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REVIEW ARTICLE

Carpal tunnel syndrome and rehabilitation approaches

Karpal tünel sendromu ve rehabilitasyon yaklaşımları

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Abstract

Carpal Tunnel Syndrome (CTS) is the most common type of peripheral nerve entrapment neuropathy, caused by the compression of the median nerve as it passes through the carpal tunnel in the wrist. Clinically, it presents with numbness, tingling, pain, and in advanced cases, motor deficits in the hand and fingers. There are two main approaches to the treatment of CTS: conservative (non-surgical) and surgical. Conservative treatments include wrist splinting, non-steroidal anti-inflammatory drugs (NSAIDs), corticosteroid injections, physical therapy modalities, and alternative therapies such as ultrasound, laser therapy, and exercises. Surgical treatment aims to relieve the pressure on the median nerve through decompression, which can be performed using open or endoscopic techniques. In this review, the etiology, diagnosis, and current treatment approaches for CTS are comprehensively discussed, and the efficacy of treatment options is evaluated in light of current literature and clinical recommendations.

Keywords: Carpal tunnel syndrome, median nerve, conservative treatment, surgical treatment, neuropathy.

Özet

Karpal Tünel Sendromu (KTS), median sinirin el bileğinde yer alan karpal tünelden geçerken sıkışması sonucu ortaya çıkan, periferik sinir tuzak nöropatilerinin en yaygın türüdür. Klinik olarak el ve parmaklarda uyuşma, karıncalanma, ağrı ve motor kayıplarla kendini gösterir. KTS tedavisinde konservatif (cerrahi dışı) ve cerrahi yaklaşımlar olmak üzere iki ana yöntem uygulanmaktadır. Konservatif tedaviler; istirahat atelleri, non-steroid antiinflamatuar ilaçlar (NSAID), kortikosteroid enjeksiyonları, fizik tedavi uygulamaları ve alternatif terapileri (ultrason, lazer, egzersiz vs.) içermektedir. Cerrahi tedavi ise, median sinir üzerindeki basının cerrahi olarak ortadan kaldırılmasını hedefler ve açık ya da endoskopik yöntemlerle gerçekleştirilebilir. Bu derlemede, KTS'nin etiyolojisi, tanısı ve güncel tedavi yaklaşımları kapsamlı şekilde ele alınarak, tedavi seçeneklerinin etkinliği ve güncel literatür doğrultusunda önerilen yaklaşımlar karşılaştırmalı olarak değerlendirilmiştir.

Anahtar Kelimeler: Karpal tünel sendromu, median sinir, konservatif tedavi, cerrahi tedavi, nöropati.

INTRODUCTION

The proximal portions of the five metacarpal bones, the distal extremities of the ulna and radius, and eight carpal bones make up the wrist region's skeletal structure (1). The wrist, which makes up the hand's proximal portion, is where the hand and forearm meet. The arrangement of these bones, which give the wrist its flexibility, creates a concave surface volarly in the transverse plane and a convex surface dorsally. The carpal bones glide over each other when the wrist is moved (2). Alongside the tendons of the forearm muscle group, the median nerve passes through the carpal tunnel. The prominences of the scaphoid and trapezium bones border the carpal tunnel on the radial side, while the pisiform and hamate bones border it on the ulnar side. A structure known as the flexor retinaculum, a transverse wrist ligament, is located on the ventral side between them. The flexor retinaculum is a dense, thick, and wide band of fibrous tissue that extends from the ulnaris to the eminentia carpi radialis. It affixes ulnarly to the pisiform and the hamate hook, and radially to the tubercles of the scaphoid and trapezium bones (3).

At the wrist level, the carpal tunnel is a fibro-osseous tunnel that is surrounded by osseous structures on the dorsal side and fibrous structures on the palmar side (4). This structure contains the median nerve and the tendons of the flexor pollicis longus (FPL), flexor digitorum superficialis (FDS), and flexor digitorum profundus (FDP) muscles (5).

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The median nerve passes between the bellies of the flexor digitorum profundus (FDP) and flexor digitorum superficialis (FDS) muscles in the forearm after emerging from the C5 to T1 spinal nerve roots and moving distally. It becomes more superficial in the distal forearm, extending between the tendon of the palmaris longus (PL) on the dorsoradial side, the flexor carpi radialis (FCR) on the radial side, and the FDS on the ulnar side (6). Motor innervation to the first two lumbrical muscles, sensory innervation to the palmar surface of the thumb, index finger, middle finger, and the radial half of the ring finger, and sensory innervation to the palm and the base of the thenar eminence are all provided by the branches of the median nerve. Furthermore, it supplies sensory innervation to the lateral half of the ring finger outside of the proximal interphalangeal joint, as well as the dorsal surface of the index and middle fingers (7). The median nerve is vulnerable to compression from the inside as well as the outside due to its anatomical arrangement within the carpal tunnel. The main reason for this is that the median nerve is the tunnel's most superficial structure (8).

EPIDEMIOLOGY

In industrialized civilizations, the prevalence of CTS varies from 5% to 15%, while in the general population, it ranges from 0.6% to 3.14%. About 90% of all entrapment neuropathy cases are of this type, making it the most prevalent (9,10). Women are three times more likely than men to have CTS. Men's incidence of CTS climbs with age, but women's incidence spikes following menopause (11). It is often known that women between the ages of 40 and 60 are more likely to have the syndrome (10, 11).

CTS is frequently bilateral, even though it usually first manifests in the dominant hand (12).

ETIOPATHOGENESIS

Localized ischemia brought on by elevated pressure on the median nerve in CTS results in a series of pathological alterations. Three phases can be distinguished in the development of CTS findings. In the first stage, venous congestion and the onset of edema occur; in the second stage, anoxia and edema develop; and in the third stage, in addition to venous congestion, arterial occlusion and eventually fibrosis occur (13).

Increased endoneural pressure results in changes in the microvascular circulation, making the median nerve more susceptible to ischemia. Elevated pressure causes focal demyelination, followed by more widespread demyelination, and ultimately axonal damage (14). In the first stage, symptoms such as paresthesia and pain occur, but if circulation returns to normal, these symptoms may resolve. In the second stage, protein accumulation in the endoneural spaces and swelling of some nerve fibers take place. The third stage involves irreversible changes (15).

Most patients with CTS do not have a specific etiological factor and are considered idiopathic. However, many have occupational histories involving repetitive wrist movements. Accordingly, the etiological factors causing CTS are summarized in Table 1(16).

Table 1. The etiological factors of carpal tunnel syndrome

1) Idiopathic
2) Anatomical: Small size of the carpal tunnel, thick transverse carpal ligament, muscle, bursa, and nerve anomalies, aberrant arteries
3) Trauma
4) Space-Occupying Lesions: Ganglion cyst, tumors, fibroma, lipoma
5) Synovitis-Causing Factors: Rheumatoid arthritis (RA), scleroderma, systemic lupus erythematosus, dermatomyositis
6) Systemic Diseases: Thyroid disorders, hypoparathyroidism, acromegaly, diabetes mellitus, osteoarthritis (OA), gout
7) Others: Pregnancy, spasticity (persistent wrist flexion), hemodialysis, edema in the body or conditions that increase total body fluid

CLINICAL SYMPTOMS

CTS is characterized by sensory and motor deficits in the hand, wrist, and fingers (thumb, index finger, middle finger, and radial part of the ring finger), which are innervated by the median nerve. Sensory symptoms predominate in the early stages of CTS, but motor symptoms typically manifest in later stages (17).

Patients with CTS often report nighttime paresthesia that awakens them from sleep, a sensation of swelling in the

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hands, pain, and difficulty gripping objects—sometimes even dropping them. Many describe shaking their hands to relieve their symptoms, which is believed to be due to transient ischemia of the median nerve (18, 19).

As the severity of CTS increases, symptoms that were once confined to nighttime begin to persist during the day. Even when the hand is in a neutral position, the median nerve may remain compressed, and repetitive use of the hand further exacerbates the symptoms. With continued progression, motor axonal damage may occur, leading to thenar muscle atrophy (20).

ASSESSMENT METHODS

CTS, the most commonly used diagnostic approach involves the combined evaluation of patient-reported symptoms, findings from physical examination, and results of electrophysiological studies. Initial diagnosis is typically made through physical examination. Although radiological or ultrasonographic imaging can support the diagnosis, a definitive diagnosis is made using electrophysiological tests (21).

Positive results in certain provocative tests performed during the physical exam—such as the Phalen and Reverse Phalen tests—strengthen the likelihood of CTS. Electrophysiological tests measure changes in nerve conduction velocity in patients with CTS. These tests are especially valuable for early diagnosis and are considered the most important and definitive diagnostic method across all stages of the condition (22).

TREATMENT APPROACHES

The severity of CTS determines how it should be treated. For mild to severe instances, conservative therapy is advised. Surgical decompression should be taken into consideration in individuals with severe CTS or obvious nerve injury on electrophysiological investigations (23).

Splinting, corticosteroids, physical therapy, therapeutic ultrasonography, and yoga are examples of conservative treatment approaches. Conservative methods usually start to show results in two to six weeks and peak in about three months. A different approach to treatment should be taken into consideration if, after six weeks, no improvement is seen (24).

Treatment approaches in CTS are generally categorized under three main headings: Pharmacological treatment, Conservative (non-surgical) treatment and Surgical treatment.

Pharmacological Treatment

The best dosage and the most effective medication have not yet been determined, but oral steroids seem to be a good short- and medium-term pharmacological treatment. It has been demonstrated that steroid injections enhance function, symptoms, and patients' perceptions of their own health. But too many steroid injections can damage cartilage and tendons, making the problem worse (24).

Prednisolone, methylprednisolone, lidocaine, triamcinolone acetonide, dexamethasone sodium phosphate, methylprednisolone acetate, and diclofenac diethylammonium are the most often used medications. The best dosage and medication selection for short-term use are still up for debate (3).

Conservative Treatment

Because of its ease of use, low cost, and good patient tolerability, splinting is regarded as a first-line treatment for mild to moderate CTS (23). The primary goal of using splints for patients with CTS is to avoid excessive wrist flexion and extension, which can raise carpal tunnel pressure (25).

A 2012 study found that nighttime wrist splinting was more effective than placebo, although it did not find sufficient evidence to favor one splint design over another or to compare splinting's effectiveness with other conservative interventions (26). Splinting is especially recommended in reversible CTS cases, such as those seen during pregnancy, and can be used in combination with other treatment methods (23). A study conducted in 2023 reported that in addition to using a splint at night, continuing to use a splint during the day as much as possible was beneficial in terms of pain, nighttime symptoms, functionality and quality of life (27).

CTS has been found to respond well to physiotherapy methods such median nerve gliding exercises, carpal bone mobilization, and therapeutic ultrasonography

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(28). Joint mobilization groups outperformed control groups in terms of pain relief, subjective symptoms, and functional status, according to a number of manual therapy-focused investigations (29). However, when it came to two-point discrimination, there was no discernible difference between the groups (30).

It has been reported that after 18 months of exercise interventions, CTS symptoms decreased in 67% of cases, with higher success rates observed in patients with mild to moderate involvement. Incorporating nerve and tendon gliding exercises into postoperative rehabilitation programs is also considered important (31). The combination of nerve and tendon gliding exercises considerably decreased pain when compared to nerve gliding exercises alone, demonstrating the efficacy of combining both techniques in a randomized controlled experiment conducted by Wulandari et al. with 30 participants (32). In a similar vein, 32 participants were split into two groups in another study by Minhas et al. One group received carpal bone mobilization, while the other group engaged in tendon gliding exercises three times a week for four weeks. Greater decreases in pain intensity and enhancements in functional capacity were observed in the group that engaged in tendon gliding activities (33).

Other Conservative Treatment Methods

Kinesiotaping and electrotherapy modalities are two more conservative treatments for CTS. According to clinical research, taping can improve overall performance, support appropriate muscle function in the early phases, and increase joint mobility and muscle activation (34). Two groups of forty-four CTS patients participated in a prospective, randomized, single-blind trial. Kinesiotaping and exercise therapy were administered to the first group (28 hands), while splinting and exercise therapy were administered to the second group (30 hands). According to the study's findings, kinesiotaping may be able to slow the evolution of mild to moderate CTS in patients by improving electrophysiological parameters and physical examination results (35). Ultrasound is also used in CTS treatment due to its regenerative and analgesic effects on nerves (34). The rationale for using low-level laser therapy (LLLT) lies in its ability to produce biophysical effects on nerve tissue, promoting nerve cell regeneration, peripheral nerve regrowth, and functional recovery (25). In a 2019 study, one group received exercise combined with ultrasound therapy, while the other received exercise combined with laser therapy. Both groups showed positive outcomes, but no significant difference was found in the superiority of one over the other (36). In a study by Asadi et al., both ultrasound and laser therapy were found to be individually effective in reducing pain. However, combined treatment was reported to be more effective for achieving functional improvement (37). Extracorporeal shock wave therapy (ESWT) is another method based on focusing high-amplitude sound waves on a targeted area of the body to produce therapeutic effects (34).

Surgical Treatment

One of the treatments for CTS is the surgical method used in cases of advanced CTS that do not respond to conservative treatment. In this method, the transverse carpal ligament is surgically released. In a meta-analysis study, it was reported that surgical treatment gave better results than conservative treatment at 6 months, but there was no significant difference at 12 months (38). Another meta-analysis found that both surgery and local steroid injections were effective and feasible in reducing CTS symptoms. Although steroid injections are superior in reducing pain, this technique is not a definitive treatment, and it's important to remember that surgery should also be considered as a treatment option (39).

Protective Approaches

Preventive approaches for carpal tunnel syndrome (CTS) include ensuring ergonomic working conditions, maintaining the wrist in a neutral position, incorporating regular exercises and breaks during repetitive tasks, and avoiding prolonged wrist flexion. Stretching and strengthening exercises for hand muscles also effectively reduce CTS risk. Additionally, controlling systemic risk factors—such as obesity, diabetes, and thyroid disorders—plays a pivotal role in prevention. These measures can significantly help prevent the development of CTS, especially in high-risk groups, and contribute to improved quality of life (40).

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CONCLUSION

The severity of CTS, the length of symptoms, and the unique characteristics of each patient all influence the therapy options examined in this study. Rest, splinting, nonsteroidal anti-inflammatory medicines (NSAIDs), and corticosteroid injections are common conservative therapy options that are most successful at reducing symptoms in the early stages of the illness.

On the other hand, in advanced cases or those unresponsive to conservative management, surgical intervention offers a permanent and effective solution by relieving pressure on the median nerve. Based on the literature review and current clinical findings, it is concluded that treatment selection should be made on a patient-specific basis using a multidisciplinary approach—an aspect that is critically important for prognosis.

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