

# ANATOMY OF THE CARPAL TUNNEL AND CARPAL TUNNEL SYNDROME

Syed Shahnawaz Ahmed<sup>1</sup>,

Student of group 219, Samarkand state medical university<sup>1</sup>,

Received: 2026-04-15 · Accepted: 2026-05-18

## Abstract

The carpal tunnel is a narrow osteofibrous canal located on the palmar aspect of the wrist that serves as a passageway for the median nerve and flexor tendons. Due to its confined anatomical structure, any condition that increases pressure within the tunnel may compress the median nerve and result in carpal tunnel syndrome (CTS), the most common entrapment neuropathy of the upper extremity. Carpal tunnel syndrome is associated with pain, numbness, paresthesia, muscle weakness, and functional impairment of the hand. The aim of this study was to examine the anatomical characteristics of the carpal tunnel, analyze the pathophysiological mechanisms underlying median nerve compression, and evaluate current approaches to diagnosis and management. Understanding the relationship between anatomy and clinical manifestations is essential for early recognition and effective treatment. Advances in imaging techniques, electrophysiological testing, and surgical interventions have improved diagnostic accuracy and patient outcomes.

**Keywords:** carpal tunnel, median nerve, carpal tunnel syndrome, wrist anatomy, nerve compression, entrapment neuropathy, electrophysiology, hand function, orthopedic disorders, peripheral neuropathy.

## 1. Introduction

The human hand represents one of the most complex and functionally important structures of the musculoskeletal system. Its ability to perform precise movements, sensory discrimination, and coordinated motor activities depends on the integrity of numerous anatomical components, including bones, ligaments, tendons, muscles, blood vessels, and nerves. Among the critical anatomical regions of the wrist, the carpal tunnel occupies a central role because it provides a protected passage for structures essential to normal hand function.

The carpal tunnel is an osteofibrous canal located at the volar aspect of the wrist. Its floor and lateral walls are formed by the carpal bones, while the roof consists of the transverse carpal ligament, also known as the flexor retinaculum. This rigid anatomical arrangement creates a confined space through which the median nerve and nine flexor tendons pass from the forearm into the hand.

The boundaries of the carpal tunnel are of considerable clinical importance. Proximally, the tunnel is bordered by the pisiform and scaphoid bones, while distally it is limited by the hook of the hamate and the trapezium. Because the tunnel possesses limited capacity for expansion, even minor increases in its contents or reductions in its dimensions may significantly elevate intracarpal pressure.

The median nerve is the most clinically significant structure within the tunnel. Originating from the

brachial plexus, the nerve carries both sensory and motor fibers. It provides sensation to the thumb, index finger, middle finger, and part of the ring finger, while also innervating several muscles responsible for thumb movement and fine motor control. Compression of the median nerve within the carpal tunnel disrupts these functions and produces the characteristic symptoms of carpal tunnel syndrome.

Carpal tunnel syndrome is recognized as the most common peripheral nerve entrapment disorder worldwide. The condition develops when increased pressure within the tunnel compromises median nerve function. Multiple factors may contribute to this process, including repetitive wrist movements, inflammation of flexor tendon sheaths, traumatic injuries, endocrine disorders, obesity, pregnancy, rheumatoid arthritis, and anatomical variations.

The pathophysiology of carpal tunnel syndrome involves a combination of mechanical compression and ischemic injury. Elevated pressure impairs intraneural blood flow, resulting in nerve edema, demyelination, and eventually axonal damage. These pathological changes contribute to progressive sensory disturbances and motor dysfunction.

Clinically, patients commonly present with numbness, tingling sensations, burning discomfort, and nocturnal pain affecting the distribution of the median nerve. Symptoms often worsen during activities requiring repetitive hand use and may interfere with occupational performance and daily activities. In advanced stages, weakness of the thenar muscles and loss of grip strength may occur, leading to substantial functional impairment.

Epidemiological studies indicate that carpal tunnel syndrome is more common in women than men and occurs most frequently during middle age. Occupational exposure to repetitive hand movements, prolonged wrist flexion, and vibration-producing tools has been identified as an important risk factor. However, the condition may also develop in individuals without significant occupational exposure due to systemic diseases or anatomical predisposition.

Accurate diagnosis requires integration of clinical findings, physical examination, and complementary investigations. Provocative tests such as Tinel's sign and Phalen's maneuver remain widely used in clinical practice. Electrophysiological studies provide objective evidence of median nerve dysfunction and are considered the diagnostic gold standard. Ultrasonography and magnetic resonance imaging have further enhanced the ability to visualize anatomical abnormalities and assess nerve pathology. Management strategies range from conservative interventions to surgical decompression. Early-stage disease may respond to activity modification, wrist splinting, physiotherapy, anti-inflammatory treatment, and corticosteroid injections. In patients with persistent symptoms or significant neurological deficits, surgical release of the transverse carpal ligament remains the most effective treatment.

The aim of this study is to explore the anatomical features of the carpal tunnel, examine the mechanisms responsible for median nerve compression, and evaluate contemporary approaches to the diagnosis and management of carpal tunnel syndrome.

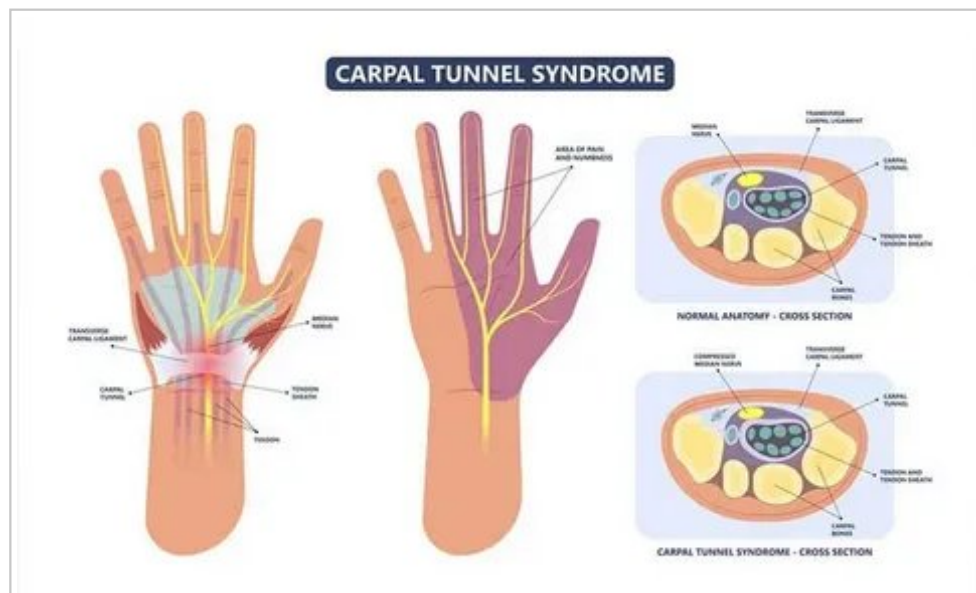


Figure 1. Figure 1

## 2. Materials and Methods

This study was conducted between 2024 and 2025 in departments of neurology, orthopedics, and rehabilitation medicine. A total of 110 patients diagnosed with carpal tunnel syndrome were included in the investigation. Participants ranged in age from 25 to 70 years and consisted of both male and female patients presenting with symptoms suggestive of median nerve compression.

A detailed medical history was obtained from each participant. Information regarding occupational activities, repetitive hand movements, duration of symptoms, previous wrist injuries, systemic diseases, and family history was recorded. Particular attention was given to conditions known to increase the risk of carpal tunnel syndrome, including diabetes mellitus, hypothyroidism, rheumatoid arthritis, obesity, and pregnancy.

Clinical examination included assessment of sensory function, muscle strength, grip force, and hand dexterity. Provocative tests such as Tinel's sign, Phalen's maneuver, and compression tests were performed to evaluate median nerve irritation. Sensory disturbances were assessed in the thumb, index finger, middle finger, and radial half of the ring finger.

Electrophysiological studies were conducted using nerve conduction testing. Distal motor latency, sensory conduction velocity, and nerve action potential amplitudes of the median nerve were measured and compared with standard reference values. Electromyography was performed in selected patients to evaluate the extent of nerve involvement and detect evidence of denervation. Ultrasonographic examination of the carpal tunnel was performed to assess median nerve morphology, cross-sectional area, and structural abnormalities within the tunnel. Magnetic resonance imaging was utilized in selected cases where anatomical variations or secondary causes of compression were suspected.

Patients received individualized treatment plans that included conservative management, physiotherapy, corticosteroid injections, or surgical decompression depending on symptom severity and neurophysiological findings. Clinical outcomes were evaluated during a twelve-month follow-up period.

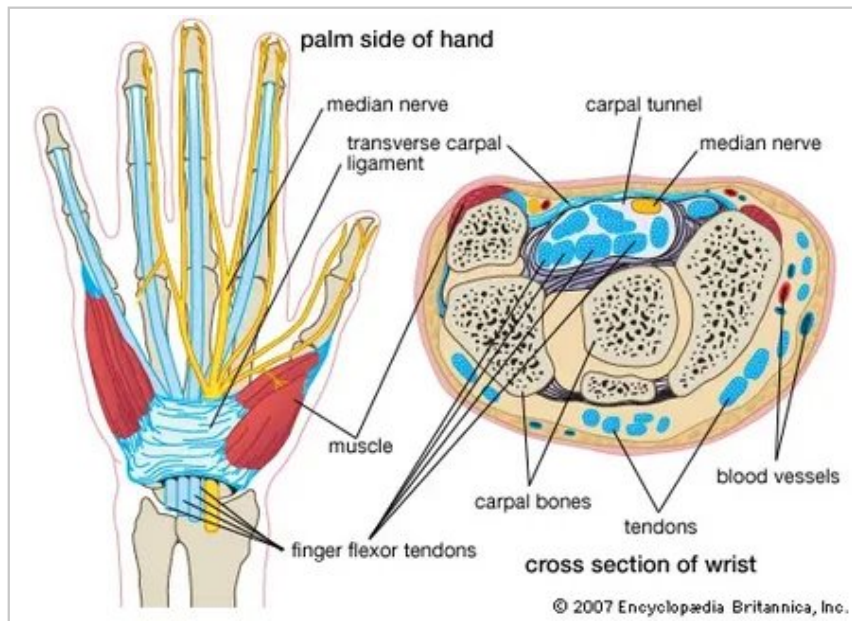


Figure 2. Figure 2

### 3. Results

The study demonstrated that carpal tunnel syndrome occurred more frequently among women than men. Most affected individuals were between 40 and 60 years of age. Occupational exposure involving repetitive wrist movements, prolonged computer use, manual labor, and repetitive gripping activities was identified as a common contributing factor.

Numbness and tingling sensations were the most frequently reported symptoms. These manifestations primarily affected the thumb, index finger, middle finger, and radial portion of the ring finger. Many patients reported worsening symptoms during nighttime, often resulting in sleep disturbance and reduced daily productivity.

Pain was commonly localized to the wrist and palm but frequently radiated into the forearm and fingers. Several patients described burning sensations and electric shock-like discomfort. Symptom intensity increased during repetitive hand activities and prolonged wrist flexion.

Clinical examination revealed sensory deficits within the median nerve distribution in a significant proportion of participants. Decreased tactile sensation and impaired two-point discrimination were commonly observed. Patients with advanced disease demonstrated weakness of thumb abduction and opposition, reflecting involvement of thenar musculature.

Electrophysiological studies confirmed median nerve dysfunction in the majority of cases. Prolonged distal motor latency, reduced sensory conduction velocity, and decreased nerve action potential amplitudes were among the most frequent abnormalities. Severe cases demonstrated evidence of axonal degeneration and significant impairment of nerve transmission.

Ultrasonographic evaluation revealed enlargement of the median nerve proximal to the site of compression. Increased cross-sectional area and structural changes within the nerve correlated with clinical severity and electrophysiological findings.

Conservative treatment resulted in symptom improvement among patients with mild and moderate disease. Wrist splinting, physiotherapy, and activity modification reduced pain and sensory disturbances. Corticosteroid injections provided temporary relief in selected cases.

Surgical decompression demonstrated favorable outcomes in patients with severe symptoms and significant neurophysiological abnormalities. Most surgically treated patients experienced substantial reduction in pain, improvement in sensory function, and restoration of hand strength during follow-up evaluations.

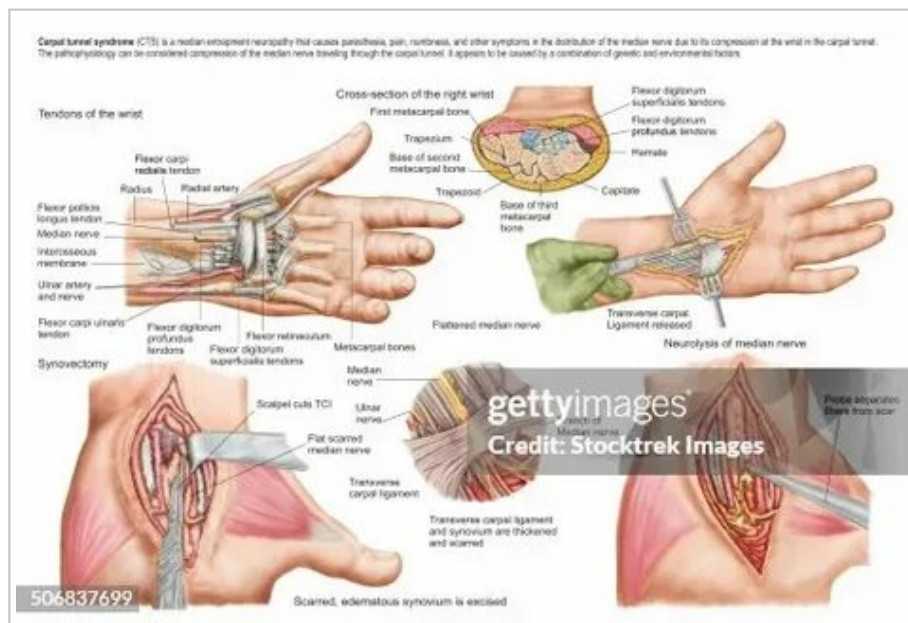


Figure 3. Figure 3

#### 4. Discussion

The findings of this study confirm that carpal tunnel syndrome remains the most common entrapment neuropathy affecting the upper extremity. The condition results from compression of the median nerve within a confined anatomical space where even small increases in pressure can significantly impair nerve function.

The predominance of female patients observed in this investigation is consistent with epidemiological studies reported worldwide. Anatomical differences in carpal tunnel dimensions, hormonal influences, and occupational exposures may contribute to the increased prevalence among women.

The characteristic sensory symptoms identified in this study reflect the anatomical distribution of the median nerve. Numbness, tingling, and nocturnal discomfort frequently represent the earliest manifestations of compression. Recognition of these symptoms is important because timely intervention may prevent progression to irreversible nerve damage.

Electrophysiological testing proved essential for confirming diagnosis and determining disease severity. Nerve conduction studies provided objective evidence of median nerve dysfunction and allowed differentiation between mild, moderate, and severe neuropathy. These findings support the continued role of electrophysiology as a cornerstone of diagnostic evaluation.

Ultrasonography emerged as a valuable complementary imaging modality. Visualization of nerve enlargement and structural changes enhanced diagnostic accuracy and provided additional information regarding anatomical factors contributing to compression. The noninvasive nature of ultrasonography makes it particularly useful for routine clinical assessment.

The favorable outcomes associated with conservative treatment highlight the importance of early diagnosis. Many patients with mild disease experienced significant improvement through activity modification, splinting, and rehabilitation interventions. However, severe cases frequently required surgical decompression to achieve lasting symptom relief.

The success of surgical treatment reflects correction of the underlying mechanical cause of median nerve compression. Release of the transverse carpal ligament reduces intracarpal pressure, restores nerve perfusion, and promotes neurological recovery. Early surgical intervention in appropriately selected patients may prevent permanent functional deficits.

Future research should focus on improved understanding of risk factors, development of preventive strategies, and optimization of minimally invasive treatment techniques. Advances in imaging and neurophysiological assessment may further enhance diagnostic precision and individualized patient management.

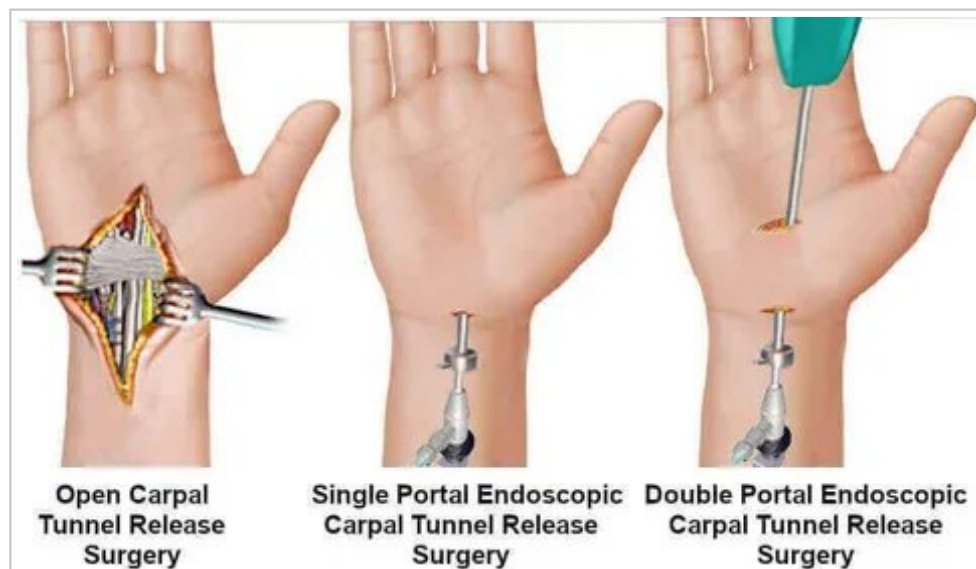


Figure 4. Figure 4

## 5. Conclusion

The carpal tunnel is a complex anatomical structure whose integrity is essential for normal hand function. Compression of the median nerve within this confined space results in carpal tunnel syndrome, the most common entrapment neuropathy of the upper limb.

Clinical manifestations include numbness, paresthesia, pain, muscle weakness, and functional impairment of the hand. Electrophysiological studies and imaging techniques provide valuable information for accurate diagnosis and assessment of disease severity.

Early recognition and appropriate treatment are critical for preventing permanent nerve injury and preserving hand function. Conservative interventions are effective in many patients with mild disease, whereas surgical decompression remains the treatment of choice for advanced cases.

A comprehensive understanding of carpal tunnel anatomy, pathophysiology, and clinical presentation is fundamental for successful diagnosis, management, and rehabilitation of patients affected by carpal tunnel syndrome.

## References

- [1] Phalen GS. The carpal tunnel syndrome: clinical evaluation of 598 hands. Clin Orthop Relat Res. 1972;83:29–40.
- [2] Keith MW, Masear V, Chung KC, et al. American Academy of Orthopaedic Surgeons clinical practice guideline on the diagnosis of carpal tunnel syndrome. J Bone Joint Surg Am. 2009;91(10):2478–2479.
- [3] Aroori S, Spence RAJ. Carpal tunnel syndrome. Ulster Med J. 2008;77(1):6–17.
- [4] Ibrahim I, Khan WS, Goddard N, Smitham P. Carpal tunnel syndrome: a review of the recent literature. Open Orthop J. 2012;6:69–76.
- [5] Chammas M, Boretto J, Burmann LM, Ramos RM, Dos Santos Neto FC, Silva JB. Carpal tunnel syndrome – Part I: anatomy, physiology, etiology and diagnosis. Rev Bras Ortop. 2014;49(5):429–436.
- [6] Atroshi I, Gummesson C, Johnsson R, Ornstein E, Ranstam J, Rosén I. Prevalence of carpal tunnel syndrome in the general population. JAMA. 1999;282(2):153–158.
- [7] Padua L, Coraci D, Erra C, et al. Carpal tunnel syndrome: clinical features, diagnosis, and management. Lancet Neurol. 2016;15(12):1273–1284.
- [8] Bland JDP. Carpal tunnel syndrome. BMJ. 2007;335(7615):343–346.
- [9] Rempel D, Diao E. Entrapment neuropathies: pathophysiology and treatment of carpal tunnel syndrome. J Electromyogr Kinesiol. 2004;14(1):71–75.

- [10] Duncan I, Sullivan P, Lomas F. Sonography in the diagnosis of carpal tunnel syndrome. *AJR Am J Roentgenol.* 1999;173(3):681–684.
- [11] Fowler JR, Gaughan JP. The role of ultrasound in carpal tunnel syndrome diagnosis. *Hand Clin.* 2018;34(1):19–24.
- [12] Werner RA, Andary M. Electrodiagnostic evaluation of carpal tunnel syndrome. *Muscle Nerve.* 2011;44(4):597–607.
- [13] Moore KL, Dalley AF, Agur AMR. *Clinically Oriented Anatomy.* 9th ed. Philadelphia: Wolters Kluwer; 2023.
- [14] Standring S. *Gray's Anatomy: The Anatomical Basis of Clinical Practice.* 43rd ed. Elsevier; 2024.
- [15] American Academy of Neurology. Practice guideline for diagnosis of carpal tunnel syndrome. *Neurology.* 2023.
- [16] American Society for Surgery of the Hand. Clinical management of carpal tunnel syndrome. *ASSH;* 2024.
- [17] World Health Organization. *Musculoskeletal Health Report.* Geneva: WHO; 2025.
- [18] Green DP, Wolfe SW, Hotchkiss RN, Pederson WC, Kozin SH. *Green's Operative Hand Surgery.* 9th ed. Elsevier; 2024.
- [19] Med1.uz. Karpal tunnel sindromi: sabablari va klinik belgilari. Available from: <https://med1.uz/articles/nevrologiya/kar-pal-tunnel>
- [20] Med1.uz. Qo'l nervlarining kompression-nevropatiyalari. Available from: <https://med1.uz/articles/nevrologiya/kom-pression-nevropatiya>
- [21] Med1.uz. Karpal tunnel anatomiyasi va klinik ahamiyati. Available from: <https://med1.uz/articles/anatomiya/karpa-l-tunnel>
- [22] Med1.uz. Elektroneymyografiya yordamida periferik nervlarni tekshirish. Available from: <https://med1.uz/articles/diagnostika/enm-g>
- [23] Med1.uz. Tunnel sindromlarining zamonaviy diagnostikasi. Available from: <https://med1.uz/articles/nevrologiya/tun-nel-sindrom>
- [24] Med1.uz. Qo'l panjasi kasalliklarida ultratovush diagnostikasi. Available from: <https://med1.uz/articles/diagnostika/ult-ratovush>
- [25] Med1.uz. Periferik nerv tizimi kasalliklarini davolash usullari. Available from: <https://med1.uz/articles/nevrologiya/per-iferik-nerv>
- [26] Med1.uz. Neyrologik reabilitatsiyada zamonaviy yondashuvlar. Available from: <https://med1.uz/articles/nevrologiya/rea-bilitatsiya>

## Indexed & Abstracted In

---

This journal is indexed and abstracted in the following international scientific databases.



Google Scholar



ISSN



ORCID



CiteFactor



ResearchBib



DOI



Zenodo



Grammarly

### Article Verification

Scan the QR code to verify the authenticity of this article

DOI: 10.4103/aams.0498