

A Review of the Carpal Tunnel Syndrome: Clinical and Diagnostic Aspects

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ABSTRACT

Carpal tunnel syndrome (CTS), an entrapment neuropathy of the median nerve, is a frequent diagnosis in the neurodiagnostic laboratory. The diagnosis of CTS requires a combination clinical history, physical examination and objective electrodiagnostic tests. While many electrodiagnostic techniques have been devised to improve the diagnosis of this syndrome, there is no agreement on the diagnostic yield of these different techniques. This review addresses clinical aspects and different neurodiagnostic techniques that help to improve diagnostic yield of this syndrome. The relevance of newer radiological diagnostic techniques is considered briefly.

Keywords: carpal tunnel syndrome, imaging, median nerve, nerve conduction study

INTRODUCTION

Carpal tunnel syndrome (CTS) is due to entrapment of the median nerve under the flexor retinaculum as it passes through the carpal tunnel. It is the most commonly encountered mononeuropathy in clinical practice.¹ Accurate diagnosis requires relevant history, physical examination and appropriate investigations. There is no consensus on the superiority of one technique over another. Hence, familiarity, reproducibility and availability may be relevant factors affecting the choice of diagnostic methods.

ANATOMY

The median nerve is formed from divisions of both lateral and medial cords. Its sensory fibres are derived from C6 to C8 dorsal root ganglion and its motor fibres from C6 through T1 anterior horn cells. Overall, most of its sensory fibres traverse the lateral cord whereas most of its motor fibres traverse the medial cord, except fibres innervating the flexor carpi radialis and pronator teres which traverse the lateral cord. The median nerve enters wrist through the carpal tunnel, which is formed by carpal bones on 3 sides and roofed by the thick transverse carpal ligament.

CLINICAL FEATURES

CTS is probably the most common entrapment neuropathy affecting human beings. It is more frequent in women than in men.² The dominant hand is more severely affected. It is often involved bilaterally. Common complaints include paraesthesia, tingling, or numbness associated with wrist pain, often radiating to the arm but rarely the shoulder. Symptoms are aggravated by strong gripping actions. In severe cases, even driving or writing may aggravate symptoms. The typical symptoms of CTS can be reproduced with Tinel's sign, Phalen's test, manual carpal compression test (mCCT) of Durkan or the closed fist test, which serves to narrow the diameter of the carpal tunnel.^{2,3} In severe cases, wasting of the thenar eminence and weakness of the abductor pollicis brevis, opponens pollicis and flexor pollicis brevis may be evident.

The "hand ratio" is a simple and useful predictive measurement advocated in determining the tendency for CTS. The hand configuration likely to develop carpal tunnel syndrome has been reported by Chroni *et al.*⁴ When external hand dimensions of normal controls and subjects with CTS were measured, it was found that the palm length and third digit length were

Table 1. Major internal comparison studies for CTS.^{14,15}

Study	Nerve	Stimulation	Recordings	Distance	Significant Difference
Palmar-mixed	Median	Median palm	Median n at wrist	8 cm	>0.4msec
	Ulnar	Ulnar palm	Ulnar n at wrist	8 cm	
Digit 4 sensory	Median	Med n at wrist	Digit 4	12 cm	>0.5msec
	Ulnar	Ulnar n at wrist	Digit 4	12 cm	
Lumbrical-Interossei	Median	Med n at wrist	2 nd Lumbrical	10 cm	>0.5msec
	Ulnar	Ulnar n at wrist	Interossei	10 cm	
Digit I Sensory	Median	Med n at wrist	Digit I	10 cm	>0.5msec
	Radial	Radial n at wrist	Digit I	10 cm	

n: nerve

significantly shorter and the palm width larger in subjects with CTS compared with controls. Regression analysis demonstrated that the hand ratio [(palm + third digit length)/palm width] was significantly correlated with median nerve conduction measurements.

Most cases of CTS are attributed to repetitive mechanical insults, tenosynovitis of transverse carpal ligament, oedema, and fibrosis of the carpal tunnel. These processes lead to demyelination and axon loss in the median nerve in severe cases. There are multiple systemic diseases associated with CTS, the most common of which are hypothyroidism, acromegaly and diabetes mellitus. Other causes include connective tissue disease and tumours including ganglions, lipomas, schwannomas, neurofibromas and haemangiomas. Persistent median artery, congenital small carpal tunnel and anomalous muscles are known congenital causes. A case of amyloidosis has been reported as a cause of CTS.⁵

ELECTRODIAGNOSIS

Electrodiagnosis is useful for confirming CTS diagnosis, assessing severity and follow-up.⁷ Many techniques have been described to improve the diagnosis of CTS but there is no well-accepted agreement on the diagnostic yield of the different techniques.⁸ Complaints of tingling and numbness in the upper limbs are commonly reported in the general population and these symptoms correlate poorly with the changes of nerve conduction studies of the median nerve. CTS is more definitely diagnosed only when typical symptoms are associated with significant electrophysiological abnormalities.¹¹ A variety of techniques have been developed to further increase the sensitivity in the electrodiagnosis of CTS.

Most studies have found the comparison of the median and another adjacent nerve as an internal control helpful. Its advantages are:

1. Axons of each nerve are of similar diameter;
2. Temperature is comparable for each distal nerve segment and muscle; and
3. Identical distances are used, allowing direct comparison of distal latencies.

These techniques create a good internal control for carpal tunnel studies where several variables are kept constant (distance, temperature and the size of the muscle and/or nerve). These techniques are reported to increase the sensitivity of diagnosis from 75 to 95%. Major internal comparison studies for CTS diagnosis are summarised in Table 1. The "Inching Test" is employed as a short segment incremental median sensory nerve conduction across the carpal tunnel recording from the third digit. Though less sensitive, it has the advantage of localising focal abnormalities of the median nerve along the carpal tunnel.^{8,9}

The amplitude of the evoked median and ulnar sensory action potential can be measured and 3 amplitude criteria have been postulated.¹² These are: median sensory nerve action potential of less than 20mV; side-to-side median-to-median amplitude percentage of less than 50%; and median/ulnar amplitude of less than 80%. CTS can be diagnosed when any one of these criteria is met. In CTS, motor nerve conduction velocity proximal to the wrist has been reported to be reduced to the degree of severity of the nerve lesion.¹³ Evoked nerve action potential is significantly reduced when recordings are made from the median nerve at the elbow and when the compound nerve is stimulated proximal to the lesion at the wrist. The extent of

retrograde changes correlated with the degree of severity and duration of nerve compression. Measurement of the evoked nerve action potential in the proximal nerve segment enables us to estimate the extent of retrograde nerve fibre degeneration and might therefore be important for prognosis. Antidromic sensory conduction and segmentary motor conduction of the median nerve, along with the median and ulnar sensory latency difference, was shown to have a high yield in the electrophysiological diagnosis of CTS in a study of 921 hands with clinical manifestations of CTS.¹⁰

A study of the supramaximal stimulation of the entrapped median nerve was undertaken to characterise the backfiring behaviour of the alpha motor neuron pool of the abductor pollicis brevis. A contraction of the normal subpopulation of active F-wave generators was found in CTS, while active neurons backfired at higher than normal frequencies. These modifications in spinal behaviour are reflected in the percentage of sensory wrist-to-palm latency estimation.¹⁸

Comparison of distal sensory latencies for the median and radial nerves has been found to be an effective, quick and simple procedure for increasing the sensitivity of electrophysiological diagnosis of CTS.¹⁶ Electromyography (EMG) of various myotomes, as well as proximal and distal muscles, remains quite useful in helping to assess other clinically suspected differentials such as plexopathy, radiculopathies, and proximal nerve entrapments.¹⁷ Thenar EMG can provide crude approximation regarding the degree of axonal loss.

Two new computer-controlled functional tests, known as the Wisconsin test battery, has been developed. The gap detection sensory test quantifies tactile thresholds for areas of the hand innervated by the median nerve. The rapid pinch and release psychomotor test measures the initiation and control of specific muscles innervated by the median nerve motor branch. In a study by Jeng *et al*, CTS patients showed significant functional deficits for both tactility and psychomotor tests.²⁰ These results indicated high correlation between median nerve electrophysiological parameters and tactility or psychomotor performance variables.

Vibrometry has been demonstrated to be an effective adjunct to electrophysiological evaluation of nerve integrity in diffuse peripheral neuropathies but as CTS is primarily a demyelinating process, it can be easily detected by nerve conduction study (NCS). Vibration threshold sensation is related to axonal loss, hence it may not be sensitive for early CTS diagnosis.²¹

NEW TECHNIQUES

Although CTS is usually diagnosed based on the clinical features and NCS, radiologic imaging has an important role in equivocal, recurrent cases or failed cases of CTS release surgery patients. High-resolution ultrasonography (US) and magnetic resonance imaging (MRI) allow the direct visualisation of the compressed median nerve and other soft tissue structures within the carpal tunnel. Due to its excellent contrast resolution, MRI is superior in detecting mild degree of nerve compression and also the potential causes like tenosynovitis of the flexor tendons or space occupying lesions.

However, due to US's low cost, easy availability and rapidity, the use of this technique as the initial imaging technique in evaluation of CTS is favoured.²² US demonstrates partial rupture, synovitis and nodular deposits such as tophi, amyloid or pannus better than MRI.²³ US is a very precise method for displaying the anatomy of the carpal tunnel and the median nerve.²⁴ In CTS, the surface of the median nerve exceeds 15mm².²⁵ There is a report of a rare case of CTS caused by accessory head of palmaris longus muscle of a soft tissue appearance which was diagnosed by US and later confirmed intra-operatively and by histopathology.²³ CTS can be identified by US less sensitively but more specifically than by NCS.²⁶

When electrodiagnostic techniques are inconclusive, MRI may be helpful. The median nerve, flexor retinaculum, retrotendinous fat, flexor tendons, thenar space, muscles and bones of the wrist are evaluated. Only retinacular bowing and increased T2W signal intensity within the median nerve are significantly related to the diagnosis of CTS. Retinacular bowing indicates increased "pressure" within the compartment (mechanical compression of the nerve) while increased T2W signal of the median nerve indicates nerve compression. These findings correlate well with more severe cases based on clinical and NCS findings.⁶ Imaging of the median nerve has the additional advantage of direct visualisation of structural abnormalities and tumour within the carpal tunnel.

Three major MRI criteria for early CTS are (a) isolated prestenotic and intracarpal swelling of the median nerve; (b) the absence of significant flattening; and (c) a generalised increase in signal intensity retrograde to the distal radius. The nerve shows sharply delineated contours and a homogeneous signal pattern. Advanced CTS is characterised by retrograde swelling of the median nerve to the distal radius, decreased signal intensity and demarcation of nerve becoming poorer. Its signal pattern appears fasciculated.²⁷

CONCLUSION

CTS is often a clinical diagnosis. The availability of electrodiagnosis and radiological techniques lends supportive evidence for making an objective assessment. However, these measurements should be interpreted in relation to the patient's clinical features.

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