Reliability, Feasibility and Value of Ecography in Clinical-functional Results in Patients Affected by Carpal Tunnel Syndrome: is There a Correlation?

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ABSTRACT

Background: The aim of this study was to evaluate how the ultrasound examination in the carpal tunnel diagnosis could contribute to the clinical and neurophysiological evaluation. This was done by evaluating the cross-sectional area (CSA) and its correlation with symptoms and functionality data assessed by the BTQC questionnaire. Methods: 60 patients were subjected to open CTR for idiopathic carpal tunnel syndrome. The median nerve CSA was assessed both pre-operatively and in follow-up at 4 and 12 weeks. The Boston Carpal Tunnel Questionanaire (BCTQ) was proposed at the same time. Results: BCTQ score significantly improved after 4 weeks, but there was a less significant increase at 12 weeks for both the BCTQ-S and the BCTQ-F. The 4-week CSA, however, did not appear to have markedly improvement, where as the 12-week CSA turned out to be statistically significant. The correlation between BCTQ and CSA shows that post-surgery, the reduction of CSA of the median nerve is correlated with the symptomatic and functional reduction in patients. Conclusions: The study shows that the symptomatology and the functionality of the hand after surgery for the carpal tunnel resolves quickly. Furthermore, the reduction of the CSA proves to show that the use of ultrasound can help in the evaluation of patients with this state.

Keywords: Median nerve, Carpal tunnel syndrome, Ultrasonography, Carpal tunnel release.

1. INTRODUCTION

Carpal tunnel syndrome is considered the most common upper limb neuropathy, with a prevalence of 5% in the general population aged 50-60 years with a female/male ratio of 4/1 (1, 2, 3). The diagnosis appears to be mainly clinical aided by imaging analysis. The gold standard appears be electromyography, even if it can only assess the functional status of the median nerve, but cannot reflect the state of the surrounding structures (4). For this reason the importance of the ultrasound has increased in recent years, both in the initial diagnostic process of carpal tunnel syndrome, as well as in the follow-up of entrapment neuropathy of the median nerve in the carpal tunnel. Ultrasound is a dynamic method, easy to perform, non-invasive, which can provide information about the anatomy of the nerve and its relationship with surrounding structures (5). Therefore, to identify the cause of nerve trunk pain, the combined use of electromyography and ultrasound is often useful to better define the type, location and severity of the nerve damage, making the diagnostic precision and the therapeutic accuracy more effective. The aim of this study is to evaluate the effectiveness of the ultrasound examination as a support to clinical and electromyographic tests in the diagnostic process of carpal tunnel syndrome.

2. MATERIALS AND METHODS

This is a retrospective study aiming to demonstrate how the use of ultrasound as a diagnostic method aids patients with carpal tunnel syndrome. All patients were informed about the study and freely decided to participate. Two groups of patients were studied: Control group A, consisting of 60 voluntary patients (47 females and 13 males) and group B, consisting of 60 patients suffering from carpal tunnel syndrome (39 females and 21 males), with an average age of 47.8 years in both groups. All patients in the second group were operated on at the Hospital "Santa Maria della Misericordia", Perugia, in the period between January and July 2015. The surgery was performed by

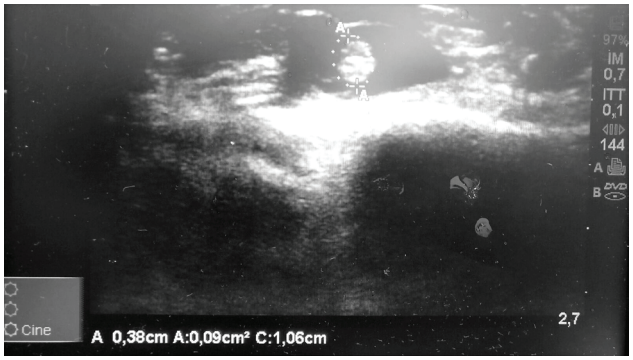

Figure 1. Ultrasound study. Patient non affected by carpal tunnel syndrome.

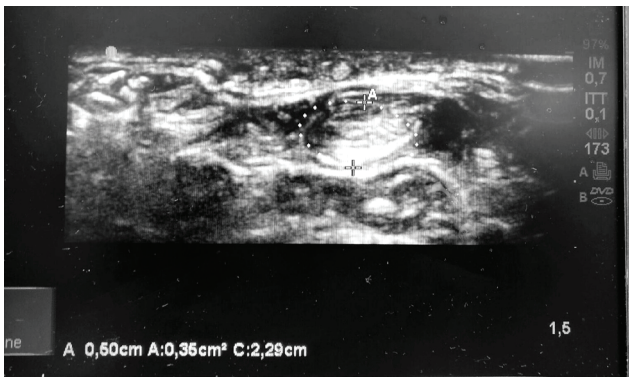

Figure 2. Ultrasound study. Patient affected by carpal tunnel syndrome.

the same surgeon. The inclusion criteria to be part of the study were pain and/or numbness in the fingers in region of the median nerve, night pain with numbness, decreased grip strength dropping objects from the hands, testing positive for the "Phalen Test" and/or "Tinel Test", or electrophysiological evidence of the presence of CTS (distal motor latency > 4.5milliseconds,wrist-digitsensorylatency > 3.5 milliseconds, or sensory conduction velocity at the carpal tunnel segment <40 m / s). The exclusion factors were: patient's age under 18 years old, clinical or electrophysiological signs of proximal nerve compression, diabetes mellitus, renal failure, rheumatoid arthritis, hypothyroidism, pregnancy, previous surgery on the wrist or the presence of pacemaker.

The dominant limb appears to be involved in the majority of cases (48 out of 60 patients) even though the symptomatology is more often bilateral. All patients in this study were evaluated before surgery with clinical, electrophysiological and ultrasound examinations (Figure 1, 2), and after decompression surgery with mini-open technique of the carpal canal, and clinical examination and ultrasound at 4 and 12 weeks post-op.

All patients were evaluated by the same operator, who has more than five years of experience with musculoskeletal ultrasounds. During the examination, the patients were sitting on a comfortable chair with the hand supinated, positioned on a stand on a table, with the wrist in hyperextension and the elbow flexed. The high frequency linear probe (715 MHz) used was positioned transversely with respect to the path of the median nerve to evaluate the cross-sectional area (CSA) and subsequently, longitudinally to the nerve to evaluate the compression below the channel. After surgery, patients were evaluated by ultrasound and by the same operator in the same position with the same ultrasound parameters at 4 and 12 weeks.

The BCTQ (Boston carpal tunnel questionnaire) was proposed for the clinical evaluation pre-operatively and at 4 and 12 weeks post-surgery (6). It consists of 2 scales: symptom (BCTQ-S) and functional (BCTQ-F) evaluation. BCTQ-S consists of 11 questions which consider the severity and frequency of pain, numbness, weakness and loss of maneuverability. Five possible responses are offered for each question and are scored from 1 (no symptom) to 5 (severe). Results are expressed as the average scores of the 11 responses. BCTQ-F is composed of 8 questions that address difficulties in performing daily tasks. Responses are also scored using a 5-point scale (1 to 5, where 5 indicates greatest difficulty), and again results are averaged. At first, we compared the average values obtained from the median nerve CSA-pisiform and from the ulnar nerve CSA-ulnare with the respective SD in the two groups, using the relationship between the two as a reference point that should be less than 1.79 to rule out the disease (5). These values were then compared with the results obtained from the BCTQ questionnaire to assess whether or not ultrasound, symptomatic, and functional correlations of this disease coexist.

We compared the average value of the CSA below the carpal canal near the pisiform in the control group and in group B before surgery and at distance of 4 and 12 weeks post-surgery to assess whether there were statistically significant differences between the control group and the group of operated patients. These values were correlated and compared with the results obtained from the BCTQ-S and BCTQ-F questionnaire to see if there was a relationship between the ultrasound and the clinical confirmation. Finally, given that the ratio CSA-pisiform/CSA-ulnar must be less than 1.79 to rule out the disease, we compared the same with the BCTQ questionnaire to see if there were any correlations (7).

Statistical analysis

For statistical analysis, the T-student tests was used which allowed us to correlate the results between the proposed questionnaire and the sectional area of the median nerve obtained in the three steps under consideration. The goal was to assess whether or not there were objective improvements of the nerve post-surgery and of symptoms. We present the average results +/- SD with statistical significance with p-value <0.05.

3. RESULTS

The values obtained of the CSA-pisiform and CSA-ulnar in control group patients (group A) were on average 7.80 +/- 1.49 mm2 and 4:37 +/- 1:39 mm2 compared to the patients in group B which were 12:43 +/- 6:43 +/- 3.23 mm2 and 1.2 mm2 with a p-value <0.001, respectively.

Furthermore, considering the relationship between CSA-pisiform/CSA-ulnar, in control group cases an average value of 1.78 +/- 0.72 mm2 was reported, whereas in the pre-operative group 1.93 +/- 0.98 mm2 with a p-value <0.01. In both cases, we obtained statistically significant results as can be assessed from Table 1.

We also compared the values of the CSA-pisiform and CSA-ulnar at 4 and 12 weeks between the control group and the group of patients operated on, as shown in Table 2, with

	Control group [A] (n =60)mean±SD	CTS group [B] (n =60)mean±SD Pre-op	p
CSA-pisiform(mm2)	7.80±1.49	12.43±3.23	0.01*
CSA-ulnar(mm2)	4.37±1.39	6.43±2.01	0.01*
CSApisiform/ CSAulnar	1.78±0.72	1.93±0.98	0.01*

Table 1. *p<0.01.CSA-pisiform: median nerve cross-sectional area measured at the level of the pisiform bone, CSAulnar: ulnar nerve cross-sectional area measured at the level of the pisiform bone, CTS: carpal tunnel syndrome.

	at 4 weeks	at 12 weeks	p
CSA-pisiform(mm2)	10,9±4,5	9,4±3,2	0.0375*
CSA-ulnar(mm2)	4.74±1,9	4,70±0.8	0.88*
CSA-pisiform/CSAulnar	2.3±0.8	2±0.5	0.015*

Table 2 *p<0.05.CSA-pisiform: median nerve cross-sectional area measured at the level of the pisiform bone, CSAulnar: ulnar nerve cross-sectional area measured at the level of the pisiform bone, CTS: carpal tunnel syndrome.

BCTQ	Pre- operatory x+/-SD x-medio	Post-op 4 weeks x+/-SD x-medio	Post- op 12 weeks x+/-SD x-medio	p (pre-op-post-op 4 weeks)	p (post -op 4 weeks post-op 12 weeks)
BCTQ -S	3.8 ± 1.5	2.1 ± 0.9	1.6 ± 1.5	P 0.001	P 0.029
BCTQ -F	2.9 ± 1.0	2.7 ± 0.8	1.9 ± 0.9	P0.23	P0.001

Table 3. The results obtained from the BCTQ questionnaire given to patients in group B pre-operatory, at 4 weeks and at 12 weeks.

CSA-pisiform (mm2)	BCTQ -S Pre-op 3.8 ± 1.5	BCTQ -F Pre-op 2.9 ± 1.0	BCTQ -S 4 weeks 2.1 ± 0.9	BCTQ -F 4 weeks 2.7 ± 0.8	BCTQ -S 12 weeks 1.6 ± 1.5	BCTQ -f 12 weeks 1.9 ± 0.9
Pre-op 12.43±3.23 mm2	P 0.001	P 0.001	-	-	-	-
4 weeks 10,9±4,5mm2	-	-	P 0.001	P0.001	-	-
12 weeks 9,4±3,2mm2	-	-	-	-	P0.001	P0.001

Table 4. Correlation between CSA-pisiform and BCTQ -F and BCTQ -S in the pre-operatory and at follow-up. p <0.01

CSA pi-siform/ CSAulnar	BCTQ -S Pre-op 3.8 ± 1.5	BCTQ -F Pre-op 2.9 ± 1.0	BCTQ -S 4 weeks 2.1 ± 0.9	BCTQ -F 4 weeks 2.7 ± 0.8	BCTQ -S 12 weeks 1.6 ± 1.5	BCTQ -f 12 weeks 1.9 ± 0.9
Pre-op 1.93±0.98	P 0.001	P 0.001	-	-	-	-
4 weeks 2.3±0.8	-	-	P 0.2	P 0.007	-	-
12 weeks 2±0.5	-	-	-	-	P 0.05	P 0.045

Table 5. Correlation between CSA-piriform/CSA-ulnare in pre- and post-operatory p<0.05

statistically significant results with p-value <0.05.

The CSA-pisiform in patients operated at 4 weeks is 10.9 +/- 4.5 mm2, which are reduced to 9.4 +/- 3.2 mm2 at 12 weeks with p 0.0375, while the value of CSA-ulnar at 4 weeks is 4.74 +/-1.9 mm2, which is reduced to 4.70 +/- 0.8 mm2 at 12 weeks with p of 0.88.

The relationship between CSA-pisiform/CSA-ulnar is 2.3 +/-0.8 mm2 at 4 weeks which is reduced to 2 +/- 0.5 mm2 at 12 weeks with p 0.015.

The results obtained by BCTQ questionnaires proposed pre-operatively and at 4 and 12 weeks, are also reported below for patients in group B. (Table 3).

Pre-operatively, the average score of BCTQ-S was 3.8 +/- 1.5 while that of BCTQ-F was 2.9 +/- 1.0, which is reduced to 2.1 +/- 0.9 (BCTQ -S) and 2.7 +/-0.8 (BCTQ -F) at 4 weeks with a p for BCTQ -S of 0.001 and for BCTQ -F 0.23 and further to 1.6 +/- 1.5 (BCTQ -S) and 1.9 +/- 0.9 (BCTQ -F) at 12 weeks with a p-BCTQ of S of 0.029 and for BCTQ -F of 0.001 (Table 3).

We also correlated the values obtained of CSA-pisiform with those of the BCTQ questionnaire evaluating the statistical significance of the results obtained, as shown in Table 4.

The p value found in the pre-operative and follow-up at 4 and 12 weeks is reported to be 0.001, and therefore statistically significant.

Finally, we correlated the relationship of CSA-piriform/ CSA-ulnar with the BCTQ-S and BCTQ-F questionnaire resulting in the results proposed in Table 5.

The obtained values of p in the pre- and post-operative at 12 weeks results are p <0.05, while in the post-operative at 4 weeks for the BCTQ-F, the p is statistically significant, contrary to the BCTQ-S which was found to be 0.2 .

4. DISCUSSION

In ultrasonographic evaluation of the median nerve, we relied on the directions proposed by Eugene G. McNally (8) in his manual. To measure the cross-sectional area of the median nerve, two methods are used: the direct method, with the ultrasound ellipse instrument, or the indirect method, using the ellipse formula (maximum antero-posterior diameter) x (maximum transverse diameter) x (π / 4)]. The two methods show a high degree of correlation, for this reason, we used the second. The position of the transducer can affect the measurement of the area of the cross section, and for this reason it should always be perpendicular to the nerve, even when the latter runs obliquely from the surface to the deep plane.

An increase of more than 10 mm2 of the cross-section in the proximal carpal tunnel is considered a diagnostic factor of carpal tunnel syndrome (7). In ultrasonographic evaluation, we decided to consider the median nerve CSA at the point of the greater protuberance of the pisiform in the carpal canal and the ulnar nerve CSA at the same point as proposed by Yurdakul (7). Yurdakul also evaluated the relationship between these two values of CSA because he found that the relationship between CSA-pisiform/CSA-ulnar ≥1.79 could be used to diagnose CTS with a sensitivity, specificity, positive predictive value, and negative predictive value of 70%, 76%, 76.6%, and 70%, respectively.

In fact, Yurdakul (7) found that there is a correlation between the ratio CSApisiform/CSAulnar and the duration of symptoms, just as we found in this study. We correlated the CSA-piriform/CSA-ulnar relationship and BCTQ questionnaire, obtaining statistically significant results both in the pre-operative that in the post-operative at 12 weeks, BCTQ-s and BCTQ-F having a p <0.05, while for the post-operative values at 4 weeks we obtained statistically significant results for BCTQ-F but non-statistically significant results for BCTQ-S. This could mean that at four weeks post-intervention the ultrasound correlation, considering the relationship between the two areas of the transverse section of the nerves, is not linked to a significant reduction in symptoms. At the moment, there are no studies in the literature correlating these two parameters. Yurdakul (7) states that CSA-pisiform/ CSA-ulnar are linked to symptoms only in advanced stages of the disease, perhaps also for recovery from the disease, longer time is needed as we found in our study. It would be neces-

sary to evaluate the causes for which there is not a statistically significant correlation for BCTQ -S at 4 weeks post-surgery.

There was no onset of symptoms related to compression of the ulnar nerve even though its CSA was slightly increased, as proposed in the literature (7, 9). As hypothesized Yurdakul (7), this may be related to morphological changes caused by the prolonged persistent symptoms that worsens with time. So much so, that we observed a similar reduction at 12 weeks, but with a non-statistically significant result. Finally, in the conclusions of his work, Yurdakul (7) affirms that the CSA-pisiform turns out to be a real method for diagnosing carpal tunnel, while the relationship between CSA-pisiform/CSA-ulnar can only be used for the diagnosis of CTS in the final stages. In this study, we saw the important correlation between the CSA-pisiform and diagnosis of CTS, but we have also shown that the ratio CSA-pisiform/CSA-ulnar can be used as a diagnostic tool and not only in the late stages of the disease.

The CSA value of the median nerve at 4 weeks did not have a clear improvement compared to the pre-operative values, while at 12 weeks the reduction was statistically significant with an average size of 9.4 +/- 3.2 mm2, which agrees with the threshold described by Eugene G. McNally (8) of 10 mm^2.

It is also in accordance with what Yesildag (10) described, where the value of the CSA of the median nerve below the transverse carpal ligament is found to have a sensitivity of 89% and a specificity of 97% when the cut-off is of 10.5 mm^2.

We decided to use the BCTQ questionnaire for the assessment of symptoms and functionality because, as described by Levine (6), it is a reproducible evaluation scale and responsive to clinical changes in symptoms following surgery. By using the BCTQ, we can also make comparisons with the literature as in the work proposed by Kim (11).

The BCTQ results obtained post-operatively at 4 weeks demonstrated a significant improvement both symptomatically and functionally. The increase was, however, less significant at 12 weeks post-surgery. In both cases the values are statistically significant. Kim (11) has shown in his work that there is an improvement in symptoms after surgery, but reported a lack of correlation between the values of BCTQ and the median nerve CSA. Compared to the work of Kim (11), our work was based on a follow-up at 4 and 12 weeks as opposed to 2 and 12 weeks. In patients evaluated, we found a correlation between the value of the CSA of the median nerve and the symptomatic and functional outcomes of the BCTQ with statistically significant p values. Many studies have in fact reported a correlation between the change in the CSA of the median nerve post-surgery and a reduction of the patient's symptoms (12, 13, 14, 15, 16).

5. CONCLUSIONS

Our work has shown that the use of ultrasound in the diagnosis of carpal tunnel syndrome is a useful adjunct to clinical and neurophysiological evaluations. The value of CSA-pisiform correlates with symptoms just as the relationship of CSA-pisiform/CSA-ulnar both in the early stages of symptoms and in the later stages, in a statistically significant manner. The ultrasound findings were correlated with those of symptomology and functionality based on the values of the BCTQ questionnaire proposed to our patients.

- **CONFLICT OF INTEREST STATEMENT:** All authors disclose any financial and personal relationships with other people or organizations that could inappropriately influence (bias) their work. Examples of potential conflicts of interest include employment, consultancies, stock ownership, honoraria, paid expert testimony, patent applications/registrations, and grants or other funding. Mattia Manni, Michele Bisaccia, Giuseppe Rinonapoli, Andrea Schiavone, Luigi Meccariello, Steven James Mccabe, Olga Bisaccia, Cristina Ibáñez Vicente, Andrea Cappiello and Auro Caraffa disclose any financial and personal relationships with other people or organizations that could inappropriately influence (bias) their work.
- **HUMAN AND ANIMAL RIGHT:** For this type of study any statement relating to studies on humans and animals is not required. Patients gave her informed consent prior to being included in the study. All procedures involving human participants were in accordance with the 1964 Helsinki declaration and its later amendments.

REFERENCES

1. Chen YT, Williams L, Zak MJ, Fredericson M. Review of Ultrasonography in the Diagnosis of Carpal Tunnel Syndrome and a Proposed Scanning Protocol Journal of Ultrasound in Medicine. 2016; 35: 2311-24. Published Online First September 14, 2016.
2. Bisaccia M, Rinonapoli G, Falzarano G. et al. Clinical and Radiological Outcomes of Distal Radius Fractures Treated with Orif with volar Fixed-angle Plates. Euromediterranean Biomedical Journal. 2016; 11(02): 9-14. doi: 10.3269/1970-5492.2016.11.02.
3. Bisaccia M, Piscitelli L, Colleluori G. et al. Epidemiology of injuries and diseases due to overuse in rugby: observational study of the players of "Cus Perugia rugby". IJSM. 2016; 2(3): 167-70. doi: 10.5455/ijsm.rugby-injury
4. Aksekili MA, Biçici V, Işık Ç, Aksekili H, Uğurlu M, Akkurt A, Doğan M. Comparison of early postoperative period electrophysiological and clinical findings following carpal tunnel syndrome: is EMG necessary? Int J Clin Exp Med. 2015; 8(6): 10011-5. Published online 2015 Jun 3.
5. Cappiello A, Stano V, Bisaccia M. et al. Is baseline strain index a prognostic factor for small unilateral supraspinatus tendon tears? A prospective study. IJSM. 2016; 2(3): 150-5. doi: 10.5455/ijsm.baseline-strain-index-tendon-tears
6. Levine DW, Simmons BP, Koris MJ, et al. A self-administered questionnaire for the assessment of severity of symptoms and functional status in carpal tunnel syndrome. J Bone Joint Surg Am. 1993;75:1585-92.
7. Yurdakul OV, Mesci N, Çetinkaya Y, Geler Külcü D. Diagnostic Significance of Ultrasonographic Measurements and Median-Ulnar Ratio in Carpal Tunnel Syndrome: Correlation with Nerve Conduction Studies. J Clin Neurol. 2016 Jul; 12(3): 289-94.
8. McNally EG. Practical musculoskeletal ultrasound second edition (2014) Elsevier Int J Clin Exp Med. 2015 Jun 3; 8(6): 10011-5. eCollection 2015.
9. Ginanneschi F, Filippou G, Reale F, Scarselli C, Galeazzi M, Rossi A. Ultrasonographic and functional changes of the ulnar nerve at Guyon's canal after carpal tunnel release. Clin Neurophysiol. 2010; 121: 208-13.
10. Yesildag A, Kutluhan S, Sengul N, Koyuncuoglu HR, Oyar O,

Guler K. et al. The role of ultrasonographic measurements of the median nerve in the diagnosis of carpal tunnel syndrome. Clin Radiol. 2004; 59: 910-5.
11. Lee CH, Kim TK, Yoon ES, Dhong ES. Correlation of high-resolution ultrasonographic findings with the clinical symptoms and electrodiagnostic data in carpal tunnel syndrome. Ann Plast Surg. 2005; 54: 20-3.
12. Tatar IG, Kurt A, Yavasoglu NG, Hekimoglu B. Carpal tunnel syndrome: elastosonographic strain ratio and cross-sectional area evaluation for the diagnosis and disease severity. Med Ultrason. 2016 Sep; 18(3): 305-11. doi: 10.11152/mu.2013.2066.183.tat.
13. Kim JK, Koh YD, Kim JO, Choi SW. Changes in Clinical Symptoms, Functions, and the Median Nerve Cross-Sectional Area at the Carpal Tunnel Inlet after Open Carpal Tunnel Release Clinics in Orthopedic Surgery. 2016; 8: 298-302.
14. Vogelin E, Nuesch E, Juni P, Reichenbach S, Eser P, Ziswiler HR. Sonographic follow-up of patients with carpal tunnel syndrome undergoing surgical or nonsurgical treatment: prospective cohort study. J Hand Surg Am. 2010; 35(9): 1401-9.
15. Abicalaf CA, de Barros N, Sernik RA, et al. Ultrasound evaluation of patients with carpal tunnel syndrome before and after endoscopic release of the transverse carpal ligament. Clin Radiol. 2007; 62(9): 891-4.
16. Smidt MH, Visser LH. Carpal tunnel syndrome: clinical and sonographic follow-up after surgery. Muscle Nerve. 2008; 38(2): 987-91.