7 \pm 7.4 \text{ ms}$) than at the distal level ($59.6 \pm 7.8 \text{ ms}$; $p = 0.034$), with a moderate effect size (Cohen's $d = 0.70$). No significant correlations were observed between anthropometric measures and CSA, T2 relaxometry, or CTS clinical and functional scores. **Conclusion:** T2 relaxometry and CSA values of the median nerve on MRI showed regional variation, with significantly higher values at the proximal carpal tunnel level in patients with CTS. T2 relaxometry values at the proximal level were abnormally elevated compared with reference values from healthy Mexican subjects. T2 relaxometry and CSA are complementary biomarkers for assessing median nerve damage in CTS.

Keywords: Magnetic resonance imaging. Relaxometry. Median nerve. Carpal tunnel syndrome.

INTRODUCTION

Carpal tunnel syndrome (CTS) is a common entrapment neuropathy caused by compression of the median nerve within the carpal tunnel, resulting in pain, paresthesia, or altered sensation. A small carpal tunnel area is considered a risk factor for CTS¹. Morphological evaluation of the median nerve is performed with conventional magnetic resonance imaging (MRI) using standardized anatomical references for the carpal tunnel. Patients with CTS typically show

an increased cross-sectional area (CSA), hyperintensity on T2-weighted images, and loss of fascicular architecture^{2,3}. Advances in MRI technology, including high-field and multi-channel coils, provide robust signal-to-noise ratios, enabling quantitative imaging of peripheral nerves using techniques such as T2 relaxometry and diffusion imaging⁴. T2 relaxometry has been proposed as a sensitive biomarker for detecting microstructural alterations, allowing differentiation between affected and unaffected nerve segments⁴⁻⁷.

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Integrating morphometric parameters, such as CSA, with quantitative T2 relaxometry improves diagnostic accuracy and characterization of nerve damage in patients with CTS⁸. T2 relaxometry may vary with magnetic field strength (1.5T versus 3.0T), the sequence used, the anatomical level, and individual factors such as age, sex, and body mass index (BMI)⁹. Disorders such as a bifid median nerve can alter measurements if not properly recognized.

There are no established diagnostic cut-off points for CSA and T2 relaxometry that differentiate healthy subjects from patients with CTS. A T2 relaxometry value of 58.8 ms at the proximal carpal tunnel level of the median nerve was reported in a previous study of healthy Mexican subjects¹⁰. Higher CSA and T2 relaxometry values have been reported in patients with CTS compared with healthy individuals⁵. The aim of this study was to assess CSA and T2 relaxometry values of the median nerve at the proximal and distal levels of the carpal tunnel using MRI in Mexican patients with CTS.

MATERIAL AND METHODS

This case series was conducted from June to November 2025 in the Magnetic Resonance Department of Hospital Angeles Lomas in Huixquilucan, State of Mexico, Mexico. Adult patients with a clinical diagnosis of CTS referred by neurology or neurosurgery specialists were included. Patients with metal implants, movement disorders, claustrophobia, incomplete or low-quality MRI, or prior wrist surgery were excluded. Written informed consent was obtained from all participants. The study was approved by the institutional Ethics and Research Committee.

Study development and variables

Data on sex, age, weight, height, BMI, occupational activity, and median nerve laterality were recorded. CSA and T2 relaxation time color maps at the proximal and distal carpal tunnel levels were obtained. CSA reference values were based on data reported by Middleton et al.¹¹. At the proximal carpal tunnel level, the CSA reference value was $\leq 7 \text{ mm}^2$. At the distal level, it was $\leq 8 \text{ mm}^2$. The T2 relaxation time at the proximal carpal tunnel level was based on Castro-Teran et al.¹⁰ with a mean of 58.8 ms in healthy Mexican subjects. No reference value was defined for T2 relaxation time at the distal carpal tunnel level.

Symptoms and functional status were assessed using the Boston Carpal Tunnel Questionnaire (BCTQ)¹²,

a disease-specific measure that includes a self-reported symptom severity scale (SSS) with 11 questions rated on a five-point scale and a functional status scale (FSS) with 8 items rated for degree of difficulty on a five-point scale.

Imaging acquisition and analysis protocol

Wrist MRI scans were performed on a 3.0T MAGNETOM Skyra Fit (Siemens Healthineers, Erlangen, Germany). Images were acquired at the wrist using a 16-channel radiofrequency hand/wrist coil. The protocol included two sequences for the median nerve: T2 turbo spin-echo (TSE) and isotropic coronal T2-weighted multiple-echo data image combination (MEDIC), and an axial T2 map spin-echo multi-echo image for relaxometry time quantification. The relaxometry images were automatically processed by the system, yielding two image series: a grayscale T2 map and a color map.

T2 MEDIC images were analyzed to determine nerve position, and the proximal and distal nerve levels were localized on both grayscale and T2 color map images. The color map was merged with the grayscale image using syngo.via software (Siemens Healthineers, Erlangen, Germany). The median nerve was assessed at the pisiform bone for the proximal level and at the hook of the hamate bone for the distal level. A region of interest (ROI) of 2.5 to 3.0 mm² was manually outlined, and the mean relaxation time across all pixels within each ROI was calculated.

Statistical analysis

All measures of central tendency were obtained at both carpal tunnel levels. The Shapiro-Wilk normality test was performed, and the p value was < 0.05 , indicating normal distributions for CSA and T2 relaxation time of the median nerve at the proximal and distal carpal tunnel levels. Inferential analysis of the ROI and comparison with published reference values for CSA¹¹ and T2 relaxometry¹⁰ were performed using Student's *t*-test. Cohen's *d* values were calculated for each test to quantify effect size and provide a standardized difference between means¹³. Pearson correlation coefficients were calculated between the proximal and distal carpal tunnel levels and between age, height, weight, BMI, SSS, and FSS. A p value < 0.05 was considered significant for all tests. RKWard v0.8.0 software was used for the analysis¹⁴.

Table 1. Characteristics of patients with CTS and quantitative values of median nerve CSA and T2 relaxometry using wrist MRI

Case	Sex	Age (years)	Weight (kg)	Height (meters)	BMI (kg/m ²)	BMI category	Occupational activity	Laterality	Median nerve					
									BCTQ		CSA		T2 relaxometry	
									SSS	FSS	Proximal (mm ²)	Distal (mm ²)	Proximal (ms)	Distal (ms)
1 ^a	w	52	70	1.65	25.7	Overweight	Housework	Left	2.0	1.6	10.8	6.3	70.78 ± 2.64	59.25 ± 5.38
2	w	52	70	1.65	25.7	Overweight	Housework	Right	2.7	2.1	11.1	7.2	76.64 ± 3.03	68.67 ± 3.18
3	w	61	47	1.56	19.3	Normal	Housework	Right	2.1	1.0	15.7	9.5	71.30 ± 5.60	71.60 ± 5.78
4	m	49	77	1.63	29.0	Overweight	Radiologist	Right	2.0	1.1	14.2	11.6	55.25 ± 0.96	65.86 ± 5.52
5	m	42	72	1.64	26.8	Overweight	Technician	Right	1.6	1.3	8.8	8.3	60.50 ± 2.55	60.86 ± 3.78
6 ^b	w	50	60	1.56	24.7	Normal	Accountant	Right	2.5	1.5	14.2	11.8	61.21 ± 5.07	60.86 ± 3.78
7	w	50	60	1.56	24.7	Normal	Accountant	Left	2.5	1.6	13.7	10.1	61.57 ± 3.92	54.38 ± 4.37
8	w	70	62	1.63	23.3	Normal	Nurse	Left	3.4	4.1	11.6	8.7	66.30 ± 6.55	48.17 ± 3.59
9	w	38	50	1.57	20.3	Normal	Housework	Right	2.0	1.6	11.1	11.2	55.87 ± 6.46	48.60 ± 3.85
10	w	48	70	1.56	28.8	Overweight	Secretary	Right	2.3	1.9	15.5	9.3	75.79 ± 3.33	66.14 ± 4.07
11	m	37	120	1.83	35.8	Obesity ^c	Physician	Right	1.2	1.0	12.0	9.3	57.50 ± 5.24	50.64 ± 1.91
12	w	35	51	1.53	21.8	Normal	Nurse	Right	2.2	1.9	13.1	12.8	63.57 ± 7.09	60.29 ± 4.84

^aCases 1 and 2 are the same patient with bilateral CTS. ^bCases 6 and 7 are the same patient with bilateral CTS. ^cGrade 2 obesity. BCTQ: Boston Carpal Tunnel Questionnaire; BMI: body mass index; CTS: carpal tunnel syndrome; CSA: cross-sectional area; FSS: functional status scale; m: man; MRI: magnetic resonance imaging; SSS: symptom severity scale; w: woman.

RESULTS

Twelve wrist MRIs from 10 patients with CTS were included, comprising 7 women and 3 men. Data for each patient are shown in table 1. The mean age was 48.2 ± 11.1 years. The mean weight was 67.9 ± 21.0 kg, the mean height was 1.61 ± 0.08 meters, and the mean BMI was 25.5 ± 4.9 kg/m². The mean SSS was 2.2 ± 0.5 , indicating moderate symptom severity, and the mean FSS was 1.7 ± 0.8 , suggesting mild functional impairment.

Comparison of median nerve CSA and T2 relaxometry at the proximal and distal carpal tunnel levels using MRI in patients with CTS

The mean CSA at the proximal carpal tunnel level was higher (12.7 ± 2.1 mm²) than at the distal level (9.7 ± 1.9 mm², $p < 0.001$) (Table 2). The median nerve CSA

showed a mean difference of 3.0 mm² between the proximal and distal levels ($p < 0.001$), with a large effect size (Cohen's $d = 1.43$). The coefficients of variation were comparable between the two levels (0.17 and 0.15, respectively), indicating similar proportional variability across the two segments evaluated.

The proximal level had a higher mean T2 relaxometry value than the distal level (64.7 ± 7.4 ms versus 59.6 ± 7.8 ms, respectively; $p = 0.034$), with a mean difference of 5.1 ms and a moderate effect size (Cohen's $d = 0.70$). The mean difference in T2 relaxometry between the proximal and distal median nerve was significant. The coefficients of variation for T2 relaxometry values at both levels were comparable (0.11 and 0.12, respectively), indicating similar proportional variability between the two segments evaluated. The difference between the means of the median nerve T2 relaxometry varied according to the level measured, with different values between proximal and distal levels. Figure 1 shows a

Table 2. Comparison of median nerve CSA and T2 relaxometry at the proximal and distal carpal tunnel levels using wrist MRI in patients with CTS

Description	n	Mean	SD	Min	Max	Coefficient of variation	Mean difference	p	Cohen's d
Median nerve CSA									
Proximal level, mm ²	12	12.7	2.1	8.8	15.7	0.17	3.0	< 0.001	1.43
Distal level, mm ²	12	9.7	1.9	6.3	12.8	0.15			
Median nerve T2 relaxometry									
Proximal level, ms	12	64.7	7.4	55.2	76.6	0.11	5.1	0.034	0.70
Distal level, ms	12	59.6	7.8	48.1	71.6	0.12			

CTS: carpal tunnel syndrome; CSA: cross-sectional area; MRI: magnetic resonance imaging; SD: standard deviation.

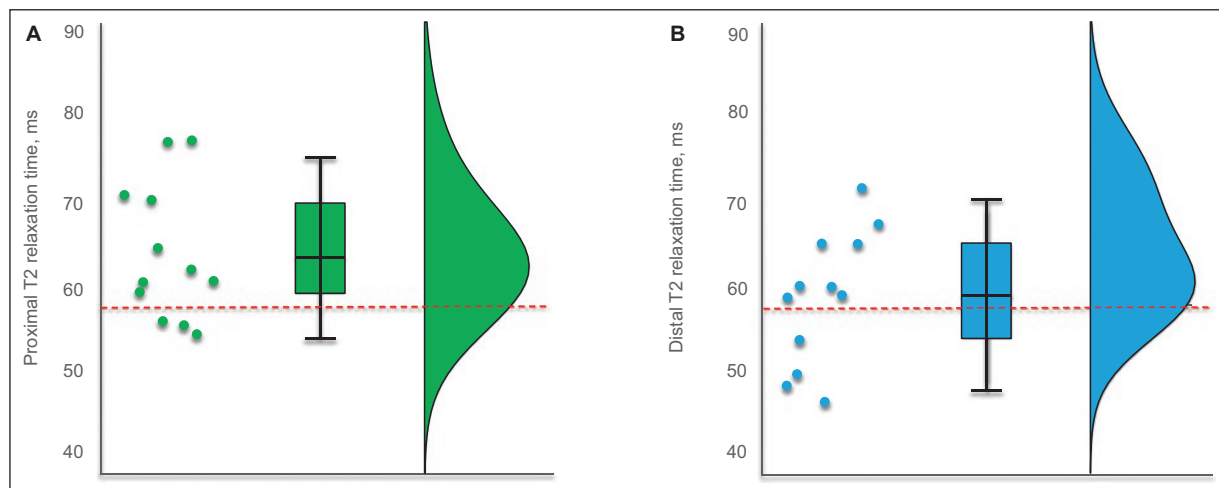


Figure 1. T2 relaxometry raincloud plot of the median nerve in patients with CTS. **A:** T2 relaxometry at the proximal carpal tunnel level. **B:** T2 relaxometry at the distal carpal tunnel level showing the scatter plot, box plot, and distribution curve. Values represent the variability of each individual measurement. The difference in means and the asymmetry of the distribution curve between levels are shown. The dotted line indicates the value reported in healthy Mexican patients^a (58.8 ms). In CTS, both proximal and distal levels show increased T2 relaxometry values, with higher values at the proximal level of the carpal tunnel.

^aCastro-Teran et al.¹⁰ CTS: carpal tunnel syndrome; SD: standard deviation.

raincloud plot displaying the dispersion of T2 relaxometry values for each affected wrist, along with their representation in a box plot and distribution curve. The mean proximal T2 relaxometry value was 64.7 ± 7.4 ms (min 55.2, max 76.6). The mean T2 relaxometry at the distal level was 59.6 ± 7.8 ms (min 48.1, max 71.6).

Figure 2 shows wrist MRI and T2 relaxometry color map of a 52-year-old woman with pain, weakness, and nocturnal paresthesias of the left hand, with a clinical diagnosis of CTS. An increased CSA (10.8 mm^2 , reference value 7 mm^2) was found at the proximal level compared with the distal level (6.3 mm^2 , reference value 8 mm^2). T2 relaxometry time of the median nerve was higher at the proximal level (70.8 ms , reference value 58.8 ms) than at the distal level (59.2 ms). The imaging diagnosis was CTS. Figure 3 shows the

right wrist MRI of the same patient as in figure 2, with a clinical diagnosis of bilateral CTS. Increased CSA (11.1 mm^2 , reference value 7 mm^2) was found at the proximal level compared with the distal level (7.2 mm^2 , reference value 8 mm^2). T2 relaxometry time of the median nerve was higher at the proximal level (76.64 ms , reference value 58.8 ms) than at the distal level (68.67 ms). The imaging diagnosis was CTS.

Figure 4 shows the wrist MRI of a 70-year-old woman with pain and nocturnal paresthesias. The proximal carpal tunnel showed increased CSA (11.6 mm^2 , reference value 7 mm^2). Increased T2 relaxometry time (66.3 ms , reference value 58.8 ms) indicated intraneural edema. The imaging diagnosis was CTS. Quantitative findings showed variability, with increased CSA and T2 relaxometry values at the proximal level.

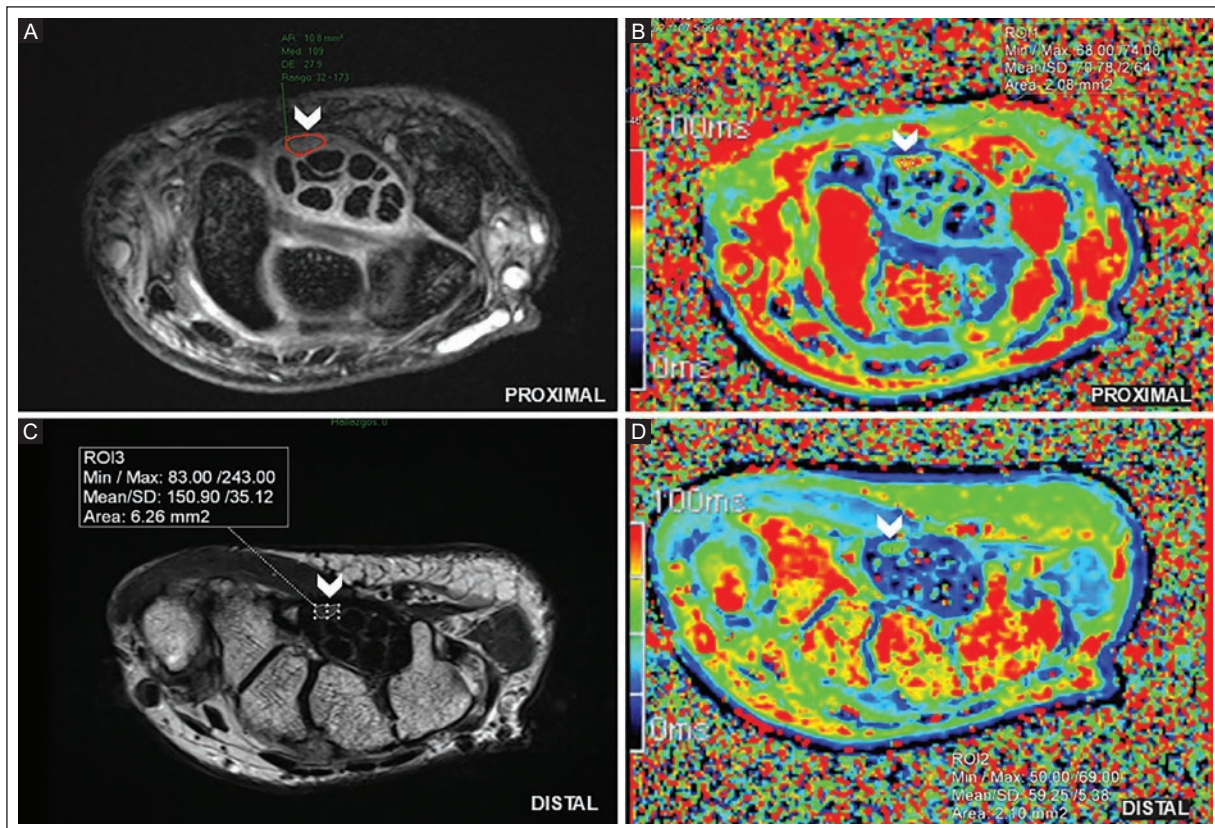


Figure 2. Wrist MRI of a 52-year-old woman with pain, weakness, and nocturnal paresthesia involving the left median nerve. The clinical diagnosis was CTS. **A:** T2 TSE axial view of the proximal carpal tunnel shows median nerve thickening with a CSA of 10.8 mm² (arrowhead) (reference value 7 mm²)^a. **B:** T2 relaxometry of 70.8 ms (arrowhead) (reference value 58.8 ms)^b, consistent with intraneural edema. The imaging diagnosis was CTS. **C:** T2 TSE axial view at the distal carpal tunnel shows the median nerve with ovoid morphology. CSA measures 6.3 mm² (arrowhead) (reference value 8 mm²)^a. **D:** T2 relaxometry map at the distal carpal tunnel shows a relaxation time of 59.2 ms (arrowhead), with no evidence of intraneural edema.

^aMiddleton et al.¹¹, ^bCastro-Teran et al.¹⁰. CSA: cross-sectional area; CTS: carpal tunnel syndrome; MRI: magnetic resonance imaging; TSE: turbo spin echo.

Pearson correlation coefficients between median nerve CSA and T2 relaxometry and age, weight, height, and BMI in patients with CTS

No correlation was found between CSA and T2 relaxometry at the proximal and distal levels of the carpal tunnel of the median nerve, and age, weight, height, or BMI in patients with CTS (Table 3). Proximal and distal CSA measurements showed a moderate positive correlation ($r = 0.47$, $p = 0.125$), but this association was not significant. T2 relaxometry values at the proximal and distal levels showed a positive relationship: as the value at one level increased, the other also increased.

Correlation between BCTQ scales and median nerve CSA and T2 relaxometry in patients with CTS

There was no significant correlation between CSA and the BCTQ for symptom severity and functional

status, with $r = 0.16$ and 0.19 , respectively, at the proximal level and $r = -0.04$ and -0.19 , respectively, at the distal level ($p > 0.05$) (Table 4). There was no significant correlation between T2 relaxometry values and the BCTQ for symptom severity and functional status, with $r = 0.41$ and 0.29 , respectively, at the proximal level and $r = -0.04$ and -0.38 , respectively, at the distal level ($p > 0.05$).

DISCUSSION

In our study of Mexican patients with CTS, MRI showed that the median nerve at the proximal carpal tunnel level had a larger CSA and a longer T2 relaxometry time than at the distal carpal tunnel level. The CSA and T2 relaxometry time at the proximal level were abnormally high compared with reference values for healthy individuals. Combining a morphological parameter, such as CSA, with a quantitative measurement, such as T2 relaxometry, may improve characterization of median nerve involvement in CTS. Our results show

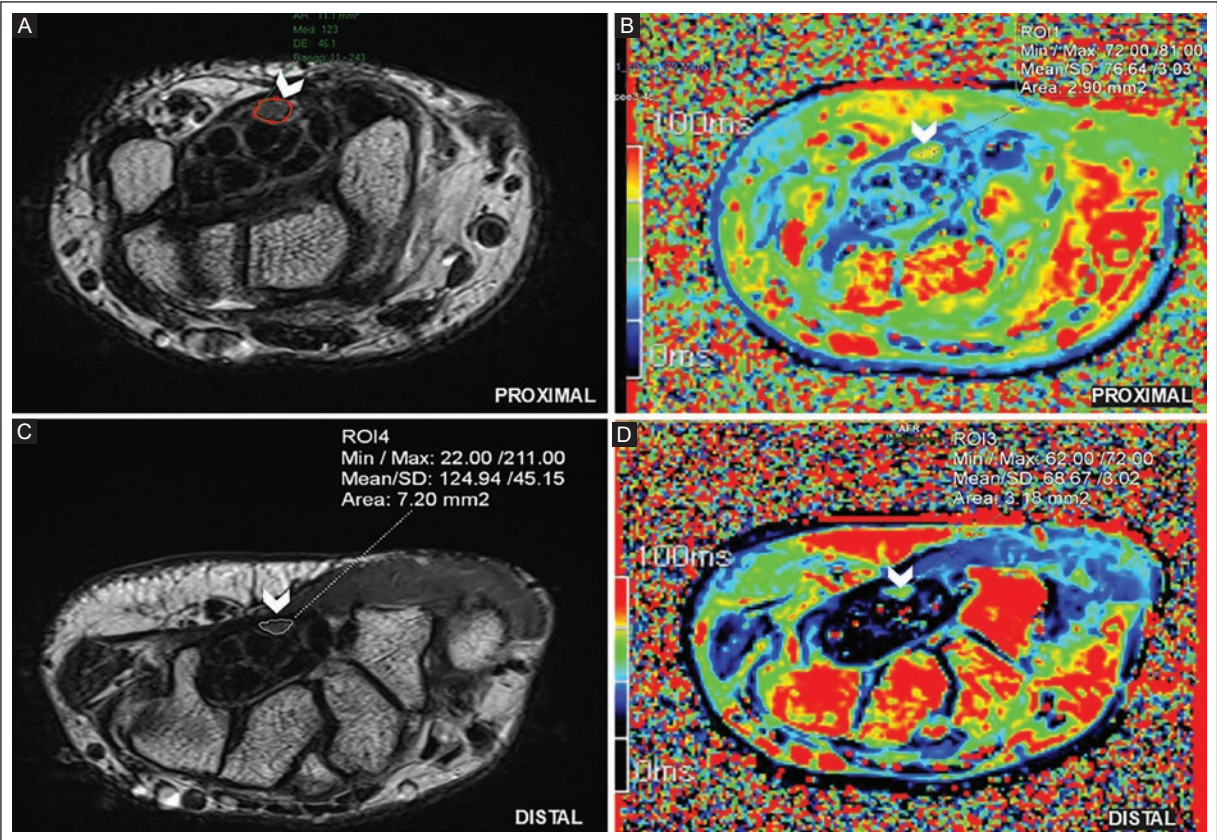


Figure 3. Right wrist MRI of the same patient as in Figure 2, with a clinical diagnosis of bilateral CTS. **A:** T2 TSE axial view at the proximal carpal tunnel level shows median nerve thickening with a CSA of 11.1 mm² (arrowhead) (reference value 7 mm²)^a. **B:** T2 relaxometry map at the proximal carpal tunnel level shows the median nerve with an increased relaxation time of 76.6 ms (arrowhead) (reference value 58.8 ms)^b, suggestive of intraneural edema. **C:** T2 TSE axial view at the distal carpal tunnel level shows the median nerve with ovoid morphology. CSA measures 7.2 mm² (arrowhead) (reference value ≤ 8 mm²)^a. **D:** T2 relaxometry map at the distal carpal tunnel level shows the median nerve with an increased relaxation time of 68.7 ms (arrowhead), consistent with intraneural edema. The imaging diagnosis was CTS.

^aMiddleton et al.¹¹, ^bCastro-Teran et al.¹⁰. CSA: cross-sectional area; CTS: carpal tunnel syndrome; MRI: magnetic resonance imaging; TSE: turbo spin echo.

Table 3. Pearson correlation coefficients between median nerve CSA and T2 relaxometry and age, weight, height, and BMI in patients with CTS

Description	Age	Weight	Height	BMI	Carpal tunnel		
					CSA		T2 relaxometry proximal level
					Proximal level	Distal level	
Median nerve CSA							
Proximal level	0.33	−0.23	−0.41	−0.12	-		
Distal level	0.07	−0.36	−0.38	−0.34	0.47	-	
Median nerve T2 relaxometry							
Proximal level	0.41	−0.21	−0.19	−0.16	0.10	−0.42	-
Distal level	0.21	−0.21	−0.29	−0.11	0.26	−0.36	0.57

BMI: body mass index; CTS: carpal tunnel syndrome; CSA: cross-sectional area.

that CSA and T2 relaxometry are sensitive biomarkers for local changes in the median nerve, especially at the proximal carpal tunnel level.

Both CSA and T2 relaxometry are typically increased in CTS compared with healthy subjects^{4,5,15}. Cha et al.,⁴ in a prospective study, compared CSA and T2 relaxometry

at three anatomical carpal tunnel levels in 12 Korean CTS patients and 12 healthy controls using a 3.0T Signa HDxt MRI (GE Medical Systems, Milwaukee, WI, USA). CSA was 18.6 mm² in CTS versus 10.2 mm² in healthy controls (p = 0.003) at the proximal level. CSA was 12.0 mm² in CTS versus 9.6 mm² in healthy

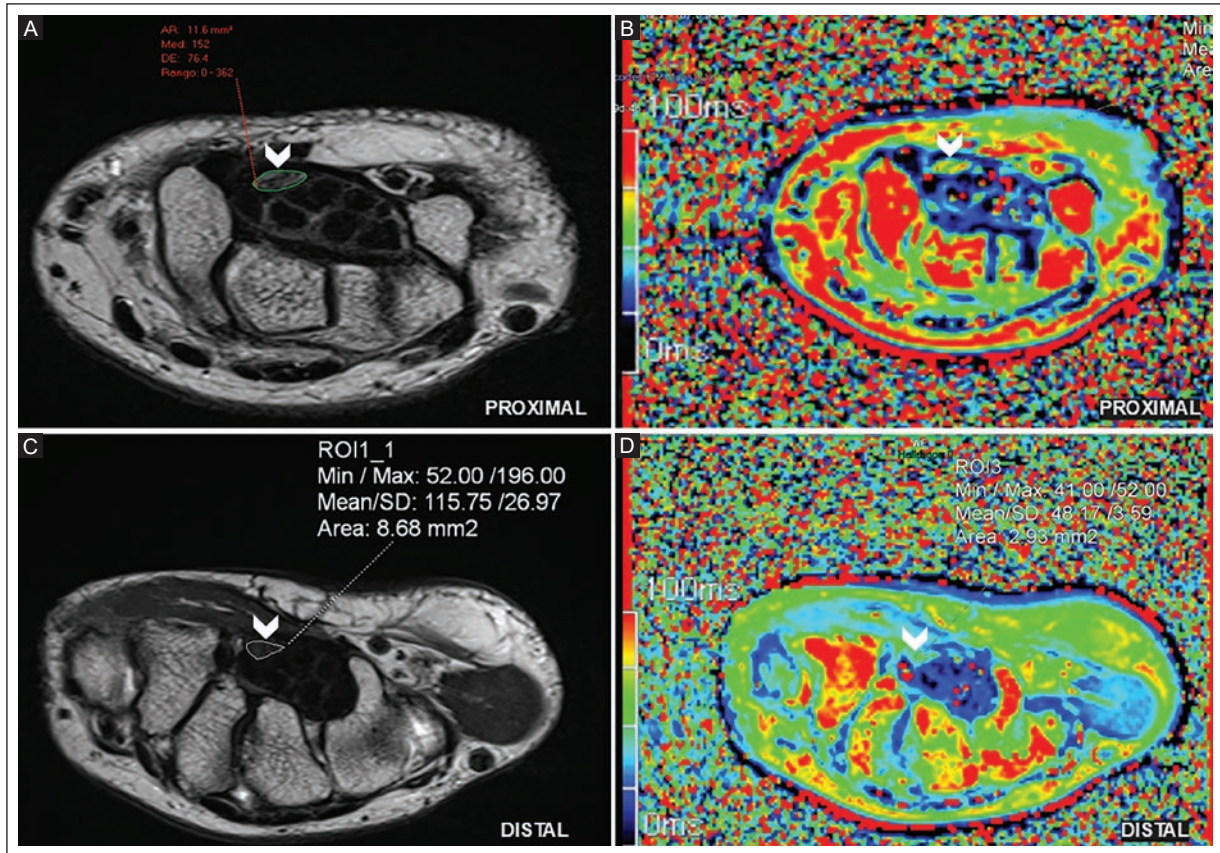


Figure 4. Wrist MRI of a 70-year-old woman with pain and nocturnal paresthesia. The clinical diagnosis was CTS. **A:** T2 TSE axial view at the proximal carpal tunnel level shows median nerve thickening with a CSA of 11.6 mm² (arrowhead) (reference value 7 mm²)^a. **B:** T2 relaxometry map at the proximal carpal tunnel level shows an increased relaxation time of 66.3 ms (arrowhead) (reference value 58.8 ms)^b, suggestive of intraneural edema. The imaging diagnosis was CTS. **C:** T2 TSE axial view at the distal carpal tunnel level shows flattening and bulging of the median nerve under the flexor retinaculum (arrowhead). CSA is 8.7 mm² (reference value 8 mm²)^a. **D:** T2 relaxometry map at the distal carpal tunnel level shows a relaxation time of 48.1 ms (arrowhead).

^aMiddleton et al.¹¹, ^bCastro-Teran et al.¹⁰. CSA: cross-sectional area; CTS: carpal tunnel syndrome; MRI: magnetic resonance imaging; TSE: turbo spin echo.

Table 4. Correlation between BCTQ scales^a and median nerve CSA and T2 relaxometry in patients with CTS

Description	Parameter	Carpal tunnel			
		Proximal level		Distal level	
		CSA	T2 relaxometry	CSA	T2 relaxometry
Symptom Severity Scale	r	0.16	0.41	-0.04	-0.04
Functional Status Scale	r	0.19	0.29	-0.19	-0.38

^aBCTQ: Boston Carpal Tunnel Questionnaire¹². CTS: carpal tunnel syndrome; CSA: cross-sectional area.

controls ($p = 0.10$) at the distal tunnel. CSA was 14.9 mm² in CTS versus 10.5 mm² in healthy controls ($p = 0.002$) at the distal radioulnar joint. Median nerve T2 relaxometry at the proximal level was 52.1 ms in

CTS versus 44.3 ms in healthy controls ($p = 0.03$), and 51.0 ms in CTS versus 41.8 ms in healthy controls ($p = 0.03$) at the distal level. At the distal radioulnar joint, it was 44.4 ms in CTS versus 44.0 ms in healthy controls ($p = 0.84$). The increased CSA and T2 relaxometry were mainly at nerve compression sites (proximal and distal) in the carpal tunnel. Maeda et al.⁵ found a significant increase in median nerve T2 relaxometry in the proximal carpal tunnel (56.7 ± 16.4 ms) compared to the control group (51.2 ± 10.8 ms) ($p = 0.02$) in 71 Japanese patients with CTS and 26 healthy controls using a 3.0T Trillium Oval scanner (Hitachi Ltd, Tokyo, Japan). There was no significant difference at the distal level ($p = 0.64$), with values of 51.0 ± 17.3 ms in CTS patients and 49.4 ± 8.5 ms in healthy controls. The authors concluded that T2 relaxometry values in CTS patients were higher in the proximal carpal tunnel than in healthy controls, with no significant difference at the

distal level. Castro-Teran et al.,¹⁰ in a cross-sectional study of 30 healthy Mexican individuals using a 3.0T Magnetom Skyra Fit (Siemens Healthineers, Erlangen, Germany), reported a mean T2 relaxometry time of 58.8 ± 9.0 ms at the proximal carpal tunnel level. In our study of Mexican patients with CTS, we found significantly increased T2 relaxometry times (64.7 ms) in the proximal carpal tunnel compared with those previously reported in healthy Mexican subjects (58.8 ms). The differences observed between our results and those of Cha et al.⁴ and Maeda et al.⁵ may, in part, be due to the use of different scanners and population characteristics¹⁵. There are currently no reference standard values for CSA and T2 relaxometry in CTS. This may reflect several technical and biological factors across populations. In CTS, the median nerve shows region-dependent alterations within the carpal tunnel, characterized by increased T2 MRI signal and nerve enlargement, predominantly at the proximal level. This pattern is attributed to the pathophysiology of compressive neuropathy, in which mechanical compression at the distal tunnel leads to impaired venous return, intraneural edema, and retrograde fluid accumulation, which cause pronounced changes proximally^{5,8,15-17}.

CSA may be affected by factors such as weight, height, and BMI⁶. In contrast, T2 relaxometry appears to be a more specific biomarker of neural microstructural damage, as it reflects intrinsic tissue alterations, such as intraneural edema and changes in water content. It is also less influenced by anthropometric variability¹⁸. Bowers et al.¹⁹ evaluated the relationship between the median nerve CSA and BMI in a prospective study of 24 American patients with CTS and 283 patients without CTS using 1.5T or 3.0T MRI. They found that higher BMI was associated with higher CSA, with significant differences at both proximal and distal levels ($p = 0.01$). Patients with CTS had significantly higher CSA, and high BMI was associated with increased median nerve size, even without CTS. The correlation between T2 relaxation time and age has not been clearly defined. Kronlage et al.,⁸ in a study of 60 healthy German subjects evaluated with 3.0T MRI, assessed T2 relaxation of the median, ulnar, and sciatic nerves and found correlations with height ($r = 0.28$), weight ($r = 0.40$), and BMI ($r = 0.35$), but not with age ($r = 0.23$). Castro-Teran et al.,¹⁰ in healthy Mexican individuals, found a weak positive correlation indicating that median nerve T2 relaxation increased with age. However, insufficient data exist to establish a definitive correlation between age and T2 relaxation time. We did not find a correlation between anthropometric variables (age, weight, height, and BMI)

and CSA or T2 relaxometry values in patients with CTS. These findings suggest that in our sample of Mexican patients with CTS, both CSA and T2 relaxometry are independent of patient anthropometric characteristics, reinforcing the concept that the primary effect is due to local nerve alterations rather than systemic influences.

The relationship between morphological parameters, such as CSA, and quantitative measurements, such as T2 relaxometry, and symptoms and functional status in patients with CTS has been rarely evaluated. Samanci et al.²⁰ reported a study of 23 Turkish patients with CTS and abnormal nerve conduction studies. The control group consisted of 24 healthy individuals matched for age, sex, and BMI. Symptoms and functional scores were assessed using the BCTQ. The preoperative BCTQ values were 3.6 ± 0.8 for the SSS and 3.3 ± 0.94 for the FSS, based on the average of all responses weighed to 5, whereas the postoperative values were 1.9 ± 0.6 for both SSS and FSS. In our study, the mean SSS value was 2.2 ± 0.5 , indicating moderate symptom severity. The mean FSS value was 1.7 ± 0.8 , suggesting mild functional impairment. No correlation was found between CSA or T2 relaxometry and the clinical scales (SSS and FSS). The lack of correlation between quantitative MRI findings and clinical scales in CTS may be due to several factors, such as the timing of diagnosis relative to imaging assessment.

The strengths of this study include the use of quantitative 3.0T MRI parameters and a standardized acquisition and analysis protocol, enabling reproducible assessment of the median nerve at two carpal tunnel levels in patients with CTS. However, there are several limitations, particularly the case-series design without a healthy control group, which limits the generalizability of the findings. Additionally, electromyographic diagnosis of CTS was not available.

CONCLUSION

In patients with CTS, the median nerve shows significantly higher CSA and T2 relaxometry at the proximal carpal tunnel level than at the distal level. CSA and T2 relaxometry are complementary MRI biomarkers that assess median nerve damage. These measurements provide objective information on microstructural changes in the nerve, regardless of clinical severity or function. Further studies should include larger sample sizes, a healthy control group, and correlations with electrodiagnostic studies to validate this diagnostic approach in clinical practice.

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Conflicts of interest

The authors declare no conflicts of interest.

Ethical considerations

Protection of human subjects and animals. The authors declare that the procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation and with the World Medical Association and the Declaration of Helsinki (1964) and subsequent amendments.

Confidentiality, informed consent, and ethical approval. The authors have followed their institution's confidentiality protocols, obtained informed consent from all patients, and secured approval from the Ethics Committee. SAGER guidelines have been followed as applicable to the nature of the study.

Declaration on the use of artificial intelligence. The authors declare that no generative artificial intelligence was used in the writing or creation of the content of this manuscript.

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