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Carpal Tunnel Syndrome: Correlating Preoperative Diagnostic Tools with Intraoperative Findings

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ABSTRACT

Background: There is no universally accepted gold standard for decision-making regarding the choice of surgery for carpal tunnel syndrome. A combination of clinical examination and electrophysiological studies has been commonly used for the diagnosis of CTS and grading its severity with the recent introduction of ultrasonographic examination as a reliable diagnostic tool. In severe cases of CTS, carpal tunnel release surgery is usually done, while patients with mild or moderate degree of the disease usually start with conservative treatment. Knowing which diagnostic test more accurately reflects the severity of CTS is mandatory for proper decision-making regarding management.

Objective: To correlate preoperative diagnostic tools (clinical presentation, Nerve conduction study, and US) findings with intraoperative findings to find out which one of these preoperative diagnostic tools plays the greatest role in the decision-making process regarding the choice of surgery.

Method: Surgically treated 18 patients diagnosed with carpal tunnel syndrome (CTS) were included in the study. A correlation between clinical, electrophysiological, and ultrasonographic data and intraoperative findings was done.

Results: Statistical analysis shows positive correlation between clinical, electrophysiological and ultrasonographic data, and intraoperative findings with electrophysiological studies being the best and only statistically significant predictor of severity.

Conclusion: Electrophysiological studies provide the best predictor of the severity of CTS but more studies are needed to test the accuracy of these results.

Key Words: *Carpal tunnel syndrome – Carpal tunnel release – Electrophysiological tests.*

Ethical Committee: The study was approved by Ethical Committee of Institutional Review Board (IRB), Mansoura Faculty of Medicine (MS.21.08.1632). Informed consent was obtained from the patients.

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INTRODUCTION

Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy, characterized by nocturnal pain and paraesthesia in the median nerve territory, and weakness or atrophy of the thenar muscles, caused by compression of the median nerve by the effect of elevated carpal tunnel pressure **[1]**.

The diagnosis of CTS depends mainly on clinical symptoms and examination, but electrophysiological studies are commonly used for confirmation of the diagnosis, grading the severity and exclusion other neuropathies **[2]**.

Recently, ultrasonography has been proposed as a replacement of electrophysiological testing for CTS diagnosis with the nerve cross-sectional area (CSA) being the best reliable indicator **[3]**.

Carpal tunnel release (CTR) is the gold standard procedure to relieve the symptoms of CTS. The intraoperative findings of CTS include fibrosis and flattening of median nerve, changes in epineurial vasculature and hour-glass appearance (pseudo neuroma) **[1]**.

Many studies have tried to assess the validity of these diagnostic methods in determination of the severity of CTS, in an effort to come out with a standard indication of surgical intervention **[4-9]**.

The decision of surgical treatment depends on multiple factors including, in addition to clinical manifestations: Age, sex, handedness, patients' awareness, workers' compensation and other subjective factors **[10]**. Due to this fact, there is no an

accepted gold standard for decision-making regarding the choice of surgery for carpal tunnel syndrome. Also, patients usually prefer nonoperative treatment due to concerns of postoperative pain **[11]**. These factors makes the decision making for CTS management very complicated.

The aim of our study is correlate preoperative diagnostic tools: Clinical presentation, Nerve conduction study and US findings with intraoperative findings as a reference standard and find out which one of these preoperative diagnostic tools plays the greatest role in decision-making regarding choice of surgery in CTS.

PATIENTS AND METHODS

This study has been carried out in the period between June 2021 and September 2022. Surgically treated 18 patients diagnosed with carpal tunnel syndrome (CTS) were included in the study. All patients were admitted to Plastic, Reconstructive and Burn Surgery Center at Mansoura University.

Diagnosis of CTS was done on the basis of clinical manifestation and nerve conduction studies. Study included patients admitted with idiopathic CTS who refused or didn't improve with conservative measures and steroid injection or those patients presenting with severe CTS. Patients presented with bilateral CTS were operated on 2 surgical sets at 4-week interval and were considered 2 cases. Patients with secondary CTS and patients who refused surgery were excluded from the study.

All patients were diagnosed clinically using data regarding pain or paraesthesia in the distribution of the median nerve, Phalen's and Tinel's tests, motor functional deficits and thenar atrophy. Clinical symptoms and signs were classified using the based scale (Hi-Ob-Db) **[12]**.

Electrophysiological testing in form of nerve conduction study (NCS) was done and graded according to degree of sensory and motor latencies and amplitude.

Wrist US was done in both short axis (at the level of scaphoid-pisiform plane) and long axis views. Data regarding median nerve cross-sectional area, echogenicity, hour-glass appearance and presence of tenosynovitis was recorded (Fig. 1).

Surgical technique: All cases were operated under wide awake local anaesthesia with initially applied tourniquet (WALAIAT) **[13]** while in supine position with extended limb after sterilization till the midforearm level. Prophylactic antibiotic was administered (Fig. 2).

A curvilinear incision of about 5cm was made just ulnar to thenar crease (Fig. 3). Superficial fibers of palmar aponeurosis were dissected using the sharp prongs of catspaw retractors. A snip was made at the distal part of palmer aponeurosis and a periosteal elevators was introduced beneath it to protect the median nerve.

Self-retaining retractors was applied. The aponeurosis was divided using scalpel or scissors. The division extended proximally, the transverse carpal ligament and antebrachial fascia was divided sequentially and complete release was verified (Fig. 4).

Operative findings as regard median nerve and tenosynovium conditions were documented (Fig. 5) and subsequently graded according to severity (Table 1). Under 2.5x loupe magnification, neurolysis and tenosynovectomy were done. Operative time was recorded in all cases.

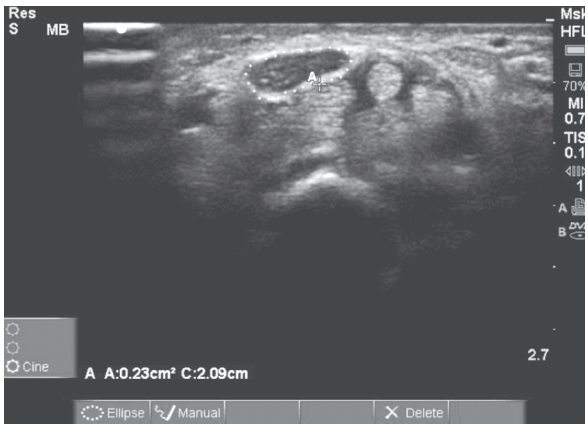

Fig. (1): US image (short axis view) of a case with CTS showing CSA of 23 mm^2. Median nerve outlined.

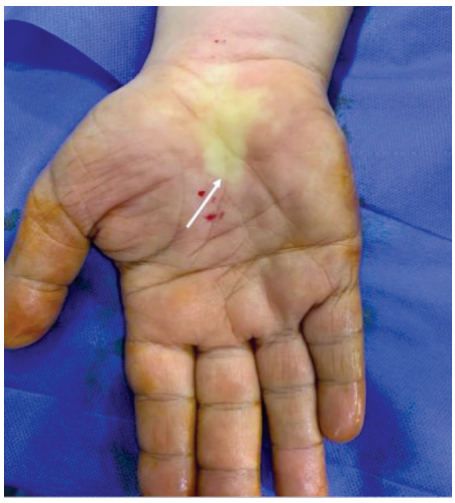

Fig. (2): Pallor of incision site after WALAIAT anaesthesia (arrow).

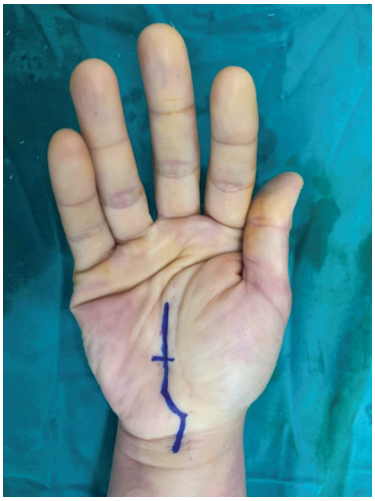

Fig. (3): Marking of incision 2mm ulnar to thenar crease.

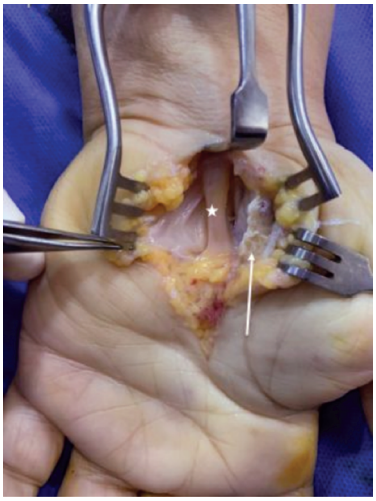

Fig. (4): Median nerve (star) after release of transverse carpal ligament (arrow).

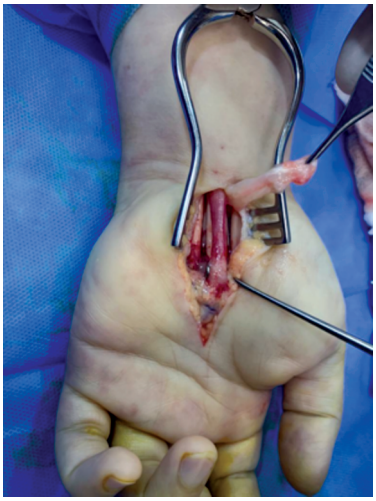

Fig. (5): Hypertrophied tenosynovium after tenolysis (arrow).

Table (1): Grading of operative findings.

Grade 1	Tenosynovitis of flexor superficialis and flexor profundus tendons only
Grade 2	Tenosynovitis of flexor pollicis longus only
Grade 3	Tenosynovitis of all flexor tendons

Tourniquet was deflated and haemostasias was done. A Redivac drain of size 12 FG was introduced in the wound, and closure was done using 4/0 monofilament sutures, A bulky dressing and a dorsal splint was applied to the wrist in 30° extension.

The drain was removed after 24 hours and the patient was discharged. patients started immediate active motion within the splint which was removed after 2 weeks.

Patients were followed-up over 6 months for clinical improvement of ROM and possible complications.

Data analysis was performed by SPSS software, version 18 (SPSS Inc., PASW statistics for windows version 18. Chicago: SPSS Inc.). Qualitative data were described using number and percent. Quantitative data were described using mean ± Standard deviation for normally distributed data after testing normality using Shapiro Wilk test. Significance of the obtained results was judged at the (0.05) level. Chi-Square, Monte Carlo tests were used to compare qualitative data between groups as appropriate. One Way ANOVA test was used to compare more than 2 independent groups with Post Hoc Tukey test to detect pair-wise comparison. The Pearsons correlation is used to determine the strength and direction of a linear relationship between two normally distributed continuous variables. Ordinal regression was used to assess the effect of combination of more than 2 independent variables on ordinal outcome to arrange factors affecting outcome. Kappa agreement was calculated by cross tabulation for categorical variables with Kappa:

- Kappa <0: No agreement.
- Kappa between 0.00 and 0.20: Slight agreement.
- Kappa between 0.21 and 0.40: Fair agreement.
- Kappa between 0.41 and 0.60: Moderate agreement.
- Kappa between 0.61 and 0.80: Substantial agreement.
- Kappa between 0.81 and 1.00: Almost perfect agreement.

RESULTS

All cases in this study were females ranging from 30 to 63 years (mean ± SD: 46.22±10.76 years). Most of them (77.8%) were housewives, 11.1% were teachers and 11.1% were farmers. 10 cases (55.6%) were operated on their right hands while 8 cases (44.4%) were on the left (Table 2).

Median period of complaints among studied cases was 1.5 years (range: 4 months - 4 years). The mean operative time was 32.78±9.11 minutes (range: 20-50 minutes). The mean follow-up period was 5.7±1.7 months (range: 3-10 months) (Table 3).

Among the studied cases, 44.4% were classified as stage 3, 22.2% stage 5, 16.7% stage 4, 11.1% stage 2 and 5.6% stage 1 as regard clinical grading (Hi-Ob-Db scale). As regard electrophysiological grading, 61.1% of cases were moderate, 27.8%

severe and 11.1% mild. Mean CSA measured by US was 19.33mm^2 (range: 14-33 mm^2). Operative grading shows that 55.6% of cases were of grade 2, 27.8% grade 3 and 16.7% grade 1 (Table 4).

Table (5) shows that there is a substantial agreement between clinical grading and operative grading with kappa agreement=0.640, percent of agreement=77.8%. Operative grading shows agreement with clinical grading; 3 cases stage 1-2 by clinical was shown to be grade 1 intra-operative, 7 cases stage 3 clinical that is confirmed to be grade 2 intra-operative and 4 cases stage 4 & 5 clinical that is confirmed to be grade 3 intra-operative.

Table (6) shows that there is a moderate agreement between electrophysiological grading and operative grading with kappa agreement=0.508, percent of agreement=72.2%; 1 case classified as mild by electrophysiological grading was classified as grade 1 by operative grading, where 8 cases classified as moderate by electrophysiological grading was classified as grade 2 by operative grading, and 4 cases classified as severe by electrophysiological grading was classified as grade 3 by operative grading with statistically significant difference (p=0.003).

Table (7) shows statistically significant positive correlation between CSA and operative findings (r=0.543, p=0.02). Mean CSA is 16.67mm^2, 18.1mm^2 & 23.4mm^2 among cases graded 1, 2 and 3, respectively by operative grading with statistically significant difference (p=0.02).

Table (8) shows predictors of operative grading and we found that the electrophysiological grading was the first predictor, clinical grading is the second and sonographic grading is the third predictor in order, electrophysiological grading was shown to be the only statistically significant predictor of intraoperative grading.

All cases improved after surgical decompression as regard pain and paraesthesia. Oedema and limited ROM were noticed in all cases which subsided completely in all cases after a mean of 21.6 days (range: 15-25 days) with full ROM. The case with thenar muscle atrophy improved also as regard pain and paraesthesia while weakness still present at the end of the follow-up period. None of our cases developed recurrence of symptoms till the end of the follow-up period. The median time to return to daily activities was 3 weeks (range: 2 weeks - 1 month).

Table (2): Age, gender, occupation and side of lesion among studied cases.

	n=18	%
Age/years:		
Mean ± SD (Min-Max)	46.22±10.76 (30-63)	
Sex:		
Female	18	100.0
Occupation:		
Teacher	2	11.1
Housewife	14	77.8
Farmer	2	11.1
Affected side:		
Right	10	55.6
Left	8	44.4

Table (3): Distribution of the studied cases according to period of compliant, and operative time.

	n=18	%
Period of complaint/years:		
Median (min-max)	1.5 years (4 months-4 years)	
Operative time/minutes:		
Mean ± SD	32.78±9.11	

Table (4): Preoperative and intraoperative grading of the studied cases.

	n=18	%
Clinical grading(Hi-Ob-Db scale):		
Stage 1	1	5.6
Stage 2	2	11.1
Stage 3	8	44.4
Stage 4	3	16.7
Stage 5	4	22.2
Electrophysiological grading:		
Mild	2	11.1
Moderate	11	61.1
Severe	5	27.8
Sonographic grading (CSA in mm^2):		
Mean ± SD (Min-Max)	19.33±4.54 (14-33)	
Operative grading:		
Grade 1	3	16.7
Grade 2	10	55.6
Grade 3	5	27.8

Table (5): Agreement between clinical grading and operative grading.

	Operative grading			Test of significance
	Grade 1 n=3(%)	Grade 2 n=10(%)	Grade 3 n=5(%)	
Clinical grading (Hi-Ob-Db scale):				
Stage 1-2	3 (100)	0	0	MC=22.02
Stage 3	0	7 (70)	1 (20)	p<0.001*
Stage 4-Stage 5	0	3 (30)	4 (80)	
Kappa agreement (95% CI) = 0.640 (0.329-0.951) % of agreement = 77.8% r=0.777, p=0.001				

MC: Monte Carlo test. * Statistically significant. *r*: Spearman correlation coefficient.

Table (6): Agreement between electrophysiological grading and operative grading.

	Operative grading			Test of significance
	Grade 1	Grade 2	Grade 3	
Electrophysiological grading:				
Mild	1 (33.3)	1 (10)	0	MC=10.76
Moderate	2 (66.7)	8 (80)	1 (20)	p<0.03*
Severe	0	1 (10)	4 (80)	
Kappa agreement (95% CI) = 0.508 (0.142-0.875) % of agreement = 72.2% r=0.656, p=0.003				

MC: Monte Carlo test. * Statistically significant. *r*: Spearman correlation coefficient.

Table (7): Relation between operative grading and sonographic grading.

	Operative grading			Test of significance
	Grade 1	Grade 2	Grade 3	
Sonographic grading (CSA in mm^2):				
Mean ± SD (Min-Max)	16.67±2.08 (15-19)	18.10±3.21 (14-25)	23.40±5.68 (19-33)	F=3.87 p=0.04*
r=0.543, p=0.02				

F: One Way ANOVA test. * Statistically significant. *r*: Spearman correlation coefficient.

Table (8): Ordinal regression for predictors of intraoperative grading.

	Estimate	*p*-value	Order
Clinical grading	1.607	0.255	2
Electrophysiological grading	2.226	0.025*	1
Sonographic grading	.426	0.194	3
Model fitting	χ^2=21.01, p<0.001*		

* Statistically significant.

DISCUSSION

Carpal tunnel syndrome is a common problem and there is no definite absolute indication for surgical intervention. A combination of clinical examination and electrophysiological studies has been commonly used for confirmation of the diagnosis and grading the severity **[14]**.

In severe cases of CTS, carpal tunnel release surgery is usually done, while patients with mild or moderate degree of the disease usually start with conservative treatment. Knowing which diagnostic test more accurately reflects the severity of CTS is mandatory for proper decision-making regarding management **[15]**.

Due to the complexity of the decision-making regarding surgical intervention, many studies have tried to put a grading scale of severity for CTS, in an effort to come out with a standard indication for surgery:

A number of studies have described the severity of CTS based on electrophysiological findings **[16-**

18], however, these schemes are arbitrary and no universally accepted scale exists.

In an effort to study the relation between the clinical provocative tests and CTS severity as indicated by electrophysiological impairment of median nerve, Novac et al., found that presence or absence of a provocative test is dependent upon the severity of the nerve compression and Tinel's sign was more likely to be positive in the later stages of nerve compression **[19]**.

Another study done by Priganc et al., in 2003, reported that the Phalen's test is highly correlated with the severity of CTS, unlike Tinel's and Durkan's tests, and hand diagrams which showed no association with the severity of CTS **[15]**.

In 2010, a modified five-stage clinical scale: Hi-Ob-Db was validated by Calindro and his colleagues which correlates with the electrophysiological abnormalities of the median nerve and depends on the hand distribution of paresthesia and pain, time of symptoms and presence or absence of abductor pollicis brevis (APB) muscle plegia **[12]**.

During the past decade, ultrasound measurement of the CSA of the median nerve at the carpal tunnel inlet has been proposed as an alternative diagnostic tool for confirmation of CTS **[5]**. And many studies have attempted to assess the validity of this measurement for grading the severity of median neuropathy using clinical symptoms and electrophysiological studies as a reference.

In 2005, Lee et al., found that the proximal swelling of the median nerve at the entrance of the carpal tunnel, seen during US examination, was found to correlate with the nerve conduction data and the clinical symptoms **[20]**.

Bayrak et al., in 2007, also found a negative correlation between motor unit number of APB muscle and the CSA of the median nerve **[21]**.

In 2016, Padua et al., showed a significant correlation between neurophysiological impairment of CTS and cross-sectional area (CSA) of the median nerve: The greater the severity of neurophysiological findings, the greater the nerve CSA **[22]**.

Addressing this debate regarding the best diagnostic tool accurately reflecting the severity of CTS, our study compares the clinical, electrophysiological and ultrasonographic data of 18 cases using intraoperative findings, in terms of presence of flexor tenosynovitis, pseudoneuroma and fibrosis of the median nerve, as a reference standard.

The results of our study show that there is a positive correlation between the three diagnostic tools; clinical, electrophysiological and ultrasonographic, and the intraoperative findings, with the electrophysiological test being the best and only statistically significant predictor of severity.

We hypothized that US would be the best predictor as it would give us a real image of what inside; but it was exactly the opposite and this may be attributed to the potential bias introduced in US measurements due to their reliance on the operator's technique and experience. So, Authors recommend that a standardized protocol for using US in the diagnosis of CTS should be developed. This should include definition of the optimal site of median nerve CSA measurement, standardization of nerve outlining technique, and further refinement of reference values.

The results of our study contradict a study conducted by Tuncali et al., in 2005 **[1]**, which could not demonstrate any statistically significant correlation between electrophysiogical studies and either clinical or intraoperative severity, which can be explained by the high false positive rates of electrophysiological tests so further studies are recommended by authors.

A limitation of the study, however, was the small sample size being restrained by the period of study. So, authors recommend further studies with larger sample size.

Conclusion:

The decision making of treatment of CTS is complicated especially with presence of multiple diagnostic tools with variable degrees of sensitivy and specificity. The indication of surgical release of carpal tunnel was mainly based on clinical symptoms and examination in addition to electrophysiogical studies to confirm diagnosis and determine severity, but with the introduction of ultrasonographic examination, more studies are needed to determine the best tool providing the best prediction of severity and need to surgical intervention.

Our study demonstrated that the electrophysiological studies provide the best predictor of severity followed by clinical exam but more studies are needed to test the accuracy of theses results.

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