3 Diagnosis and Clinical Presentation of Carpal Tunnel Syndrome

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Introduction

Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy with a bimodal age distribution of 50–54 and 75–84 years of age [1, 2] The majority of cases are idiopathic and genetic predisposition has been found to be the strongest predictor for development of carpal tunnel syndrome [3].

Carpal tunnel syndrome, by definition, is a constellation of signs and symptoms. However, it is unclear how many or what combination of signs and/or symptoms a patient must have in order to make the diagnosis. Expert physicians may reasonably disagree on the presence or absence of CTS in some cases. The lack of a clear reference standard makes research on the diagnosis and outcomes of carpal tunnel syndrome more difficult.

Symptoms may include paresthesia and/or anesthesia of the radial three and a half fingers, weakness of the thenar muscles, and nocturnal symptoms. Signs may include a Tinel sign, Phalen test, compression test, increased two-point discrimination, increased Semmes-Weinstein monofilament testing, atrophy and/or weakness of the thenar musculature, and many other physical examination findings. It is important to recognize that any one sign or symptom, in isolation, has a low sensitivity and specificity for diagnosis of carpal tunnel syndrome [4]. Multiple studies have demonstrated that additional diagnostic testing in cases of "classic" carpal tunnel syndrome adds little additional value [5, 6].

The purpose of this chapter is to review the clinical presentation of carpal tunnel syndrome and to review the clinical and diagnostic tests that are commonly utilized to make the diagnosis of carpal tunnel syndrome.

Clinical Presentation

The classic presentation of carpal tunnel syndrome is numbness and paresthesias in the radial three and a half fingers. The symptoms are often exacerbated at night and with activities that require wrist flexion such as driving, knitting, etc. As the syndrome becomes more advanced, patients may experience weakness of the thenar muscles and clumsiness of the hand. Pain is not typically considered to be part of classic carpal tunnel syndrome, although the "pins and needles" sensation can certainly be interpreted as painful. In addition, in patients where the main driver of nerve compression is flexor tendonitis/tenosynovitis, these patients may complain of radiating pain into the forearm and/or hand.

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Compression of the median nerve within the carpal tunnel results in decreased epineural blood flow, edema, and changes in nerve conduction [7, 8]. The majority of cases are idiopathic, meaning there is not an identifiable systemic, anatomic, or traumatic etiology [7]. Systemic conditions with known associations with carpal tunnel syndrome include amyloidosis, renal failure, diabetes, hypothyroidism, congestive heart failure, obesity, rheumatologic conditions (rheumatoid arthritis, lupus, scleroderma), vitamin deficiencies, and alcoholism [7, 9]. Anatomic causes can include space occupying lesions such as ganglions, lipomas, neurofibromas, schwannomas and other rare tumors. Anomalous muscles may be present in the carpal tunnel and include the palmaris profundus, extra slips of the flexor pollicis longus, and a more proximal origin of the lumbricals. A persistent median artery is also described as a potential anatomic variation that can result in carpal tunnel syndrome. Traumatic etiologies include median nerve contusion from a distal radius fracture and/or perilunate dislocation, distal radius malunion, and post-traumatic arthritic changes [7].

Certain activities have been postulated as contributing to carpal tunnel syndrome. Typing is probably the most widely cited in the lay press, however, several large studies have failed to find a difference in the rates of carpal tunnel syndrome in patients who type and those who do not [10, 11]. Occupations with vibrational exposure and those which require a high volume of repeated heavy grasp appear to have more clear associations with carpal tunnel syndrome [10, 11].

Physical Examination

The physical examination shoulder should start with inspection. The entire arm should be inspected for signs of atrophy, color changes, and differences in skin moisture. The cervical spine is evaluated for range of motion, tenderness to palpation, and a Spurling's maneuver is performed to determine if cervical radiculopathy is present. Examination for thoracic outlet syndrome should also be considered. This may include shoulder abduction, external rotation, and asking the patient to inhale deeply (Wright's test) and having the patient extend his/her neck, look toward the affected side, and take a deep breath (Adson's test). A positive test would be reproduction of the patient's symptoms with the maneuver.

Sensation in the digits is evaluated using Semmes-Weinstein monofilament testing and 2-point discrimination. Semmes-Weinstein is a threshold sensory test and has been shown to have a sensitivity of 91% and specificity of 80% for CTS [12, 13]. Numerous provocative maneuvers have been described for carpal tunnel syndrome. It is important to note that, individually, the provocative maneuvers have low specificity and sensitivity for CTS [4]. Percussion of the median nerve resulting in radiating paresthesias to the median nerve distribution represents a positive Tinel's sign. Flexion of the wrist for 60 seconds that results in paresthesias in the median nerve distribution represents a positive Phalen's test. Durkan's compression test involves compression of the median nerve within the carpal tunnel for 30 seconds. A positive test is reproduction of paresthesias in the median nerve distribution. MacKinnon described the scratch collapse test, where the examiner asks the patient to bilaterally externally rotate the shoulder with the shoulder abducted, elbow flexed to 90°, wrist in neutral, and shoulder in neutral rotation while the examiner applies an internal rotation force. The examiner then scratches over the carpal tunnel on the affected side and repeats the internal rotation force against patient resistance [14]. In patients with carpal tunnel syndrome, the patient "collapses" against the internal rotation force on the affected side, but not the unaffected side. Follow-up studies have questioned the diagnostic ability of this test [15].

Clinical Diagnostic Tools

In an effort to standardize the physical examination and to determine which combination of history and physical examination findings were most predictive of carpal tunnel syndrome, a

number of diagnostic tools have been developed. The Katz hand diagram was one of the first attempts to standardize findings from the history and physical examination and to compare the constellation of these findings to the results of EMG/NCS [16]. Subjects were provided with a hand diagram and asked to mark the areas on the diagram corresponding to their symptoms. Subjects also underwent moving 2-point discrimination testing, assessment for thenar atrophy, thumb abduction strength testing, Phalen test, Tinel sign, and EMG/NCS. After multivariate regression, only the Tinel sign and hand diagram were significant predictors in the model. The authors found that subjects older than 55 with a positive Tinel sign had a positive EMG/NCS in 89% of cases while subjects young than 40 with a positive Tinel sign had a positive EMG/NCS in 71% of cases [16]. Levine et al. developed a self-administered questionnaire, now known as the Levine-Katz or Boston Carpal Tunnel Questionnaire [17]. This questionnaire assesses both functional and symptom severity. The questionnaire has been shown to be reproducible, internally consistent, and sensitive to change after treatment [17].

The CTS-6 was developed by Graham and colleagues to determine the probability of carpal tunnel syndrome based on the presence or absence of 6 criteria (Table 3.1). The authors started with 57 signs and symptoms associated with carpal tunnel syndrome and an expert panel ranked them in order of importance. The top 8 criteria were then used to create 256 unique case presentations. An expert panel made a binary decision as to whether each case represented carpal tunnel syndrome. A logistic regression model was created and it was determined that only 6 of the criteria contributed to the model. A CTS-6 score of 12 represents an 80% probability for a diagnosis of carpal tunnel syndrome. The CTS-6 was found to have a higher sensitivity and specificity than EMG/NCS using latent class analysis [18] and has been used as the reference standard in a prospective study comparing EMG/NCS and ultrasound for diagnosis of carpal tunnel syndrome [19].

Table 3.1 CTS-6

Finding	Points
Numbness predominately or exclusively in median nerve territory	3.5
Nocturnal numbness	4
Thenar atrophy and/or weakness	5
Positive Phalen test	5
Loss of 2-point discrimination	4.5
Positive Tinel sign	4

Several other clinical diagnostic tools have been developed. Lo et al. developed a clinical prediction rule which included the following components: gender, duration of symptoms, nocturnal symptoms, neck pain, wrist pain, median nerve sensory symptoms, abductor pollicis brevis (APB) weakness, thenar atrophy, and pinprick sensation [20]. Point values were assigned to each component, some with negative points (neck pain, wrist pan, and female gender), and a higher total point score was found to have a higher probability of having a positive electromyogram (EMG)/nerve conduction study (NCS). Wainner and colleagues developed a clinical prediction rule which included five variables: hand shaking improves symptoms, a wrist-ratio >0.67 (calculated by dividing the anteroposterior diameter of the wrist by the mediolateral diameter of the wrist), a symptom severity score (from Levine-Katz Carpal Tunnel Questionnaire) >1.9, diminished sensation in the thumb, and age >45 years [21]. The authors found that when all five variables were present, EMG/NCS was positive in 90% of cases. When at least four out of five variables were present, EMG/NCS was positive in 70% of cases [21]. Kamath et al. used a nine question assessment based on patient symptoms and found that a score of 5 or more on the assessment would allow it to replace EMG/NCS as a screening tool [22].

EMG/NCS

Electrodiagnostic testing, a combination of NCS and EMG, has historically been the most widely utilized diagnostic test for carpal tunnel syndrome. NCS involves placing electrodes along the path of the nerve being tested. The proximal

electrode sends an electrical impulse along the nerve and the more distal electrode measures the result. NCS evaluation of a pure motor nerve produces a motor nerve action potential (MNAP) and evaluation of a pure sensory nerve produces a sensory nerve action potential (SNAP). Evaluation of a mixed nerve results in a compound nerve action potential (CNAP). Latencies and nerve conduction velocity (NCV) are calculated using the distance between the electrodes. Factors such as age, height, and weight can affect the latencies and NCV [23].

Large, myelinated fibers are most affected in chronic compressive neuropathies such as carpal tunnel syndrome [24]. As the myelin is damaged (demyelination), the electrical impulse is able to "leak" into surrounding tissues, resulting in increased latency [25]. As compression becomes more chronic, axonal degeneration occurs. Sensory fibers are more sensitive to compression and therefore SNAP values typically decrease before MNAP/CNAP values [25].

EMG evaluates the muscle contraction through either surface or intramuscular electrodes. There has been much interest in using surface electrodes to reduce patient pain and discomfort, however, intramuscular needle EMG remains the reference standard. When stimulated with a needle, normal muscle exhibits brief activity and then quickly returns to electrical silence. This is called insertional activity. If the tip of the EMG needle approaches a motor end plate, miniature endplate potentials (MEPPs) may be recorded. Voluntary muscle contraction is also recorded and termed the muscle unit action potential (MUAP) [26]. Muscle denervation leads to membrane instability, spontaneous depolarization, and cyclical activation of muscle fibers. If these depolarizations occur due to needle movement, they are called fasciculations. Positive sharp waves are similar to fasiculations, but are monophonic waveforms of larger amplitude [27].

The American Association of Neuromuscular and Electrodiagnostic Medicine (AANEM) practice parameters for electrodiagnostic studies reports a high sensitivity (>85%) and high specificity (>95%) for the diagnosis of carpal tunnel syndrome [28, 29]. Sensitivity and specificity are highly dependent on the cut-off values used for diagnosis and one often sacrifices sensitivity to increase specificity and vice versa. There has been an anecdotal trend to lower the absolute cut-off values for distal motor latency and distal sensory latency and to include other comparisons such as relative sensory latencies and the combined sensory index [30]. The effect of these changes has been to increase the sensitivity of nerve conduction studies by detecting "early" or "very mild" cases of CTS, but it also likely leads to an increase in the number of false positive EMG/NCS tests in patients without clinical signs and symptoms of CTS [31]. A recent systematic review of EMG/NCS for diagnosis of carpal tunnel syndrome found only three studies that met criteria for inclusion in the review and those studies found cut-off values of 3.3 ms for peak sensory latency and 4.5 ms for distal motor latency [32]. These values are much higher than those used by my local EMG/NCS laboratory and have the effect of lowering the specificity of the test.

The use of EMG/NCS for diagnosis of carpal tunnel syndrome has several potential benefits, including grading the severity of carpal tunnel syndrome, identification of additional or unexpected causes of nerve compression (cervical radiculopathy, pronator syndrome, polyneuropathy), and documenting recovery of the nerve after intervention [6, 18, 33, 34]. Several different grading schemes have been proposed. The simplest scales classify CTS as mild, moderate or severe using absolute cut-off values for distal motor and sensory latencies [35–37]. Bland developed a 7-point scale ranging from "no abnormality" to "no recordable sensory or motor potential" [38]. There is conflicting evidence regarding whether or not EMG/NCS is a predictor of outcome after carpal tunnel release. Bland et al. found that EMG/NCS was the best predictor of successful outcome after CTR [35, 39]. In contrast, Braun et al. and Grundberg found no correlation between EMG/NCS and outcome after CTR [40, 41]. These studies are hampered by arbitrarily chosen delineations between groups and confounding factors such as age and gender.

Recent studies have questioned the benefit of EMG/NCS in the diagnostic workup when compared to other commonly used diagnostic tests and/or clinical diagnostic tools [5, 18, 19, 34, 39]. Glowacki and colleagues found no differences in outcomes between patients who underwent carpal tunnel release with pre-operative EMG/NCS and those who had the diagnosis based on the history and physical examination alone [6]. In addition, several studies document and high rate of false positives and false negatives for EMG/NCS [42, 43]. Atroshi et al. noted that 18% of patients in their series had a positive EMG/NCS despite no clinical signs and symptoms of CTS and 30% of patients had negative nerve tests despite "clinically certain" CTS based on clinical signs and symptoms [42]. Buch-Jaeger and Foucher found EMG/NCS was positive in only 61% of patients with clinical signs and symptoms of CTS [44]. Additionally, most studies have found a poor correlation between patient reported symptoms and function and the results of nerve conduction studies. Levine et al. reported a correlation coefficient of 0.11 between median nerve sensory latency and symptom severity and a correlation coefficient of 0.12 between median nerve sensory latency and functional severity [17].

Ultrasound

Ultrasound has emerged as a viable alternative to NCS for diagnosis of CTS. Median nerve compression within the carpal tunnel results in nerve swelling proximal and distal to the location of the compression. Nerve swelling is likely multifactorial; however, compression of the nerve leads to changes in the permeability of the blood-nerve barrier. Based on animal models, the epineurium is the first layer to experience changes and the result is isolated swelling in this layer. The endoneurium than becomes involved, resulting in changes in nerve conduction. Chronic nerve compression may lead to fibrosis of the intrafasicular tissues [25–27, 45–47]. Nerve swelling results in an increased in the cross-sectional area (CSA) of the nerve. If the CSA exceeds a predefined cut-off, then the diagnosis of carpal tunnel syndrome is confirmed (Figs. 3.1 and 3.2).

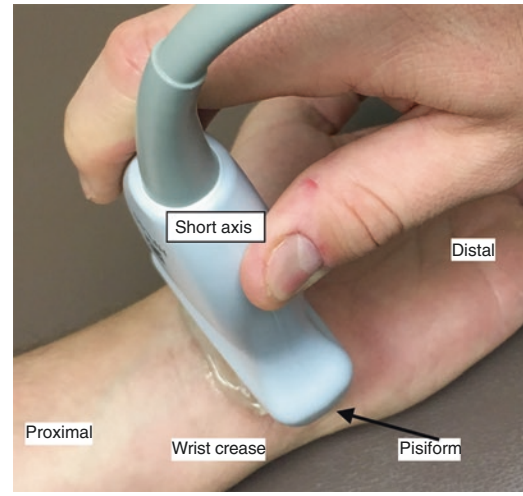

Fig. 3.1 Photograph demonstrating the technique and location for the short axis measurement of the cross-sectional area of the median nerve at the level of the pisiform

While MRI is widely considered the most accurate diagnostic modality to evaluate and measure soft-tissue structures such as nerve, obtaining an MRI to evaluate patients with CTS is not a cost-effective strategy. Musculoskeletal ultrasound was proposed as a lower cost modality and Buchberger et al. demonstrated that ultrasound measurements of the median nerve were comparable to MRI measurements [48]. Nakamichi et al. compared CSA measurements in the distal forearm, carpal tunnel inlet (level of pisiform), middle of carpal tunnel, and carpal tunnel outlet (level of hook of hamate [49]. The authors found that the most sensitive and specific level to measure the CSA was at the carpal tunnel inlet/level of the pisiform [49]. Various cut-off values have been utilized in the literature for a positive diagnosis of carpal tunnel syndrome, ranging from 10 to 14 mm^2 [19, 50–53]. Fowler and colleagues used a cut-off of 10 mm^2 and demonstrated that US had a similar sensitivity and greater specificity that EMG/NCS in patients with a clinical diagnosis of carpal tunnel syndrome [19]. However, Cartwright et al. has suggested an upper limit of 14.6 mm^2 as being 2 standard deviations above

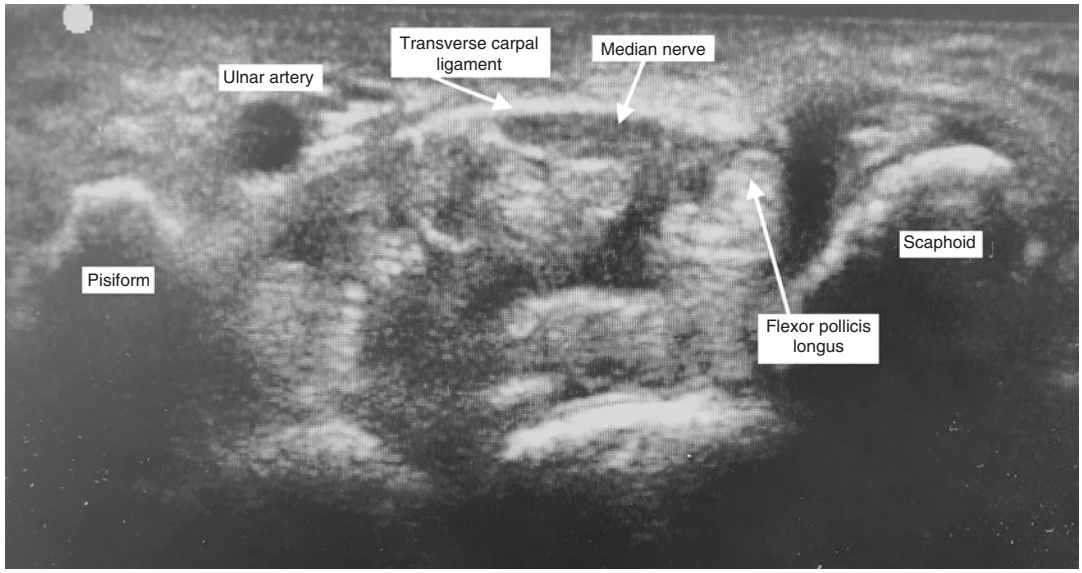

Fig. 3.2 Ultrasound image demonstrating the view obtained from Fig. 3.1

the mean in their study of 100 arms [54]. Age, gender and ethnicity may play a role in the baseline values used for cross-sectional area.

Numerous studies have been performed in an attempt to compare the sensitivity and specificity of EMG/NCS and US for diagnosis of carpal tunnel syndrome. A systematic review of these studies demonstrated similar sensitivity and specificity between US and EMG/NCS when clinical diagnosis was used as the reference standard [55]. Ziswilier and colleagues found a 98% probability of CTS in a prospective study of 110 wrists using a cut-off CSA of 12 mm^2 [56]. A meta-analysis of high quality studies concluded that US "as accurate as" EMG/NCS with respect to sensitivity, specificity, and accuracy for diagnosis of CTS [57].

Some authors have criticized the use of absolute CSA values when using US for diagnosis of CTS and have proposed the use of ratios to account for differences in nerve size and morphology. Hobson-Webb and colleagues [58] described the wrist-to-forearm ratio (WFR), a ratio between the CSA of the median nerve at the wrist crease and CSA of the median nerve 12 cm proximal to the wrist crease. In this series, if the WFR was ≥1.4, there was 100% sensitivity for CTS. Buchberger et al. described bowing of the flexor retinaculum, calculated by drawing a line on the short axis ultrasound from the trapezium to the hamate and then measuring from that line to the most volar part of the transverse carpal ligament. The authors noted the amount of palmar displacement of the transverse carpal ligament in normal controls was 2.1 mm, compared to 3.7 mm in patients with carpal tunnel syndrome [48]. The flattening ratio of the median nerve is determined on the short axis ultrasound by dividing the nerve's medial-lateral diameter by the anterior-posterior diameter. The flattening ratio is typically greatest at the level of the hamate in patients with carpal tunnel syndrome [48].

Ultrasound may be a useful adjunct in patients with normal nerve conduction studies despite signs and symptoms consistent with carpal tunnel syndrome. Al-Hashel and colleagues found that nearly 50% of the patients in their series with normal nerve conduction studies but clinically certain carpal tunnel syndrome had an elevated CSA of the median nerve at the level of the pisiform [59]. Aseem et al. found 92% of wrists with clinical evidence of CTS and normal NCS had an increased CSA and 100% had an elevated WFR [60]. At a minimum, ultrasound should be considered an alternative test to EMG/NCS in the correct clinical scenario. Fowler and colleagues

demonstrated that ultrasound as a first line test is a cost-effective strategy for diagnosis of carpal tunnel syndrome [61].

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