ORIGINAL STUDY — HAND AND WRIST

acta orthopaedica belgica, 2025, 91, 61-69

doi.org/10.52628/91.1.13658

Influence of Preoperative Nerve Conduction Studies on the Outcome of Carpal Tunnel Release Surgery

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Nerve conduction study (NCS) is the most common investigative tool used in diagnosing and determining the severity of carpal tunnel syndrome (CTS). We aimed to evaluate the relationship between preoperative NCS and the outcome of patients who underwent carpal tunnel release (CTR). Medical records of patients who underwent CTR from January 2018 to December 2023 were reviewed retrospectively. Demographic, clinical characteristics and NCS reports were extracted. CTS severity was graded according to the Canterbury criteria. The outcome was defined as improved or not improved based on subjective symptoms at 2 months post-surgery. A total of 283 CTR cases were identified, with a mean patients age of 58.0±15.1 years and predominantly females (n=189, 75.0%). The main risk factors were obesity (34.6%) and diabetes mellitus (27.0%). Surgeries were performed on the right hand in 60.4% of cases. The mean duration of symptoms and the interval between NCS and surgery were 16.4±21.6 months and 10.1±13.4 months, respectively. Of the 201 reports of NCS, the majority had very severe CTS (25.4%), followed by mild (20.4%), moderate (18.9%), severe (17.4%), extremely severe (11.4%), normal (6.0%) and very mild (0.5%). From multivariate analysis, younger age (OR 0.95; 95% CI 0.91-0.99; p=0.024), more items of preoperative history and physical examination (OR 1.58; 95% CI 1.01-2.47; p=0.045) and preoperative NCS severity (p=0.006) were associated with improved outcomes. In addition to known prognostic factors, the utilization of NCS before CTR is crucial as the severity of preoperative NCS can be a predictor of postoperative outcomes.

Keywords: Canterbury scale, carpal tunnel release, carpal tunnel syndrome, entrapment neuropathy, median nerve entrapment, nerve conduction study.

INTRODUCTION

Nerve conduction study (NCS) is considered a reliable tool for supporting the diagnosis of carpal tunnel syndrome (CTS) and objectively quantifying its severity[1]. In patients with CTS, the median nerve parameters are affected, demonstrating focal slowing of nerve conduction velocity due to demyelination and reduction in the amplitude of sensory and motor potentials as a result of axonal loss[2]. Several criteria are available to classify the severity of CTS based on the NCS result, with commonly used ones including Canterbury NCS severity scale, Padua classification and Stevens classification[2].

There has been an ongoing debate surrounding the use of NCS in CTS[3,4]. The utilization of NCS has been found to be associated with a delay in time to surgery and increased costs[5]. Previous studies have also found that NCS has little diagnostic utility if there is a high pretest probability of CTS based on clinical estimation using the Six-item CTS Symptoms Scale (CTS-6), which is a validated diagnostic criteria for CTS[6]. According to the 2016 American Academy of Orthopaedic Surgeons (AAOS) guideline on the management of CTS, the use of electrodiagnostic studies is only of moderate evidence in aiding the diagnosis of CTS[7]. The updated guideline represents an obvious shift from the previous 2009 version where routine usage of NCS was once recommended for all patients with CTS who were considered for carpal tunnel release (CTR) surgery[8]. Few studies have shown that preoperative NCS severity was only poorly or not at all associated with clinical recovery post-op, however some studies have supported the

use of preoperative NCS due to its predictive value in prognosticating the outcome of surgery[9,10].

In this study, we aimed to investigate the relationship between preoperative NCS and the outcome of patients who had undergone CTR.

MATERIALS AND METHODS

Study subject

This was a retrospective study conducted in a tertiary teaching hospital. Cases were identified from a group of patients who underwent elective CTR, either open or endoscopic, between January 2018 and December 2023. The exclusion criteria encompassed carpal tunnel exploration and release in cases involving trauma, tumor excision or infection such as necrotizing fasciitis, hand or wrist abscess and flexor tenosynovitis. The study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the hospital's medical research ethics committee (MREC ID: 20221223-11859). Informed consent was waived by the ethics committee in view of the retrospective nature of the study.

Medical records of each patient were reviewed to collect the relevant demographic and clinical information, including age, sex, race, dominant hand, side of the hand on which the surgery was performed, steroid injection, as well as preoperative utilization of NCS.

NCS were performed by neurologists and/or neurophysiologists in our center. In brief, two upper limb nerves i.e. median and ulnar nerves were assessed bilaterally. For median motor study, median nerve was stimulated at the wrist and antecubital fossa using supramaximal intensity with the recording electrode over abductor pollicis brevis muscle. Whereas, for ulnar motor study, abductor digiti minimi muscle was recorded with the supramaximal stimulation at the wrist, below elbow and above elbow. Orthodromic method was used for the sensory studies. Both median and ulnar nerves were recorded over the wrist with the stimulation at the index and little finger respectively. More sensitive median-vs-ulnar comparison studies were performed if the above routine studies were normal or equivocal. NCS parameters of sensory and motor amplitudes, latencies and conduction velocities were recorded.

NCS reports were reviewed and the severity was graded according to the Canterbury NCS severity scale for CTS, ranging from normal (Grade 0), very mild (Grade 1), mild (Grade 2), moderate (Grade 3), severe (Grade 4), very severe (Grade 5) to extremely severe (Grade 6), based on NCS parameters[11].

Relevant risk factors of CTS (diabetes mellitus, obesity, rheumatoid arthritis, hypothyroidism, hemodialysis, and amyloidosis) were also recorded. The obesity status of the patients was determined based on their body-mass index (BMI) with a cut-off value of ≥30 kg/m2 according to the WHO classification[12].

The interval between the onset of symptoms to the initial visit, initial visit to surgery and NCS to surgery were also calculated based on the date of visit recorded in the electronic medical record. The number of items documented based on the CTS-6 was scored after reviewing the history and physical examination findings as documented. The CTS-6 is a validated tool used to diagnose CTS and the items included are the presence of numbness in the median nerve distribution, nocturnal symptoms, thenar muscle atrophy, sensory disturbances, Phalen test and Tinel sign[13]. For the purpose of this study, each item in the criteria was entitled to 1 point as long as it was documented in the notes, regardless of whether that particular history or test is positive.

Evaluation of outcome

As per standard of care in this center, patients who underwent CTR were followed up at two weeks and two months postoperatively. The outcomes of surgery at each follow-up session were measured on a scale of 1 to 5 based on patients' self-reported overall change in condition, with 1 indicating "cured", 2 indicating "much better", 3 indicating "better", 4 indicating "unchanged" and 5 indicating "worse"[10]. The outcome at the 2-month postoperation, which was considered as the final outcome was further dichotomized into two groups: "improved" and "not improved". Outcomes from scale 1 to 3 were grouped as "improved" whereas 4 and 5 were considered "not improved"[14].

Statistical analyses

Statistical analysis was performed using IBM SPSS version 26 (IBM Corp., Armonk, NY, USA) to identify factors that significantly affect the outcome of post-CTR. The normality of continuous data was checked using the Kolmogorov-Smirnov test. For univariable analysis, Chi-squared test was used for categorical data while Student t-test was used for continuous data. For multivariable analysis, the binary logistic regression model was used, including all variables with a P-value of <0.1 from univariable analysis. The level of significance was set at $P<0.05$ for all analyses.

RESULTS

This study included 283 hands that had CTR, involving 252 patients (Fig. 1). Of the 252 patients, 31 had bilateral CTS which were operated on within the timeframe of the study, however none had simultaneous bilateral CTR.

The mean age of the patients was 58.0 ± 15.1 years (Table I). Females were predominant (n=189, 75%) and half of the patients were Malays (50.8%). Of the 252 patients, 233 (94.3%) were right-handed and the majority had surgery on the right hand (60.4%). Obesity was the most common comorbid condition (34.6%), followed by diabetes mellitus (27.0%), hypothyroidism (5.2%), hemodialysis (2.0%), rheumatoid arthritis (1.6%) and amyloidosis (1.2%).

The number of items of preoperative physical examination and history taking based on the CTS-6 criteria averaged at 4.7 ± 1.1. The mean duration of symptoms was 16.4 ± 21.6 months. The mean interval between initial visit and surgery was 7.2 ± 11.7 months and the mean interval between NCS and surgery was 10.1 ± 13.4 months. There were only 4.9% of patients received steroid injection before the surgical intervention.

Table I. — Demographic and clinical characteristics of patients who had CTR.

Characteristics	n (%)/mean ± SD
Age (years)	58.0 ± 15.1
Sex (n=252)	
Female	189 (75)
Male	63 (25)
Race (n=252)	
Malay	128 (50.8)
Chinese	80 (31.7)
Indian	36 (14.3)
Others	8 (3.2)
Dominant hand (n=247)†	
Left	14 (5.7)
Right	233 (94.3)
Side of hand (n=283)	
Left	112 (39.6)
Right	171 (60.4)
Diabetes mellitus (n=252)	68 (27.0)
Obesity (BMI ≥ 30 kg/m^2) (n=185)†	64 (34.6)
Rheumatoid arthritis (n=252)	4 (1.6)
Hypothyroid (n=252)	13 (5.2)
Hemodialysis (n=252)	5 (2.0)
Amyloidosis (n=252)	3 (1.2)
NCS utilization	
Utilized	206 (72.8)
Not utilized	77 (27.2)
Number of items of preoperative physical examination and history taking (CTS-6)	4.7 ± 1.1
Interval (months)	
Between symptom onset and initial visit	16.4 ± 21.6
Between the initial visit and surgery	7.2 ± 11.7
Between NCS and surgery	10.1 ± 13.4
Steroid injection	14 (4.9)
Preoperative NCS severity (n=201)†	
Normal (0)	12 (6.0)
Very mild (1)	1 (0.5)
Mild (2)	41 (20.4)
Moderate (3)	38 (18.9)
Severe (4)	35 (17.4)
Very severe (5)	51 (25.4)
Extremely severe (6)	23 (11.4)

†Missing data/not documented; BMI, body mass index; NCS, nerve conduction study; CTS, carpal tunnel syndrome.

NCS was utilized in 206 (72.8%) patients prior to surgery (Fig. 1), however five NCS reports were unavailable for interpretation as the tests were conducted at other hospitals. The majority of the patients were in the category of "mild to very severe" (17.4%-25.4%). There was only one patient (0.5%) who had "very mild" CTS and 23 (11.4%) patients had "extremely severe" CTS.

Postoperative outcomes at 2 weeks and 2 months are illustrated in Fig. 2. Most patients reported that their symptoms were "better" (60.2%) at 2 weeks, and the number of patients who reported their symptoms as "much better" and "cured" at 2 months increased from 8.3% to 20.6% and from 12.4% to 26.7% respectively. Symptoms remained unchanged in 18% of patients at 2 weeks but decreased to 12.3% at 2 months. There was a slight increase in the percentage of patients who complained of worsened symptoms in pain and/or numbness from 2 weeks to 2 months after surgery (from 1.1% to 3.7%).

Fig. 3 represents the relationship between preoperative NCS severity and the outcome of post-CTR at 2 months. A vast majority (86.9%, 96.5%, 90.6%, and 93.5%) of patients with "mild" to "very severe" preoperative NCS severity reported an "improved" outcome, compared to the "normal" (58.3%) and "extremely severe" (55.5%) CTS groups.

Outcome data were only available for 243 CTR cases at 2 months (Fig. 1). Of the 182 cases that utilized NCS, four reports were missing. Preoperative NCS severity ($P < 0.001$) and the number of items of preoperative physical examination and history taking (CTS-6) ($P = 0.014$) were found to be significant predictors of postoperative outcome in univariable analysis (Table II). These two variables along with age and obesity (with a P-value of <0.1) were included in the multivariable logistic regression model. The "very mild" category was excluded from the multivariable analysis as there was only one case in that category. From the multivariable analysis, preoperative NCS severity ($P = 0.006$), the number of items of preoperative physical examination and history taking (CTS-6) (OR 1.58, 95% CI 1.01-2.47, $P = 0.045$), and

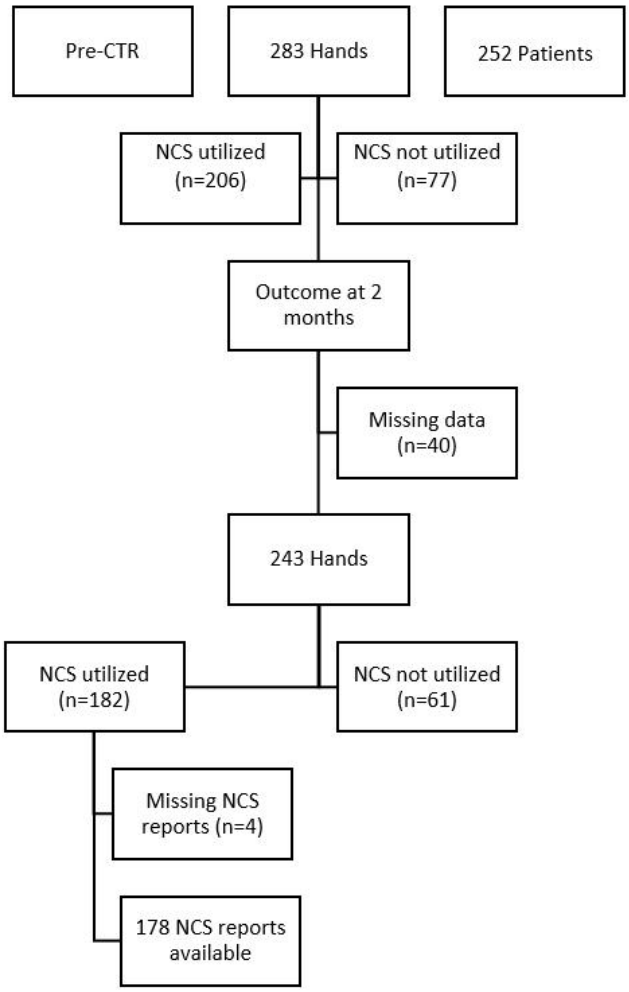

Fig. 1 — Inclusion of cases for data analysis.

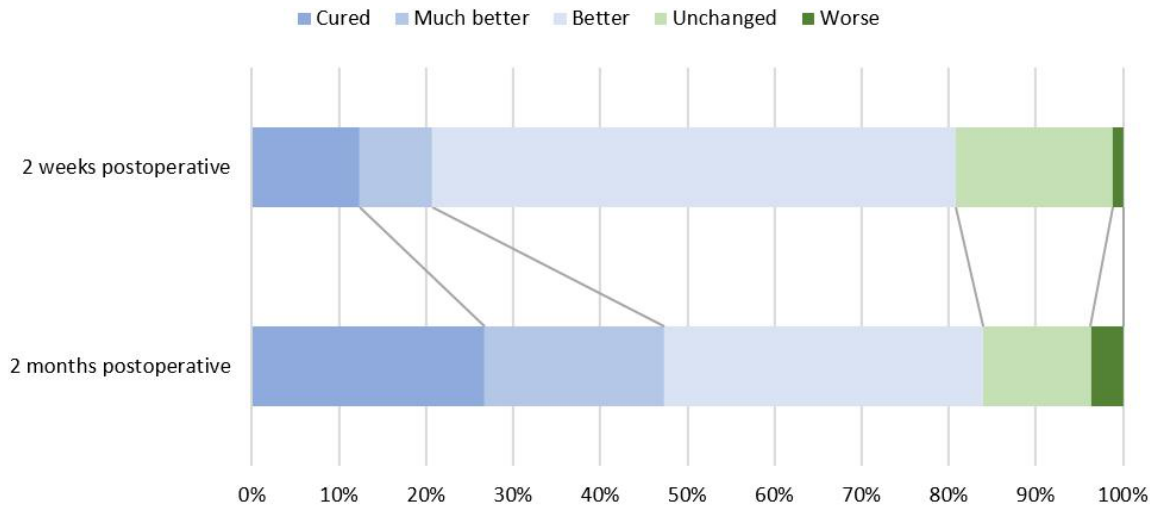

Fig. 2 — Postoperative outcome at 2 weeks and 2 months.

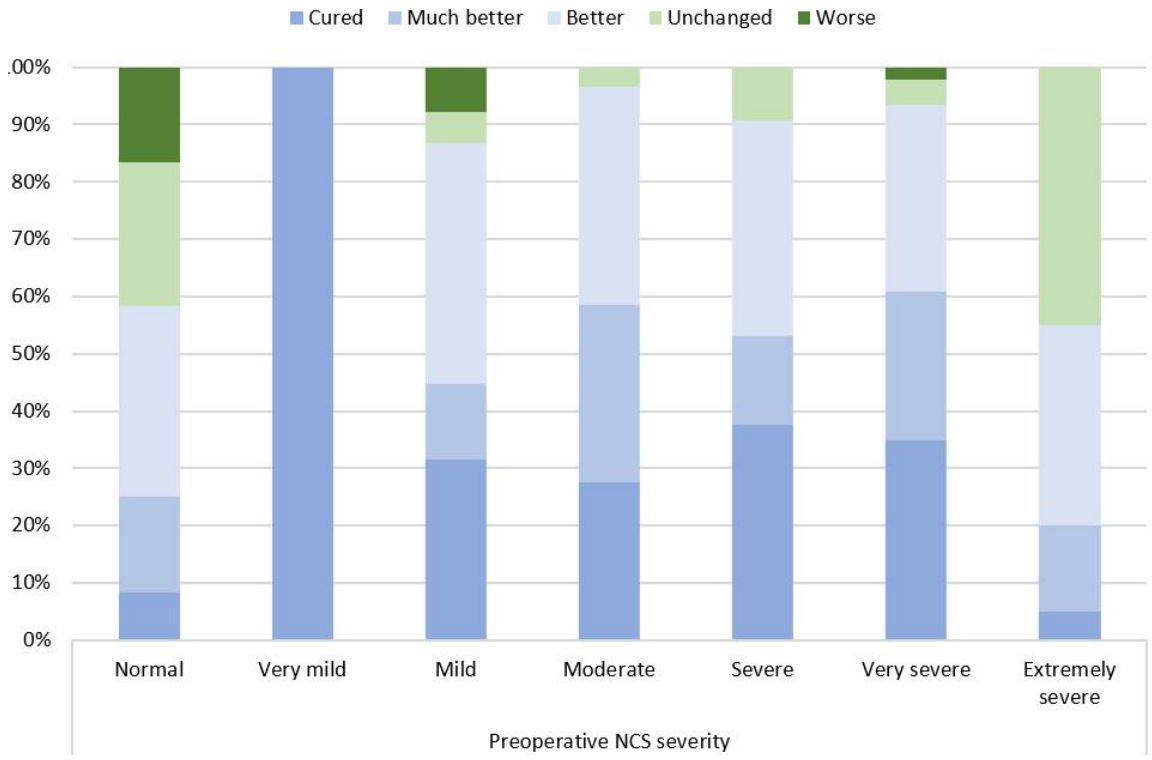

Fig. 3 — Postoperative outcome at 2 months in relation to preoperative NCS severity.

age (OR 0.95, 95% CI 0.91-0.99, P = 0.024) were the independent predictors of outcome (Table III).

DISCUSSION

In the current study, we found that age, the number of items of preoperative history and physical examination according to CTS-6 and preoperative NCS severity were the independent predictors of outcome post-CTR. These findings were in keeping with previous studies[10,15,16]. In contrast, traditionally known prognostic factors of CTS such as sex, and the presence of comorbidities including obesity, diabetes mellitus, rheumatoid arthritis, hypothyroidism, hemodialysis and amyloidosis were not found to significantly affect surgical outcome[10,15,16].

This study confirmed that older age is a significant predictor of worse outcome post-CTR as reported in previous studies[10,15,16]. Based on previous studies, elderly patients have shown less predictable improvement in symptoms and functional outcomes post-CTR[17]. One possible explanation for this could be that the rate of repair of segmental demyelination in elderly patients is twice as slow as that in younger

Table II. — Univariable analyses of postoperative outcome at 2 months.

Characteristics, n (%)/mean ± SD	Improved	Not improved	P-value
Total number of cases (n=243)†	204 (84.0)	39 (16.0)	
Age (years)	57.0 ± 14.6	62.0 ± 17.7	0.056*
Sex			0.575
Female	160 (78.4)	29 (74.4)	
Male	44 (21.6)	10 (25.6)	
Race			0.318
Malay	109 (53.4)	17 (43.6)	
Chinese	59 (28.9)	15 (38.5)	
Indian	28 (13.7)	7 (17.9)	
Others	8 (3.9)	0 (0.0)	
Dominant hand			0.103
Left	13 (6.4)	0 (0.0)	
Right	189 (93.6)	39 (100.0)	
Side of hand			0.245
Left	83 (40.7)	12 (30.8)	
Right	121 (59.3)	27 (69.2)	
Diabetes mellitus	53 (26.0)	11 (28.2)	0.773
Obesity (BMI ≥ 30 kg/m^2)	52 (36.1)	7 (20.0)	0.069*
Rheumatoid arthritis	2 (1.0)	0 (0.0)	0.535
Hypothyroid	13 (6.4)	1 (2.6)	0.350
Hemodialysis	4 (2.0)	1 (2.6)	0.808
Amyloidosis	3 (1.5)	1 (2.6)	0.623
NCS utilization			0.196
Utilized	156 (76.5)	26 (66.7)	
Not utilized	48 (23.5)	13 (33.3)	
Preoperative NCS severity (n=178)‡			<0.001*
Normal (0)	7 (4.6)	5 (19.2)	
Very mild (1)	1 (0.7)	0 (0.0)	
Mild (2)	33 (21.7)	5 (19.2)	
Moderate (3)	28 (18.4)	1 (3.8)	
Severe (4)	29 (19.1)	3 (11.5)	
Very severe (5)	43 (28.3)	3 (11.5)	
Extremely severe (6)	11 (7.2)	9 (34.6)	
Number of items of preoperative physical examination and history taking (CTS-6)	4.8 ± 1.0	4.4 ± 1.12	0.014*
Interval (months)			
Between symptom onset and the initial visit	16.4 ± 22.1	17.8 ± 21.9	0.717
Between the initial visit and surgery	7.2 ± 10.6	10.0 ± 18.7	0.204
Between NCS and surgery	10.6 ± 13.6	11.4 ± 16.6	0.785
Steroid injection	1 (2.6)	1 (2.6)	0.399

*P-value <0.1; †n at 2 months; ‡Missing data (n=4); BMI, body mass index; NCS, nerve conduction study; CTS, carpal tunnel syndrome.

patients[18]. As a result, elderly patients in our cohort experienced less improvement with CTR, as demonstrated in this study.

It was also not surprising that a greater number of items of preoperative physical examination and history taking were found to be independent predictor of an improved outcome. CTS is a clinical syndrome that encompasses a constellation of signs and symptoms, and none of them on its own is conclusive of CTS, even though the presence of certain signs and symptoms carries more value in making its diagnosis[13,19]. Therefore, comprehensive history taking and clinical examination are fundamental in establishing the diagnosis, minimizing misdiagnosis of CTS, and leading to better outcome with appropriate surgical intervention.

Our findings showed that patients in the mild to very severe category achieved significantly higher percentages of an "improved" outcome compared to those in the normal and extremely severe categories. This aligns with the results of previous studies that demonstrated a non-linear relationship between

Table III. — Multivariable analysis of the predictors of postoperative outcome.

Variables	Odds ratio	95% CI	P-value
Age	0.95	0.91-0.99	0.024*
Obesity	2.66	0.72-9.76	0.141
Preoperative NCS severity			0.006*
Normal	1 (ref)		
Mild	12.71	1.90-84.98	
Moderate	25.62	2.04-321.96	
Severe	14.06	1.92-103.17	
Very severe	34.58	3.72-321.78	
Extremely severe	3.91	0.48- 31.81	
Number of items of preoperative history and physical examination (CTS-6)	1.58	1.01-2.47	0.045*
*P-value <0.05			

preoperative NCS severity and outcomes, with moderately severe nerve conduction abnormality being a significant prognostic factor for better outcomes[10,14]. In contrast, there were also several studies that showed no difference in outcomes between different preoperative NCS severity groups[20,22].

There was a dip in the proportion of patients with "extremely severe" preoperative NCS severity who achieved an "improved" outcome (Fig. 3). Previous studies have reported that although CTR is beneficial to patients with severe CTS, the degree of improvement and extent of symptom resolution are poorer in patients who are at the severe end of the disease spectrum, particularly those with thenar muscle atrophy and absent sensory nerve action potentials[9]. In addition, it has been reported that patients with an electrophysiological diagnosis of severe CTS experienced persistent sensory or motor deficits even six months post-op and slower resolution of daytime numbness and tingling compared to the mild and moderate severity groups[9,23]. This could be due to the fact that myelination of fibers occurring post-surgery would still be insufficient to completely restore the normal function of the nerve fibers if the degree of demyelination and axonal degeneration was too severe preoperatively, especially in cases of unrecordable motor potential of the abductor pollicis brevis muscle[24].

In this study, there was a lower proportion of cases with "improved" outcomes in patients with normal preoperative NCS compared to the mild to very severe groups. Our findings were consistent with previous studies[24,25]. Prior to this, studies have shown a significantly lower satisfaction rate and persistence of symptoms post-op leading to a higher rate of changing jobs in clinically diagnosed CTS patients who underwent CTR despite normal NCS[25,26]. In theory, CTS would only affect the areas of the hand supplied by the median nerve, but subjective symptoms reported by patients are variable, and only 12.6% of patients had a classic distribution of symptoms when assessed using the Katz's hand diagram[27]. Atypical symptom distribution reported by CTS patients is not uncommonly encountered, with symptoms extending to other nerve territories[28,29]. Similarly, other pathologies such as pronator syndrome, peripheral neuropathy and cervical radiculopathy can be confused with CTS, which is why NCS is needed to confirm the diagnosis especially before surgery[30].

Our study findings were consistent with previous studies that reported the significance of preoperative NCS severity as an independent predictor of surgical outcomes[10,14]. Apart from that, studies analyzing the relationship between individual NCS parameters and postoperative outcomes also found that shorter distal sensory latency, greater compound muscle action potential amplitude and shorter median nerve motor latency which represents milder disease were also significantly associated with greater improvement of symptoms after CTR[31,32], further confirming the value of NCS in predicting outcomes. In contrast, another study reported that only modest correlation was found between individual parameters in the NCS with clinical outcome measures of CTS[33]. However, the authors suggested that stronger outcomes could be obtained if the result of the NCS were classified into different severity groups. As there was no universal severity grading tool for CTS, there were studies that broadly categorized the NCS severity into only three grades (mild, moderate and severe) and found no relationship between the preoperative NCS severity and symptom recovery post-op[20-22]. On the other hand, there is a chance that the use of such a simpler classification system might have diminished the actual predictive power of NCS severity on the postoperative outcomes[4]. In the current study, we applied the Canterbury NCS severity scale comprising six distinct severity groups, which clearly

demonstrated the significant differences in outcomes between the groups.

From the univariable analysis, NCS utilization itself was not found to be a significant predictor of outcome, as demonstrated previously[34]. This can be explained by the fact that NCS is purely an investigative tool that carries no therapeutic effect, and therefore the use of NCS alone is not expected to directly improve symptoms and outcomes. The significance of NCS utilization lies in its ability to reveal the objective severity of the disease prior to surgery, providing additional information to aid decision making in the management of the patient.

There were several limitations in this study. Firstly, as this was a retrospective study, certain data were missing due to incomplete medical records. Secondly, validated outcome measurement tools, such as the Levine-Katz Questionnaire, also known as Boston Carpal Tunnel Syndrome Questionnaire (BCTQ)[35], could not be used to assess symptoms severity and functional status of patients post-op in view of the nature of the study. In addition, the outcome was only assessed at 2 months post-op. Thus, we could not exclude the benefits of CTR that may only be apparent later. Thirdly, the CTR and NCS were performed by different surgeons and operators respectively. These could have influenced the outcome of the CTR and the findings of the NCS. Fourthly, there was a long interval between the NCS and surgery. Therefore, there is a possibility that the severity of CTS could have progressed within the period. However, the long waiting time for the NCS is not uncommonly encountered in clinical practice, and because of that, the surgeons were reluctant to request the test. Lastly, we did not routinely perform postoperative NCS to objectively assess the outcome of CTR.

For patients with documented abnormalities of the median nerve parameters but continue to complain of persistent or worsening symptoms, preoperative NCS is unequivocally useful as it provides baseline median nerve functional parameters that can be used to compare with a repeat NCS after surgery[36]. Median nerve parameters usually do not normalize after CTR even with improvement of symptoms[37], but successful surgical decompression was associated with an improvement of the parameters or their severity grades[4,38]. There were various reasons behind persistent symptoms post-surgery including incomplete release, scar tissue, infection and polyneuropathy[39]. One of the most feared reason would be an incorrect diagnosis as other conditions can commonly masquerade as CTS[30]. Without a baseline NCS, one could not determine if a normal NCS after surgery is due to improvement post-decompression or due to the absence of electrophysiological evidence of median nerve neuropathy even before surgery.

CONCLUSION

In conclusion, age, detailed history and physical examination, and preoperative NCS severity are the prognostic factors for post-CTR outcomes. In particular, the utilization of NCS before CTR is not only crucial as a confirmatory tool for diagnosing CTS, but also the severity of NCS can be useful in prognosticating outcomes.

Declarations of interest: None.

Funding: None.

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