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Clinical Significance of Anatomical Variations in the Carpal Tunnel: Review

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Anatomical variations of the structures related to the carpal tunnel are numerous and involve muscles, tendons, vessels and nerves. The structures passing through the carpal tunnel include the tendons of the flexor digitorum superficialis, flexor digitorum profundus and flexor pollicis longus, as well as the median nerve. Anatomical variations in this region may predispose the median nerve to compression and lead to carpal tunnel syndrome, which is the most often reported compression neuropathy. The most common muscle variations involve the palmaris longus muscle, the flexor digitorum superficialis, the abductor digiti minimi (ADM) and the lumbrical muscles. Vessels anomalies refer to the presence of a persistent median artery and a superficial ulnar artery. The median and ulnar nerves can also be present with variant course, division and anastomoses. The present manuscript reviews literature data on these variations and underlines their clinical implications.

Key words: anatomical variations, carpal tunnel, wrist, median nerve, clinical significance

Introduction

Anatomical variations in the carpal tunnel structures include variations in the nerves, vessels, muscles and tendons of the wrist and hand and represent an often encountered phenomenon [20]. The carpal tunnel is situated directly below the flexor retinaculum (also known as transverse carpal ligament), which in turn extends from the trapezium and scaphoid bones radially to the triquetrum and hamate bones in ulnar direction [20]. The tendons of the flexor digitorum superficialis (FDS) and flexor digitorum profundus (FDP) for the index, middle, ring and little finger and the tendon of the flexor pollicis longus (FPL) pass through the canal, as does the median nerve [20]. This explains why anatomical variations in the region of the carpal canal may predispose the median nerve to compression, a fairly frequent condition known as carpal tunnel syndrome (CTS). CTS is the most common compression neuropathy and its surgical treatment is the most

often performed type of hand surgery [1, 16, 19]. Compression neuropathies in the wrist region can be provoked by different anomalous muscles and vessels, ligamentous attachments, ganglia, neoplastic masses, etc. [26]. Apart from causing these conditions, anatomical variations in the structures of the wrist can in turn suffer iatrogenic injury during diagnostic and surgical procedures in the hand if they are not taken into consideration [20].

The aim of the present article was to review the pertinent literature regarding anatomical variations of the carpal tunnel structures and to discuss their clinical significance with regard to CTS and possible iatrogenic injury to these anomalous structures.

Variations in muscle and tendon anatomy

Muscle variations which are most commonly associated with compression neuropathies in the carpal tunnel include those of palmaris longus (PL), flexor digitorum superficialis (FDS) abductor digiti minimi (ADM) and the lumbrical muscles. PL is one of the most variable muscles in the human body. Its variations include absence, duplication, digastric PL, reversed PL, reversed PL coexisting with an additional ADM, PL with intermediate muscle belly, deep PL, etc. [3-11]. Mitchell et al. [20] indicate that the most significant variations of the PL in the context of CTS include the reversed PL with a possible location of the muscle belly within the carpal tunnel, as well as the passing of the final tendon of the PL through the carpal tunnel and its insertion onto the distal part of the palmar fascia. Some authors associate the hypertrophy of this reversed PL due to overuse in certain professional groups with a higher risk for median nerve compression and development of CTS [8, 22]. Anatomical variations of the FDS include extension of the muscle body inside the carpal tunnel (which is also the most common variation of this muscle), additional muscle belly or an anastomosis between the FDS and PL [3]. Slavchev and Georgiev [26] reported the presence of an additional ADM, which manifested itself as the concomitant presence of a CTS and distal ulnar tunnel syndrome. Anatomical variations of the flexor carpi ulnaris muscle [13] have also been implicated in the possible development of median nerve compression, as well as impairment of the function of the ulnar nerve and thrombosis of the ulnar artery [21]. Such variant muscles are best visualised through the new imaging techniques, such as magnetic resonance imaging [14]. It is also worth mentioning the Linburg-Comstock syndrome which develops on the basis of a tendinous connection between the tendons of the FDP and the FPL. A symptomatic tendonitis of this connection may simulate the symptoms of CTS [20].

Variations in vessel anatomy

Variations in the arterial network of the wrist include a persistent median artery and a superficial ulnar artery [1, 3, 20]. The persistent median artery is a remnant from the embryonic period and can be found in 1-16% of cases [1, 3] or 1.2-23% of cases [20]. This anatomical variation can be found together with a bifid median nerve [3]. Some authors classify the persistent median artery into two types: antebrachial type – a short, thin artery, which does not reach the level of the wrist and palmar type – a longer, large vessel, which reaches the hand [10, 23]. This artery is usually asymptomatic and can play a significant role in the blood supply of the forearm, the hand and the median nerve in particular, which is why an injury to the vessel can compromise blood circulation in that area [10, 20]. The presence of a persistent median artery of the palmar type, however, especially with a diameter of more than 2.0 mm, can cause compression of the median nerve and lead to CTS [2]. As reported by Barfred et al. [2], this artery can be found within the carpal tunnel during surgery for carpal tunnel release and it can also worsen the symptoms of CTS due to induced inflammation [1]. Jelev and Georgiev [15]

also describe an unusual type of median artery, which they refer to as 'superficial brachiomedian artery' due to its high origin from the brachial artery and superficial course throughout the forearm.

The term 'superficial ulnar artery' refers to an ulnar artery situated deep to the antebrachial fascia but superficial to the muscles of the forearm, which is found in 0.7-9.4% of cases [20]. It can be found together with other concomitant anatomical variations such as absence of PL and aberrant superficial palmar arch [25]. This course and location of the artery place it at risk of puncture during injuries, diagnostic and surgical procedures, which is why knowledge of this anomalous course of the ulnar artery is important to physicians and nurses [25]. In particular, extended incision of the carpal tunnel reaching proximally to the wrist crease during various interventions in this area may jeopardize the structural integrity of the superficial ulnar artery [20].

Variations in nerve anatomy

One of the main structures found inside the carpal tunnel is the median nerve. Numerous variations of its usual anatomical course have been described, including bifid median nerve (resulting from a high bifurcation of the median nerve above the level of the carpal tunnel), variations of the motor branch and the palmar cutaneous branch of the nerve, as well as anomalous communications between the median and ulnar nerve [1, 3, 12, 18, 20, 28].

Usually, the median nerve divides into digital branches distal to the carpal tunnel. A bifid median nerve refers to a high point of division of the median nerve, proximal to the flexor retinaculum and has an incidence between 1 and 3.3% [20]. Georgiev et al. [12] studied the prevalence of this variation in the Bulgarian population and found one case of a bifid median nerve among 51 studied formol-carbol fixed cadavers and two cases among 154 upper limbs of patients undergoing open carpal tunnel release. This anomaly is more often associated with compression syndromes, since the cross-sectional area is bigger than in the case of a single nerve [28]. As mentioned above, this variation can coexist with a persistent median artery.

Variations in the take-off of the motor branch of the median nerve were classified by Lanz based on studies by Poisel [18]. The extraligamentous type refers to a motor branch taking off distal to the flexor retinaculum on the radial side of the wrist. This is the most commonly encountered type (46% of cases) and is thus considered a usual anatomical presentation. The second most common type is the subligamentous one (31% of cases), in which the motor branch arises from the median nerve inside the carpal tunnel. The transligamentous type (23% of cases) is characterised by a motor branch piercing the flexor retinaculum before continuing its course towards the muscles of the thenar. Kozin [17] found the presence of more than one motor branch in 4% of cases during a study on 101 fresh-frozen cadavers. Due to the usual presentation and variations of the motor branch of the median nerve, Lanz [18] also underlines the importance of approaching the median nerve from the ulnar side when performing surgical interventions in the carpal tunnel. The palmar cutaneous branch arises from the radial side of the median nerve and passes distally between the superficial and deep layer of the antebrachial fascia, superficial to the flexor retinaculum. Reported variations of this branch include a transligamentous course, as well as a palmar cutaneous branch located ulnar to the median nerve [20]. Knowledge of the anomalous courses of the palmar cutaneous branch is important during surgical interventions in the area of the carpal tunnel, since damage to the nerve fibres may result in a painful neuroma [20].

Anastomoses between the median and ulnar nerves are a frequently encountered phenomenon. A sensory anastomosis between the median and ulnar nerve in the palm is known as Berrettini's anastomosis and is found in as high as 92% of individuals [1].

Riche-Cannieu's motor anastomosis (found in 77-100% of cases) most often refers to a communication between the motor branch of the median nerve and deep branch of the ulnar nerve [1]. The Martin-Grüber's anastomosis refers to a median to ulnar connection in the forearm, which is found in 6 to 31% of individuals and provides alternative patterns of innervation to the intrinsic muscles of the hand [20]. Finally, the Marinacci's anastomosis, referred to also as reverse Martin-Grüber's anastomosis, is a rare, ulnar to median nerve connection, described by Stancic et al. [27] during extended incision of the carpal tunnel. Knowledge of these anastomoses between the median and ulnar nerves is important for the accurate interpretation of electrophysiological studies and reducing the risk of iatrogenic damage during surgical interventions [24].

Conclusion

Anatomical variations of the structures related to the carpal tunnel are numerous and involve muscles, tendons, vessels and nerves. The present manuscript reviews literature data on these variations and underlines their clinical implications. Knowledge of such anomalies is important not only from a descriptive point of view, but also during everyday surgical practise, as they may be associated with pathological conditions, such as carpal tunnel syndrome or can in turn be damaged during diagnostic and surgical interventions, which may impair the normal anatomy and function of the upper limb.

References

1. **Afshar, A., B. Nasiri, S.A. Mousavi, H. Hesarikia, N. Navaeifar, H. Taleb.** Anatomic anomalies encountered in 467 open carpal tunnel surgeries. – *Arch. Iran. Med*., **19**(4), 2016, 285-287.
2. **Barfred, T., A.P. Hojlund, K. Bertheussen.** Median artery in carpal tunnel syndrome. – *J. Hand Surg. Am*., **10**, 1985, 864-867.
3. **Chammas, M., J. Boretto, L. M. Burmann, R. M. Ramos, F. C. dos Santos Neto, J. B. Silva.** Carpal tunnel syndrome. Part I (anatomy, physiology, etiology and diagnosis). – *Rev. Bras. Ortop*., **49**(5), 2014, 429-436. [in Portuguese].
4. **Georgiev, G. P.** Significance of anatomical variations for clinical practice. – *Int. J. Anat. Var*., **10**(3), 2017, 43-44.
5. **Georgiev, G. P., A. A. Iliev, I. N. Dimitrova, G. N. Kotov, L. G. Malinova, B. V. Landzhov.** Palmaris longus muscle variations: clinical significance and proposal of new classifications. – *Folia Med. (Plovdiv)*, **59**(3), 2017, 289-297.
6. **Georgiev, G. P., L. Jelev, L. Stokov.** Anomalous muscle of the wrist. Case report. – *Health and Science*, **1**, 2011, 17-18. [In Bulgarian]
7. **Georgiev, G. P., L. Jelev, L. Surchev.** Presence of a palmaris longus related variations in three members of a family. – *J. Hand Surg. Eur. Vol.*, **34**, 2009, 277-278.
8. **Georgiev, G. P., L. Jelev, L. Surchev.** Reversed palmaris longus muscle simulating soft-tissue mass as a possible cause of median nerve compression. – *Bulg. J. Orthop. Traumatol.*, **45**, 2008, 92-94.
9. **Georgiev, G. P., L. Jelev, L. Surchev.** Variations of the hypothenar muscles. – *Acta Morphol. Anthropol*., **13**, 2008, 313-315.
10. **Georgiev, G. P., L. Jelev, W. A. Ovtscharoff.** Unusual combination of muscular and arterial variations in the upper extremity: a case report of a variant palmaris longus and an additional tendinous portion of the flexor carpi ulnaris together with a persistent median artery. – *Int. J. Exp. Clin. Anat.*, **3**, 2009, 58-61.
11. **Georgiev, G. P., L. Jelev.** Unusual coexistence of a variant abductor digiti minimi and reversed palmaris longus and their possible relation to median and ulnar nerves entrapment at the wrist. – *Rom. J. Morphol. Embryol.*, **50**(4), 2009, 725-727.
12. **Georgiev, G. P., S. A. Slavchev, I. N. Dimitrova, B. Landzhov.** Bifid median nerve in the Bulgarian population: an anatomical and clinical study. – *Adv. Anat*., **2015**, 2015, Article ID 191749, 4 pages.

13. **Iliev, A., G. P. Georgiev, B. Landzhov.** A rare case of bilateral flexor carpi ulnaris variation: anatomical and clinical considerations and literature review. – *Rev. Arg. Anat. Clin.*, **8**(2), 2016, 98-103.
14. **Iliev, A., G. P. Georgiev, I. N. Dimitrova, B. Landzhov.** Extensor indicis brevis muscle: anatomical and clinical considerations. – *Acta Morphol. Anthropol*., **22**, 2015, 75-78.
15. **Jelev, L., G. P. Georgiev.** A rare case of superficial median artery of high brachial origin: anatomical and clinical considerations of the superficial brachiomedian artery. – *Int. J. Exp. Clin. Anat.*, **5**, 2011, 39-43.
16. **Karabinov, V., G. P. Georgiev.** Carpal tunnel syndrome – frequent and underestimated condition. – *MD Journal*, **4**, 2017, 75-78. [In Bulgarian]
17. **Kozin, S. H.** The anatomy of the recurrent branch of the median nerve. – *J. Hand Surg. Am.,* **23**(5), 1998, 852-858.
18. **Lanz, U.** Anatomical variations of the median nerve in the carpal tunnel. – *J. Hand Surg. Am.,* **2**(1), 1977, 44-53.
19. **Lindley, S. G., J. M. Kleinert.** Prevalence of anatomic variations encountered in elective carpal tunnel release. – *J. Hand. Surg. Am.,* **28**(5), 2003, 849-855.
20. **Mitchell, R., A. Chesney, S. Seal, L. McKnight, A. Thoma.** Anatomical variations of the carpal tunnel structures. – *Can. J. Plast. Surg*., **17**(3), 2009, e3-e7.
21. **Moss, D.P., C. L. Forthman.** Ulnar artery thrombosis associated with anomalous hypothenar muscle. – *J. Surg. Orthop. Adv.*, **17**, 2008, 85-88.
22. **Natsis, K., S. Levva, T. Totlis, N. Anastasopoulos, G. Paraskevas.** Three-headed reversed palmaris longus muscle and its clinical significance. – *Ann. Anat.,* **189**(1), 2007, 97-101.
23. **Rodríguez-Niedenführ, M., J. R. Sañudo, T. Vázquez, L. Nearn, B. Logan, I. Parkin.** Median artery revisited. – *J. Anat.,* **195**, 1999, 57-63.
24. **Roy, J., B. M. Henry, P. A. Pękala, J. Vikse, K. Saganiak, J. A. Walocha, K. A. Tomaszewski.** Median and ulnar nerve anastomoses in the upper limb: A meta-analysis. – *Muscle Nerve*, **54**(1), 2016, 36-47.
25. **Salunke, A. A., G. I. Nambi, A. D. Dhanwate, H. A. Siriwardana.** Superficial ulnar artery: Clinical recommendations to avoid iatrogenic complications due to variation in arterial system. – *Niger Med. J*., **55**(3), 2014, 276-277.
26. **Slavchev, S. A., G. P. Georgiev.** Aberrant abductor digiti minimi muscle found during open surgical decompression of the carpal tunnel: case report. – *Rev. Arg. Anat. Clin.*, **5**(2), 2013, 88-91.
27. **Stancic, M. F., N. Burgic, V. Micovic.** Marinacci communication. – *J. Neurosurg*., **92**, 2000, 860-862.
28. **Willis, C. B., A. Alderman, D. S. Louis.** Anatomic anomalies and carpal tunnel syndrome: a review. – *Tech. Hand Up. Extrem. Surg*., **3**(2), 1999, 99-104.