Proceedings of the 3rd International Conference on Modern Medicine and Global Health
DOI: 10.54254/2753-8818/89/2025.20313

Research Progress in the Carpal Tunnel Syndrome (CTS)

Qinglong Meng[1,a,*]

[1]*Macquarie University, Sydney, 2113, Australia*
a. qinglong.meng@students.mq.edu.au
**corresponding author*

Abstract: Carpal tunnel syndrome (CTS) is a common condition that causes pain, numbness, and weakness in the hand due to a pinched median nerve in the wrist. A higher percentage of women than men have carpal tunnel syndrome, which affects about 3.8% of the population. The diagnosis procedure includes the patient's medical history, physical examination, and electrodiagnostic testing, all of which are essential for assessing the nervous system's function and severity. Based on these assessments, CTS is classified as mild, moderate, or severe. Conservative treatment, including corticosteroids, wrist splints, and a range of physical therapy, is usually recommended for mild to moderate cases, while surgical treatment is reserved for severe cases. Endoscopic carpal tunnel release (ECTR) and open carpal tunnel release (OCTR) are surgical options. The purpose of this article is to explore risk factors, diagnostic approaches, and treatment approaches in order to provide better individualized care in clinical practice, and to make recommendations for future treatment improvements and research.

Keywords: Carpal tunnel syndrome, risk factors, treatment.

1. Introduction

Carpal tunnel syndrome (CTS) is a condition caused by abnormalities in the carpal bones and ligaments that compress the median nerve. Compression of the positive nerve is the cause. In general, patients experience discomfort in the radial ends of their thumb, index, and middle fingers as well as in the nerves close to the orthonormal nerve. Additionally, ninety percent of all neuropathies are caused by CTS, which is the most prevalent median neuropathy. In addition, patients with CTS may experience varied degrees of muscle atrophy, decreased range of motion, impaired hand strength, and pain-related behavioral problems. CTS affects 3.8% of persons overall, with a higher incidence among women [1].

CTS may be caused by a number of circumstances, although the precise mechanism is still unclear. The diagnosis is made using the patient's medical records, physical examination, electrodiagnostic testing, and auxiliary tests. For physical diagnosis, there are three highly sensitive and specific tests: the Durkan, Phalen, and Tinel tests. The most significant of these tests is electrodiagnostics, which can be used to analyze the median nerve's recovery before and after surgery and to identify potential future recurrences.

Therapists can use these tests to classify these patients as mild, moderate, and severe. There are many treatments for CTS, including conservative treatment and surgical treatment. Still, no more effective course of treatment exists. For mild to moderate patients with CTS, corticosteroids, wrist

© 2025 The Authors. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

DOI: 10.54254/2753-8818/89/2025.20313

splints, and medication-based conservative treatment are typically advised. For individuals who had severely CTS, surgery is typically advised. Surgery is the most costly among them, but it has a positive recovery outcome. It is essential in lowering pain, easing symptoms, and shielding the positive nerve from additional harm.

At present, there is relatively little progress in clinical research on mild to moderate CTS, because this paper intends to explore the risk factors, diagnosis, and treatment strategies of mild to moderate CTS based on relevant studies at home and abroad, in order to provide a better theoretical basis for better individualized treatment in the future.

2. Anatomical structures

The spinal root of the C5-T1 brachial plexus is the source of the median nerve. The tucked artery runs between the two roots, which are the medial and lateral fascicles, and they unite to produce this structure. The median nerve then passes through the medial biceps sulcus on its way to the arm's cubital fossa. Proceed through the flexor carpi radialis from the cubital fossa and follow the superficial flexor muscles through the carpal tunnel to reach the palm. In addition to innervating the thenar muscle and the first and second lubrical muscles lateral to the hand muscle, the median nerve also innervates the pronator muscles, flexor carpi radialis, palmaris longus, and superficial flexors of the forearm.

The condition is caused by an external force that increases pressure in the narrow carpal tunnel, compressing the median nerve. As a result of this continual compression, the median nerve eventually becomes painful, numb, and weak in the hand region.

3. High-risk groups

Over the past 30 years, a significant amount of research has been done that points to a link between CTS and occupational activity [2]. There is evidence to suggest that employment requiring a lot of repetitive hand motions or physically demanding hand movements are more likely to cause CTS. These widely distributed occupations include jobs like supermarket cashiers, dentists, stone carvers, forestry workers, textile workers, and slaughterhouse workers. Among occupational upper limb injuries, CTS is also one of the reasons for the longest absence, the highest cost and compensation for workers. It is further separated into three primary categories: repetitive assembly labor, work using vibrating equipment, and food processing and packing [3]. The high force and repeatability are the reason that results in compression of the carpal tunnel.

Some occupations such as frequent use of hands, such as teachers, musicians, programmers, etc., also have a higher incidence of CTS. In addition to occupational factors, CTS is also more common in pregnant women, rheumatism, diabetes, arthritis, hypertension and thyroid degeneration. It may be caused by increased intravascular pressure due to the influence of hormone secretion or increased permeability of the vascular wall, resulting in an increase in carpal tunnel contents and increased pressure.

4. Evidence for diagnosis of injury

Diagnostic methods can be divided into physical examination, electrodiagnostic testing and ancillary test. These tests should not be done alone, and a combination of tests can improve the accuracy of the diagnosis.

DOI: 10.54254/2753-8818/89/2025.20313

4.1. Physical examination

The physical examination should focus on the patient's signs, symptoms, and a combination of tests. These tests include Tinel, Phalen and Durkan test which can accurately diagnose pinprick and downward sensation in the median nerve [4].

In some normal signs, thenar muscles are generally full, but thenar muscle atrophy may be evident in patients with late CTS. Although thenar muscle atrophy shown high specificity, sensitivity has been determined to be only 12.6% [5].

The Tinel test, When the finger is pierced by the examiner pressing on the transverse palmar ligament's median nerve, the test is considered successful [6]. The sensitivity of this trial was approximately 61% [7]. Nevertheless, there are a number of variables that can distort the results of the Tinel test, making it an inaccurate tool. First, a constantly regenerating nerve in the distal wrist fold is seen in CTS patients. Another reason is that the inspector's force on the patient is unpredictable, and the amount of force varies depending on the patient. It is not possible to interpret a high Tinel test result for a normal median nerve since excessive force might also cause tingling in the fingers.

The Phalen test is positive if there is increased pain or paresthesias in the hand's median nerve distribution and requires 90 degrees of palmar flexion or dorsiflexion of the wrist for one minute [8]. The sensitivity of this test is around 70%. The idea behind the test is that as the wrist flexes, the median nerve between the carpal tunnel flexor tendon and the transverse carpal ligament (TCL) is compressed, causing paresthesia throughout its distribution.

The Durkan test compresses the median nerve by compressing the carpal tunnel for 1 to 2 minutes and is positive if the numbness in the hand worsens and the pain shifts to the index and middle fingers [9].

Muscle strength test will be evaluated based on the patient’s signs, symptoms, and muscle tolerance. The inability to pinch or frequent dropping of gripped things owing to finger weakness are signs of atrophic shenar, which differs from normal thenar muscle. And it is difficult for the patient to notice the atrophy of the thenar unless the two hands are placed side by side. This test is best performed in conjunction with the Phalen test, as atrophy of the abductor pollicis brevis muscle can be well observed at the same time as the flexion of the Phalen test and can provide evidence for further diagnosis of CTS [10].

4.2. Electrodiagnostic testing

Clinical carpal tunnel syndrome can be diagnosed by electrodiagnostic techniques, which effectively record electrical abnormalities of median nerve fibers within the carpal tunnel.

Electromyography and nerve conduction studies are examples of electrodiagnostics. By determining whether there is a deficit in median nerve conduction, nerve conduction tests (NCS) validate the diagnosis of CTS [11]. Every patient with CTS should get NCS to confirm the diagnosis prior to surgery. This is because the data of preoperative EDX can be compared with the objective baseline obtained in the event of persistent or recurrent postoperative symptoms. With an 85% sensitivity and a 95% specificity, NCS is useful in verifying the clinical manifestations of CTS [12]. The pathophysiology of the abductor pollicis brevis muscle, which is one of the muscles innervated by the median, may also be evaluated by EMG. In cases of prolonged orthonormal nerve compression, an EMG revealed that the abductor pollicis brevis muscle was denervated.

4.3. Ancillary test

As the additional test with imaging, MRI, MRA, and ultrasound are options. All work well for full-thickness tears; MRI is a great imaging technique that can show alterations in the median nerve's structure. Two extremely sensitive metrics in CTS are the median nerve's CSA and FR at the tunnel's

DOI: 10.54254/2753-8818/89/2025.20313

exit. Secondary reasons can be ruled out by MRI as well. The MRI demonstrates the median nerve's superstrength. Long TR superstrength and muscle lipoatrophy are two more muscular anomalies that can be found with MRI. NMR can more accurately evaluate anomalies in nearby structures because soft tissues have a high resolution. In individuals with CTS, DTI demonstrated an increase in ADC and RD and a decrease in FA when compared to the control group.

5. Non-surgical treatment

Conservative measures are usually used to treat mild to severe CTS. Medication, wrist splints, and physical therapy (including acupuncture, laser, and ultrasound) are examples of these conservative therapies.

5.1. Medication

Short-term oral corticosteroids are effective in the symptomatic treatment of CTS, but their side effects and toxicity are significant and are not recommended for the first treatment.

A growing body of trials has shown that topical corticosteroid injections are useful. A controlled trail including 12 trials with 651 participants showed that topical corticosteroid injections improved clinical symptoms after one month compared with placebo [13]. It is hypothesized that corticosteroids injected directly in the flexor band of the hand can reduce pressure on the median nerve due to muscle atrophy and cytotoxic effects. Corticosteroids are less disruptive and complications than surgery, and there is less subcutaneous atrophy compared to soft tissue steroid injections [14].Then recent trials have shown that corticosteroid injections can improve symptoms for 10 weeks or even more than a year.

Despite the fact that corticosteroid injections are usually safe, tendon rupture and injury to the median nerve are possible side effects. Ultrasound-guided injections, which enable direct visualization to guarantee precise and secure needle placement, are frequently used to lessen this accident. After six months, the injection can be repeated at the same site. Other therapies or procedures should be taken into consideration, though, if symptoms return after two injections. Furthermore, soft tissue atrophy can occur in as many as 40% of people who receive corticosteroid injections; the precise prevalence varies depending on the patient's features and the exact method used.

5.2. Wrist splints

Wrist splints are the first treatment for mild to moderate CTS because it is simple, low-cost, and highly tolerated. The symptoms of CTS improve with rest, while worsen with activity. In order to decrease pressure on the carpal tunnel and lessen its compression, wrist splints are intended to be used.

Wrist splints at night were more beneficial than a placebo, and patients who wore neutral splints were twice as likely to report fewer symptoms than those who wore extension splints. Splinting can be performed in combination with other treatments and is advised for reversible CTS illnesses, such as those that occur during pregnancy. A splint is recommended for healing after carpal tunnel release surgery.

5.3. Physical therapy

The symptoms of CTS can be effectively relieved by physiotherapy methods such nerve gliding exercises, ultrasound therapy, and carpal tunnel passive movement.

DOI: 10.54254/2753-8818/89/2025.20313

Passive movements can be done by pressing on the pain points about 20 to 30 times with light strokes. Then gently extend the person's hand and rotate it 10 to 20 times. This relaxes the transverse carpal ligament and gives more space to the median nerve.

Ultrasonic devices convert electrical energy into piezoelectric sound waves, which are then absorbed by different muscle tissues, causing them to be released by heating. This method is combined with local anti-inflammatory injections, and the sound waves enhance the absorption of the drug into the skin. The use of ultrasound also stimulates nerve regeneration, increases nerve conductivity, and reduces inflammatory processes.

Simple hand and finger activities called nerve glide exercises have the potential to lessen nerve compression and return the median nerve to its normal range of motion. These techniques are simple to learn and can be applied at home, despite the lack of data supporting their efficacy. It can be used in conjunction with other therapies, such wrist splints.

6. Surgical treatment

Patients with severe or moderately severe CTS should be treated with surgery. In particular, the patient should be monitored for thumb weakness or atrophy of the thenar muscles, regardless of how severe it is. Open carpal tunnel release and endoscopic carpal tunnel release are the two categories of surgical therapy techniques.

6.1. Open carpal tunnel release (OCTR)

In 1924, Canada performed the first open carpal tunnel release (CTR) surgery for transverse carpal ligaments, and it has been widely used since 1940. The success rate of the procedure is 54% to 75%. The transverse carpal ligament (TCL) is sliced longitudinally in the wrist during an open operation called OCTR in order to relieve pressure on the median nerve. Open carpal tunnel release has the following benefits: it is simple to do, provides a clear view and space during the surgery, and can directly cut the transverse carpal ligament, which is the flex band of the flexion muscle. It safeguards vital blood arteries and nerves, including the ulnar and median nerves. And OCTR has a low recurrence rate, which can provide good symptom relief in many cases. Within a week, the majority of patients experience noticeable improvement, and within two weeks, they can resume their regular activities. However, it can take up to a year for some individuals to fully recover, particularly those with severe CTS. Splints should not be worn postoperatively because they may increase stiffness and the formation of muscle adhesions [15].

Incomplete TCL incision, neuropathic or median nerve or ulnar nerve injury, palmar skin injury of the median nerve, or ulnar artery injury are among the complications that can arise during and following open carpal tunnel surgery. These complications are rare, while the postoperative complications, such as the scar tenderness, loss of grip, and sympathetic atrophy, are common, ranging from 6% to 36% [16]. These complications make it much longer for patients to return to their daily activities and return to work, as well as mental illness, which all contribute to increased healthcare costs.

Early consequences include incomplete TCL release and damage to the median or ulnar nerve. The fact that the procedure is visible makes this complication uncommon. It is typical for surgical complications, though. The OTCR incision's length, position, and form have all changed recently in an effort to decrease postoperative problems and hospital stays. The ideal surgical transverse incision length should be less than two centimeters [17].

DOI: 10.54254/2753-8818/89/2025.20313

6.2. Endoscopic carpal tunnel release (ECTR)

ECTR is another type of surgery to treat carpal tunnel syndrome, and it has grown in popularity since it was introduced by Okutsu et al. two decades ago. ETCR is a small incision in the wrist and the center of the palm, which is passed under the transverse carpal ligament through a special tubular instrument and drilled through the incision in the palm. This visualizes the transverse carpal ligament. A scalpel with a blunt front and a sharp back is inserted into the lateral carpal canal.Before cutting, the anatomical location needs to be marked to avoid potential damage to the normal structure. Distal to proximal to the initial cut, the probing knife is employed. The distal boundary of the TCL should be preserved throughout the process. The intact TCL will be cut when the retrograde knife makes another cut from the proximal to the distal end.

ECTR is less invasive, patients can recover function and return to work at an early stage, and the postoperative pain index (VAS) is low. However, ECTR requires sophisticated instruments and higher technical requirements for the surgeon, and the cost is higher than OCTR, so this method is not the first choice in clinical practice. Major consequences, such as damage to the median or ulnar nerves, are as common with ECTR as with OCTR, however mild issues, such as scar discomfort and infection, may be less common with ECTR.

7. Conclusion

This study summarizes the best evidence for non-surgical and surgical treatments for different degrees of CTS (mild, moderate, and severe patients), and provides recommendations for patients before receiving treatment. Mild and moderate patients should use wrist splints, steroid drugs, physical therapy treatment reasonably, which has the advantages of being safe, simple, and effective in solving patients' pain. Conservative therapy can provide therapeutic results in three months and often relieves symptoms in two to six weeks. Surgery should be considered if, after six weeks, there is still no improvement. OCTR and ECTR are two categories of surgical therapy. Although the former can significantly lower the risk of median nerve compression and is more effective at severing the transverse carpal ligament, the risk is still higher and there are more problems than with ECTR. Although ECTR can enable patients to recover faster and return to society, its operation is difficult and costly, and it is not yet popular. In the future, researchers can find more effective conservative treatments and improve, them simplify ECTR to reduce its cost and reduce the occurrence of severe complications.

References

[1] *Damms, N. A., McCallum, L. M., Sarrigiannis, P. G., & Zis, P. (2020). Pain as a determinant of health-related quality of life in patients with carpal tunnel syndrome; a case-controlled study. Postgraduate medicine, 132(1), 52–55. https://doi.org/10.1080/00325481.2019.1694840*

[2] *Hagberg, M., Morgenstern, H., & Kelsh, M. (1992). Impact of occupations and job tasks on the prevalence of carpal tunnel syndrome. Scandinavian journal of work, environment & health, 18(6), 337–345. https://doi.org/10.5271/sjweh.1564*

[3] *Newington, L., Harris, E. C., & Walker-Bone, K. (2015). Carpal tunnel syndrome and work. Best practice & research. Clinical rheumatology, 29(3), 440–453. https://doi.org/10.1016/j.berh.2015.04.026*

[4] *Aroori, S., & Spence, R. A. (2008). Carpal tunnel syndrome. The Ulster medical journal, 77(1), 6–17.*

[5] *Gomes, I., Becker, J., Ehlers, J. A., & Nora, D. B. (2006). Prediction of the neurophysiological diagnosis of carpal tunnel syndrome from the demographic and clinical data. Clinical neurophysiology : official journal of the International Federation of Clinical Neurophysiology, 117(5), 964–971. https://doi.org/10.1016/j.clinph.2005.12.020*

[6] *Hoffmann, P., Buck-Gramcko, D., & Lubahn, J. D. (1993). The Hoffmann-Tinel sign. 1915. Journal of hand surgery (Edinburgh, Scotland), 18(6), 800–805. https://doi.org/10.1016/0266-7681(93)90249-f*

DOI: 10.54254/2753-8818/89/2025.20313

[7] Katz, J. N., Larson, M. G., Sabra, A., Krarup, C., Stirrat, C. R., Sethi, R., Eaton, H. M., Fossel, A. H., & Liang, M. H. (1990). The carpal tunnel syndrome: diagnostic utility of the history and physical examination findings. Annals of internal medicine, 112(5), 321–327. https://doi.org/10.7326/0003-4819-112-5-321

[8] Phalen G. S. (1966). The carpal-tunnel syndrome. Seventeen years' experience in diagnosis and treatment of six hundred fifty-four hands. The Journal of bone and joint surgery. American volume, 48(2), 211–228.

[9] Buch-Jaeger, N., & Foucher, G. (1994). Correlation of clinical signs with nerve conduction tests in the diagnosis of carpal tunnel syndrome. Journal of hand surgery (Edinburgh, Scotland), 19(6), 720–724. https://doi.org/10.1016/0266-7681(94)90244-5

[10] Phalen G. S. (1966). The carpal-tunnel syndrome. Seventeen years' experience in diagnosis and treatment of six hundred fifty-four hands. The Journal of bone and joint surgery. American volume, 48(2), 211–228.

[11] Werner, R. A., & Andary, M. (2011). Electrodiagnostic evaluation of carpal tunnel syndrome. Muscle & nerve, 44(4), 597–607. https://doi.org/10.1002/mus.22208

[12] Alanazy MH. Clinical and electrophysiological evaluation of capal tunnel syndrome: approach and pitfalls. Neurosciences(Riyadh). 2017; 22(3): 169-180, doi: 10.17712/nsj.2017.3.20160638, indexed in Pubmed: 28678210.

[13] Marshall, S., Tardif, G., & Ashworth, N. (2007). Local corticosteroid injection for carpal tunnel syndrome. The Cochrane database of systematic reviews, (2), CD001554. https://doi.org/10.1002/14651858.CD001554.pub2

[14] Roghani, R. S., Kara, S., Taheri, M. J., Gohari, F., Sadrneshin, S., Thant, H. L., Diaz, J. J., & Lokk, J. (2022). Intra-flexor retinaculum steroid injection in elderly patients with carpal tunnel syndrome: A randomized clinical trial. Interventional pain medicine, 1(3), 100106. https://doi.org/10.1016/j.inpm.2022.100106

[15] American Academy of Orthopaedic Surgeons. Management of carpal tunnel syndrome evidence-based clinical practice guideline. December 15, 2016. http://www.aaos.org/ctsguideline. Accessed December 15, 2016.

[16] Mirza, M. A., King, E. T., Jr, & Tanveer, S. (1995). Palmar uniportal extrabursal endoscopic carpal tunnel release. Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association, 11(1), 82–90. https://doi.org/10.1016/0749-8063(95)90093-4

[17] Jimenez, D. F., Gibbs, S. R., & Clapper, A. T. (1998). Endoscopic treatment of carpal tunnel syndrome: a critical review. Journal of neurosurgery, 88(5), 817–826. https://doi.org/10.3171/jns.1998.88.5.0817