Clinical Presentations and Diagnosis

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Carpal Tunnel Syndrome: A Definition

For a general definition of carpal tunnel syndrome, the American Association for Orthopaedic Surgeons clinical practice guidelines on the diagnosis of carpal tunnel syndrome (2007) are as good as any.

"Carpal Tunnel Syndrome is 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. Carpal Tunnel Syndrome can be caused by many different diseases, conditions and events. It is characterized by patients as producing numbness, tingling, hand and arm pain and muscle dysfunction. The disorder is not restricted by age, gender, ethnicity, or occupation and is associated with or caused by systemic disease and local mechanical and disease factors." [1].

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Burden of Disease and Impact of CTS in the USA

"During 1998, an estimated three of every 10,000 workers lost time from work because of carpal tunnel syndrome. Half of these workers missed more than 10 days of work. The average lifetime cost of carpal tunnel syndrome, including medical bills and lost time from work, is estimated to be about $30,000 for each injured worker [2]." 2005 statistics indicate nearly half the workers who lost time from work because of carpal tunnel syndrome missed over 31 days of work [3]. The US Bureau of Labor Statistics [4] indicates there were 16,440 cases of carpal tunnel syndrome involving lost work days in 2005. Carpal tunnel syndrome has the highest median number of days away from work [3], and the major industry division with highest number of events and exposures is manufacturing [5].

Etiology

The consensus opinion of the AAOS Clinical Practice Guideline Workgroup states that patients with carpal tunnel syndrome experience numbness and tingling in the sensory distribution of the median nerve. They may also have hand pain. If the syndrome is untreated over time, pain may be felt proximally in the forearm. Some

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combination of pressure × time is thought to result in progression of this condition. The duration and intensity of the paresthesias may increase. Sensory loss and median motor paralysis with atrophy of the thenar muscles may occur. It is believed that the earlier the diagnosis is made, the less likely is the occurrence of irreversible damage to the nerve. The accuracy of differential diagnosis from radiculopathy and metabolic, genetic, and other forms of neuropathy is achieved through careful history taking, physical examination, and laboratory tests, as well as clinical experience with all of these conditions [6].

Typical and Atypical Presentations

Patients with carpal tunnel syndrome usually present with clinical symptoms. These may include pain, weakness, and numbness. The typical anatomic distribution of these symptoms is the median nerve distribution, mainly the thumb, index, middle finger, and the radial one half of the ring finger.

A "typical" patient will complain of pain with repetitive or heavy use of the hand, thumb symptoms of weakness, and radiating numbness in the median nerve distribution. The patient may have nocturnal waking and describe a typical maneuver of having to sit up or "shake the hands" to try to relieve such symptoms. Patients may have tried anti-inflammatories or a wrist immobilizer splint to try to decrease symptoms, and these may or may not have been effective.

It is important that the clinician does not fall into the trap of assuming that every case of hand numbness or tingling is carpal tunnel syndrome. Clearly, at least in the USA, carpal tunnel syndrome is a clinical entity that is relatively well known. However, most patients don't know the specifics of what this clinical entity is and certainly are not able to differentiate this more popularly described condition and differentiate it with many other conditions that may "mimic" classic carpal tunnel syndrome. Thus, the burden of making or confirming the diagnosis falls on the clinician.

Confounding the diagnosis of carpal tunnel syndrome is the fact that there are instances of "double crush" where a nerve compression in one part of the peripheral nervous system potentiates a lower irritation or pressure threshold for compression syndrome in another part of the peripheral nervous system. Most classically proximal nerve compression at the cervical spine, thoracic outlet, or about the elbow or forearm can mimic carpal tunnel syndrome and/or be a cause of "double crush." A partial list of diagnoses is listed in Table 4.1.

Table 4.1 Differential diagnosis for CTS

Cervicalgia	Cervical spine compression
Herniated cervical disk	Cervical root compression
Herniated cervical disk	Brachial plexopathy
Thoracic outlet syndrome	Humeral level nerve compression
Parsonage turner syndrome	Cubital tunnel syndrome
Elbow tendonitis (medial or lateral)	Pronator syndrome
Radial tunnel syndrome	Tendonitis of the flexor compartments (FCR, FCU)
Flexor tenosynovitis or the wrist or hand	Trigger finger
Extensor tendonitis in any of the six dorsal compartments	Dupuytren's contracture
De Quervain's tendonitis	Basal joint of thumb arthritis

Atypical innervation may result in an atypical pattern of nerve compression, particularly with the Martin-Gruber anastomosis. Rarely, patients may present with atrophy and yet deny prior symptoms of pain or numbness. Thus, the presentation of carpal tunnel syndrome in patients may vary significantly from case to case.

Risk Factors

Several key comorbidities and/or human factors are associated with an increased incidence of carpal tunnel syndrome. These include pregnancy, advancing age, female gender, specific occupations, hand-related repetitive motions, strong family history, and specific medical disorders such as hypothyroidism, diabetes, autoimmune diseases, rheumatological diseases, arthritis,

obesity, renal disease, trauma, anatomic predisposition in the wrist and hand due to shape and size, infectious diseases, and substance abuse. In many cases, there is no identifiable comorbidity or causal relationship. These are "idiopathic CTS cases" [1].

History

It is essential to ask the right questions in obtaining the history for a patient who is suspected of carpal tunnel syndrome. This is particularly important since the patient may have their own ideas of what the etiology of the problem is, which might be correct or incorrect. The index of suspicion must reside with the clinician in terms of asking the right questions.

The way I like to approach this is to ask the typical questions in obtaining information in any investigation, modified for carpal tunnel syndrome. Very simply these are who, how, what, when, and where.

Who/How?

It means asking these questions: How did it start? Was there a single traumatic episode? Was there repetitive use over time, with a slow gradual onset?

What?

What are the symptoms? Is it pain, is it numbness, is it tingling, or is it weakness? What are the activities that are primarily impaired? What are the activities that are provocative that reproducibly and reliably "bring out" the symptoms?

When?

When do the symptoms occur? Is it stable throughout the day? Are there provocative activities that bring it out or tend to bring it out? Are symptoms worse at night? Is nocturnal waking a feature? If so, does this happen nightly? This symptom has a lot to do with the intensity of the condition and may be very useful in guiding the decision to embark on treatment, including surgery.

Where?

Where do the symptoms occur? What is the distribution of symptoms? Is it all five fingers? Is it a "classic" median nerve distribution of the thumb, index, middle, and the radial portion of the ring finger? Is the pinky finger spared? Furthermore, is it just the hand, or does it involve more proximal upper extremity or the entire arm? If it's the entire arm, a strong suspicion of a "double crush" involving proximal nerve compression should be more thoroughly evaluated and considered.

Pattern

What is the pattern up until now? What might the pattern be going forward? Often patients would like the clinician to "predict the future," in terms of progression of their symptoms based on their current situation. In order to get a complete history, you have to know what the pattern up until the present has been.

In terms of the future pattern or "natural history" of this or any other disorder, there are always three choices: it gets better, it gets worse, or it stays the same. Yes, this is absurdly simplistic, but it is important to try to elicit the past pattern and get more detail on the progression of symptom etiology that has brought the patient to the physician's office.

In terms of the present, and the future, there are two key things to try to consider. One is the duration of symptoms, and the second is the severity of the symptoms. The duration can be ascertained to some degree with the patient's cooperation and if the patient is a reasonable historian. On the other hand, severity cannot be easily determined by history or physical exam, but this can be inferred by the careful conducting of the history and support of physical exam.

Electrodiagnostic testing may give some indication of this severity, but not the likelihood of progression or rate. Confirmation of CTS can be obtained in the diagnostic testing which will be discussed in the sections to follow.

Physical Exam

Inspection of the involved upper extremity should start with the neck and shoulder girdle exam. The contralateral side should always be inspected in unilateral cases. The neck should be tested for range of motion in terms of rotation, flexion and extension, and lateral bend. Nerve compressive signs should be observed, and compression testing performed. Any tenderness should be noted, either locally or especially if there is any radiating pain.

In terms of the shoulder girdle, palpation of the trapezius, the paracervical area, the supraclavicular area, the area around the clavicle, and the infraclavicular area of the upper chest should be carefully and sequentially palpated to elicit tenderness or irritation symptoms. The axilla should be palpated, and any radiating pain should be noted. The shoulder girdle should be tested for range of motion, instability, and impingement. Any pain should be noted.

Provocative tests for the thoracic outlet syndrome (TOS) such as Wright's maneuver, Adson's maneuver, and overhead fisting should be performed. Thoracic outlet syndrome is a very commonly diagnosed condition in my clinical practice. Because of the lack of good diagnostic tests for this condition, I find that the condition of TOS is often overlooked. TOS is the cause for many patients to have arm and hand symptoms that can mimic or exist in conjunction with carpal tunnel syndrome.

The elbow exam is extremely important in these patients. There are many conditions about the elbow that cause pain and disability that can mimic carpal tunnel syndrome. Direct palpation of the elbow with particular attention to the biceps insertion anteriorly, the medial epicondyle, the lateral epicondyle, and posteriorly the olecranon should be performed. Tenderness about the elbow with epicondylitis is another common clinical scenario seen in my practice.

Nerve compression about the elbow and forearm that does not involve the median nerve can cause significant symptoms. The cubital tunnel is located between the medial epicondyle and the olecranon tip, on the posteromedial side of the elbow. It is a common site of compression and in fact is the no. 2 upper extremity compressive diagnosis. A positive Tinel's sign, or sensitivity to palpation, or nerve subluxation with elbow flexion and extension, or increase in symptoms with elbow flexion, is a maneuver that should be performed by the clinician. The medial epicondyle may be tender to palpation either on the bony prominence or slightly distally at the muscle belly of the flexor-pronator mass. As the ulnar nerve enters the forearm between the heads of the flexor carpi ulnaris, provocative or resistive testing of the flexor pronator muscles including the flexor carpi ulnaris is recommended.

On the lateral side, lateral epicondylitis is a common condition that may or may not be related to sports activities or repetitive use. The tenderness may be on the lateral epicondylar ridge itself or more distally in the supination/extension muscle group.

On the lateral side, the radial nerve courses around the head and neck of the radius bone and between the heads of the supinator muscle. Compression of the radial nerve should always be evaluated. Radial tunnel syndrome is another condition that should be carefully assessed by the clinician. Tenderness several centimeters distal to the lateral upper condyle to deep palpation and/or a positive Tinel's test is an indicator of this condition. Provocative testing of wrist extension against resistance can be positive with radial tunnel syndrome. More fulminant radial nerve compression can result in motor weakness in the radial nerve-supplied muscles. These two entities, lateral epicondylitis and radial tunnel syndrome, can exist together.

In terms of the forearm, the volar forearm should not be neglected. Tenderness of the flexor pronator muscles either coming off the medial upper condyle on the medial side of the elbow or in the midline of the volar aspect of the forearm in supination

and the proximal one third can be associated with pronator syndrome. This is a compressive neuropathy of the median nerve proximal to the wrist. This can exist alone or in conjunction with traditional carpal tunnel syndrome at the wrist.

At the wrist itself, all flexor tendons and all extensor tendons should be inspected and palpated in their compartments for tenderness or crepitus or swelling. Any of these structures can have a tenosynovitis associated with them. Of course the most common is the first dorsal compartment, or de Quervain's tendinitis, but flexor carpi ulnaris and flexor carpi radialis tendinitis are common. Extensor carpi ulnaris, flexor digitorum communis, and extensor carpi radialis brevis and longus tendinitis are all additional clinical entities that can cause pain and require treatment including surgery.

In the hand, inspection should be performed for any sign of thenar atrophy. Basal joint arthritis or other radial-sided bone and joint deformities can "mimic" thenar atrophy. Having the patient touch the thumb to fifth fingertip allows evaluation of both the thenar and the hypothenar muscle bulk and strength; this also tests aspects of ulnar nerve motor function. Intrinsic muscle testing by crossing the fingers should be carried out to further test ulnar nerve motor function.

The palm should be palpated for trigger finger or tendinitis or A1 pulley fullness. Digital flexion and extension should be performed actively and then passively to further check for flexor tenosynovitis/trigger finger.

Sensory examination using two-point discrimination, Semmes-Weinstein monofilament, vibrometry, texture discrimination, etc. are important for defining the anatomical distribution of any sensory changes that may be present. According to the American Academy of Orthopaedic Surgeons, sufficient evidence does not exist from the literature to recommend one test over another or to suggest the overall utility of a test in diagnosing carpal tunnel syndrome. Manual muscle testing of the upper extremity including evaluation for obvious muscle atrophy is important especially for the thenar muscle area. I recommend grip and pinch strength measurements bilaterally for all of my patient evaluations. The presence of thenar atrophy has a high predictive value in carpal tunnel syndrome, but its appearance can be rare [7].

Provocative Tests

There are several provocative tests that should be considered to aid in the evaluation and diagnosis of carpal tunnel syndrome. The Tinel's sign (Fig. 4.1) involves percussion over the median nerve along its pathway from the forearm to the wrist in the proximal to distal direction.

Where Tinel's sign is positive, paresthesias are elicited in the median nerve distribution. The Tinel's sign, however, is diagnostically valid in a percentage between 58% and 67% of the cases of patients whose electromyographic tests are positive; in 20% of the cases, instead, Tinel's sign may be positive in the absence of compression disease [5]. It is important to do Tinel's testing from the axilla to the wrist on both sides to avoid a "false-positive" test at the carpal tunnel.

Another important test is Phalen's test (Fig. 4.2). This is done by holding the wrist in maximal flexion for up to 60 s: if a sensation of numbness as well as paresthesia on the first three fingers occurs within that time, it is considered diagnostic.

Phalen believed that this was due to compression of the nerve between the proximal edge of the transverse ligament and the adjacent flexor tendons. This has been validated by several modern studies. It has been demonstrated that

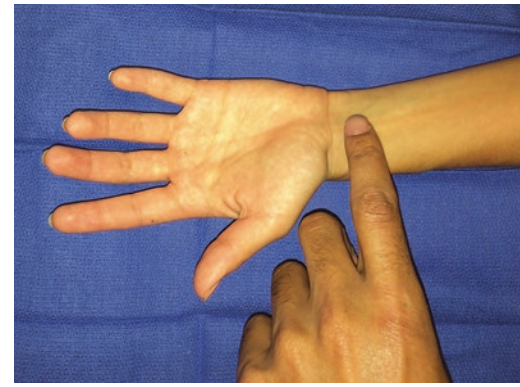

Fig. 4.1 Tinel's sign involves percussion over the median nerve

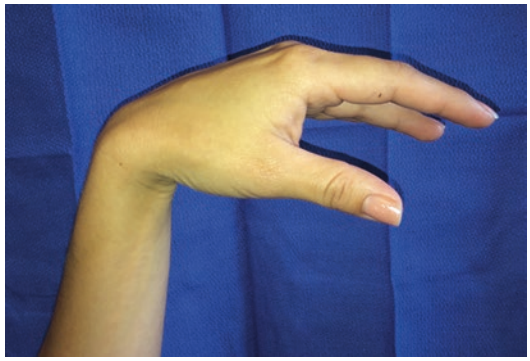

Fig. 4.2 Phalen's test is done by holding the wrist in maximal flexion for up to 60 s. Numbness and paresthesia on the first three fingers is considered diagnostic

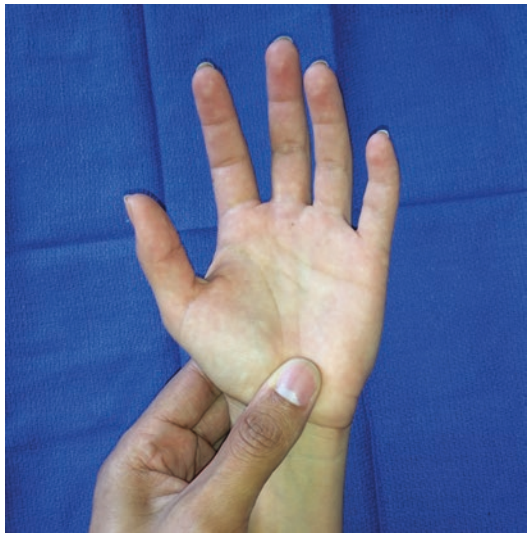

Fig. 4.3 The carpal compression test will elicit paresthesia in the territory of the median nerve distribution when the physician applies pressure for up to 30 s

Phalen's test is positive in 66–88% of the patients with CTS, even if it can be positive in almost 20% of normal patients. A positive response obtained by combining Phalen's and Tinel's test is diagnostically important insofar as it identifies close to 90% of positive patients with CTS [8, 9].

A third important test is the compression test (Fig. 4.3) of the median nerve, described by Durkan [10]. This test involves evaluating the onset of paresthesia in the territory of median nerve distribution when the physician applies pressure with his thumb at the level of the carpal tunnel for up to 30 s.

Durkan reports that this test is positive in 87% of patients with CTS. Williams [11] reports that this test is positive in 100% of patients.

Sensibility Testing

The most widely used test is Von Frey's pressure test with Semmes-Weinstein monofilaments. This test involves perpendicular application on the fingertips of monofilaments with different thicknesses; the amount of pressure applied is just enough to obtain flexion of the filament: the test is positive when the patient correctly identifies the stimulated finger. During a study carried out on a series of patients with CTS, Von Frey's test proved to be significant in 52% of the cases, while Weber's two-point discrimination test was significant only in 30% of the cases.

Another threshold test is the vibration test described by Szabo et al. [12]. Just as the ability to discriminate between two points deteriorates with age, so does the perception of vibrations in the threshold value with aging has not been defined. Sensitivity evaluation tests must prove to be altered only in the territory of distribution of the median nerve. Therefore, if extension of hypoanesthesia to the palm is present, the involvement of the sensitive palmar branch (originating proximally to the transverse ligament) should be suspected, and further differential diagnostic evaluations should be undertaken.

Atrophy

Examination of the muscles of the hand to screen for thenar atrophy or weakness is recommended. Thenar prominences are thenar muscles innervated by the motor branch of the median nerve which arises from the nerve where it emerges from the carpal canal; however, there is ulnar innervation of a portion of the flexor pollicis brevis. Concomitant or confounding basal joint of thumb arthritis must be considered.

To test that of the thumb's abductor pollicis brevis muscle (Fig. 4.4), the patient is asked to place the first finger perpendicular to the palm

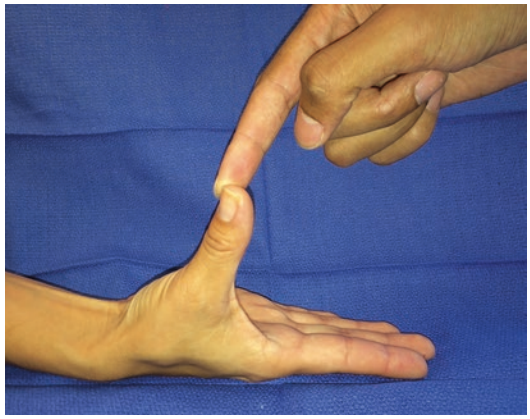

Fig. 4.4 Testing the abductor pollicis brevis muscle requires placing the patient's first finger perpendicular to the palm; pressure is exercised directly in the adducted direction

and to resist pressure exercised, directly in adducted direction, on the distal phalanx.

Position and force are compared to the other hand. With a weak short abductor, the first digital ray can be abducted with the APL, which is innervated from the radial nerve, and can be brought toward the palm with the long flexor which is innervated by the median nerve proximally to the carpal tunnel. The position of the thumb will facilitate flexion of the IP joint. However, the patient will not be able to position the thumb at a full 90° from the palm's surface if there is a median nerve motor deficit.

The opposition function (Fig. 4.5) can be tested by having the patient touch the tip of the thumb to the tip of the fifth finger.

The patient is asked to resist, while the examiner is trying to separate the two digits. All the thenar muscles are tested, and the opponens pollicis muscle is the primary contributor to this motion and function.

Lastly, hypotrophy or atrophy of the thenar muscle may be a result of chronic nerve compression. In rare cases, this finding may be the most prominent characteristic of carpal tunnel syndrome.

Sensitivity and Specificity of Tests

No one test has been identified as a "gold standard" for identifying carpal tunnel syndrome. In several studies, Phalen's sign ranged in sensitivity from 0.46 to 0.80 and in specificity from 0.51 to 0.91 [13–16]. Tinel's sign ranged in sensitivity from 0.28 to 0.73 and in specificity from 0.44 to 0.95 in several studies [7, 14–16]. The median nerve compression test ranged in sensitivity from 0.04 to 0.79 and in specificity from 0.25 to 0.96 in several studies [14, 16, 17]. Combining the results of more than one provocative test increases the sensitivities and specificities of the testing. For example, in one study, combined results of Phalen's and median nerve compression tests yielded a sensitivity of 0.92 and a specificity of 0.92 [16]. Reverse Phalen's, tethered median nerve stress test and the tourniquet test have been evaluated only a few times, leaving insufficient evidence to draw any conclusions as to their accuracy in the diagnosis of carpal tunnel syndrome [7, 14, 15]. The clinical tests for carpal tunnel syndrome by themselves do not reliably diagnose carpal tunnel syndrome. Similarly, electrodiagnostic studies by themselves also do not reliably diagnose carpal tunnel syndrome. However, when the symptoms, clinical tests, and electrodiagnostic tests are combined, statistical significance ($p < 0.05$) is obtained when compared

Fig. 4.5 The thenar and opponens pollicis muscle can be tested by having the patient touch the tip of the thumb to the tip of the fifth finger and resist as the physician tries to separate the two digits

to postsurgical outcomes. Some of these studies have looked at:

- Motor and sensory tests + distal motor latency of the median nerve, antidromic sensory nerve conduction velocity, EMG examination of abductor pollicis brevis [1, 18]
- Range of motion, grip strength, pinch strength, monofilament sensory evaluation, Phalen's, Tinel's + sensory latency over 3.5 ms [1, 4]
- Phalen's or Tinel's + motor latencies > 4.0 ms, sensory latencies > 3.7 ms, amplitudes < 20 μV, or a conduction velocity < 50 m/s with evidence of fibrillation [1, 13]
- Sensory tests + prolonged median sensory conduction velocity, distal motor latency to abductor pollicis brevis [1, 5]

I routinely use Phalen's, Tinel's, and carpal tunnel compression (Durkan) tests in the office. I note any thenar atrophy and do basic sensibility testing to light touch and two-point discrimination.

Summary The clinician should be knowledgeable about the range of presentations, typical and atypical, for carpal tunnel syndrome and also the various other upper extremity conditions from which carpal tunnel syndrome should be distinguished. Skillful history taking should be coupled with a broad general neck to fingertip exam with appropriate specialized tests.

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