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Hand Volume as a Diagnostic Tool in Carpal Tunnel Syndrome

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Abstract

Objectives: To determine whether patients with carpal tunnel syndrome have an objective swelling of their hands.

Design: A prospective, cross-sectional study of consecutive patients.

Setting: Two independent electromyographic laboratories.

Participants: Sixty-three patients referred for electrodiagnostic work-up.

Interventions: NCS/EMG testing and volumetric analysis. Limb volume was measured using the water displacement method using a volumeter.

Main Outcome Measures: Differences in volume (DHV) and EMG/NCS data.

Results: EMG results indicated that 24 subjects (38%) had findings consistent with CTS. Data concerning subjective swelling was available for only six of these 24 subjects. The data, which are limited by low power, indicate that there was no difference 1) between the volume of the affected hand and the unaffected hand among those with CTS; 2) between the DHV of those with CTS and those without;. 3) Patients with lower extremity complaints had significantly less DHV than those with an upper extremity complaint ($p< 0.0034$, excluding patients with both upper and lower extremity complaints).

Conclusions: Though a patients' perception of hand swelling has previously been determined to be an indicator of CTS severity, there was no correlation found in this study between CTS and objective measures of swelling. However patients with an upper extremity complaints had a statistically larger DHV than those with a lower extremity complaint ($p<0.0034$), suggesting that objective swelling might be present under some unknown circumstances. As this study was limited by a low power, further investigation is warranted in this area.

Keywords: Carpal tunnel syndrome; Orthopaedic surgeons; Neuropathy; Diagnosis of CTS

Introduction

Carpal Tunnel Syndrome (CTS) is the most common compressive neuropathy in the upper extremity. The American Academy of Orthopaedic Surgeons (AAOS) Clinical Guideline on the Diagnosis of Carpal Tunnel Syndrome defines CTS as a symptomatic compression neuropathy of the median nerve at the level of the wrist, characterized physiologically by evidence of increased pressure within the carpal tunnel and decreased function of the nerve at that level [1]. The syndrome is also defined as a constellation of signs and symptoms that result from median nerve damage at the carpal tunnel, including pain, numbness, or tingling in the median nerve distribution of the hand [2]. Carpal Tunnel Syndrome affects approximately 3-6% of the overall population [3].The diagnosis of CTS has traditionally relied on one or more of three physical signs or symptoms: (1) hypoesthesia in the median nerve distribution of the hand; (2) Tinel's sign: a tingling sensation in the median nerve distribution of the hand after light percussion of the median nerve at the wrist; and (3) Phalen's test: numbness and paresthesias in the median nerve distribution after flexing the wrist completely for 60 seconds [4,5]. A recent meta-analysis of diagnostic tests for CTS by Massy-Westropp supports the use of Tinel's sign and Phalen's test as diagnostic tools [6]. Yet studies have demonstrated a wide range of sensitivities and specificies for Phalen's test and Tinel's sign, 30%-100% [7,8]. Studies have demonstrated the inconsistency of clinical evaluations [9].Investigators have thus searched for other diagnostic tools for CTS. Durkan introduced the carpal tunnel compression test [10]. In his 1991 study, he compared nerve conduction studies with carpal tunnel compression and found 87% sensitivity and 90% specificity, superior to most studies of Tinel's and Phalen's test [10]. The scratch-collapse test was developed by Beck JL. While trying to complete a resistive-type motor task, the patient is scratched by the clinician at the location of the peripheral nerve compression. Upon completion of the exam, the patient will then try to replicate the task. A short-term loss of proximal postural stability will occur if the test is positive [11]. Early studies of this method have shown sensitivity and specificity of scratch-collapse test comparable and even in some studies greater than Tinel's and Phalen's test. Others have challenged these results. Miedany et al. even suggested that Tinel's, Phalen's, Reverse Phalen's and carpal tunnel compression tests are more sensitive, as well as being specific tests for the diagnosis of tenosynovitis of the flexor muscles of the hand, rather than being specific tests for carpal tunnel syndrome [12]. In our previous study of CTS splinting, many of the patients offered the unsolicited complaint of swelling of the affected hand [13]. A follow-up study of 186 patients referred for splinting for CTS demonstrated that the subjective complaint of swelling in the hand or wrist was comparable diagnostically to the Phalen test and carpal tunnel compression test [14]. Additionally, subjective swelling was predictive of a poor response to splinting, providing useful prognostic information.While the complaint of subjective swelling has been mentioned in the literature, to our knowledge no research has addressed the objective difference in hand volumes of patients and its subsequent diagnostic and prognostic value. This study is designed to further investigate the issue of swelling of the hand by providing quantifiable volumetric data and comparing this established diagnostic tests.

Methods

This prospective, cross-sectional study included sixty-three consecutive patients sent for electrodiagnostic work-up to confirm a diagnosis of CTS. All subjects were referred to the clinic with a clinical history consistent with CTS. EMG/NCS were completed for each patient at one of two university based electromyographic laboratories. The two locations were Massachusetts General Hospital and Louisiana State University Rehabilitation.

Before testing, all subjects underwent volumetric analysis. The upper extremity limb volume was measured using the water displacement method in a volumeter. For this test, each hand was placed in a fluid filled cylinder, with the fingers slightly apart, and the hand submerged to the level of the styloid process of the radius. Volume was determined by fluid displacement. Volumes of the affected and unaffected hands were compared. The DHV and EMG/NCS data were compared for this study's main outcome measure.

Results

EMG results indicated that 24 (38%) of the 64 subjects had EMG/NCS evidence of CTS (Table 1).

There was no difference found between the volume of the affected hand and the unaffected hand among those with EMG/NCS diagnosis of CTS and hose with EMG/NCS results negative for CTS (Table 2).

Of the patients queried, 22.5% of these subjects reporting a sensation of swelling in their hands.

ID	Gender	CTS	Vol R(mL)	Vol L(mL)
Patient 1	Female	No	375	370
Patient 2	Female	No	450	435
Patient 3	Female	Yes	360	370
Patient 4	Female	No	430	410
Patient 5	Female	No	440	440
Patient 6	Female	No	365	360
Patient 7	Male	No	515	475
Patient 8	Female	No	535	555
Patient 9	Male	No	615	590
Patient 10	Female	Yes	525	500
Patient 11	Female	Yes	410	375
Patient 12	Male	No	645	600
Patient 13	Male	No	540	545
Patient 14	Female	Yes	535	520
Patient 15	Female	Yes	525	500
Patient 16	Male	No	570	580
Patient 17	Male	Yes	570	520
Patient 18	Male	No	485	485
Patient 19	Female	No	440	445
Patient 20	Male	No	625	615
Patient 21	Male	No	510	550
Patient 22	Male	Yes	650	630
Patient 23	Female	No	380	360
Patient 24	Female	No	460	445
Patient 25	Male	No	550	525
Patient 26	Male	No	645	675
Patient 27	Female	Yes	435	485
Patient 28	Male	Yes	655	675
Patient 29	Female	Yes	550	505
Patient 30	Female	Yes	510	495
Patient 31	Male	Yes	710	700
Patient 32	Female	Yes	360	350
Patient 33	Female	No	380	370
Patient 34	Female	Yes	418	391
Patient 35	Female	No	410	375
Patient 36	Male	No	460	445
Patient 37	Male	Yes	655	595
Patient 38	Male	No	445	380
Patient 39	Male	Yes	725	702
Patient 40	Male	No	470	435
Patient 41	Female	No	378	360
Patient 42	Female	No	365	420
Patient 43	Male	No	585	590
Patient 44	Male	No	558	506

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Patient 45	Male	No	570	542
Patient 46	Female	Yes	380	360
Patient 47	Male	No	495	472
Patient 48	Female	No	410	375
Patient 49	Female	Yes	296	292
Patient 50	Male	No	575	580
Patient 51	Male	No	560	520
Patient 52	Male	No	485	457
Patient 53	Male	No	540	500
Patient 54	Female	Yes	455	444
Patient 55	Female	Yes	440	428
Patient 56	Female	No	415	410
Patient 57	Female	No	340	310
Patient 58	Female	Yes	465	455
Patient 59	Female	Yes	310	275
Patient 60	Female	Yes	533	493
Patient 61	Female	No	335	325
Patient 62	Male	No	525	570
Patient 63	Female	No	385	400
Patient 64	Male	Yes	563	553

Table 1: EMG/NCS evidence of CTS.

Group	Frequency	Mean Volume Difference	Standard Deviation	95% Confidence	Interval
No CTS	40	22.92308	16.62811	17.53287	28.31329
CTS	24	24.25	3.156687	17.7199	30.7801
Combined	64	23.42857	2.026036	19.37858	27.47856
Difference		-1.326923	4.202677	-9.730696	7.07685

Table 2: Two-sample t test with equal variances. P > 0.7533.

Various studies have documented hand edema in CTS; however, these reports are for the most part limited to observations from surgical procedures, with investigators noting soft tissue and perineural edema [15,16]. Vascular sclerosis and edema were consistent findings, present in 98% and 85%, respectively, in one study [16,17]. This study also demonstrated that edema varies with the degree of carpal tunnel syndrome; increasing from mild to moderate disease and then decreasing with advanced disease. This association between edema and nerve entrapment has been seen in other conditions including gestational edema, colles' fracture and postmastectomy lymphedema [18,19].

Group	Frequency	Mean Hand Volume Difference	Standard Deviation	95% Confidence	Interval
Lower Extremity Swelling	6	13.83333	15.03884	-1.94896	29.61563
Upper Extremity Swelling	10	29.4	17.34102	16.99498	41.80502
Combined	16	23.5625	17.78752	14.0842	33.0408
Difference		-15.56667		-33.51285	2.37952

Table 3: Two-sample t test with unequal variances. P>0.0831.

Discussion

One study may have indirectly quantified edema in CTS. Winn, et al. assessed carpal tunnel area as a risk factor for CTS using computerized axial tomography [20]. The authors hypothesized that a small canal area would be a risk factor for the development of CTS; however, their findings suggested that CTS patients demonstrated significantly larger carpal tunnel areas than did controls. It is possible that they were documenting edema of the carpal tunnel. Previous studies of hand and wrist dimensions have reported a higher wrist index (wrist depth/wrist width) in patients with CTS when compared with controls [21]. In one study by Farmer, the findings provided some support for an association between a high wrist index and CTS [22]. This study took 50 patients with CTS and compared them with 50 age and sex matched controls. The wrist index was greater in the CTS group than the control group. However as in the previous studies, the difference between the wrist index in the CTS and control groups was small and there was much overlap between the two populations, as shown by their standard deviation. Thus, the wrist index has little value in clinical practice as a diagnostic tool and cannot be used to identify subjects at risk of developing CTS in the future. More recent volume estimates have employed ultrasonagraphy. In one study the 27 patients with CTS were compared to 30 controls. Cross sectional area and AP diameter of median nerve at carpal tunnel outlet. Results showed significant differences between the control and CTS group with CTS groups have larger area and diameter [23].

Diagnostically, volumetric analysis of patients with CTS has the potential to objectively establish the presence of hand edema by comparing the volume of the affected hand to that of the contralateral hand. However, in our study we did not detect any significant difference in the volume of affected and non-affected hands. Several limitations exist that may have affected our analysis.

An earlier study established a 3.4% volume discrepancy between normal subjects' dominant and non-dominant hands [24]. Our analysis did not take into account whether patient's affected hand was their dominant or their non-dominant hand. Therefore, it is possible that CTS of the non-dominant hand resulted in swelling that was not considered significant when compared to the dominant hand, effectively masking the baseline volume differences in hands. Future work should note if the dominant hand is involved or study only those with dominant hand CTS. Hand-to-hand comparison is also problematic if the disease is bilateral. Our study population consisted of several bilateral CTS cases. Similarly, with bilateral disease one may detect similar hand volumes, yet hand edema cannot be excluded.

Further limitations may be attributed to the pathophysiology of carpal tunnel syndrome. The presence of thenar atrophy, usually present in severe disease, may mask edema when assessing total hand volume. In future studies, a method of discriminating this phenomenon is to assess strength as well as volume in the affected and unaffected hand; with thenar atrophy one would expect similar volumes but disparate strength measurements. Also, swelling may wax and wane throughout the day as do the symptoms, therefore a single measure of hand volume is not sufficient to detect edema. Other confounding factors include foreign causes of edema, such as constrictive hand jewelry and preexisting hand deformity.

This study implemented a cross-sectional data analysis and therefore did not allow for a temporal comparison of hand volume. Future studies should measure hand volumes before and after the onset of CTS. This would circumvent the need to compare one's hand to the contralateral side as a form of baseline information, therefore reducing the limitations caused by handedness, deformity and bilateral disease. It also would provide multiple data points, thereby increasing the chance of detecting swelling in a waxing and waning disease course.

Lastly, the small number of study subjects resulted in difficulty stratifying the study population based on sex, age, lifestyle, degree of disease progression, volume vs. severity of injury, and time since surgery.

Although prior research has documented subjective swelling, this study did not find an objective volumetric measure of swelling in CTS patients [14]. However, there were significant limitations to our study. Therefore, future work is still needed to clarify the incidence and significance of swelling and its relationship with patients' subjective complaints. Such studies may employ a temporal volumetric comparison or use other methods of assessing swelling, such as computed tomography or magnetic resonance imaging.

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