

Review Article

Carpal tunnel syndrome: from diagnosis to treatment – A Review of the Literature

Síndrome do Túnel do Carpo: do diagnóstico ao tratamento – uma revisão da literatura

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ABSTRACT

Carpal tunnel syndrome (CTS) is the most common peripheral neuropathy. The clinical condition of CTS is characterized by pain and paresthesia in the hand, forearm, arm and shoulder, depending on the level of compression present. The aim is to understand the anatomophysiology of carpal tunnel syndrome, as well as its disease profile, clinical presentation, diagnosis, treatment, complications and prognosis. The research carried out in the Pubmed/Medline and Lilacs databases aims to understand peripheral neuropathy in general and was based on the inclusion and exclusion criteria described, considering the most relevant clinical trials. The condition presents a clear involvement profile evidenced in the study, in addition to a similar clinical condition in most cases. The diagnosis of the syndrome is based on electrophysiological and clinical criteria, the second parameter being aided by the Phalen maneuver and the Tinel sign. The treatment is broad and it has pharmacological, physiotherapeutic and surgical alternatives, each ideal for specific cases. The prognosis for CTS is variable, being associated with the degree of symptoms and the loss of the individual's functional capacity.

RESUMO

A Síndrome do Túnel do Carpo (STC) é a neuropatia periférica mais comum. O quadro clínico da STC é caracterizado por dor e parestesias na mão, no antebraço, braço e ombro, a depender do nível de compressão que se apresenta. Objetiva-se conhecer a anatomofisiopatologia da Síndrome do Túnel do Carpo, bem como seu perfil de acometimento, quadro clínico, diagnóstico, tratamento, complicações e prognóstico. A pesquisa realizada nas bases de dados Pubmed/Medline e Lilacs visa a compreender a neuropatia periférica de forma geral e foi baseada nos critérios de inclusão e exclusão descritos, considerando os ensaios clínicos mais relevantes. A condição apresenta um perfil de acometimento claro evidenciado no estudo, além de uma clínica semelhante na maioria dos casos. O diagnóstico da síndrome é baseado em critérios eletrofisiológicos e clínicos, sendo o segundo parâmetro auxiliado pela manobra de Phalen e pelo sinal de Tinel. O tratamento é amplo e possui alternativas farmacológicas, fisioterapêuticas e cirúrgicas, cada uma ideal para casos específicos. O prognóstico da STC é variável, sendo associado ao grau dos sintomas e à perda da capacidade funcional do indivíduo.

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INTRODUCTION

The carpal tunnel is an osteofibrous region that houses four tendons of the superficial flexor muscles of the fingers (FSD), four tendons of the deep flexor muscles of the fingers (FPD), one tendon of the long flexor muscle of the thumb (FLP), and the median nerve, which originates from the brachial plexus¹. Commonly, the carpal tunnel is the target of inflammation due to compressive neuropathies, favored by the delicate location of the median nerve². This nerve originates from the C5–C7 and C8–T1 roots of the brachial plexus, in the respective lateral and medial fascicles, and changes in it have repercussions on the innervation pathway it carries out³.

Carpal Tunnel Syndrome (CTS) is the most common peripheral nerve compression, characterized by damage to the median nerve at the wrist, which results in edema and axonal damage^{4,5}. Numerous factors may be involved in the development of this syndrome, including repetitive movements, hormonal changes, inflammations, and traumas⁶. Nevertheless, CTS is idiopathic in many cases⁷.

Clinically, CTS causes pain, paresthesia, decreased tone, and trophism in the hand and the first three fingers, which correspond to the sensory innervation pathway of the median nerve⁸. In the syndrome, even minor injuries cause a reduction in the individual's functional capacity, as de-

myelination and impaired nerve conduction do not directly relate to symptom expression⁹. Although not the only peripheral neuropathy, CTS retains a significant share of studies due to its high prevalence and clinical importance⁵. For this reason, this work aims to present the anatomopathophysiology of carpal tunnel syndrome, as well as its profile of involvement, clinical picture, diagnosis, treatment, complications, and prognosis.

MATERIAL AND METHODS

This is a literature review concerning Carpal Tunnel Syndrome conducted using the PubMed and LILACS databases. The selection of scientific articles for the narrative review was carried out between January and March 2024, employing the keywords: "carpal tunnel syndrome," "median nerve compression," and "peripheral neuropathy in the wrist". (**Figure 1**) Regarding inclusion criteria, clinical trials published in Portuguese, English, and Spanish were considered. The selected publications span from 1996 to 2024 and, within the described criteria, guide the results and discussion of the topic. Exclusion criteria were duplicate works and those unrelated to the objectives of this study. This manuscript was translated with the assistance of ChatGPT, an AI language model developed by OpenAI.

FLOWCHART OF SELECTED ARTICLES

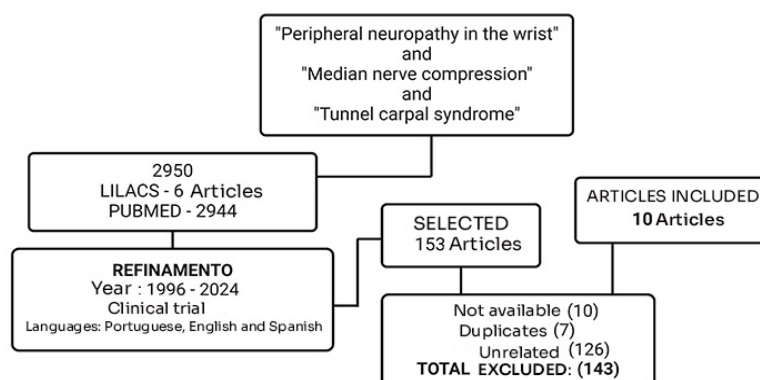


Figure 1. Flowchart of the Articles

RESULTS AND DISCUSSION

Median Nerve Compressions

The median nerve can be compressed in various areas along its innervation pathway. The most common site is the wrist, resulting in Carpal Tunnel Syndrome (CTS). The literature review also identified the pronator syndrome¹⁰, characterized by compression of the median nerve in the elbow and forearm regions, and the anterior interosseous syndrome (AIS), which occurs due to compression of the anterior interosseous nerve, a branch of the median nerve, by the forearm's flexor musculature¹¹.

Each of the three median nerve compression syndromes presents its own causes, clinical manifestations, prevalence, and prognosis⁵. For example, AIS typically results in the inability to flex the distal interphalangeal joints of the thumb and index finger, unlike what is observed in CTS¹¹.

Anatomy of the Carpal Tunnel and Causes of Narrowing

The carpal tunnel is an osteofibrous canal located anteriorly in the wrist region, so named for its anatomical boundaries below: the carpal bones. The floor of this tunnel is formed by the scaphoid, lunate, trapezium, trapezoid, capitate, and hamate bones in their topographic arrangement from the radial to the ulnar edge^{1,2}. Besides the bony boundaries, the carpal tunnel is defined by the tendon of the flexor carpi radialis muscle (FCR) and is roofed by the transverse carpal ligament (or flexor retinaculum). The capsule that encloses the tunnel's limiting structures is comprised of important ligaments that are clinically significant for the manifestation of CTS.

The median nerve, along with myotendinous structures, composes the contents of the carpal tunnel¹. The excessive stimulation of the wrist and finger flexor musculature, specifically the FSD, FPD, and FLP muscles, is attributed as a major cause of carpal tunnel narrowing and subsequent compression of the median nerve, characterizing the anatomopathophysiology of CTS. On the other hand, narrowing of the canal can also be attributed to changes in the capsulo-lig-

amentous structure, given the importance of the ligaments in stabilizing the wrist, which consequently results in compression of the median nerve. The radiocarpal joint capsule is reinforced by the palmar and dorsal radiocarpal ligaments, which also allow for hand movement in conjunction with the radius.

A clinical example of compression of the structures passing through the carpal tunnel is the dislocation of the lunate bone, which moves toward the palmar surface, typically occurring through falls with hand support. In such cases, individuals should seek medical attention with typical complaints of Carpal Tunnel Syndrome: paresthesias in the territory innervated by the median nerve and loss of palmar grip strength.

CTS: Profile of Involvement and Risk Factors

Middle-aged women are more frequently affected by CTS, with a prevalence peak between the ages of 45-54¹². According to research published in the journal 'Acta Ortopédica Brasil'⁷, cases of CTS in women account for 80% of the total. A meta-analysis study concluded that overweight individuals have an increased risk of developing the syndrome, which includes this demographic in the profile of CTS involvement^{7,13}. Additionally, smoking

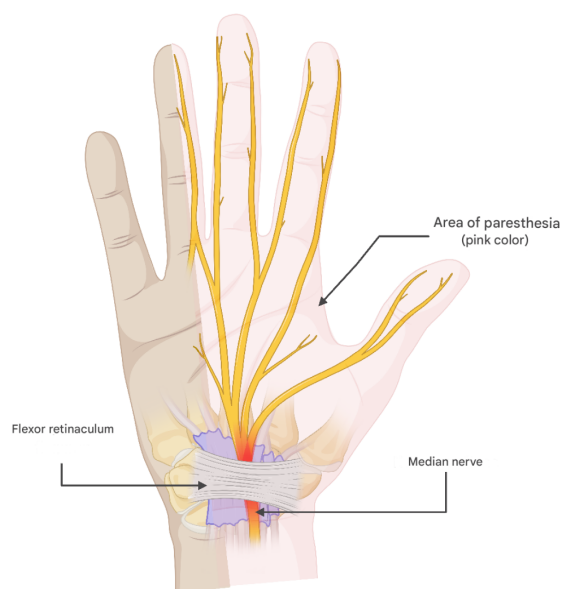


Figure 2. Compression of the Median Nerve at the Level of the Carpal Tunnel. Created with BioRender.com

and diabetes mellitus (DM) - commonly associated with peripheral neuropathies, of which CTS is a frequent manifestation - are also considered risk factors for CTS¹⁴. Other related diseases include hypothyroidism, rheumatoid arthritis, and gout¹⁵.

As a condition more common in adult individuals, the syndrome is often associated with the occupational activities of patients who engage in jobs that involve constant use of the hands. Depending on the severity of symptom expression, the relationship of CTS to work is reflected in the individual's disability, which prevents them from performing their labor tasks as the disease progresses¹².

Clinical Presentation of CTS

Considering the pathophysiology of CTS, which is characterized by nerve compression at the wrist level, the clinical presentation is marked by paresthesia along the radial edge of the hand, in the sensory territory of the median nerve, after passing through the carpal tunnel. Many patients report a loss of sensitivity or numbness in the fingers innervated by this nerve, namely the thumb, index finger, middle finger, and the radial side of the ring finger^{4,5}.

Painful symptoms may also be present, typically starting at night and progressively worsening. This painful sensation is often reported up to the elbow. As the disease progresses, it also leads to weakness and atrophy of the muscles in the thenar region, resulting in functional impairment of the individual, particularly affecting fine motor skills and palmar grasp¹².

Various symptoms are depicted in cases of CTS, which has a range of possibilities for clinical expression. Despite this, some symptoms are very characteristic of the syndrome, facilitating diagnosis. An important and common sign in CTS is the worsening of pain at night, which should be given significant consideration. In addition to the worsening of pain, some patients report tremors and redness of the affected hand¹⁶.

Diagnosis of CTS

There is not just one method for diagnosing CTS, nor is there a single standard adopted for this process. CTS is defined as an electroclinical

syndrome, meaning it is diagnosed through clinical or electrophysiological bases¹².

In the clinical context, to test sensitivity in CTS, the Tinel and Phalen tests are used, which, although not highly specific, assist in diagnosing the syndrome based on clinical criteria. The former involves tapping on the wrist followed by a sensation of shock radiating to the hand and fingers, and the latter induces paresthesia through compression of the median nerve in the affected hand resulting from sustained wrist flexion (action of the wrist and finger flexor musculature)¹⁷.

Additionally, the CTS-6 is a symptomatic patient assessment score that serves as a symptom scale. This score evaluates criteria such as predominant or exclusive numbness in the territory innervated by the median nerve, symptoms commonly occurring at night, thenar atrophy and/or weakness, positive Phalen's test and Tinel's sign, and other characteristics of the syndrome¹⁸.

To cover the electrophysiological bases, electroneuromyography is a diagnostic standard for CTS. This method aids in the diagnostic confirmation of doubtful cases and also establishes the severity of the condition. Moreover, for individuals suspected of peripheral neuropathies, electroneuromyography is the first choice, as it provides details about the axonal damage present^{19,20}.

Differential Diagnosis of CTS

Although the diagnosis of CTS is primarily clinical, the patient's symptoms can confuse the examiner due to their resemblance to other neuropathies, also considering epidemiology. In this context, the differential diagnosis of CTS includes other mononeuropathies, polyneuropathies, and cervical radiculopathies involving the C5 and C6 routes, among others. Generally, all pathologies that present with painful complaints and changes in hand sensitivity are candidates for the differential diagnosis of CTS²¹.

All polyneuropathies in the forearm and wrist region can be confused with CTS, as they affect more than one nerve and present a clinical picture similar to the syndrome¹. Neuropathic disorders that affect autonomic fibers and are related to diabetes, amyloidosis, and autoimmune

diseases also fall within the differential diagnosis for CTS¹⁵. Additionally, De Quervain's tenosynovitis, which affects the sheath of the long abductor and the short extensor of the thumb, is also included in this group. The primary diagnostic method for this condition is the clinical examination, specifically aided by the Finkelstein test²².

Treatment of CTS

Therapy for CTS is based on physiotherapeutic approaches and pharmacological treatment. Regarding the former, immobilization techniques, electrotherapy, and manual therapy are particularly emphasized²³⁻²⁵. Of these, immobilization improves symptom severity, especially pain, and this technique combined with laser therapy, transcutaneous electrical nerve stimulation (TENS), ultrasound, or paraffin therapy ensures better outcomes^{23, 25, 26}. Physiotherapeutic techniques constitute the gold standard for non-surgical treatment of CTS.

The specifics of pharmacokinetics and pharmacodynamics are not as evident for the adoption of an ideal pharmacological standard. However, considering the clinical picture of the disease and the mechanism of action of the drugs, the most commonly used classes for the treatment of CTS are non-steroidal anti-inflammatory drugs (NSAIDs), corticosteroids, and analgesics. In this context, oral steroids appear to fulfill their roles by reducing complaints in the short to medium term²⁷.

Surgical Complications and Prognosis of CTS

In general, the rate of surgical complications in median nerve decompression within the carpal tunnel is very low, and the surgery is highly safe and effective for treating CTS. However, as an invasive procedure, some adverse effects may occur, such as infection, hypertrophic scarring, neuropraxia, injuries to arteries and tendons, incision sensitivity, and pillar pain²⁸.

The incidence of nerve, artery, or tendon injury does not exceed 0.5% in open or endoscopic surgeries, with the main distinction between these approaches being the occurrence of transient neuropraxia. In this context, the endoscopic

approach leads to temporary nerve injuries more frequently, although still in small numbers. According to research published in the *Journal of Plastic and Reconstructive Surgery*²⁹, nerve injuries occurred in 1.45% of endoscopic surgery cases, while open-release surgery had an incidence of 0.25%^{5,30}.

Postoperative pain at or around the incision site is another reported complication, often associated with neurogenic inflammation. Pain management is individualized, with specific recommendations in each case for physical therapy, rest, or splinting^{5,31}.

Regarding the prognosis of CTS, some studies have concluded that the majority of patients are symptom-free in the long term³². According to a prospective study by Tan and Tan³³, 72% achieved complete symptom relief, 74% experienced improved function, and 66% gained strength. The lowest post-surgical improvement rates were associated with greater functional and symptomatic severity in the preoperative period.

Approach to CTS

As previously mentioned, there is no single ideal treatment approach for CTS, and with advancements in current medical practice, each alternative is considered based on the severity of the syndrome's manifestation. There are discrepancies in the conclusions of selected clinical trials, with partial or complete improvement resulting from each therapeutic approach. Such factors are considered implications for the progression of CTS³⁴⁻⁴³.

The randomized controlled trial presented by de Moraes et al. (2021)³⁶, for example, aimed to clarify the efficacy of two non-surgical methods for managing CTS: corticosteroid therapy and splinting. In this study, remission rates of nocturnal paresthesia were higher in individuals using corticosteroids. Notably, 100 patients were randomly allocated to one of the treatment arms. Besides this outcome, pain scores were also reduced more significantly in the group using the medication. Although the results favored one arm, both therapies showed short-term benefits.

In another selected study, the clinical trial by Meshkini et al. (2023)⁴² investigated the effect

of the corticosteroid injection site. This study found that distal access was more favorable compared to the conventional proximal approach. The clinical trial concluded that distal application can effectively treat symptoms of mild to moderate CTS, and both groups showed significant improvement.

To investigate the effectiveness of acupuncture as an alternative for pain management in CTS, another controlled study was conducted. It demonstrated that electroacupuncture had comparable benefits to nocturnal splinting in managing symptoms of mild to moderate CTS cases. Another comparison, conducted over 13 months, assessed the efficacy of acupuncture versus oral corticosteroids. Although both groups showed improvement on the global symptom scale, patients who received acupuncture presented better results in distal motor latency (DML) and distal sensory latency (DSL)³⁹.

For patients who do not respond to conservative treatment, surgical options are available for CTS management. In such cases, patients often report symptomatic relief following carpal tunnel release. Eberlin et al. (2022)³⁷ designed a clinical trial to analyze outcomes of ultrasound-guided carpal tunnel release and mini-incision procedures, aiming to establish the effectiveness of these approaches.

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