# Review Article

# Surgical anatomy of carpal tunnel in view of carpal tunnel syndrome

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Carpal tunnel is a space present in front of the wrist in between the volar carpal ligament in front and carpal bone at behind. The median nerve passes through this tunnel from the forearm to the palmar aspect of the hand. This nerve is known as "eye of hand" and "million-dollar nerve" due to its major sensory supply to the lateral two third of palmar skin and also motor supply to muscles for the thumb (thenar muscles). This median nerve can get compressed inside the carpal tunnel in various medical, surgical, and traumatic conditions. Many anatomical patterns of branching and course of the median nerve have been reported within the carpal tunnel. Hence, knowledge of the surgical anatomy of carpal tunnel and the pattern of branching and course of the median nerve may help during any surgical procedure in carpal tunnel diseases.

**KEYWORDS:** Carpal tunnel, median nerve, volar carpal ligament

## INTRODUCTION

Carpal tunnel syndrome (CTS) is neuropathy of the median nerve due to its compression at the wrist while passing through deep to the volar carpal ligament. In 1854, Paget described this syndrome.[1] For hand pain in manual workers and compression neuropathies of the upper limb, this syndrome is the most common causative factor.[2-6]

## REVIEW

### Surgical Anatomy

Carpal tunnel is located in front of the wrist (palmar aspect). It is a narrow space which is anteriorly bounded by flexor retinaculum (transverse carpal ligament [TCL]), posteriorly and on either side bounded by the concavity of carpal bones.

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The flexor retinaculum is a thickening of deep fascia of palm over the wrist. It is a strong fibrous band around 2.5 cm × 3 cm long and broad. Medially, it attached to the pisiform bone and hook of hamate bone. Laterally by two slips, it attached to tubercle of scaphoid bone and trapezium bone (superficial slip) and groove of trapezium (deep slip). Synovial sheath lines area between two slip and groove of trapezium which covers the tendon of flexor carpi radialis muscle. On the medial side, a slip from retinaculum after covering the ulnar vessels and nerves got attached to pisiform bone and forms a tunnel called as Guyon's canal. Sometimes, ulnar nerve gets trapped in it. TCL crossed superficially by palmar cutaneous branch of median nerve and ulnar nerve, tendon of palmaris longus muscle if present and superficial branch of the radial artery. Various structures pass deep to it, long flexor tendon of digits (four tendons of each flexor digitorum superficialis [FDS] and flexor digitorum profundus [FDP]), wrapped in synovial pouch known as ulnar bursa, tendon of flexor pollicis longus with radial synovial bursa, and median nerve. This TCL provides attachments to a few intrinsic muscles of the thumb (thenar muscles) and little finger (hypothenar muscles) at its distal margin, and at the proximal margin, it gives attachment to tendon of flexor carpi ulnaris and palmaris longus muscles[7] [Figure 1].

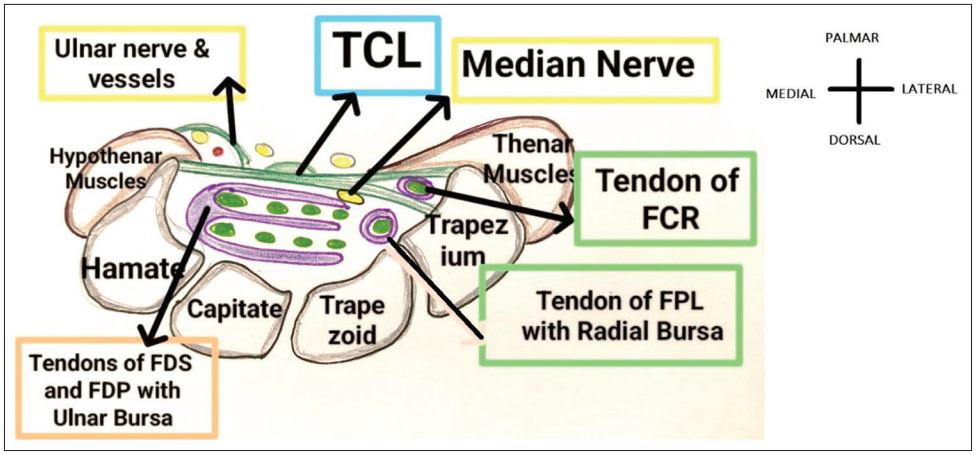


**Figure 1:** Schematic diagram showing Boundaries and content of carpal tunnel. FCR: Flexor carpi radialis, FPL: Flexor pollicis longus, FDS: Flexor digitorum superficialis, FDP: Flexor digitorum profundus, and TCL: Transverse carpal ligament

### Median Nerve

This nerve is a branch of brachial plexus and arises from two roots, one from the lateral cord and one from the medial cord of the plexus with root values of C5, 6, 7, 8, and T1. It passes deep to the TCL and overlies the tendon for the index finger of muscle FDS and FDP. After crossing the carpal tunnel, the nerve gives two branches, medial and lateral. The lateral branch gives digital branches and muscular branch (known as recurrent motor branch [RMB]) which supplies the intrinsic muscles of the thumb known as thenar muscles. They are abductor pollicis brevis, flexor pollicis brevis, and opponens pollicis. Digital branch for index finger also supplies 1st lumbrical. The medial branch divides into two common digital branch which supplies the adjacent side of the index, middle, and ring finger and also supplies the 2nd lumbrical muscle[8,9] [Figure 2]. The RMB is also known as the million-dollar nerve. By common and proper digital branches, it supplies the radial and ulnar side of 1st, 2nd, and 3rd digit and radial side of the 4th digit.[10] Palmar aspect of the skin over lateral half of palm is innervated by the palmar cutaneous branch which arises from the median nerve 6 cm proximal to TCL [Figure 3].

Many anatomical variations for the branching pattern of RMB of the median nerve were described and classified by Lanz[11], as shown in [Figure 4].

#### *First group (Group I)[11] – Variation of origin and course of motor branch of median nerve*

This further has subgroups, in Group I-A, RMB arises distal to the carpal tunnel, from the lateral side of median nerve (palmar aspect) and arches above the distal margin of TCL, in Group I-B, RMB originates within the carpal tunnel and arches above the flexor retinaculum, in Group I-C, RMB arises within the carpal tunnel from the lateral side of median nerve and pierces the TCL, in Group I-D, RMB arises from medial side of median nerve and arches above the distal margin of TCL, and, in Group I-E, RMB arises from medial part of median nerve and runs over the surface of TCL to thenar muscles[11] [Figure 4].

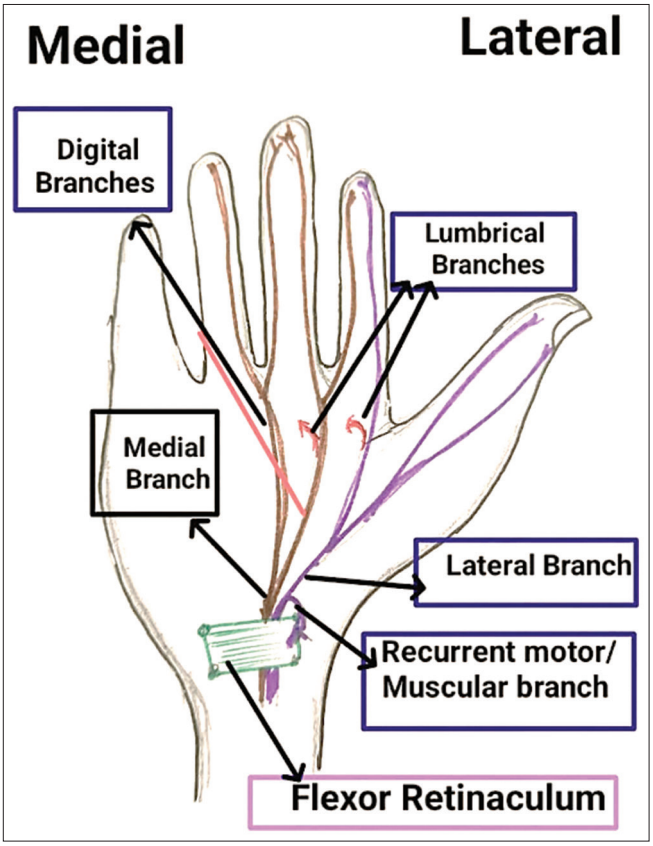


**Figure 2:** Schematic diagram showing branches of median nerve in hand

#### *Second group (Group-II)*

Additional motor branches (AMBs) arise from the median nerve at the distal part of the carpal tunnel, from the first palmar common digital branch[11] [Figure 4].

#### *Third group (Group-III) – Proximal division of the median nerve*

In subgroup – Group III-A, median nerve divides higher into lateral and medial parts. Origin of RMB is typical, in Group III-B, there is proximal division of the median

nerve which accompanies persistent median artery (PMA), and in Group III-C proximal division of the median nerve which accompanies the extra branch to lumbrical[11] [Figure 4].

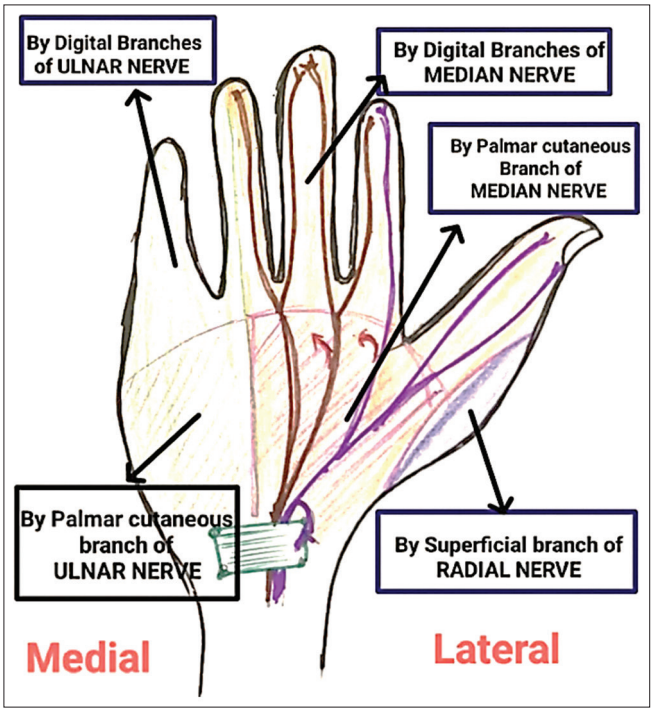


**Figure 3:** Schematic diagram showing cutaneous nerve supply of palm

***Fourth group (Group-IV) – AMB, proximal to TCL***

In this, Group IV-A, AMB arises from the trunk of the median nerve proximal to TCL and runs within the fibers of TCL and joining the RMB, in Group IV-B, AMB arises proximal to TCL and enters into carpal tunnel, pierces TCL, and, in Group IV-C, AMB arises from medial part of median nerve and crosses the nerve from the front and runs along its lateral side; then, it enters the carpal tunnel and pierces TCL and fuses with first common digital branch of median nerve[11] [Figure 4].

For the 1st time in 1974, Poisel proposed the classification of thenar motor branch.[12]

In retro-ligamentous type – Thenar motor branch originates distal to the flexor retinaculum, from the first common digital branch of median nerve and arches above the TCL, reaching to thenar muscles (in 46% of cases). In subligamentous type – RMB arises from first common digital branch inside the carpal tunnel, and arches above the distal margin of TCL and supplying the thenar muscles (in 31% of cases). In transligamentous type – RMB originates from the first common digital branch of median nerve, pierces the TCL, and runs obliquely to supply the thenar muscles (in 23%cases).[12]

Hence, each case of CTS needs special attention due to variations in median nerve branching. Hence, it is advised that in minimal open carpal tunnel release procedures, TCL should preferably be cut open in the line of the lateral border of 4th finger to minimize the risk of injury to the recurrent muscular branch.[13]

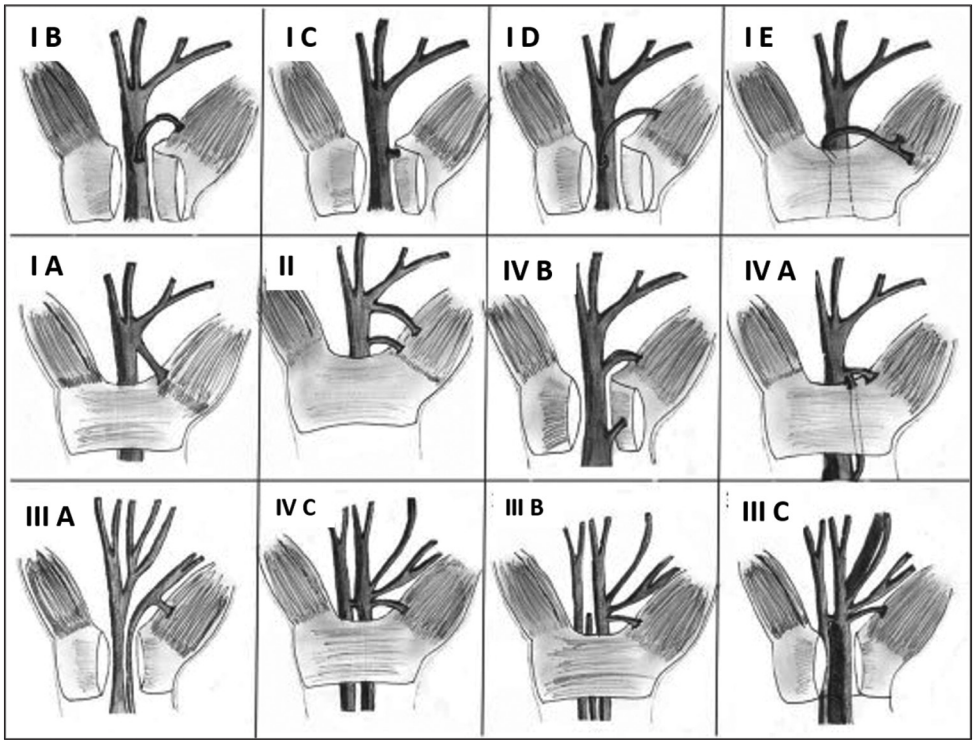


**Figure 4:** Lanz classification of the median nerve anatomical variations at the wrist. Group I, Thenar branch variations; (1A) subligamentous, (1B) transligamentous, (1C) ulnarwards, (1D) supraligamentous, (1E) Ulnarwards and Supraligamentous. Group 0, extraligamentous thenar branch. Group II, distal accessory thenar branch. Group IV, proximal accessory thenar branch; (4A) running directly in the thenar muscles, (4B) joining another branch. Group III, high division of the median nerve; (4C) AMB from medial side of median nerve. (3A) without an artery of muscle, (3B) with artery, (3C) with lumbrical muscle.[8]

For carpal tunnel release procedures along with median nerve variations, one should also look for PMA. Osiak *et al.*, reported PMA in 2.8% of cases (i.e., 36 cases in 1285 operated hands), in 2%, it was in the right hand, and 3.9% of cases, it was present in the left hand.[14]

The presence of communicating branch between the ulnar nerve and median nerve in the hand was first reported in 1763 by Martin and later on reported by Gruber. That's why this communicating branch is known as Martin–Gruber anastomosing branch.[15-17] These connections present from the median to ulnar nerve in the majority of cases. Rarely, these connections present from ulnar nerve to the median nerve in forearm instead of hand[15-17] and are termed as reverse Martin–Gruber anastomosis.[17] These types of connections may interfere motor conduction test's result and give unusual finding in the presence of CTS, like total or partial sparing of thenar muscles. Due to these connections, there may be unusual motor loss of muscles of the hand in cases of peripheral nerve lesions.[15,17,18]

Many variations of these Martin–Gruber anastomoses were described and classified as Patterns I and II. In pattern I, there is one anastomotic branch and in pattern II there are two anastomotic branches present. In pattern I, subdivision type IA, superficial muscular branches of the forearm from median nerve give rise anastomotic branch, in type IB main trunk of the median nerve give rise to this anastomotic branch, and in subdivision type IC anterior interosseous branch gives this anastomotic branch.[15-17,19]

## CAUSES AND RISK FACTORS OF CTS

This carpal is the repeated trauma disorders. Occupations that have a risk for CTS are worker doing work manually.[20,21]

Causes – In most of the cases, it is idiopathic (7–16%), common in female with increasing age (45–64 years), occupations related to gripping, vibrations, and repetitive flexion and extension at the wrist.[22,23] Traumatic causes – like fractures at the distal end of the radius and carpals, post traumatic arthritis, Tumors – like ganglionic cyst, certain neuropathies – due to alcoholism, diabetes, vitamin insufficiency, etc., morphological, and mechanical changes in retinaculum, persistent median artery.[24,25] Other causes – include hypothyroidism, pregnancy, obesity, congestive heart failure, renal failure, oral contraceptive pills, and mucopolysaccharidosis type I, II, IV, and VI.[26]

### Pathophysiology

Pressure in the carpal tunnel recorded 2 mm Hg to 10 mm Hg as normal pressure. However, due to repetitive movements of the wrist joint, the pressure of it fluctuates and increases ten-fold during extension and eight-fold during the flexion. Pressure may increase due to increase interstitial pressure, which leads to compression of the median nerve in the carpal tunnel and lead to ischemic demyelination of the nerve fibers.[27] Increase pressure in the carpal tunnel leads to compartmental syndrome, in this due to compression, epineural blood flow compromises and causes ischemia, swelling, and demyelination of nervous tissue.[28] At this time if surgical decompression is done, rapid reversible of symptoms occurs.[29] If compression persists for a long time, it can cause irreversible damage to the median nerve.[28]

During decompression surgeries, it was found that the nerve is thinned out in the region of compression and swelling was found in nervous tissue just proximal to entrapment. Swelling of nervous tissue may be due to increase axoplasm and chronic inflammatory process. This inflammation is due to increase production of E2 prostaglandins and other factors like vascular endothelial growth factors. It can cause the slow nerve conduction.[30]

There are also genetic predispositions for CTS. There is the involvement of synthesis and breakdown of collagen compounds, proteins which are protractive against oxidative stress. COL1A1, COL5A1, and COL11A1 are the group of genes which play an important role in CTS predisposition. Another group of genes like matrix metalloproteinases encodes the enzymes which responsible for glutathione S-transferases synthesis. It reduces the toxic effect caused by oxidative stress. Genetic predisposition of CTS can be suspected if it occurs early in age and bilateral involvement is there.[31]

## SYMPTOMS

Clinically, the patient presents as – (a) Irregular nocturnal paresthesia more frequent when person is awake, (b) sensory loss in the first, second, third, and lateral side of the fourth digit, and (c) weakness or atrophy of muscles of the thumb. Unique feature of CTS is that there is no sensory loss over the thenar eminence because this area is supplied by the palmar cutaneous branch of the median nerve which passes superficial to TCL.[32]

Symptoms increase at night or doing repetitive movements which involved prolonged flexion at the wrist.[30] Stages of CTS according to clinical symptoms are-

Stage I: Sleep is disturbed due to a feeling of numbness and swelling in hand. There is brachialgia paresthesia nocturna, in this pain radiating to shoulder from wrist along with tingling in the hand and digits. Flick sign: shaking of the hand may relieve the pain known as flick sign.

Stage II: Experience pain during day with frequent clumsiness during grasping the objects with hands.

Stage III: Diminished sensory symptoms, loss of contour over thenar eminence sometimes there is hypotrophy.[33]

### Acute CTS

It usually presents as a complication of trauma to the hand or wrist like fracture of radius. It may not be associated with trauma. In this condition, the emergency release of compression requires which is done by the complete release of TCL.[28]

## SIGNS OF CTS

### Tinel's Sign

This was described in 1915 by Tinel.[34] If there is discomfort and tingling over the median nerve supplied area (especially

fingers) while tapping over this nerve at the wrist, known as positive sign [Figure 5]. It is not a definite sign to diagnose the CTS.[29] Some factors which influence outcome of test-[36,37]

a) Decrease efficacy due to continuous regeneration of nerve
b) Amount of pressure applied for the test
c) Procedure/method used for test

### Phalen's Test

Phalen's test was described by Phalen and Kendrick in 1957.[38] This flexion of the wrist joint causes more pressure on the nerve in the tunnel which, in turn, causes paresthesia over the area of distribution of the median nerve [Figure 6]. It is termed positive if paresthesia develops in <1 min of test.[36]

## DIAGNOSIS OF CTS

While making a diagnosis of CTS, we consider the sign, symptoms, and diagnostic test. Diagnostic test are as follow-

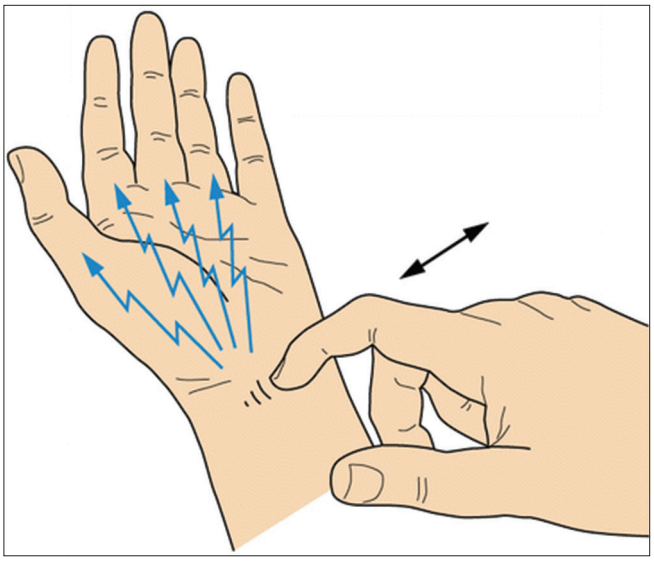

**Figure 5:** Tinel sign[35]

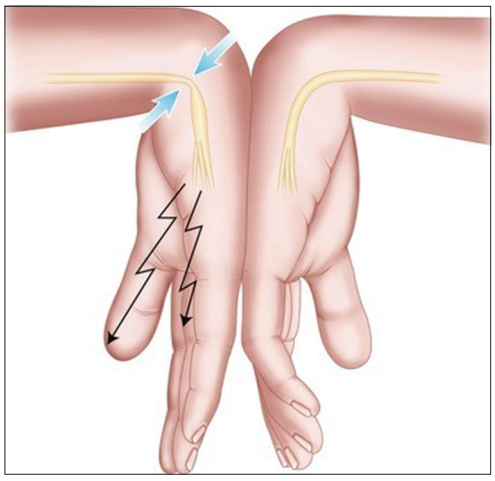

**Figure 6:** Phalen's sign[39]

### Electrodiagnostic (EDX)

EDX tests are the most reliable way to diagnose CTS.[38,40] It includes nerve conduction studies (NCS) and electromyography (EMG)

a) NCS: By this, we can detect the impaired conduction of the median nerve across the carpal tunnel. So to confirm the CTS, in CTS conduction of the median nerve impaired only in the carpal tunnel, elsewhere the conduction of this nerve is normal. It is a valid diagnostic test for CTS.[41]
b) EMG: By this test, we can assess that the pathological changes occur in muscles especially the abductor pollicis brevis which is supplied by the median nerve. This test used in the clinical diagnosis of CTS, to evaluate the severity, and to find out its pathophysiology.[42,43]

### Ultrasound

It can detect the diagnostic features of CTS such as (a) thickening or flattening of the nerve inside the tunnel, (b) bowing of the flexor retinaculum, and (c) increased diameter of the nerve just before the compression, measured at the level of the pisiform.[43]

### Magnetic Resonance Imaging

It defines the borders of carpal tunnel clearly, easily differentiate nerve from the tendons running in the carpal tunnel. It is a very useful tool to detect primary nerve pathologies and space-occupying lesions which can cause nerve compression in carpal tunnel.[44]

## CONCLUSIONS

There are varieties of anatomical variations reported by many researchers along with their incidence. Hence, the thorough knowledge of surgical anatomy of carpal tunnel and course and branching pattern of the median nerve in hand along with its variations is important. This knowledge may be helpful in planning treatment or performing any surgical procedure in cases of carpal tunnel diseases or injuries.

## REFERENCES

1. Paget J. Lectures on Surgical Pathology. Philadelphia, PA: Lindsay and Blakiston; 1854.
2. Stapleton MJ. Occupation and carpal tunnel syndrome. ANZ J Surg 2006;76:494-6.
3. Eversmann WW Jr. Compression and entrapment neuropathies of the upper extremity. J Hand Surg Am 1983;8:759-66.
4. Omer GE Jr. Median nerve compression at the wrist. Hand Clin 1992;8:317-24.
5. Blanc PD, Faucett J, Kennedy JJ, Cisternas M, Yelin E. Self-reported carpal tunnel syndrome: Predictors of work disability from the National Health Interview Survey Occupational Health Supplement. Am J Ind Med 1996;30:362-8.
6. Patterson JD, Simmons BP. Outcomes assessment in carpal tunnel syndrome. Hand Clin 2002;18:359-63, viii.
7. Standring S, Gray H. In: Borley NR, editor. Gray's Anatomy: The Anatomical Basis of Clinical Practice. 41st ed. Philadelphia, PA: Elsevier Limited; 2016. p. 863-4.

8. Lanz U. Variations of the median nerve at the carpal tunnel. Handchirurgie 1975;7:163-4.
9. Krishnan P, Mishra R, Jena M, Das A. Transligamentous thenar branch of the median nerve: The million dollar nerve. Neurol India 2013;61:311-2.
10. Iskra T, Mizia E, Musial A, Matuszyk A, Tomaszewski KA. Carpal tunnel syndrome - anatomical and clinical correlations. Folia Med Cracov 2013;53:5-13.
11. Lanz U. Anatomical variations of the median nerve in the carpal tunnel. J Hand Surg Am 1977;2:44-53.
12. Poisel S. Ursprung und Verlauf des Ramusmuscularis des N. digitalis palmaris communis I (N. medianus). Chir Prax 1974;18:471-4.
13. Elsaftawy A, Gworys B, Jabłecki J, Szajerka T. "Dangerous" anatomic varieties of recurrent motor branch of median nerve. Pol Przegl Chir 2013;85:419-23.
14. Osiak K, Elnazir P, Mazurek A, Pasternak A. Prevalence of the persistent median artery in patients undergoing surgical open carpal tunnel release: A case series. Transl Res Anat 2021;23:100113.
15. Kazakos KJ, Smyrnis A, Xarchas KC, Dimitrakopoulou A, Verettas DA. Anastomosis between the median and ulnar nerve in the forearm. An anatomic study and literature review. Acta Orthop Belg 2005;71:29-35.
16. Rodriguez-Niedenführ M, Vazquez T, Parkin I, Logan B, Sañudo JR. Martin-Gruber anastomosis revisited. Clin Anat 2002;15:129-34.
17. Taams KO. Martin-Gruber connections in South Africa. An anatomical study. J Hand Surg Br 1997;22:328-30.
18. Iyer V, Fenichel GM. Normal median nerve proximal latency in carpal tunnel syndrome: A clue to coexisting Martin-Gruber anastomosis. J Neurol Neurosurg Psychiatry 1976;39:449-52.
19. Nakashima T. An anatomic study on the Martin-Gruber anastomosis. Surg Radiol Anat 1993;15:193-5.
20. Bernard BP, editor. Musculoskeletal Disorders and Workplace Factors. Critical Review of Epidemiologic Evidence for Work-Related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back. NIOSH Publication No 97 - 141. U.S. Department of Health and Human Services, Public Health Service Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health; 1997. Available from: https://www.cdc.gov/niosh/docs/97-141/97-141pdhtml [Last accessed on 2023 May 04].
21. Brain WR, Wright AD, Wilkinson M. Spontaneous compression of both median nerves in the carpal tunnel; six cases treated surgically. Lancet 1947;1:277-82.
22. Ferry S, Pritchard T, Keenan J, Croft P, Silman AJ. Estimating the prevalence of delayed median nerve conduction in the general population. Br J Rheumatol 1998;37:630-5.
23. Lawson IJ. Is carpal tunnel syndrome caused by work with vibrating tools? Occup Med (Lond) 2020;70:8-10.
24. Marquardt TL, Evans PJ, Seitz WH Jr., Li ZM. Carpal arch and median nerve changes during radioulnar wrist compression in carpal tunnel syndrome patients. J Orthop Res 2016;34:1234-40.
25. Shen ZL, Li ZM. Ultrasound assessment of transverse carpal ligament thickness: A validity and reliability study. Ultrasound Med Biol 2012;38:982-8.
26. Patel P, Antoniou G, Clark D, Ketteridge D, Williams N. Screening for carpal tunnel syndrome in patients with mucopolysaccharidosis. J Child Neurol 2020;35:410-7.
27. Werner RA, Andary M. Carpal tunnel syndrome: Pathophysiology and clinical neurophysiology. Clin Neurophysiol 2002;113:1373-81.
28. Gillig JD, White SD, Rachel JN. Acute carpal tunnel syndrome: A review of current literature. Orthop Clin North Am 2016;47:599-607.
29. Ostergaard PJ, Meyer MA, Earp BE. Non-operative treatment of carpal tunnel syndrome. Curr Rev Musculoskelet Med 2020;13:141-7.
30. Rosario NB, De Jesus O. Electrodiagnostic evaluation of carpal tunnel syndrome. In: StatPearls. Treasure Island, FL: StatPearls Publishing; 2021.
31. Żyluk A. The role of genetic factors in carpal tunnel syndrome etiology: A review. Adv Clin Exp Med 2020;29:623-8.
32. Padua L, Coraci D, Erra C, Pazzaglia C, Paolasso I, Loreti C, *et al.* Carpal tunnel syndrome: Clinical features, diagnosis, and management. Lancet Neurol 2016;15:1273-84.
33. Wulle C. The synovial flap as treatment of the recurrent carpal tunnel syndrome. Hand Clin 1996;12:379-88.
34. Hoffmann P, Buck-Gramcko D, Lubahn JD. The Hoffmann-Tinel sign. 1915. J Hand Surg Br 1993;18:800-5.
35. Epomedicine. Tinel Sign. Epomedicine; 2021. Available from: https://epomedicine.com/medical-students/tinel-sign [Last accessed on 2023 Mar 16].
36. Heller L, Ring H, Costeff H, Solzi P. Evaluation of Tinel's and Phalen's signs in diagnosis of the carpal tunnel syndrome. Eur Neurol 1986;25:40-2.
37. Mondelli M, Passero S, Giannini F. Provocative tests in different stages of carpal tunnel syndrome. Clin Neurol Neurosurg 2001;103:178-83.
38. Phalen GS, Kendrick JI. Compression neuropathy of the median nerve in the carpal tunnel. J Am Med Assoc 1957;164:524-30.
39. Andrews R, Isaacson A, Kanzer D. Carpal tunnel syndrome. In: Kahn S, Xu R, editors. Musculoskeletal Sports and Spine Disorders. Cham: Springer; 2017.
40. Stevens JC. AAEE minimonograph #26: The electrodiagnosis of carpal tunnel syndrome. Muscle Nerve 1987;10:99-113.
41. Sonoo M, Menkes DL, Bland JD, Burke D. Nerve conduction studies and EMG in carpal tunnel syndrome: Do they add value? Clin Neurophysiol Pract 2018;3:78-88.
42. Fowler JR. Nerve conduction studies for carpal tunnel syndrome: Gold standard or unnecessary evil? Orthopedics 2017;40:141-2.
43. Fowler JR, Gaughan JP, Ilyas AM. The sensitivity and specificity of ultrasound for the diagnosis of carpal tunnel syndrome: A meta-analysis. Clin Orthop Relat Res 2011;469:1089-94.
44. Kumari A, Singh S, Garg A, Prakash A, Sural S. Tingling hand: Magnetic resonance imaging of median nerve pathologies within the carpal tunnel. Pol J Radiol 2019;84:e484-90.