Original Article

Diagnostic Use of Ultrasonography in Carpal Tunnel Syndrome and Its Correlation with the Chinese Version of Boston Carpal Tunnel Questionnaire

Xue Deng[1], Lai-Heung Phoebe Chau[2], Suk-Yee Chiu[2], Kwok-Pui Leung[3], Yong Hu[1], Wing-Yuk Ip[1]*

[1]Department of Orthopedics and Traumatology, The University of Hong Kong, Pokfulam, Hong Kong, [2]Clinical Neurodiagnostic Unit, Tung Wah Hospital, Hong Kong, [3]Department of Medicine, The University of Hong Kong, Hong Kong

Abstract

Introduction: There were yet no correlation studies performed between ultrasound and the Chinese version of Boston Carpal Tunnel Questionnaire (C-BCTQ). Besides, controversies still remain regarding the correlation between ultrasound and different language versions of BCTQ. **Purpose of the Study:** To examine whether ultrasound can (i) reflect symptom severity and/or functional status, (ii) differentiate primary/secondary symptom, and (iii) correlate with subscale items in C-BCTQ. **Methods:** Forty-two Chinese female individuals (aged 58.84 ± 9.02 years) with 73 hands were enrolled in the study. Factor analysis was used to identify the hidden factors of C-BCTQ. Correlations were examined between hidden factors, relevant subscale items of C-BCTQ, and ultrasound. **Results:** Three factors were identified as Factor One (functional status, 36.534%), Two (sensory symptoms, 15.057%) and Three (pain, 11.867%), with 63.458% of total variance explained in C-BCTQ. All the ultrasound parameters were positively correlated with Factor One ($r = 0.29$-0.411, $P < 0.05$), while no correlations were found with Factor Two and Three. Meanwhile, correlation between wrist cross-sectional area and functional status scale (FSS) was also found (W-CSA, $r = 0.266$, $P = 0.023$), whereas no correlation was found with symptom severity scale (SSS), subscales of primary symptom (Paresthesia) and secondary symptom (pain) related items in C-BCTQ. **Conclusion:** Morphological information via ultrasound can reflect the impact on functionality that carpal tunnel syndrome (CTS) exerted. However, it can be used neither to describe symptom severity nor differentiate primary/secondary symptom of CTS.

Keywords: Boston Carpal Tunnel Questionnaire, carpal tunnel syndrome, factor analysis, nerve conduction studies, ultrasound

Introduction

Carpal tunnel syndrome (CTS) is primarily caused by localized pressure over carpal tunnel at the wrist, with an overall prevalence of 2%–3%, accumulative incidence rate of 8%, and around 10% of lifetime risk in the general population.[1-3] Primary symptoms such as paresthesia and numbness/tingling were present, whereas sometimes the secondary symptom such as pain may occur, which is usually associated with musculoskeletal disorders such as fibromyalgia.[4] In order to confirm the diagnosis and grade the severity, the prevalent diagnostic package is mainly assessed from neurophysiological, morphological, and clinical perspectives. For neurophysiological aspect, nerve conduction studies (NCS) has been considered as a golden standard assessment tool, combined with clinical provocative tests such as Tinel's sign and Phalen's test for diagnostic confirmation.[5,6] Whereas, from morphological perspective, ultrasound has been gradually widely applied to compensate the technical pitfalls of NCS via providing anatomical and structural information about the injured nerve and other tissues.[7-10] In addition, to describe the clinical symptoms and its impact on hand function, Boston Carpal Tunnel Questionnaire (BCTQ), a self-administered and disease-specific assessment tool, was prevalently used in clinical practice.[11-14] It has been translated into many different

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Address for correspondence: Dr. Wing-Yuk Ip, PB505, Professorial Block, Queen Mary Hospital, Pokfulam, Hong Kong. E-mail: wyip@hku.hk

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languages, with a variety of studies performed regarding its validity, reliability, responsiveness, and correlation with other assessment tools.[15-19]

Although there were previous validation studies done regarding the Chinese version of BCTQ (C-BCTQ),[15] to the best of our knowledge, there were yet no correlation studies performed between ultrasound and the C-BCTQ. In addition, remarkable controversies still remain regarding the correlation between ultrasound and different language versions of BCTQ.[16] To better serve the enormous disease group in the Chinese societies, it is of great clinical significance to clarify this long-term disputation. Therefore, this study was proposed, primarily aiming at exploring if ultrasound can be used to reflect symptom severity, functional status, and differentiate primary/secondary symptom using the C-BCTQ. We hypothesized correlations exist between ultrasound and the C-BCTQ.

Methods

This prospective, nonrandomized, and cross-sectional study was approved by the Institutional Review Board of the University of Hong Kong/Hospital authorities in Hong Kong West (HKU/HA HKW IRB, Ref. Number: UW17-129) and conducted strictly in accordance with the Declaration of Helsinki.

Participants were prescreened by an experienced hand surgeon via performing provocative clinical tests (Phalen's test and Tinel's Sign) from August 2017 to August 2018. Participants with positive signs were referred to the clinical neurodiagnostic unit for further diagnostic confirmation. A physician with over 20 years of experience in clinical neurophysiological and ultrasonographic diagnostics was in charge of diagnosing and grading the severity of CTS under the principle of Bland's classification.[20]

Procedures of nerve conduction studies and ultrasound assessment

As for procedures of NCS, it started with assessing sensory nerve function by placing recording rings at the 2nd finger via orthodromic stimulation [Figure 1.1]. Then, the median motor nerve status was measured by stimulating at palm [4 cm distal to the wrist, Figure 1.2], wrist [6.5 cm proximal to the thenar muscle, Figure 1.3], and elbow [just above the crease of antecubital fossa, Figure 1.4]. Following NCS, ultrasound assessment was performed, using a 4–13 MHz linear array transducer to perform transverse scan from carpal tunnel inlet [Figure 2.1] to the distal one-third forearm [Figure 2.2]. Wrist cross-sectional area (W-CSA) and perimeter at the wrist were traced continuously by outlining the hyperechoic epineurium. Ratio of cross-sectional area of the wrist over one-third distal forearm and ratio of perimeter of the wrist over one-third distal forearm (R-CSA and R-P) were calculated by dividing measurements at the wrist over measurements at the one-third of the distal forearm. Changes from wrist to distal one-third forearm (ΔCSA and ΔP) were acquired via the corresponding measurements at the wrist minus measurements at one-third distal forearm.

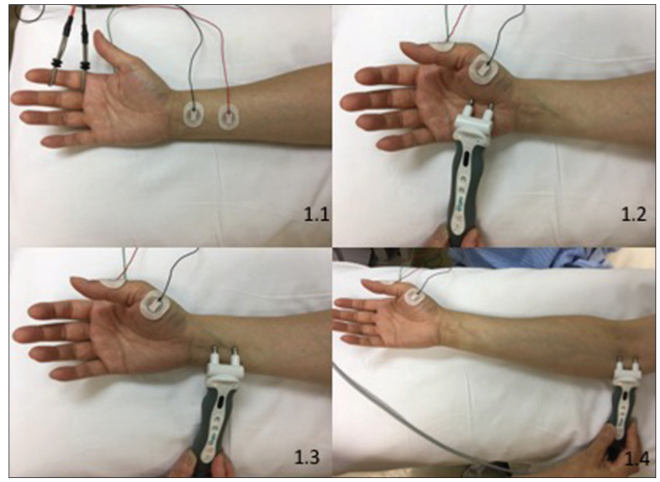

Figure 1: Nerve conduction studies. (1.1) Assessment of sensory-evoked potential of median nerve; (1.2-1.4) assessment of motor-evoked potential of median nerve from mid-palm, (1.2) wrist, (1.3) and elbow (1.4)

Procedures of the Chinese version of Boston Carpal Tunnel Questionnaire

Then, individuals were enrolled by convenience sampling and completed the C-BCTQ under the guidance of an occupational therapist. The questionnaire, which was translated through a rigorous cross-cultural adaptation process, has been verified as a reliable, valid, and responsive disease-specific measure for evaluating symptoms and functional status of Chinese CTS patients.[15] It contains two subscales, composing of 11-item Symptom Severity Scale (SSS) and 8-item Functional Status Scale (FSS). In SSS, the items 1–5 are pain-related questions, whereas items 6–10 evaluate paresthesia-relevant symptoms. Meanwhile, the 8 items in the FSS assess the hand function in daily activities. Participants were required to rate their severity of symptom based on a 5-point scale, from 1 (no relevant symptoms) to 5 (the worst relevant symptom) for SSS as well as their difficulty of executing functional tasks, ranging from 1 (no difficulty) to 5 (cannot perform the activity at all) for FSS. The pain-related (1–5 in SSS), paresthesia-related subscales (6–10 in SSS), SSS and FSS score were calculated by averaging the subtotal score of relevant items.

Inclusion/exclusion criteria

The inclusion criteria were as follows: (1) Chinese female individuals aged between 50 and 75 years; (2) right-handedness; (3) diagnosis confirmed when (i) NCS: Distal motor latency >4.5 ms, and/or sensory/motor conduction velocity <50 m/s; (ii) ultrasound: W-CSA >9 mm^2 and/or R-CSA >1.4, and (iii) clinical symptoms sustained at least over 3 months, with positive result of Tinel's Sign and Phalen's test. On the other hand, the exclusion criteria were as follows: (1) comorbidities such as diabetes mellitus, rheumatoid arthritis, gout, history of wrist fracture, cancer, cardiopulmonary disease, cervical radiculopathy, myelopathy,

Figure 2: Ultrasound assessment. (2.1) Assessment of cross-sectional area and perimeter over the inlet of carpal tunnel at the wrist; (2.2) assessment of cross-sectional area and perimeter of one-third of the distal forearm

and other peripheral neuropathies; (2) abnormal anatomical structures (e.g., bifid structure of median nerve) displayed via ultrasound; and (3) surgical history at the wrist.

Statistical analysis

SPSS software version 24.0 (SPSS Inc., IBM, Armonk, New York) was utilized for data analysis. Demographic, ultrasonographic, and electrophysiological performance of the enrolled participants was analyzed descriptively. To identify unobserved dimensions of the C-BCTQ, factor analysis was performed via reducing and categorizing similar variables into fewer unobserved variables. Principal component analysis (PCA) was used for the extraction of variables, while varimax rotation was performed to interpret the factors. After taking those obtained factors into account as a unit, normality and equal variance were checked via Shapiro–Wilk test and Levene test, respectively, which revealed BCTQ data, ultrasound and NCS parameters were not normally distributed. Therefore, Spearman's correlation coefficient test was used to investigate the correlation between identified factors of the C-BCTQ, primary symptom (paresthesia-related items), secondary symptom (pain-related items), two subscales of BCTQ (SSS and FSS), NCS, and ultrasound parameters.

Results

Forty-two Chinese female individuals with 73 hands were enrolled in the study. Their demographic, ultrasonographic, electrophysiological, and clinical characteristics are displayed descriptively in Table 1. The overall performance in NCS, ultrasound, and C-BCTQ was in accordance with the diagnostic criteria for confirming CTS.

Kaiser–Meyer–Olkin was 0.736, indicating that factor analysis was appropriate and variables were correlated (Bartlett's test of sphericity: $\chi^2 = 932.586$, $P < 0.0001$). Three hidden factors were identified via PCA, including Factor One (functional status, 36.53%), Factor Two (sensory symptoms, 15.057%), and Factor Three (pain, 11.867%), all of which explained 63.458% of the total variance.

Table 1: Demographics, ultrasonographic, electrophysiological and clinical characteristics

Demographics	
Patient volume (*n*)	42
Age (year)	58.84±9.02
Gender	Female only
Hand side: Right/left (%)	40 (54.79)/33 (45.21)
Symptom duration (months)	49.626±32.773
Diagnostic severity according to Bland's classification *n* (%)	
Mild	30 (41.1)
Mild to moderate	13 (17.8)
Moderate	10 (13.7)
Moderate to severe	6 (8.2)
Severe	14 (19.2)
Ultrasound parameters	
W-CSA (mm^2)	14.0±4.98
W-P (mm)	17.92±2.99
R-CSA	2.15±0.75
R-P	1.67±0.272
ΔCSA (mm^2)	7.32±4.78
ΔP (mm)	7.106±2.796
Parameters of nerve conduction studies	
DML (ms)	5.08±1.814
CMAP (mV)	7.9±2.312
MCV (m/s)	27.88±10.0
DSL (ms)	3.081±0.585
SNAP (μV)	12.845±6.002
SCV (m/s)	40.069±6.948
Chinese version of Boston Carpal Tunnel Questionnaire	
SSS	1.985±0.653
FSS	1.808±0.693

DML (ms): Distal motor latency, CMAP (mV): Compound motor action potential, ML (ms): Motor latency, MCV (m/s): Motor conduction velocity, DSL (ms): Distal sensory latency, SNAP (μV): Sensory nerve action potential, SCV (m/s): Sensory conduction velocity, W-CSA (mm^2): Wrist cross-sectional area, W-P (mm): Wrist perimeter, R-CSA: Ratio of cross-sectional area of the wrist over one-third of the distal forearm, R-P: Ratio of perimeter of the wrist over one-third of the distal forearm, ΔCSA (mm^2): Changes of cross-sectional area from the wrist to one-third of the distal forearm, ΔP (mm): Changes of perimeter from the wrist to one-third of the distal forearm. SSS: Symptom Severity Scale, FSS: Functional Status Scale

Factor One (functional status) relates to most items in FSS, involving "buttoning of clothes," "holding a book while reading," "gripping of a telephone handle," "household chores," "carrying of grocery bags," and "bathing and dressing," as well as "severity of pain at night" in SSS. Factor Two (sensory symptoms) relates to items in SSS, including "presence of numbness," "presence of weakness," "severity of numbness/tingling at night," "numbness/tingling awakening," and "difficulty with grasping;" meanwhile, it also relates to items in FSS, including "writing," "opening of jars," "household chores," and "bathing and dressing." Factor Three (pain) relates to all pain-relevant items

Table 2: Factor analysis of the Chinese Version of Boston Carpal Tunnel Questionnaire

	Component		
	Factor One (functional status)	Factor Two (sensory symptoms)	Factor Three (pain)
I. Symptom severity			
1. Severity of pain at night	0.443		0.379
2. Pain awakening			0.336
3. Presence of pain during daytime			0.745
4. Frequency of pain during daytime			1.125
5. Duration of episode of pain			1.117
6. Presence of numbness		0.445	
7. Presence of weakness		0.725	
8. Presence of tingling			
9. Severity of numbness/tingling at night		0.601	
10. Numbness/tingling awakening		0.378	
11. Difficulty with grasping		0.56	
II. Functional status			
1. Writing		0.721	
2. Buttoning of clothes	0.459		
3. Holding a book while reading	0.657		
4. Gripping of a telephone handle	0.79		
5. Opening of jars		0.817	
6. Household chores	0.636	0.427	
7. Carrying of grocery bags	0.957		
8. Bathing and dressing	0.472		0.301

Rotated component matrix shows the performance of each component of the C-BCTQ in the three selected factors. Items with absolute values >0.3 were listed in the table. Bathing and dressing is factorially complex since it loads Factors One, Two, and Three simultaneously (the value was not shown in Factor Two as it was below 0.3). Household chores are factorially complex as they load Factors One and Three simultaneously. Severity of pain at night is factorially complex as it loads Factors Two and Three simultaneously. These variables are removed as they diminish the internal consistency of the test, while the remaining loading variables are taken into account as a unit since each of the rest loads just one factor. C-BCTQ: Chinese version of Boston Carpal Tunnel Questionnaire

Table 3: Correlation between factors of C-BCTQ and ultrasonography

	Factor One (functional status)	Factor Two (sensory symptoms)	Factor Three (pain)
Ultrasound parameters			
W-CSA	0.411†	−0.024	−0.133
W-P	0.312†	−0.135	−0.105
R-CSA	0.368†	−0.071	−0.15
R-P	0.255*	−0.116	−0.15
ΔCSA	0.396†	−0.082	−0.142
ΔP	0.29*	−0.153	−0.12

*$P<0.05$; †$P<0.01$. C-BCTQ: Chinese version of Boston Carpal Tunnel Questionnaire, W-CSA (mm^2): Wrist cross-sectional area, W-P (mm): Wrist perimeter, R-CSA: Ratio of cross-sectional area of the wrist over one-third of the distal forearm, R-P: Ratio of perimeter of the wrist over one-third of the distal forearm, ΔCSA (mm^2): Changes of cross-sectional area from the wrist to one-third of the distal forearm, ΔP (mm): Changes of perimeter from the wrist to one-third of the distal forearm

in SSS, including "severity of pain at night," "pain awakening," "presence of pain during daytime," "frequency of pain during daytime," and "duration of episode of pain," while it also includes "bathing and dressing" in FSS [Table 2].

Regarding correlation between ultrasound and factors of C-BCTQ, Spearman's correlation coefficient test revealed significant correlation between all the ultrasound parameters and Factor One (functional status) (r = 0.255–0.411, $P < 0.05$), while no significant correlations with Factor Two (sensory symptoms) and Factor Three (pain) [Table 3]. It indicated that a larger value of each ultrasound parameter was correlated with a worse hand function. On the other hand, there was correlation between W-CSA and FSS (r = 0.266*, P = 0.023), while no correlation was found between neither subscale in C-BCTQ and each ultrasound parameter, suggesting that a larger W-CSA is correlated with a worse hand function [Table 4].

Discussion

To the best of our knowledge, this is the first study to explore the correlation between ultrasound and the C-BCTQ. Our major findings indicate that ultrasound can be used to describe the impact on hand function that CTS exerted; however, it can be used neither to reflect symptom severity, nor to differentiate primary/secondary symptoms of CTS. Our findings are consistent with Italian version studies by Padua *et al*.,[21] indicating that there was correlation between CSA and functional status but no correlation with symptom severity. Nevertheless, some literatures seem paradoxical with our findings. It diverges not only among different language versions, but also within the same language version. Mondelli *et al*.[19] and Kaymak *et al*.[22] reported no correlations

Table 4: Correlation between averaged score of subscales in C-BCTQ, ultrasound and nerve conduction studies

	Averaged score of subscales in C-BCTQ			
	Pain-related items	Paresthesia-related items	SSS	FSS
Ultrasound parameter				
W-CSA	0.091	−0.005	0.03	0.266*
W-P	0.092	0.006	0.025	0.128
R-CSA	0.058	−0.005	0.006	0.21
R-P	0.037	0.095	0.048	0.131
ΔCSA	0.08	0.000	0.016	0.219
ΔP	0.077	0.06	0.047	0.132

*$P<0.05$. C-BCTQ: Chinese version of Boston Carpal Tunnel Questionnaire, W-CSA (mm^2): Wrist cross-sectional area, W-P (mm): Wrist perimeter, R-CSA: Ratio of cross-sectional area of the wrist over one-third of the distal forearm, R-P: Ratio of perimeter of the wrist over one-third of the distal forearm, ΔCSA (mm^2): Changes of cross-sectional area from the wrist to one-third of the distal forearm, ΔP (mm): Changes of perimeter from the wrist to one-third of the distal forearm, SSS: Symptom Severity Scale, FSS: Functional Status Scale

between subscales of BCTQ and CSA in Italian and Turkish versions. Conversely, Karadağ *et al*.[23] suggested that CSA was positively correlated with SSS of BCTQ, supporting that symptom severity can be reflected by the degree of median nerve swelling using Turkish version. In addition, El Miedany *et al*.[5] also reported correlation between SSS and CSA in Arabic version, but there were no concrete statistics displayed in the result session. Among the East Asian countries, Lee *et al*.[24] reported a negative correlation between subscales of the Korean version of BCTQ and CSA. Obviously, it was at odds with previous mainstream findings and against the theory of ultrasound to reflect the symptom severity. By contrast, Tajika *et al*.[16] reported positive correlation between CSA and SSS in Japanese version, which was in accordance with the findings in Arabic and Turkish versions. It is speculated that these discrepancies can be complicated to explain, due to the diversity of the demographics in enrolled samples in different studies, the standard of practice for ultrasound and NCS, diagnostic criteria, etc.

Temporally, although there is yet no consensus in international societies regarding correlation between ultrasound and BCTQ, we held a point of view that BCTQ is literally a subjective rating scale, in which potential bias may co-exist due to the divergence of interethnic perception on pain and disability.[25,26] It can generate diverse outcomes, resulting in difficulties to reflect the enlarged nerves. In addition, CTS-induced paresthesia is strongly associated with damage of nerve fiber with large diameter (e.g., nociceptive A-beta fiber), whereas pain in CTS is linked with injury of nerve fiber with small diameter (e.g., myelinated A-delta fiber).[27] When the disease occurs, both large and small nerve fibers can be simultaneously affected, causing a mixed clinical symptom in terms of primary/secondary symptom dominance.[28] Consequently, there are difficulties in clearly differentiating or selectively correlating with specific damaged nerve fiber, merely by tracing the margin of the whole nerve bundles via ultrasound. In addition, Rempel *et al*.[2] pointed that CSA in 30% of severe CTS patients was not necessarily enlarged due to atrophy of nerve fiber. It was also noted that 57.1% (8 out of 14 hands) of the enrolled severe CTS hands in our study had CSA below 18 mm^2, the cutoff value for diagnosing severe grade suggested by Fujimoto *et al*.[29] All these disparities further illustrated the flaws to study symptom severity merely relying on the morphological information.

On the other hand, the unobserved factors identified in our study were consistent with that of previous similar studies which used factor analysis for data processing.[4,18] Those factors identified in all the studies explained over 60% of the total variance, respectively, indicating that factor analysis is appropriate for analyzing the data under the three-factor structure. A recent study about C-BCTQ by Lue *et al*.[30] also indicated that three-factor model, composing of hand function, pain, and paresthesia, demonstrated better reliability and validity than two-factor model, which covers overall symptom severity and functional status.

Nevertheless, there are several limitations in our studies. This is a nonrandomized study with small sample size. In addition, the data were not normally distributed. These limitations may affect the generalizability of our findings. However, this is the first study to discuss this issue in the Chinese societies, which can contribute to the clinical adaptation of BCTQ in the oriental society as a whole. Further longitudinal studies with a larger sample size are required to examine the applicability and cultural feasibility of BCTQ.

Conclusion

Morphological information obtained by ultrasound can reflect the impact on functionality that CTS exerted. However, it can be used neither to describe the symptom severity nor to differentiate the primary/secondary symptom of CTS.

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Conflicts of interest

There are no conflicts of interest.

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