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## MEDIAN NERVE (ANATOMICAL VARIATIONS) AND CARPAL TUNEL SYNDROME — REVISITED

**Abstract:** Carpal tunnel syndrome belongs to the most common causative factors of surgical interventions in the wrist region. Anatomy of carpal tunnel and median nerve is a subject of current revision. Authors paid attention to etiology of the syndrome based on review of literature and their own anatomical studies. They remind basic knowledge on the median nerve and indicate that only based on number of dissections a good orthopedic surgeon may acquire experience necessary to perform procedures in a most appropriate way.

**Key words:** median nerve, anatomical variation, carpal tunnel syndrome.

### INTRODUCTION

The knowledge on the topography of the median nerve and its anatomical variation is important in hand surgery. Most common surgical interventions in the region of the wrist are carried out in cases of trauma or treatment of carpal tunnel syndrome and other compression syndromes in the forearm [1].

It is a result of exceptional vulnerability of this area which may be a subject of direct injury (during a work, fall, defense, commitment of suicide) or anatomical composition (superficial course of nerves). Problems with definition of an injury to thenar motor branch of median nerve may be causative factors of significant manual dysfunction. Only a reconstruction of the nerve using microsurgery may cause restoring of satisfactory manual ability [2–4].

Posttraumatic changes which cause change of the carpal tunnel consist of:

- Fractures of distal radial extremity (the most common)
- Fractures and subluxations of carpal bones
- Calcified hematomas
- Iatrogenic injuries

Non-traumatic factors consist of diseases which lead to increase of tissue turgor, hypertrophy of connective tissue, and deposition of products of metabolism i.e. amyloidosis [5].

- Hormonal changes in course of: pregnancy, acromegaly, hypothyreosis, menopause
- Metabolic diseases: diabetes, amyloidosis, mucopolisacharydosis, uremia
- Vascular diseases: arterial hypertension, morbus of Raynaud, variation of median artery
- Allergic reactions, myxoid oedema
- Inflammations and degenerations within the tendinous sheaths
- Additional and atavistic anatomical structures, i.e. large persistent median artery
- Neoplasms and pseudoneoplastic tumors
- Mycotic changes
- Vascular anomalies
- Overload
- Changes caused by specific type of work [6].

Median nerve is one out of two largest nerves of the upper limb. It originates in axillary fossa with two roots, a medial ( $C_8-T_1$ ) and a lateral ( $C_5-C_7$ ). These roots create a fork-like structure which embraces axillary artery. In the arm median nerve runs in a company with brachial artery traversing medial bicipital sulcus of the arm. Next, together with artery it descends to cubital fossa beneath aponeurosis of biceps brachii muscle. From cubital fossa median nerve exits between two heads of pronator teres muscle, positioned between flexor digitorum profundus and superficialis muscles. In the lower 1/3 of the forearm median nerve goes more superficial. It is covered anteriorly by fascia of forearm and partially tendon of palmaris longus muscle. Lateral to it one can find a tendon of flexor carpi radialis. The nerve neighbors to flexor pollicis longus tendon. Traversing carpal tunnel it is placed anterior and medial to tendon of flexor pollicis longus and its vaginal sheath. Medial to it one can find flexor digitorum superficialis and profundus tendons covered by ulnar vaginal sheath. After emerging from behind the flexor retinaculum, in the palm of the hand, median nerve gives off three terminal branches: palmar common digital nerves. A motor branch to thenar muscles originates typically from the main trunk of the median nerve — its radial aspect (part) or together with first palmar common digital nerve, in the vicinity of the distal border of flexor retinaculum. It courses anterior and lateral, arching over the distal margin of transverse carpal ligament and reaches abductor pollicis brevis, opponens pollicis and superficial head of flexor pollicis brevis. This branch (or these branches) is located next to the radial vaginal sheath for tendon of flexor pollicis longus muscle. That is why one should be very careful during surgical revision of this sheath.

#### ANATOMICAL VARIATIONS

Majority of authors of anatomical textbooks do not consider even major anatomical variations in the course and position of the main trunk of the median nerve within the distal forearm, carpal tunnel, and hand, as well as anomalies which

deal with motor branch to thenar muscles [7]. Variations considering the location and branching pattern of the median nerve are not so frequent, but first of all they are rarely described.

Still in 1968 Papathanassiou [8] presented a case where the main trunk of the median nerve was divided within the wrist (carpal tunnel) into radial and ulnar parts. Ulnar part gave rise to a motor branch which pierced flexor retinaculum proximally from its distal border.

Kessler [9] presented a case where a high subdivision of the median nerve in the lower 1/3 of the forearm occurred. Radial part ran medial to flexor carpi radialis tendon. In the carpal tunnel it was located above tendon of flexor pollicis longus, whereas on the level of lower margin of flexor retinaculum it adhered to the mentioned above tendon directly. Next it subdivided into terminal branches, i.e. motor branch to thenar muscles. Medial or ulnar part, about twice thicker paralleled the radial part and seemed to have a typical course of the entire median nerve.

Limburg *et al.* [10] described a case where two motor branches originated from a median nerve, proximal and distal to the flexor retinaculum.

Also numerous reports of other authors confirm that a high subdivision of the median nerve is possible [11–14].

Eiken *et al.* [11] reported in their paper three cases of high subdivision of the median nerve into radial and ulnar parts. Two cases were accompanied by the median artery adhering to the radial fragment of the median nerve. Course of these parts was studied at the distance of 10 cm above distal flexor line, but the location of subdivision has not been found. The third case presented the high subdivisions without median artery. The distance between radial and ulnar parts measured 20 mm. Also in this case the beginning of the separation of main trunk has not been found.

The high subdivision of the median nerve into radial and ulnar parts may cause atypical course of the radial fragment. Szabo *et al.* [15] presented a situation where radial part within the carpal tunnel ran through a separate fibro-ligamentous tunnel (an additional compartment). One could see the ulnar part only on the revision of carpal tunnel. Both radial and ulnar divisions were connected by a communicating branch placed distal in respect to the additional tunnel. On the revision of the carpal tunnel one could treat the ulnar part with its connecting branch as the entire median nerve with a motor branch to thenar muscles.

It is confirmed by many authors that motor branch does not always originate typically from radial part. Graham [16] presented a case where motor branch arose from ulnar part of the median nerve, proximal to the carpal tunnel, and next it crossed the main trunk palmarly, to reach the thenar muscles beneath the flexor retinaculum.

After skin incision one can see overgrown muscular tissue, which usually represents hypertrophied superficial head of flexor pollicis brevis or (and) palmaris brevis muscle and is located over the flexor retinaculum, should remember the

atypical course of muscular branch to be possible. Based on the intraoperative analysis of carpal tunnel syndromes Mannerfelt *et al.* [17] paid attention to a particular variation of the motor branch which existed in 2,52%. In these cases the motor branch originated from palmar or ulnar aspect of the median nerve, ran distal and moved radially hidden in hypertrophied muscles, approaching thenar.

Treatment of carpal tunnel syndrome is primarily based on pressure reduction upon the median nerve through incision of the transverse carpal ligament. Not always however simple resection causes reduction of symptoms. In some variations a single [18, 19] or double [20–22] motor branch arises from radial portion of median nerve within the carpal tunnel, which next traverse a tunnel within the retinaculum. Within this separate tunnel the branches are surrounded by fatty vaginal sheath, that mounts it to the walls of the canal. Sometimes at the entrance one can see circular fibers which may obstruct the motor branch. Thus revision not only of the main trunk but also the motor branch is so crucial.

It was Poisel [23] who in 1974 based on his own studies and current literature proposed for the first time classification of thenar motor branch.

- Retroligamentous type

Branch to thenar muscles originates distal from flexor retinaculum, so it arises beyond the carpal tunnel. It branches off from the first palmar common digital nerve, next arches reaching thenar muscles (46% of studied hands — type most commonly described in textbooks).

- Subligamentous type

Thenar motor branch arises from first palmar common digital nerve within the carpal tunnel, next arches over the distal margin of flexor retinaculum, reaching thenar muscles (31% of studied hands).

- Transligamentous type

Thenar motor branch begins similarly to previous type, but after a short course it pierces flexor retinaculum and runs obliquely towards thenar muscles (23% of studied hands).

In 1977, based on his own studies and earlier reports, Lanz [24] described more than few variations in the composition of the median nerve and its thenar motor branch within carpal tunnel. He has distinguished four main groups. First group considers variation of origin and course of thenar motor branch. Second group includes additional motor branches which arise within the distal portion of the carpal tunnel. Into the third group he included high subdivision of the median nerve. In the fourth group finally one can find additional motor branches which arose proximal to the carpal tunnel.

According to Lanz all Poisel's variants were included into the first group.

**First group:**

- Group I — thenar motor branch arises slightly below carpal tunnel from palmar aspect of the radial part of median nerve, arching over the distal margin of flexor retinaculum

- Group II — thenar motor branch arises within the carpal tunnel and arches over the flexor retinaculum
- Group III — thenar motor branch arises from radial part of median nerve, within carpal tunnel, next pierces flexor retinaculum and reaches thenar muscles
- Group IV — thenar motor branch originates from ulnar part of median nerve and arches over the distal margin of flexor retinaculum
- Group V — thenar motor branch originates from ulnar part of median nerve and runs on the surface of the retinaculum to the muscles

**Second group:**

- Group VI — double motor thenar branch — one of them arises typically, whereas the other goes from the first palmar common digital nerve

**Third group:**

- Group VII — high subdivision of the median nerve into radial and ulnar parts. Thenar motor branch originates typically
- Group VIII — high subdivision of the median nerve is accompanied by the persistent median artery
- Group IX — high subdivision of the median nerve is accompanied by additional lumbrical muscle

**Fourth group:**

- Group X — additional motor branch arises from a trunk of the median nerve before it enters the carpal tunnel and runs between fibers of retinaculum fusing with thenar motor branch
- Group XI — additional motor branch arises proximally, enters carpal tunnel, pierces flexor retinaculum
- Group XII — additional motor branch arises from ulnar part of median nerve and crosses nerve anteriorly running toward radial side, enters tunnel and pierces flexor retinaculum fusing with first palmar common digital nerve

Tountas *et al.* [25] carried out studies on cadavers and during operations. They subdivided obtained data following Lanz's classification.

MacKinnon *et al.* [26] studied location of bundles which created motor component (branch) within the median nerve. In 60% of cases the bundles originated from radial, in 20% from palmar, and in 18% between radial and palmar aspects. High subdivision of median nerve was observed in about 2% of cases [27].

Based on careful analysis of patients with carpal tunnel syndrome, Hurwitz [28] found motor thenar branch in 9% within hypertrophied muscular tissue, which covered anterior aspect of flexor retinaculum. In all of these cases thenar branch originated from palmar aspect of the median nerve.

In 1998 Kozin [29] studied 101 non embalmed cadavers. After a detailed analysis, based on Poisel's classification he accepted the following:

Type I — transligamentous — 7%

Type II — 74%, distal with respect to the retinaculum within additional fascial tunnel created by fibers arising from inferior aspect of palmar aponeurosis to individual fascia of thenar muscles

Type III — 18%, distal with respect to the retinaculum, without fascial tunnel, surrounded only by thenar muscles

Two last types — 93% according to Poisel's classification belonged to extraligamentous type. The authors did not find subligamentous type. In 4% of cases — two motor thenar branches originated. In 80 cases motor thenar branch arose from first palmar common digital nerve. In one example they found connection between thenar motor and palmar branches of the median nerve.

The studies carried out on cadavers present different percentage (9–80%) of the presence of thenar motor branch traversing the flexor retinaculum. Clinical studies report different frequency of such course (1–48%) [25, 28, 30]. Such differences may result from problems with identification of the distal margin of retinaculum.

Different complications may arise in a course of the surgical treatment of carpal tunnel syndrome [31–34]. The most serious intraoperative complication is a sectioning of the motor branch to thenar muscles, which causes permanent disability. This is why the knowledge on the topography of the median nerve and its thenar motor branch seems to be of great importance.

Palmer and Toivonen [31] carried out anonymous tests among the members of American Association of Hand Surgery. The members have been asked about complication after surgical treatment of carpal tunnel syndrome. The questionnaires were delivered to 1253 surgeons, out of which 708 described complications after endoscopic treatment, and 616 — after traditional “opened” treatment. Operations were made in years 1990–1995. 708 out of questioned reported large complications, i.e.

- 100 injuries of the median nerve
- 88 injuries to the ulnar nerve
- 77 injuries to palmar common digital nerves
- 121 vascular traumas
- 69 tendinous lesions

Out of 616 surgeons using traditional treatment, 283 reported large complications, i.e.

- 147 injuries to median nerve
- 29 injuries to ulnar nerve
- 54 injuries to palmar common digital nerves
- 34 vascular injuries
- 19 lesions of tendons

Treatment of carpal tunnel syndrome is associated with a pressure releasing upon a nerve through sectioning the flexor retinaculum. Traditional method including gentle dissection shows subsequent layers [24], what allows careful anatomical evaluation. On preparation of the following layers one should remember

that thenar motor branch may course on the surface of flexor retinaculum [17, 35]. In some cases the mentioned above branch traverses superficial head of flexor pollicis brevis or palmaris brevis muscle which are placed on the surface of flexor retinaculum. In these cases thenar motor branch originates from palmar or ulnar aspects of the median nerve, arches over the distal margin of flexor retinaculum and invisibly enters the hypertrophied muscle, running next within it to supply thenar muscles. Thus finding hypertrophied muscular tissue one should be especially careful during retinaculum sectioning. Before sectioning flexor retinaculum one must find the motor thenar branch first to avoid its injury. Usually flexor retinaculum is sectioned ulnarly to avoid injury of the thenar motor branch, although in some cases, when abductor pollicis brevis is overgrown, its mass can dislocate thenar motor branch to the ulnar side [24].

The same procedure carried out endoscopically, when retinaculum is sectioned from behind, causes inability to evaluate the structures located anterior to it.

In some cases sectioning flexor retinaculum is not enough to eliminate signs of carpal tunnel syndrome. It may be caused by an incidental course of thenar motor branch through a separate connective tissue tunnel [10, 18, 19, 22, 36], which compresses this branch. In each example of carpal tunnel revision it is inevitable to estimate if the motor thenar branch courses through a separate fascial tunnel or not, to section it, causing impingement elimination [37, 38].

We should also take into consideration the composition of the main trunk of the median nerve within the carpal tunnel. In a situation when it is divided into radial and ulnar divisions, one of them may be closed in an additional tunnel. Then after sectioning flexor retinaculum one can see one part only, which may be treated as the main trunk of the nerve. Szabo *et al.* [15] found during operation a non-typical course of the median nerve, divided into radial and ulnar divisions. Radial part was hidden in additional tunnel. Both parts were connected by a branch located above the additional tunnel. This branch could be misinterpreted as branch to thenar muscles.

Apart from the main motor branch, thenar muscles may be supplied by additional branches, which may arise still in the forearm, and traverse carpal tunnel superficially on the flexor retinaculum or between its fibers [39]. This is why it is necessary to revise the median nerve before it enters the carpal tunnel and estimate the course of possible additional motor branches, also palmar (sensory) branch, because when sectioned, may lead to sensory deficits in the hand [40].

Flexor retinaculum possesses between its fibers a rich network of free sensory nerve endings (nociceptors) and Paccini corpuscles responsible for superficial and deep sensation. Stimulation of these structures may give pain excitement similar to symptoms of the carpal tunnel syndrome. Incision of the flexor retinaculum may increase symptoms.

In certain surgical centers endoscopic method is preferred, because of minimization of operation trauma and shortening of time of recovery. Ferdinand and

Mac Lean [41] operated 25 patients with bilateral idiopathic carpal tunnel syndrome. On one side they used endoscopy, while on the other side they applied open surgery technique. Timing of endoscopy was about 134 minutes, while open surgery last around 102 minutes. They did not show specific differences in recovery after treatment, even the time of absence at work was comparable. They did not state complications although in one case of open surgery palmar branch of the median nerve was damaged.

Hulsizer *et al.* [42] compared open and endoscopic surgical methods. They operated 23 patients with 30 carpal tunnel syndromes. In 14 out of patients (17 wrists) open surgery was applied, in 9 (13 wrists) = endoscopic treatment was performed. Patients operated using endoscopy were subsequently operated using open surgery. Positives of endoscopy consist of: small incision, and because of it causes less pain and quick recovery, while positives of open surgery include: easy identification of flexor retinaculum, direct viewing of retinaculum, median nerve and its thenar motor branch [43, 44].

The above given report, as well as work of Lee *et al.* [43] suggests that endoscopic treatment brings relatively high risk of incomplete sectioning of flexor retinaculum, although not all reports agree with it [44].

Based on these reports and article of Palmer and Toivonen [31] which deals with complication in both methods we can assume that both methods do not belong to simple procedures. This is why a knowledge on normal anatomy and anatomical variations within the carpal tunnel is so much important for the surgeons [1, 45, 46].

## CONFLICT OF INTERESTS

None.

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