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Comparison of Treatment Methods for Carpal Tunnel Syndrome: Surgical vs. Non-Surgical

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ABSTRACT

Introduction

Carpal tunnel syndrome (CTS) is a common condition that results from the compression of the median nerve within the carpal tunnel in the wrist. Both surgical and non-surgical treatments are used to manage CTS. While surgery is necessary in some cases, many patients can be treated effectively with conservative methods. This review compares the efficacy of surgical treatment for CTS against various conservative approaches.

Aim

The study aims to evaluate and compare the outcomes of surgical versus conservative treatments for CTS, focusing on symptom relief, patient outcomes, and long-term prognosis.

State of Knowledge

The carpal tunnel is a narrow passage in the wrist formed by carpal bones and the flexor retinaculum. Compression of the median nerve within this tunnel leads to CTS, which can be caused by anatomical variations or systemic conditions like diabetes. Symptoms include pain, numbness, and tingling in the hand, which may worsen at night or with repetitive movements.

Summary (Conclusions)

Surgical treatment, especially decompression, offers superior symptom relief and functional improvement but carries risks of complications. Conservative treatments like wrist immobilization and anti-inflammatory medications are effective for many patients, supporting their use as initial treatment. Further research is needed to optimize CTS management.

Keywords :Carpal tunnel syndrome, surgical management, surgical repair, minimally invasive surgery, wrist, non-pharmacological interventions

INTRODUCTION

Carpal tunnel syndrome (CTS) is the most prevalent peripheral nerve entrapment condition, arising when the median nerve is compressed as it traverses the rigid carpal tunnel. Activities that involve repeated flexion and extension of the wrist, common in daily tasks and certain occupations, can lead to thickening of the transverse carpal ligament, thereby compressing the median nerve. Additionally, factors such as synovial hyperplasia, ganglion cysts, or schwannomas can increase the content within the carpal tunnel, exacerbating nerve compression. Early symptoms typically include abnormal sensations or numbness in areas innervated by the median nerve (the thumb, index finger, middle finger, and the radial side of the ring finger), with nocturnal numbness being a frequent initial complaint. As the condition progresses, it can lead to thenar muscle atrophy and impaired thumb opposition, significantly impacting sleep quality, daily activities, and mental health.(Chammas et al., 2014)

In the initial stages of CTS, conservative treatments may be effective. These include physical therapy to reduce inflammation and the use of wrist splints to limit movement. However, if conservative treatments fail, persistent compression can cause irreversible damage to the median nerve, necessitating surgical intervention. Traditional open nerve decompression surgery can fully relieve the compression but often involves a long incision and extended recovery period. Postoperative complications such as scar tissue formation can limit wrist movement, and in severe cases, additional surgery may be required.

Recently, minimally invasive techniques, such as neurolysis of the median nerve using wrist arthroscopy or endoscopy, have gained popularity. These methods, however, require significant surgical expertise and carry a risk of damaging the median nerve and its branches. An alternative approach involves a mini-open incision to cut the transverse carpal ligament, which offers effective decompression with less trauma and scarring, and faster recovery.

Definition, Epidemiology, and Characteristics

Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy, affecting 1% to 3% of the population, with incidence peaking in the late 50s. Certain occupational groups, such as meatpackers, poultry processors, and automobile assembly workers, have a higher prevalence due to repetitive manual tasks. CTS is also associated with systemic conditions like rheumatoid arthritis, hypothyroidism, diabetes mellitus, gout, and pregnancy.(Bicha et al., 2024; Çupi et al., 2023; Omole et al., 2023)

Treatment Approaches

Both conservative and surgical treatments are employed in CTS management. Non-surgical options include splinting, steroid injections, activity modification, non-steroidal anti-inflammatory drugs. Among these, only splinting and steroids have strong supporting evidence. Surgical release is typically reserved for patients who do not achieve relief with conservative treatments or those with moderate to severe symptoms. Although surgical intervention is definitive, it is not the first line of treatment. Conservative management is preferred for transient cases, such as those associated with pregnancy, or for partial relief while awaiting surgery.

Anatomy(Honis et al., 2023)

The carpal tunnel is formed by the carpal bones and the transverse carpal ligament (TCL), which is a thick, fibrous band. The median nerve, along with the flexor tendons, passes through this tunnel. Variations in individual anatomy and wrist movements can affect the tunnel's structure and size, impacting CTS symptoms. The TCL's laminar structure and its attachments to surrounding bones and tissues

are crucial for understanding CTS and its treatment, particularly surgical interventions.

The carpal tunnel is a narrow, rigid passageway composed of carpal bones and the transverse carpal ligament (TCL), a dense fibrous band. Within this tunnel, the median nerve and flexor tendons travel, and individual anatomical variations and wrist movements can influence the tunnel's dimensions, thereby affecting carpal tunnel syndrome (CTS) symptoms. Understanding the TCL's layered structure and its connections to adjacent bones and tissues is essential, particularly for surgical treatments of CTS.

Boundaries

The carpal tunnel is a fixed osteofibrous channel, located between the flexor retinaculum (forming the roof) and the carpal sulcus (forming the floor). It is bordered on the ulnar side by the hook of the hamate, triquetral, and pisiform bones, and on the radial side by the scaphoid, trapezium, and the tendon of the flexor carpi radialis (FCR) muscle. The base consists of the joint capsule and anterior radiocarpal ligaments that cover parts of the scaphoid, lunate, capitate, hamate, and trapezium.

Contents

Within the carpal tunnel, the median nerve is accompanied by four tendons from the superficial flexors of the fingers, four from the deep flexors, and the tendon of the flexor pollicis longus (the most radial element). At the tunnel's entry, the median nerve lies dorsally relative to the palmaris longus muscle or between the FCR and the palmaris longus. In a neutral wrist position, the median nerve is situated anterior to the superficial flexor tendon of the index finger or between the flexor pollicis longus and the superficial flexor of the index finger, or in front of the superficial flexor of the middle finger. Distally, the median nerve splits into six branches: the motor or thenar branch; three proper palmar digital nerves (to the thumb and index finger); and the common palmar digital nerves of the second and third interdigital spaces. In 56% of cases, the thenar branch travels through a separate tunnel before reaching the thenar muscles.

Anatomical Variations

Anatomical differences can influence symptom presentation and surgical risks.

Variations in the Median Nerve

A bifid median nerve, caused by an early division, occurs in 1-3.3% of cases and may coincide with a persistent median artery or an accessory branch of the superficial flexor of the third finger. In such instances, the radial segment is more significant.

Variations of the Motor Branch of the Median Nerve

Lanz identified five types of origins and pathways for the thenar branch: the extraligamentous form (most common at 46%), subligamentous (31%), and transligamentous (23%). Kozin found that 4% of cases had two motor branches crossing the flexor retinaculum. Typically, the thenar branch nerve bundles are radial to the median nerve in 60% of cases, anterior in 20%, and central in 18%. Variations in the thenar branch's pathway can affect motor function in severe median nerve compression cases.

Variations of the Palmar Cutaneous Branch of the Median Nerve

The palmar cutaneous branch generally originates 4-7 cm above the wrist crease, traveling alongside the median nerve for 1.6-2.5 cm before entering a fascial tunnel at the FCR’s medial edge, emerging 0.8 cm above the wrist flexion crease to innervate the skin of the thenar eminence. This branch may cross the transverse carpal ligament or pass to the median nerve's ulnar side.

Intratunnel Positioning of the Ulnar Nerve

It is exceedingly rare for the ulnar nerve to be inside the carpal tunnel. This anomaly presents with symptoms of both median and ulnar nerve compression.

Areas Innervated by the Median Nerve

The median nerve innervates the palmar surface of the thumb, index, middle, and radial half of the ring fingers. On the dorsal side, it innervates the distal phalanges of the first three fingers and the radial half of the fourth finger. The median nerve's motor functions include the short abductor of the thumb, opponens pollicis muscle, superficial head of the flexor pollicis brevis, and the first two lumbricals. There are sensory anastomoses with the ulnar nerve on the palmar side (Berrettini) and motor anastomoses on the dorsal side (Martin-Gruber in the forearm and Riche-Cannieu in the hand).

Berrettini’s Palmar Sensory Anastomosis

This anastomosis, present in 67-92% of cases, is situated below the superficial palmar arch and explains the variations in the sensory area of the ulnar border of the third and fourth fingers and the radial border of the fifth finger, between the median and ulnar nerves.

Riche and Cannieu’s Motor Anastomosis

This frequently observed anastomosis (77-100%) is responsible for innervation variations of the thenar muscles between the median and ulnar nerves, taking several forms, including communication between the thenar branch of the median nerve and the deep branch of the ulnar nerve.

Martin-Gruber and Marinacci’s Median-Ulnar Anastomosis in the Forearm

Described by Martin and Gruber, these anastomoses occur in 5-40% of cases and involve connections from the median nerve or anterior interosseous nerve to the ulnar nerve, often coexisting with hand anastomoses and containing fibers that innervate deep flexors and intrinsic muscles.

Leibovic and Hastings’ Anastomoses

These are classified into four types based on their continuation into the hand and the specific muscles they innervate, ranging from muscles typically innervated by the median nerve to those usually innervated by the ulnar nerve.

Vascular Variations

Persistence of the median artery, a remnant from embryonic development, is observed in 1-16% of cases and may contribute significantly to the superficial palmar arch, sometimes accompanied by a bifid median nerve. Complications such as thrombosis can lead to acute CTS. The ulnar artery is superficially positioned, beneath the fascia but above the muscle.

Muscle and Tendon Variations

The palmaris longus muscle can vary, sometimes extending into the tunnel as the deep palmaris longus, potentially compressing the median nerve. The flexor digitorum superficialis can also extend into the tunnel, with muscle variations more common in women (46%) than in men (7.8%). Lumbrical muscle variations, such as abnormal insertion, may also compress the median nerve.

Characteristic Features of Pain

CTS symptoms can vary, including localized wrist pain, hand pain, and pain radiating up the forearm. As CTS progresses, patients may experience hand weakness, reduced fine motor skills, and thenar muscle atrophy. Initially, symptoms often occur at night but can become persistent with time, especially during repetitive activities.(Ashour et al., 2023; Liu et al., 2022)

Risk Factors

Risk factors for CTS include previous wrist fractures, rheumatoid arthritis, osteoarthritis, obesity, diabetes, and certain medications. Smoking and hormone therapies have not been strongly linked to CTS. Understanding these risk factors is essential for early diagnosis and effective management of CTS.(Bicha et al., 2024; Çupi et al., 2023; Demissie et al., 2023)

Systematic Review Objective

This study builds on previous systematic reviews by adopting broader inclusion criteria and incorporating recent trials. The objective is to conduct a meta-analysis to quantitatively synthesize evidence comparing surgical and non-surgical treatments for CTS.

Tabl. 1 Comparison of Treatment Methods (Ashour et al., 2023; Carmo, 2020; Chen et al., 2021; Fernandes et al., 2022; Graesser et al., 2023; Jiménez-del-Barrio et al., 2022; Karjalainen et al., 2023; Ku et al., 2023; Li et al., 2020; Liawrungrueang et al., 2023; Lo et al., 2021; Ng et al., 2021; Pripotnev & Mackinnon, 2022; Scalise et al., 2021; Schäfer et al., 2022; Sveva et al., 2024; Tumpaj et al., 2022; Wade et al., 2018; Wielemborek et al., 2022; Wu et al., 2022; Yang et al., 2024; Yoshii et al., 2020; Yu et al., 2023; Zeng et al., 2023; Zheng et al., 2023; Q. Zhou et al., 2023; T. Zhou et al., 2023)

Treatment Method	**DESCRIPTION**	**EFFECTIVENESS**	**PROS**	**CONS**
Wrist Splinting	Wearing a splint to keep the wrist in a neutral position	Effective for mild to moderate symptoms	Non-invasive, inexpensive, can be used at night	May not be effective for severe cases
Nonsteroidal Anti-inflammatory Drugs (NSAIDs)	Medications like ibuprofen to reduce inflammation	Provides temporary relief	Easily accessible, can reduce pain and swelling	May cause gastrointestinal issues with long-term use
Corticosteroid Injections	Injection of steroids to reduce inflammation	Effective for temporary relief	Quick reduction in	Potential side effects, not a

			pain and inflammation	long-term solution
Physical Therapy	Exercises and stretches to improve wrist strength and flexibility	Can help reduce symptoms and prevent worsening	Non-invasive, improves overall hand function	Requires time and consistent effort
Activity Modification	Changing hand/wrist positions and avoiding repetitive tasks	Helps prevent symptom exacerbation	Non-invasive, cost-free	May require significant changes to daily habits
Oral Steroids	Systemic steroids to reduce inflammation	Effective for short-term relief	Reduces inflammation and pain	Side effects with long-term use, not a permanent solution
Ultrasound Therapy	Use of sound waves to reduce inflammation and pain	Some evidence of effectiveness	Non-invasive	Limited evidence, may require multiple sessions
Surgery (Carpal Tunnel Release	Surgical procedure to relieve pressure on the median nerve	Highly effective for severe cases	Permanent solution, high success rate	Invasive, risk of complications, requires recovery time
Alternative Therapies	Acupuncture, chiropractic, yoga	Varies widely in effectiveness	May provide relief for some individuals	Limited scientific evidence, varies by practitioner

Endoscopic Median Nerve Decompression	Minimally invasive procedure using an endoscope to cut the transverse carpal ligament.	High, similar to traditional surgery, but with shorter recovery time.	Smaller scars, faster return to daily activities.	Requires specialized equipment and skills.
High-Intensity Laser Therapy (HILT)	Use of a laser for deep tissue penetration to reduce pain and inflammation.	Promising in reducing pain symptoms and improving hand function.	Painless, non-invasive.	Requires multiple sessions, limited long-term studies.
Percutaneous Ultrasonic Tenotomy	Technique using ultrasound to cut the transverse carpal ligament through a small incision.	Initial studies indicate effectiveness in symptom relief.	Minimally invasive, shorter recovery time.	New technique requiring further research.
Collagen Injections	Injections in the wrist area to improve tissue structure and reduce nerve compression.	Promising initial results in improving hand function.	Minimally invasive, can be repeated.	Further clinical trials needed.
Biological Therapy (PRP - Platelet-Rich Plasma)	Injection of platelet-rich plasma into tissues around the median nerve.	May support regenerative processes and reduce inflammation.	Natural healing method, minimally invasive.	Expensive, requires further research.
Radiofrequency Therapy (RF Therapy)	Use of radio waves to heat tissues to reduce inflammation and pain.	Effective in reducing pain for some patients.	Non-invasive, can be repeated.	Requires multiple sessions, variable effectiveness.

CONCLUSION

Both conservative and surgical treatments are beneficial for CTS, with surgery providing superior symptom relief and functional improvement at six and twelve months. Given the potential for adverse effects with surgery, initial conservative management is supported, followed by surgical intervention for severe or persistent symptoms. Ongoing research into new treatments is crucial for advancing CTS management.

This document provides a comprehensive overview of carpal tunnel syndrome, including its definition, anatomy, characteristic features, risk factors, and treatment approaches. It compares the efficacy of surgical and conservative treatments, concluding with a recommendation for initial conservative management followed by surgery if necessary.

Disclosure

Author's contribution

Conceptualization: Julia Szałajska; Methodology: Natalia Wierzejska; Software: Barbara Kopczyńska and Oliwia Czyżniewska; Check: Karina Otręba; Formal analysis: Barbara Kopczyńska; Investigation: Maria Wojcieszek; Resources: Karolina Czupryńska and Maria Wojcieszek; Data curation: Barbara Kopczyńska and Mikołaj Domański; Writing - rough preparation: Julia Szałajska; Writing - review and editing: Karolina Czupryńska; Visualization: Oliwia Czyżniewska and Maria Wojcieszek; Supervision: Natalia Wierzejska; Project administration: Karina Otręba; Receiving funding - no specific funding.

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Conflict of interest

The authors deny any conflict of interest.

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