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CARPAL TUNNEL SYNDROME: A REVIEW

Neurology

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ABSTRACT

Carpal tunnel syndrome is the most common entrapment neuropathy. Symptomns and signs are caused by compression of the median nerve in carpal tunnel. Disorder is commonly diagnosed clinically and is supported by electrodiagnostic studies as objective method of diagnosis. There has been recent development of nerve imaging in diagnosis, but their exact benefit is still unknown. There also has been development of wide treatment options including both non-surgical and surgical. This review addresses the carpal tunnel syndrome in detail including recent developments in diagnosis and treatment.

KEYWORDS

Carpal tunnel syndrome, median nerve, entrapment neuropathy

INTRODUCTION

Entrapment neuropathies are the most frequent mononeuropathies encountered in clinical practice. Carpal tunnel syndrome (CTS) is the most frequent entrapment neuropathy of upper limbs. It refers to a complex of symptoms and signs caused by compression of the median nerve as it travels through the carpal tunnel.[1-5] Different perspectives with different methods have been used to approach CTS. This variation is because of its high incidence, its tendency to be symptomatic even in mild cases, availability of sensitive electrophysiological measures, and novel nerve imaging techniques, and availability of several therapies ranging from non-surgical to surgical management. Moreover, it is a cause of significant disability and hence a timely diagnosis and proper treatment is necessary.

HISTORICAL PERSPECTIVES

The first clinical description of median nerve compression in carpal tunnel was given in 1854, when Paget[6] published two cases of compression of median nerve within carpal tunnel, one idiopathic and one post-traumatic. In his report, he also noted efficiency of splint to treat the condition. Later, Putnam[7] published the first case histories on 37 patients, most of them women, who all had the same symptoms in common: " a disturbance of the subjective sensibility of the skin, giving rise to what is known popularly as numbness, recurring periodically, coming on especially at night or very early in the morning,…in some cases simply letting the arm hang out of the bed or shaking bit about for some moments would drive the numbness away". These words clearly correspond perfectly to the present-day clinical description of CTS. Marie and Foix[8] in 1913, published an article which contained a splendid anatomopathological description of the structural alterations involving the median nerve after carpal tunnel compression. In 1933, Learmonth[9] described surgery for carpal tunnel syndrome in case of post traumatic compression. However, first description of an operation for idiopathic CTS was published in 1946[10]. Brain[11] was the first to state that idiopathic compression of the median nerve was very frequent , and hypothesized it as age-related "vascular degeneration" involving ischaemia of the nerve, with consequent reactive oedema. This in turn aggravated compression of the nerve itself, initiating a vicious circle, and concluded that early surgical treatment was necessary to interrupt it. However, it's because of Phalen[12-14] that the knowledge of CTS became well known in the medical field. Phalen published a series of articles in which he clearly described epidemiology, the clinical picture, diagnostic tests (including one named after him) and, and recommended surgical treatment.

Gilliatt and Wilson[15] published a description of the tourniquet test in 1953, supporting diagnosis of CTS, and the first paper on use of electromyography for this appeared in 1956[16] . CTS was finally definitely characterized at the end of the 1950s, and since then research on CTS has become very extensive, stimulated by the enormous impact of the syndrome in terms of healthcare and costs.

EPIDEMIOLOGY

Estimated prevalence of CTS in general population ranges from 1 to 5 percent. It is more frequent in women (0.7 to 9.2 percent) than in men (0.4 to 2.1 percent). Prevalence of CTS appears to be highest in obese women and lowest in thin and normal-sized men. The female-to-male ratio for its prevalence is approximately 3:1.[17-24]

PATHOPHYSIOLOGY OF CTS

Peripheral nerve entrapment occurs as a result of its passage through an anatomical compartment that has become too tight, resulting in altered function within the nerve from the site of compression and beyond. The most common example of this is median nerve entrapment in carpal tunnel at wrist. The available literature indicates a combination of several pathophysiologic mechanisms responsible for abnormal intraneural microcirculation, lesions in the myelin sheath and the axon, as well as alterations in the supporting connective tissue.

a. Compression and increased carpal tunnel pressure. Dramatic changes of the fluid pressure in the carpal tunnel have been reported with wrist movement, with wrist extension increasing the pressure by 10-fold, and flexion increasing it by 8-fold.[25] This is thought to cause ischemic compression of the median nerve, and a number of experimental studies support this theory.
b. Median nerve microcirculation injury. Ischemic vascular injury and breakdown in the blood-nerve barrier have also been identified as an essential component in CTS. An increase in pressure within the tunnel can cause a breakdown of vasculature within blood-nerve barrier, causing an accumulation of proteins and inflammatory cells.[26] This may induce a miniature closed compartment syndrome by increasing the permeability, contributing to increased endoneurial fluid pressure and development of an intra-fascicular edema. [27] Patients with vascular problems and prolonged exposure to static loading are particularly prone to a breakdown in the blood-nerve-barrier. [28]
c. Median nerve connective tissue alterations**.** Nerve fibres have layers of connective tissue surrounding it. The extensibility of this layer is critical to nerve gliding , which is necessary to accommodate joint motion; otherwise, nerves are stretched and become injured.[29] It is estimated that in normal subjects, median nerve at wrist can move up to 9.6 mm between full flexion and extension of this joint but in the presence of stiff surrounding connective tissue, this is limited and exposes nerve to shearing forces that could lead to injury. [30]
d. Synovial tissue hypertrophy. Hypertrophy of the synovial tissue of the flexor tendons can also increase pressure within carpal tunnel and result in the development of CTS. [31]

RISK FACTORS

There are certain risk factors that have been associated with CTS. Most significant are environmental factors. Prolonged postures in extremes of wrist flexion or extension, repetitive use of the flexor muscles, and exposure to vibration remains the primary exposures that

have been reported. Hence an increased occurrence is being seen in people working on computers, with excessive use of the mouse.[32-35]

Medical risk factors could be extrinsic, intrinsic and neuropathic. Increase in the tunnel pressure is defined as extrinsic which could be due to conditions that alter the fluid balance in the body like in pregnancy, menopause, obesity, renal failure, hypothyroidism, the use of oral contraceptives and congestive heart failure or factors that change the contour of tunnel as in fractures of distal radius and post traumatic arthritis. Intrinsic factors are those that increase the volume of the nerve like tumours and tumour-like lesions. The factors that lower the threshold for nerve damage are classified as neuropathic factors such as diabetes, alcoholism, vitamin toxicity or deficiency, and exposure to toxins.[26]

CLINICAL FEATURES

CTS is characterisd by pain in hand, unpleasant tingling or numbness in the distal distribution of median nerve (thumb, index, middle finger and the radial side of ring finger), and a reduction of the grip strength and function of the affected hand. Symptoms tend to be worse at night, and clumsiness is reported during day with activities requiring wrist flexion . Patients often describe a phenomenon "flick sign", in which shaking or flicking their wrists relieves symptoms. [36-39]

CTS can be classified on the basis of symptoms and signs into three stages:
Stage 1: Patients have frequent awakenings during night with sensation of numb hand. They report severe pain that can irradiate from wrist to shoulder, and an annoying tingling in hand and finger. Hand shaking relieves the symptoms. During morning, a sensation of hand stiffness usually persists.

Stage 2: Symptoms are also present during the day, mostly when patient remains in the same position for a long time, or performs repeated movements with their hand. When motor deficit appears, patient reports that objects often fall from his/her hands because they are unable to feel their fingers anymore.

Stage 3: Final stage in which atrophy (wasting) of the thenar eminence is evident, and there is poor response to surgical decompression. In this stage, sensory symptoms may diminish . There is also aching in thenar eminence, and with severe compression, weakness and atrophy of the abductor pollicis brevis and opponens pollicis. [40-43]

DIAGNOSIS

Clinical assessment is considered the gold standard in diagnosis of carpal tunnel syndrome. A thorough case history should be taken which must focus on the following [44]:

symptom onset - which in early stage is mainly nocturnal paraesthesias.

provocative factors - hand positions and repeated movements.

working activity - instrument , vibrating tools use
pain localisation and irradiation - in the cutaneous median nerve region with ascending, sometimes up to the shoulder, or descending irradiation.

manoeuvres which alleviate symptoms - e.g. hand shaking, position changes.

presence of predisposing factors - e.g. diabetes, adiposity, chronic polyarthritis, myxoedema, sports activity - e.g. baseball, body-building.

Two commonly used provocative test are Phalen's and Tinel's tests. In Phalen's [31] test, patient is asked to flex their wrist and keep it in that position for 60 seconds. A positive response is if it leads to pain or paraesthesia in the distribution of median nerve. Its sensitivity is in the range of 67% to 83%, while specificity ranges between 40% and 98% [45-47]

Tinel's test is performed by tapping over the volar surface of wrist. A positive response is if this causes paraesthesia in the fingers innervated by the median nerve: thumb, index, middle finger and the radial side of the ring finger. [41] It has a sensitivity of 48% to 73% and specificity is 30% to 94%.[45-47] These significant variations in these values may be attributed to the fact that there are substantial inconsistencies in the method of examination and interpretation of the results.

Controversies exist regarding the need for confirmatory testing and the role of nerve conduction studies, electromyography, and nerve ultrasonography in treatment decision making.

NERVE CONDUCTION STUDIES

NCS is considered to be the gold standard as an objective test in the diagnosis of CTS because it provides information on the physiological health of the median nerve across the carpal tunnel. The standard method of diagnosis is comparing the latency and amplitude of a median nerve segment across the carpal tunnel to another nerve that does not go through the carpal tunnel, such as ulnar or radial nerve. The nerve is stimulated by a transcutaneous pulse of electricity, inducing an action potential in the nerve. A recording electrode, placed either distally or proximally, detects wave of depolarization as it passes by the surface electrode. [48] It is more accurate to compare the median nerve response to another nerve response that does not travel through the carpal tunnel, as opposed to using 'normal' values for the amplitude and latency of individual nerves as many factors may influence the amplitude and latency of an individual nerve, giving a false positive or false negative result. Such factors include age, gender, finger diameter, concurrent systemic disease, obesity and temperature. [49-51]The use of a relative comparison of two nerve segments controls these factors. This is the most sensitive as well as accurate technique, with a sensitivity of 80- 92% and specificity of 80-99%. [48]

However, false negative and false positives [52,53] can still occur due to lack of a standardized diagnostic criteria, resulting in 16-34% of clinically defined CTS being missed with NCS [54]. Blanket referrals for NCS remains an expensive and inefficient approach to the diagnosis of CTS. [55] Another issue to be considered is the fact that many studies have reported that NCS does not change the probability of diagnosing CTS, emphasising importance of clinical history and examination [56]

Ultrasonography Of Wrist

In clinical practice, electro-diagnostic (EDX) test is the most common and reliable evaluation method for carpal tunnel syndrome. However, it is uncomfortable, doesnot provide anatomic information, also has a limitation of being false negative in early stages.

Ultrasonography is a non-invasive, easily accessible diagnostic tool and also provides spatial information and hence is helpful in patients requiring injectable local corticosteroids. It is also helpful to rule out external median nerve compression by ganglia, tumors and tenosynovitis. Patients who have to undergo surgery for carpal tunnel morphological information about median artery can also be obtained. Also postoperative complications like hematoma, scarring or insufficient resection of retinaculum can be visualized by ultrasonography. [57]

Direct Sonographic signs of CTS

According to the pathophysiologic concept of CTS, median nerve compression causes changes of nerve caliber: at the site of maximum nerve compression the nerve gets flattened and above this region it is swollen because of vasocongestion with increase in endoneurial fluid and localized edema. This change in nerve size has long been used as a single measure for the sonographic definition of CTS. [57] Buchberger [58] et al. were the first to describe the use of four distinct measurements for the diagnosis of CTS: Increased flattening ratio of the median nerve measured at the level of the hook of the hamate. Increased cross-section area at the level of the pisiform bone and to a lesser extent at the level of the hook of the hamate. Significantly increased cross-section area at the level of the pisiform bone compared with the cross-section area at the level of the distal radius, Significant bowing of the retinaculum.

Cross sectional area of median nerve

The cross-sectional area of the median nerve is measured with ultrasound equipment by use of a continuous boundary trace or ellipsoid calculation and its value for the diagnosis of CTS has been subject of thorough clinical investigation. There is some debate regarding where to measure the median nerve, with some investigators advocating measurement of the nerve at the level of the pisiform bone, some under the proximal edge of the retinaculum (i.e., the carpal tunnel inlet) , while others suggest at the level of the maximum cross-section area along the carpal tunnel. There is still no general agreement on cutoff value to differentiate normal subjects from patients, or mild CTS

from severe CTS. Normal values for median nerve cross-sectional area have been reported from 7 to 9.4 mm^2 , and the values for diagnosing CTS from 9 to 15 mm^2. These quite profound differences in the literature are due to differences in measurement technique and study populations. The sensitivity of ultrasonographic measurements also varies widely among studies. The sensitivity of the CSAs ranged from 48% to 89%.[57]

Flattening ratio

The flattening ratio (FR) is defined as the ratio of the nerve's transverse axis to the antero-posterior axis and is assessed at the level of the pisiform bone. Sensitivities of FR ranged from 37% to 100%. In a study by Kim et al, the AUC of FR was 0.74 at cut off value of 3.4 indicating a sensitivity and specificity of 77.8% and 50.0% respectively.[59]

Palmar bowing

The palmar bowing (PB) of the flexor retinaculum is displacement (measured in mm) of the retinaculum from the attachments of a ligament connecting the pisiform bone with the scaphoid bone. The sensitivities of increased PB of the flexor retinaculum varied from 40% to 81%. In a study by Kim et al, The AUC of PB was 0.94 at cut off value of 3.0 mm indicating a sensitivity and specificity of 87.2% and 93.3% respectively.[59]

Although useful, ultrasound has its own limitations. Sensitivity varies among different studies, exact cut-off value is not defined, is operator dependent and donot assess functional severity.

MAGNETIC RESONANCE IMAGING

Magnetic Resonance Imaging (MRI) is helpful for picking up rare pathological causes of CTS such as ganglion, haemangioma or bony deformity, presence of which may alter treatment. [60] Further, sagittal images are helpful in showing the site accurately and allows determination of severity of nerve compression with sensitivity of 96%. However, specificity remains low 33-38% .[61]

MRI is also able to predict patients who would benefit from surgical intervention, because the length of the abnormal nerve signal on T2-weighted MRI and median-ulnar sensory latency difference are good predictors of surgical outcome . However, results do not correlate well with patients perceived severity of symptoms, mainly because MRI provides anatomical information as opposed to information on nerve impairment and function.[62]

Management-

various surgical and non-surgical treatments are available for carpal tunnel syndrome

Non-surgical treatment

The first-line management should include education of the patient.[63] Changes in habits including limitation of heavy work and wrist movement should be considered and use of ergonomically friendly work tools can be useful in reducing median nerve stress. However, there is little adequate evidence about the success of this approach.[64-65]

Musculoskeletal manipulation and splinting

Musculoskeletal manipulation includes massage, exercise, and mobilisation of the wrist joint. Another important approach is the use of devices such as splints. These methods are designed to reduce the mechanical stress due to contact between the median nerve and the surrounding tissues within carpal tunnel. The possible mechanism of splinting and exercises is oedema reduction.[66]The use of a splint for 8 weeks along with a formal education, improved hand function and reduced symptom severity compared with no intervention. [67] However, a meta-analysis has shown that sufficient evidence does not exist to confirm the clinical usefulness of splints.[68]

Laser therapy

Low-level laser therapy exposes tissue to low levels of red and near-infrared light is one of options for treatment of carpal tunnel syndrome. It is able to improve function, symptoms, and electrophysiological measures in the short term; results of a randomised controlled study showed that laser treatment is more effective than placebo, especially if used in patients with mild to moderate disease.[69] In another study, use of the gallium aluminium-arsenide laser with wrist splint showed higher efficacy than placebo laser therapy with wrist splint, especially in improvement of hand grip strength, even up to 3 months after treatment.[70]

Pharmacotherapy

Local corticosteroid injections are commonly used to treat carpal tunnel syndrome. The rationale for the use of this treatment is its ability to reduce oedema, improving spatial relation between the carpal tunnel and the median nerve and tendons. In a randomised trial [71]of 111 patients, methylprednisolone(80 mg or 40 mg) injection into the carpal tunnel was more effective than placebo, reducing symptoms severity as well as rate of surgery at 1 year. However, the effectiveness of corticosteroid for halting disease progression was limited, because three-quarters of patients had surgery within 1 year. The preferred site for local corticosteroid injection has been assessed; in a comparison of distal (palmar) needle insertion with proximal (wrist) needle insertion, the palmar approach proved less painful from the perspective of patients(pain measured by visual analogue scale), however no difference was observed in objective measures, such as nerve conduction findings.[72]

Non-steroidal drugs have been assessed as treatment for carpal tunnel syndrome. Palmitoylethanolamide, a nuclear factor agonist, improved median nerve motor latency, reduced proportion of patients with positive Tinels sign, and reduced symptoms of discomfort compared with placebo. [73] Gabapentin was no more effective than placebo in reducing pain, numbness, paraesthesia, weakness , or nocturnal awakening in a randomized controlled trial. [74] Repetitive local injection of lidocaine resulted in symptom reduction as well as electrophysiological improvement compared with single injection.[75]

Therapeutic ultrasound

Therapeutic ultrasound is based on the hypothesis that mechanical waves interacting with the tissues of the carpal tunnel (including the median nerve) reduces inflammation. No clear evidence about the effectiveness of therapeutic ultrasound exists, but reported results are similar to those obtained with placebo and other non-surgical therapies. [76,77] However, findings from randomised trial suggest that ultrasound therapy is more effective than paraffin therapy, a deep heat treatment that ameliorates local blood flow.[78]

Surgical treatment

Surgical treatment, consists of release of carpal tunnel content by transection of transverse carpal ligament. It is considered the most effective treatment to alter the relation between content (the median nerve and tendons) and container.

Surgical decompression can be done by a traditional open technique (long longitudinal wrist incision and direct visualisation of transverse carpal ligament); by minimally invasive approach (short wrist incision); or by an endoscopic approach. Studies have shown that, in terms of long-term functional outcome, there is no significant difference between open and endoscopic release.

However, some other differences exist. The endoscopic technique shows a shorter postoperative recovery period, reduced scar tenderness, and allows earlier return to work than the open technique.[79,80] However, endoscopic release is more expensive and is associated with higher rates of transient and nerve damage.[81]

CONCLUSION

Although, Carpal tunnel syndrome is well studied entrapment neuropathy, still many questions are unanswered till date. Does confirmation by Nerve conduction studies is necessary? Can ultrasound of wrist (easily available, comfortable) be used as an alternative to Nerve conduction studies (painful) ? What is the best treatment approach ?

In this review, we have tried to provide overview of this condition as well as recent developments in diagnosis and treatment of carpal tunnel syndrome.

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