BJCR
BRAZILIAN JOURNAL OF CASE REPORTS

PCAA PUBLICAÇÕES CIENTÍFICAS DE ACESSO ABERTO

Case Report

A transmuscular path of the medial branch of the high division of the median nerve: an anatomical variation of clinical and surgical importance

Caio Siqueira Kuhn [1], Lucimário de Carvalho Barros [1], Iapunira Catarina Sant'Anna Aragão [2], Felipe Matheus Sant'Anna Aragão [3], Francisco Prado Reis [4], Deise Maria Furtado de Mendonça [5], José Aderval Aragão [6,*]

1 Medical Student, Department of Medicine, Federal University of Sergipe (UFS), Aracaju, SE, Brazil.
2 Medical Clinic Resident of Municipal Hospital Munir Rafful (HMMR), Volta Redonda, RJ, Brazil.
3 Medical Clinic Resident of Faculty of Medicine of São José do Rio Preto (FAMERP), São José do Rio Preto, São Paulo, Brazil.
4 Titular Professor, Medical School of Tiradentes University (UNIT), Aracaju, SE, Brazil.
5 Associate Professor of Human Anatomy, Department of Morphology, Federal University of Sergipe (UFS), Aracaju, SE, Brazil.
6 Titular Professor of Clinical Anatomy, Department of Morphology, Federal University of Sergipe (UFS), Aracaju, SE, Brazil.

* Correspondence: adervalufs@gmail.com.

Citation: Kuhn CS, Barros LC, Aragão ICS, Aragão FMS, Reis FP, Mendonça DMF, Aragão JA. A transmuscular path of the medial branch of the high division of the median nerve: an anatomical variation of clinical and surgical importance. Brazilian Journal of Case Reports. 2024 Oct-Dec; 04(4):101-108.

Received: 8 April 2024
Accepted: 7 May 2024
Published: 9 May 2024

Abstract: The median nerve (MN) is a mixed nerve formed in the brachial plexus, which innervates a large part of the upper limb. It presents several variations in its trajectory, resulting in many pathologies and iatrogenic surgical compromises. This report highlights a transmuscular route of the medial branch of the upper division of the MN, which to date does not fit into the classifications described in the literature on MN variations. Knowledge of this high division of the MN, as well as its transfixation by the flexor digitorum superficialis muscle, is of fundamental importance in neuropathy syndromes due to entrapment of the MN, as well as in surgical guidance to prevent injuries. Late diagnosis of traumatic peripheral nerve injuries results in greater functional impairment and greater socioeconomic loss, especially in young patients. Therefore, timely identification is essential to minimize long-term consequences and improve the patient's quality of life.

Keywords: Anatomical variation; Brachial plexus; Median nerve; Median nerve compression; Carpal tunnel syndrome.

1. Introduction

The median nerve (MN) originates in the axillary region and is formed by the union of the medial and lateral fascicles of the medial and lateral divisions of the brachial plexus, respectively, containing fibers from the roots of the C5-T1 spinal nerves [1]. Its name is derived from the intermediate position it occupies at the end of the brachial plexus and its location on the forearm [2]. It is one of the two largest nerves of the upper limb. In the arm, it runs alongside the brachial artery, crossing the medial bicipital groove of the arm and reaching the cubital fossa below the aponeurosis of the biceps brachii muscle.

From the cubital fossa, the MN passes between the two heads of the pronator teres muscle, positioned between the flexor digitorum profundus and flexor digitorum superficialis muscles. In the lower third of the forearm, the MN becomes more superficial and is covered anteriorly by the forearm fascia and partially by the tendon of the palmaris longus muscle. Lateral to it, is the flexor carpi radialis tendon [3]. After its path through the forearm, the MN passes beneath the transverse carpal ligament. Its sensory distribution extends from the thumb to half of the fourth finger and part of the thenar eminence, while the motor supply is distributed to the two most lateral lumbricals and to the muscles of the thenar eminence [4].

Regarding embryology, the MN undergoes several variations during its development, including in relation to other structures. Knowledge of these anatomical variations in the wrist, hand and forearm has been highlighted as important [5], enabling the repair of traumatic injuries and assisting in the treatment of compressive syndrome, as these situations require precise dissection of the nerve [6, 7]. Understanding the anatomical variations of the nerves in the wrist, hand, and forearm is crucial for treating traumatic injuries and compressive syndromes. Precise dissection of the nerves is necessary in these situations. In clinical-surgical practice, knowledge of nerve formation patterns, topographic spaces in which they are found, their relationships with vascular structures and their distribution in muscle compartments is essential [8]. Therefore, our objective was to report a case of high bifurcation of the MN with perforation of the flexor digitorum superficialis muscle and transmuscular path.

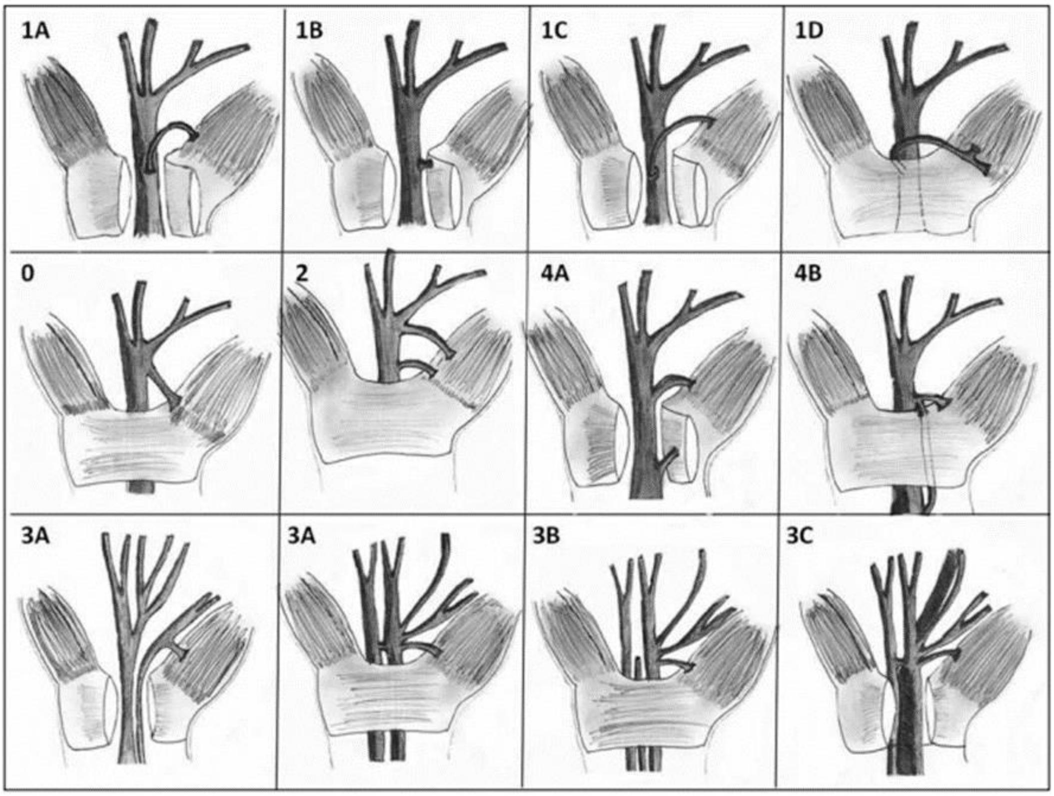
2. Case Report

Dissection of the right upper limb was performed to expose the vascular, nervous, and muscular structures. A longitudinal incision was made in the forearm region, lateral to the cubital fossa, to remove skin, fascia, adipose tissue, and superficial muscles. This allowed for better visualization of the cubital fossa and identification of nervous and vascular structures. A new incision was made towards the hand, using the exposed structures in the forearm as a guide to continue the dissection from the forearm to the hand. During the dissection of a right forearm, an anatomical variation of the MN was observed, which was similar to Group III, in subgroup 3A, of the Lanz classification, [9] modified by Demircay et al. [10] (Figure 1), which groups the high division of the MN without the existence of a muscle or artery separating the bifurcation.

The Lanz classification consists of groups 0 to 4, as described in the following. Group 0 - an extra-ligamentous thenar branch rounds backward at the distal margin of the transverse ligament before entering the muscles. Group 1 which is related to variations of the thenar branch and is subdivided into 4 subgroups, being them: 1A – subligamentous, that begins below the ligament and then bends around it, 1B – transligamentous, that crosses a foramen in the distal part of the transverse ligament, 1C – thenar, that emerges from the ulnar side of the MN, 1D - supraligamentous thenar, folds around the distal margin of the transverse ligament and then proceeds along the surface of the ligament before entering the muscles. Group 2 - Presence of an accessory thenar branch in the distal part of the tunnel. Group 3 - A high division of the MN with subgroups: 3A to 3C. 3A - high division of the MN that is not separated from the main branch by a muscle or artery; 3B - a high division associated with a median artery; 3C - an accessory lumbrical of the muscle is present between the two branches of a MN high division. Group 4 - an accessory branch is present in the proximal part of the tunnel with subgroups: 4A and 4B. 4A – accessory branch with a direct route in the thenar muscles proximal to the carpal tunnel, 4B - and a nearby accessory branch that joins the other branch.

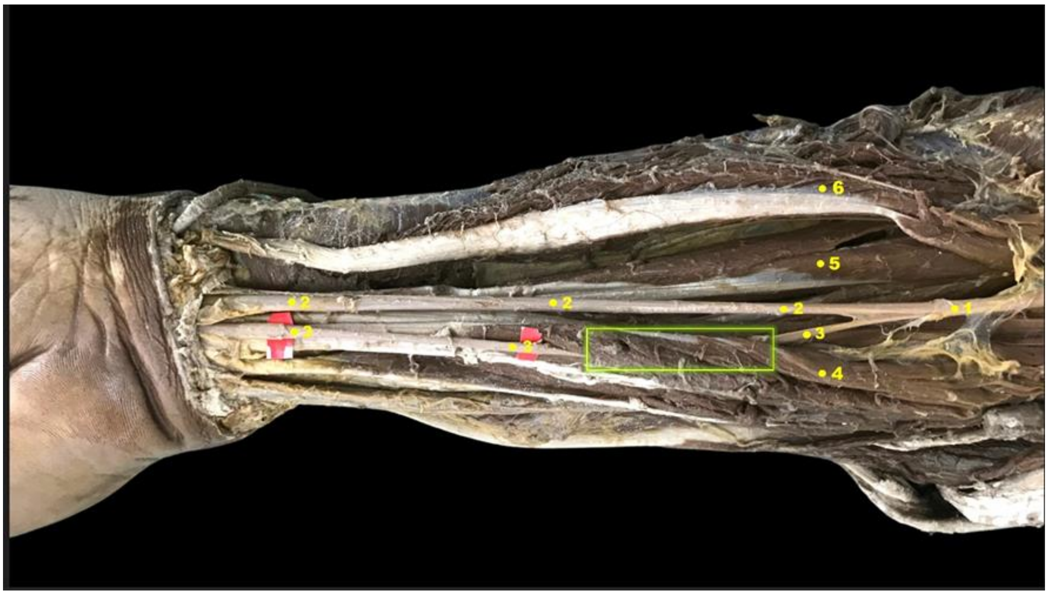
In our findings, the MN, when passing through the cubital fossa along its typical path between the humeral head and the ulnar head of the pronator teres muscle, bifurcated into a lateral branch and a more medial branch, at a distance of 18.5 cm from the flexor retinaculum and 8 cm from the elbow joint, specifically from the upper edge of the cubital fossa. However, the significant difference observed was that the medial branch of the MN, when piercing the flexor digitorum superficialis muscle, took a transmuscular route (Figure 2).

Figure 1. Lanz's [9] classification of the anatomical variations of the MN in the wrist, modified by Demircay et al., [10].



Legend. Group I, Thenar branch variations; 1A: subligamentous; 1B: transligamentous; 1C: ulnarwards; 1D: 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; 3A: without an artery of muscle; 3B: with artery; 3C: with lumbrical muscle [9-10].

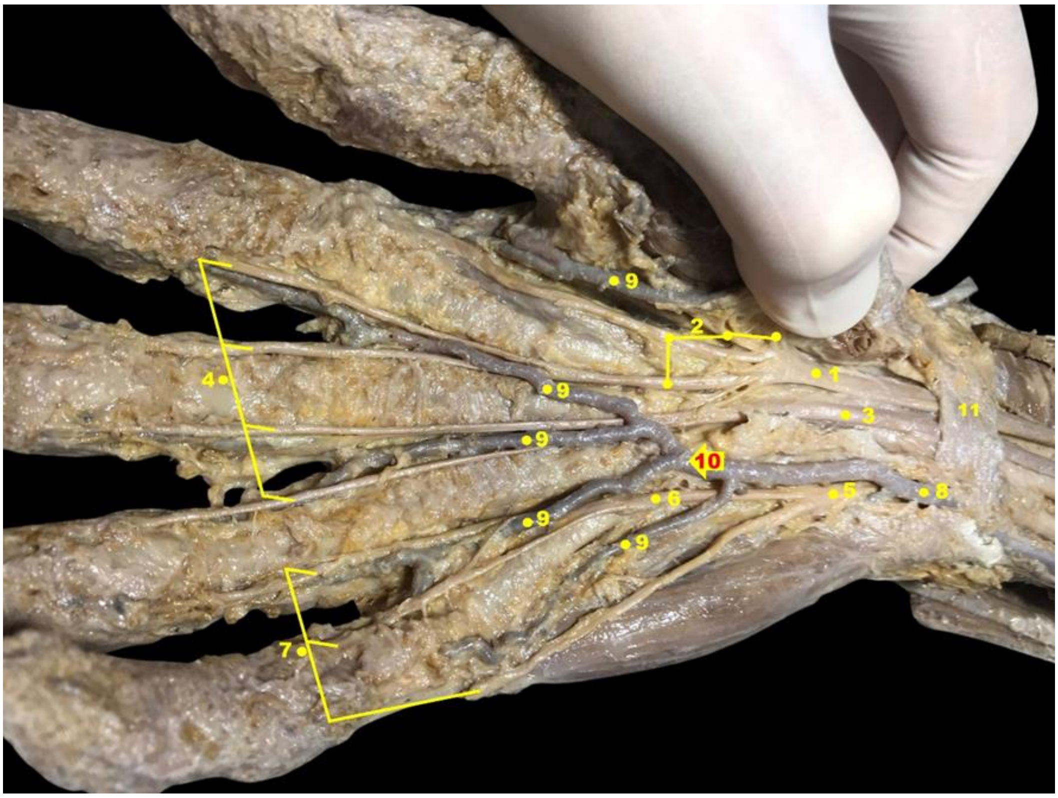
Figure 2. Transmuscular trajectory of the medial branch of the upper division of the MN.



Legend. 1. Median nerve. 2. Lateral branch of the high division of the MN. 3. Medial branch of the high division of the MN. 4. Flexor digitorum superficialis muscle. 5. Flexor digitorum profundus muscle. 6. Flexor pollicis longus muscle.

The lateral branch of the MN followed a typical path, running superficially through the flexor digitorum profundus muscle until emitting a more lateral branch, located 14 cm from its bifurcation and 5 cm from the flexor retinaculum, continuing towards the thenar region of the hand. The MN, when passing deeply through the flexor retinaculum and beginning to branch at the level of the lower (distal) edge of the transverse carpal ligament, gave off four trunks: two lateral ones for the first finger (thumb), a short one for the most proximal region, and another long one for the most distal region; an intermediate trunk to innervate the lateral margin of the second (index) finger; and a medial trunk that bifurcated 4 cm from its origin into a lateral branch, which ran parallel to the common palmar digital artery between the second and third fingers, until innervating the medial margin of the second finger (index), and a medial branch that passed deep to the common palmar digital artery between the second and third fingers to innervate the lateral margin of the third finger (Figure 3).

Figure 3. Innervation of the palmar aspect of the hand provided by the lateral and medial branches of the MN and ulnar nerve.



Legend. 1. Lateral branch of the median nerve. 2. Common palmar digital nerves of the median nerve. 3. Medial branch of the median nerve. 4. Proper palmar digital nerves of the median nerve. 5. Superficial branch of the ulnar nerve. 6. Common digital nerve of the ulna nerve. 7. Proper palmar digital nerves of the ulnar nerve. 8. Ulnar artery. 9. Common palmar digital arteries. 10. Superficial palmar arch (arterial). 11. Flexor retinaculum.

The medial branch of the MN, located at the same level as the lateral branch, traveled a 6 cm path until it perforated the posterior surface of the flexor digitorum superficialis muscle. In those who followed a transmuscular path of 3 cm, it exited the anterior surface of this muscle, from where it traveled a more superficial path of 9.5 cm until it passed deep into the flexor retinaculum and transverse carpal ligament. At this level, it bifurcated at 5.5 cm from the flexor retinaculum, and at a deep level of the superficial palmar arch, it gave off a medial branch, which passed beneath the common palmar digital artery between the fourth and third fingers and became directed towards the lateral margin of the fourth (ring) finger (Figure 3).

The remaining innervation of the hand came from the ulnar nerve, which followed the path of the ulnar artery, passing deep into the flexor retinaculum and transverse carpal ligament until it bifurcated at 3 cm from the retinaculum. A medial branch followed to the medial margin of the fifth (little) finger, and a lateral branch bifurcated at a distance of 4 cm from its origin into two branches: a medial one, which ran parallel to the common palmar digital artery between the fifth and fourth fingers until it innervated the lateral margin of the fifth (minimal) finger, and a lateral branch, which deeply followed the common palmar digital artery between the fifth and fourth fingers until it innervated the medial margin of the fourth finger (Figure 3). After a 6-month follow-up, the patient underwent a tomography for reassessment (Figure 3A), which showed good bone neoformation. Thus, he was able to proceed with dental implant treatment and oral rehabilitation. At the 1-year postoperative follow-up, the exams demonstrated good bone consolidation, and there was no radiographic recurrence evidence so far, suggesting a favorable prognosis (Figure 3B).

3. Discussion and conclusions

Kessler [11] was the first author to report a case of high division of the MN. This finding became important given the anatomical and clinical-surgical injuries related to MN variations. One example is carpal tunnel syndrome (CTS), a common focal peripheral neuropathy characterized by increased pressure in the carpal tunnel resulting in compression of the MN and impaired nerve perfusion, leading to discomfort and paresthesia in the affected hand. In-depth knowledge of normal anatomy and MN variations at the wrist level is essential to avoid complications during endoscopic carpal tunnel release [12, 13]. This is the most common nerve entrapment syndrome, which can be idiopathic or associated with various conditions, such as expansive lesions, Colles fractures, and systemic diseases like diabetes mellitus, hypothyroidism, and rheumatoid arthritis [14]. A bifid MN occurs relatively frequently in patients with CTS, as it increases the mean cross-sectional area (CSA) at the wrist joint by 1.5 mm2 [15-17]. Manifestations of CTS in association with trifid MN have also been described [18]. Bifid MN has been considered an independent risk factor for CTS [19].

The occurrence of bifid MN is rare and varies among different populations (Table 1), with a reported incidence of 1 to 3.3% among patients with CTS. More recent reports based on radiological studies suggest a possibly much higher incidence of 18 to 19%. This points towards an anatomical entity that is often unrecognized [20, 21]. Schwabl et al. [22] described a prevalence of 15.4% in the normal population.

Table 1. Occurrence of MN high division in different populations.

Authors	Population	Occurrence
Lanz [9]	German (246)	2.8%
Ahn et al. [23]	Korean (354)	0,3%
Barbe et al. [24]	North American (89)	2.6%
Mizia et al. [25]	Polish (60)	5%
Agarwal et al. [26]	Indian (52)	11.5%
Shinagawa et al. [27]	Japanese (698)	16.9%
Asghar et al. [28]	Bulgarian (154)	0.02%
Neumann, Suchomlinov [29]	Lithuanian (30)	10%

Ultrasonography (US) has been shown to be a reliable tool for detecting the morphology of the bifid MN, which is generally not an infrequent variation, particularly in hands with CTS [30-32]. It is also important in the diagnosis of CTS, based on the enlargement of the MN with an area greater than 9 mm² or 10 mm² at the level of the pisiform bone [33-36]. Monagle et al., [37] demonstrated with magnetic resonance imaging that the MN in CTS was enlarged both proximally and within the carpal tunnel. The researchers also showed that the median areas of the MN at the level of the pisiform bone were 17.83 mm² in CTS and 10.20 mm² in asymptomatic patients. Propeck et al., [38], who were the first to describe radiologically the image of a bifid MN, reported that US and magnetic resonance imaging can allow for the effective diagnosis and delineation of a bifid MN in the wrist. However, the ultrasonographic size criteria for diagnosing CTS in non-bifid MNs may not be accurate in the evaluation of bifid ones. As a result, many studies have recommended the use of MRI and US as diagnostic methods, in association with physical examination. Electroneuromyography tests are only necessary in cases of diagnostic uncertainty or if there is a need for surgical intervention [39].

CTS can be caused by entrapment of an anatomical variant of Lanz type IIIA [9], bifidus MN, or in association with the trifidus MN [18]. Preoperative US would help identify patients who present anatomical variants with an increased risk of iatrogenic injuries to better plan surgery. Therefore, the use of US should be encouraged as a routine preoperative evaluation in STC surgery [40]. The study of variation in the peripheral nerve is useful in procedures such as peripheral nerve block, electromyography, fracture treatment and others. It is also a useful anatomical tool for diagnosing neural crest cell defects [41].

In addition to CTS, several other clinically relevant abnormalities are usually associated, such as vascular malformations, such as a persistent median artery [42], aberrant muscles [43-45], development of neuritis [46], and the possibility of iatrogenic injuries in surgical procedures [10, 47-49].

Lanz [9] described the various MN anomalies in the carpal tunnel and classified the bifid MN as Group III. He noted that the two parts of the nerve are generally equal in size. However, Schultz, Endler, Huddleston [50] noted that the two parts may be unequal in size, with the larger radial division being approximately equal in size to a normal MN [51]. The report of the present finding is in accordance with that described by these authors. Considering also that the present finding does not fit into Lanz's classification [9], modified by Demircay et al. [10], the present finding, in accordance with what was suggested by Kadar, Virág, Matei [7], may contribute to improving the current classification of MN variants in the carpal tunnel.

4. Conclusions

The present study shows that, due to the variations of the MN, there is a need for more comprehensive classifications. This will ensure an expansion of information for health professionals during various surgical procedures involving this nerve, making possible to minimize the risks of iatrogenic incidents.

Funding: None.

Research Ethics Committee Approval: We declare that this work did not pass the ethics committee, as all cadavers found in the Human Anatomy Laboratory of the Federal University of Sergipe were obtained in accordance with Law 8,501, of November 30, 1992, which provides for the use of unclaimed corpses for the purposes of studies or scientific research and provides other measures. However, the study followed the ethical guidelines established by the Declaration of Helsinki.

Acknowledgments: The authors wish to sincerely thank those who donated their bodies to science so that anatomical research could be carried out. The results of this research can potentially improve patient care and increase the overall knowledge of humanity. Therefore, these donors and their families deserve our utmost gratitude.

Conflicts of Interest: None.

Supplementary Materials: None.

References

1. Jatoi M. Role of sonography in assessment of upper extremity nerve pathologies: A literature review. J Med Imaging Radiat Sci. 2022 Jun;53(2):305-313. doi: 10.1016/j.jmir.2022.01.006.
2. Soubeyrand M, Melhem R, Protais M, Artuso M, Crézé M. Anatomy of the median nerve and its clinical applications. Hand Surg Rehabil. 2020 Feb;39(1):2-18. doi: 10.1016/j.hansur.2019.10.197.
3. Mizia E, Tomaszewski K, Depukat P, Klimek-Piotrowska W, Pasternak A, Mroz I, Bonczar T. Median nerve (anatomical variations) and carpal tunel syndrome - revisited. Folia Med Cracov. 2013;53(4):37-46.
4. 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 Aug 20;49(5):429-36. doi: 10.1016/j.rboe.2014.08.001.
5. Natsis K, Paraskevas G, Tzika M. Five Roots Pattern of Median Nerve Formation. Acta Medica (Hradec Kralove). 2016;59(1):26-8. doi: 10.14712/18059694.2016.52.
6. Agarwal P, Gupta S, Yadav P, Sharma D. Cadaveric study of anatomical variations of the median nerve and persistent median artery at wrist. Indian J Plast Surg. 2014 Jan;47(1):95-101. doi: 10.4103/0970-0358.129632.
7. Kadar IA, Virág TH, Matei IR, Georgescu AV. High Division of the Median Nerve with Unusually High Origin of the 3rd Space Common Digital Nerve. Injury. 2020 Dec;51 Suppl 4:S96-S102. doi: 10.1016/j.injury.2020.03.024.
8. Encarnacion M, Nurmukhametov R, Barrientos RE, Melchenko D, Goncharov E, Bernard E, Huerta JM, Uhl JF, Efe IE, Montemurro N, Ramirez I. Anatomical Variations of the Median Nerve: A Cadaveric Study. Neurol Int. 2022 Aug 23;14(3):664-672. doi: 10.3390/neurolint14030054.
9. Lanz U. Anatomical variations of the median nerve in the carpal tunnel. J Hand Surg Am. 1977 Jan;2(1):44-53. doi: 10.1016/s0363-5023(77)80009-9.
10. Demircay E, Civelek E, Cansever T, Kabatas S, Yilmaz C. Anatomic variations of the median nerve in the carpal tunnel: a brief review of the literature. Turk Neurosurg. 2011;21(3):388-96. doi: 10.5137/1019-5149.JTN.3073-10.1.
11. Kessler I. Unusual distribution of the median nerve at the wrist. A case report. Clin Orthop Relat Res. 1969 Nov-Dec;67:124-6.
12. Jeon IH, Kim PT, Park IH, Park BC, Ihn JC. High bifurcation of median nerve at the wrist causing common digital nerve injury in endoscopic carpal tunnel release. J Hand Surg Br. 2002 Dec;27(6):580-2. doi: 10.1054/jhsb.2002.0832.
13. Rotman MB, Donovan JP. Practical anatomy of the carpal tunnel. Hand Clin. 2002 May;18(2):219-30. doi: 10.1016/s0749-0712(01)00003-8.
14. Preston DC, Shapiro BE. Median Neuropathy at the Wrist. Electromyography and Neuromuscular Disorders. 2013;267–288. doi:10.1016/b978-1-4557-2672-1.00017-9.
15. Asghar A, Patra A, Satish Ravi K, Tubbs RS, Kumar A, Naaz S. Bifid median nerve as an anatomical risk factor for carpal tunnel syndrome: A meta-analysis. Clin Anat. 2022 Oct;35(7):946-952. doi: 10.1002/ca.23900.
16. Bayrak IK, Bayrak AO, Kale M, Turker H, Diren B. Bifid median nerve in patients with carpal tunnel syndrome. J Ultrasound Med. 2008 Aug;27(8):1129-36. doi: 10.7863/jum.2008.27.8.1129.
17. Yerasu MR, Ali M, Rao R, Murthy JMK. Bifid median nerve: a notable anomaly in carpal tunnel syndrome. BMJ Case Rep. 2022 May 17;15(5):e249220. doi: 10.1136/bcr-2022-249220.
18. Siddiq MAB, Hossain Parash MT. Incidental Trifid Median Nerve Unveiled in a Lactating Mother. Cureus. 2019 Sep 30;11(9):e5809. doi: 10.7759/cureus.5809.
19. Güleç GG, Aktaş İ. Carpal Tunnel Symptoms With Normal Nerve Conduction Study Findings in Patients With Bifid Median Nerve Treated With Ultrasound-Guided 5% Dextrose Hydrodissection: A Case Series. Cureus. 2023 Mar 25;15(3):e36669. doi: 10.7759/cureus.36669.
20. Ibrahim M, Hattori Y, Doi K, Sakamoto S, Madura T. Bifid Median Nerve--A Case Report. Hand Surg. 2015 Oct;20(3):482-3. doi: 10.1142/S0218810415720260.
21. Stancić MF, Eskinja N, Stosić A. Anatomical variations of the median nerve in the carpal tunnel. Int Orthop. 1995;19(1):30-4. doi: 10.1007/BF00184911.
22. Schwabl C, Hörmann R, Strolz CJ, Drakonaki E, Zimmermann R, Klauser AS. Anatomical Variants of the Upper Limb Nerves: Clinical and Preoperative Relevance. Semin Musculoskelet Radiol. 2023 Apr;27(2):129-135. doi: 10.1055/s-0043-1761952.
23. Ahn DS, Yoon ES, Koo SH, Park SH. A prospective study of the anatomic variations of the median nerve in the carpal tunnel in Asians. Ann Plast Surg. 2000 Mar;44(3):282-7. doi: 10.1097/00000637-200044030-00006.
24. Barbe M, Bradfield J, Donathan M, Elmaleh J. Coexistence of multiple anomalies in the carpal tunnel. Clin Anat. 2005 May;18(4):251-9. doi: 10.1002/ca.20086.
25. Mizia E, Klimek-Piotrowska W, Walocha J, Rutowski R, Wojtala R. The median nerve in the carpal tunnel. Folia Morphol (Warsz). 2011 Feb;70(1):41-6.
26. Agarwal P, Gupta S, Yadav P, Sharma D. Cadaveric study of anatomical variations of the median nerve and persistent median artery at wrist. Indian J Plast Surg. 2014 Jan;47(1):95-101. doi: 10.4103/0970-0358.129632.
27. Shinagawa S, Tajika T, Oya N, Endo F, Kuboi T, Hamano N, Sasaki T, Ichinose T, Shitara H, Takagishi K, Chikuda H. Prevalence of Bifid Median Nerve and the Cross-Sectional Area as Assessed by Ultrasonography in Healthy Japanese Subjects. J Hand Surg Glob Online. 2019 Mar;1(2):74-78. doi:10.1016/j.jhsg.2019.01.004.
28. Asghar A, Patra A, Satish Ravi K, Tubbs RS, Kumar A, Naaz S. Bifid median nerve as an anatomical risk factor for carpal tunnel syndrome: A meta-analysis. Clin Anat. 2022 Oct;35(7):946-952. doi: 10.1002/ca.23900.

29. Neumann M, Suchomlinov A. Pilot Cadaveric Study of Anatomical Variations of the Median Nerve at the Wrist in the Lithuanian Population. Cureus. 2023 May 21;15(5):e39282. doi: 10.7759/cureus.39282.
30. Trachani E, Rigopoulou A, Veltsista D, Gavanozi E, Chrysanthopoulou A, Chroni E. Occurrence of bifid median nerve in healthy and carpal tunnel syndrome patients. J Electromyogr Kinesiol. 2018 Apr;39:77-80. doi: 10.1016/j.jelekin.2018.01.009.
31. Wu WT, Chang KV, Hsu YC, Tsai YY, Mezian K, Ricci V, Özçakar L. Ultrasound Imaging and Guidance for Distal Peripheral Nerve Pathologies at the Wrist/Hand. Diagnostics (Basel). 2023 May 31;13(11):1928. doi: 10.3390/diagnostics13111928.
32. Honis HR, Gruber H, Honold S, Konschake M, Moriggl B, Brenner E, Skalla-Oberherber E, Loizides A. Anatomical considerations of US-guided carpal tunnel release in daily clinical practice. J Ultrason. 2023 Sep 11;23(94):e131-e143. doi: 10.15557/jou.2023.0022.
33. Chen P, Maklad N, Redwine M, Zelitt D. Dynamic high-resolution sonography of the carpal tunnel. AJR Am J Roentgenol. 1997 Feb;168(2):533-7. doi: 10.2214/ajr.168.2.9016242.
34. Duncan I, Sullivan P, Lomas F. Sonography in the diagnosis of carpal tunnel syndrome. AJR Am J Roentgenol. 1999 Sep;173(3):681-4. doi: 10.2214/ajr.173.3.10470903.
35. Uz C, Umay E. Ultrasonographic measurement of median nerve and wrist skin thickness in patients with carpal tunnel syndrome: relationship with clinical, electrophysiologic and functionality. Acta Orthop Belg. 2023 Mar;89(1):167-172. doi: 10.52628/89.1.11029.
36. Aloi NF, Cluts LM, Fowler JR. Ultrasound Measurements of the Median Nerve at the Distal Wrist Crease Correlate With Electrodiagnostic Studies. Hand (N Y). 2023 Jul;18(5):765-771. doi: 10.1177/15589447211066349.
37. Monagle K, Dai G, Chu A, Burnham RS, Snyder RE. Quantitative MR imaging of carpal tunnel syndrome. AJR Am J Roentgenol. 1999 Jun;172(6):1581-6. doi: 10.2214/ajr.172.6.10350293.
38. Propeck T, Quinn TJ, Jacobson JA, Paulino AF, Habra G, Darian VB. Sonography and MR imaging of bifid median nerve with anatomic and histologic correlation. AJR Am J Roentgenol. 2000 Dec;175(6):1721-5. doi: 10.2214/ajr.175.6.1751721.
39. Osiak K, Elnazir P, Walocha JA, Pasternak A. Carpal tunnel syndrome: state-of-the-art review. Folia Morphol (Warsz). 2022;81(4):851-862. doi: 10.5603/FM.a2021.0121.
40. Corte E, Gelmi CAE, Acciarri N. Carpal tunnel syndrome caused by the entrapment of a bifid Lanz IIIA Type anatomical variant of median nerve: A case report and systematic literature review. Surg Neurol Int. 2021 Feb 3;12:37. doi: 10.25259/SNI_765_2020.
41. Ghatak S, Agrawal D, Deka D, Faizal M. Highup Division of Median Nerve with Vascular Malformations: A case report. Afr J Health Sci. 2021 May – June;34(3):401-405.
42. Elhossiny AH, Bakir M, Dawalibi A, Behiery A. Persistent Median Artery, Bifid Median Nerve, and Reversed Palmaris Longus Encountered During Cadaveric Dissection: The First Reported Case. Cureus. 2023 Jun 12;15(6):e40324. doi: 10.7759/cureus.40324.
43. Bagatur AE, Yalcinkaya M, Atca AO. Bifid median nerve causing carpal tunnel syndrome: MRI and surgical correlation. Orthopedics. 2013 Apr;36(4):e451-6. doi: 10.3928/01477447-20130327-21.
44. Georgiev GP, Slavchev SA, Dimitrova IN, Landzhov BV. Bifid Median Nerve in the Bulgarian Population: An Anatomical and Clinical Study. Advances in Anatomy. 2015 Nov;2015:191749. doi: 10.1155/2015/191749.
45. Saenz C, Rahimi OB, Kar R. Cadaveric study of division of the median nerve by the persistent median artery. Surg Radiol Anat. 2022 Nov;44(11):1455-1460. doi: 10.1007/s00276-022-03035-1.
46. Knarr J, Schmitt R, Mühldorfer-Fodor M. Partial Neuritis of a Bifid Median Nerve. Clin Neuroradiol. 2021 Dec;31(4):1205-1208. doi: 10.1007/s00062-021-01022-4.
47. Henry BM, Zwinczewska H, Roy J, Vikse J, Ramakrishnan PK, Walocha JA, Tomaszewski KA. The Prevalence of Anatomical Variations of the Median Nerve in the Carpal Tunnel: A Systematic Review and Meta-Analysis. PLoS One. 2015 Aug 25;10(8):e0136477. doi: 10.1371/journal.pone.0136477.
48. Dag F, Dirim Mete B, Gursoy M, Uluc ME. Variations ignored in routine wrist MRI reports: prevalence of the median nerve anatomical variations and persistent median artery. Acta Radiol. 2022 Jan;63(1):76-83. doi: 10.1177/0284185120985502.
49. Ganen DC, Rueda ACG, Pinzón JAG, Mondragón EA, Guzmán NG, Suárez RG. Nervio mediano bífido en antebrazo. Rev Col Cirugía Plástica y Reconstructiva. 2021 June;27(1):42-7.
50. Schultz RJ, Endler PM, Huddleston HD. Anomalous median nerve and an anomalous muscle belly of the first lumbrical associated with carpal-tunnel syndrome. J Bone Joint Surg Am. 1973 Dec;55(8):1744-6.
51. Al-Qattan MM, Al-Zahrani K, Al-Omawi M. The bifid median nerve re-visited. J Hand Surg Eur Vol. 2009 Apr;34(2):212-4. doi: 10.1177/1753193408089572.