VARIATIONS OF MEDIAN NERVE IN CARPAL TUNNEL AND ITS DISTRIBUTION IN HAND

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ABSTRACT

Aim of the study was to study the variations in the branching pattern of median nerve in the carpal tunnel and hand, which would form useful data for hand surgeons doing open/endoscopic carpal tunnel release. Median nerve and its branches were explored by dissection in fifty hands of twenty-five formalin fixed adult human cadavers over a period of three years. We found variations in 35 out of 50 hands. Based upon Lanz classification, frequency of variations in present series was variation in the course of thenar branch (58%), accessory branches at the distal portion of the carpal tunnel (34%), high divisions of the median nerve (8%) and accessory branches proximal to the carpal tunnel (nil). Rare variations including transligamentous median nerve and multiple thenar branches were also observed. Medial take off of thenar branch as observed in this series has special clinical significance in carpal tunnel release. Knowledge of the variable anatomy of median nerve would help to avoid incomplete decompression at operations for nerve entrapment and injury to thenar branch.

Keywords: Median nerve, carpal tunnel, thenar branch, anatomic variation, transverse carpal ligament.

INTRODUCTION

Variations ranging from subtle to remarkable affect every part of the human body. They may have important influences on predisposition to illness, symptomatology, clinical examination and patient management including operative surgery. There are several anatomic variations in the branching pattern of the median nerve in the forearm and hand, and its communications with various nerves.[1] Based upon findings in 246 hands Lanz[2] classified the variations into four groups: variation in the course of thenar branch (88.2%), accessory branches at the distal portion of the carpal tunnel (7.3%), high divisions of the median nerve (2.8%), and accessory branches proximal to the carpal tunnel (1.7%). Barbe et al[3] examined 89 cadaveric forearm-hand hands to determine the frequency of anomalous structures within the carpal tunnels. Twenty-nine percent of all hands examined had two to five anomalies/variations per tunnel, whereas another 27% had one anomaly or variation per tunnel. In the series of 748 endoscopic carpal tunnel releases, Cavallo et al[4] found six variations in the median nerve anatomy, in two patients conversion to open release was necessary to avoid nerve injury. Frequency of occurrence of observed variations of median nerve is extremely variable in the published literature. The purpose of this work was to study the anatomical variations of median nerve in the carpal tunnel, its branching pattern and the distribution in hand.

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MATERIAL AND METHODS

Fifty hands of twenty-five adult human cadavers from the department of Anatomy, Government Medical College, Patiala comprised the material for this study. Study was done over a period of three years (2006-09). All cadavers were fixed in formalin-phenol-alcohol solution. The hands were labeled from 1 to 50 with letters (R) or (L) corresponding to the right or left hand respectively. Of these 25 cadavers, 23 were males and 2 were females. Skin incision was made in the wrist and palm as mentioned in the Manual of Practical Anatomy.[5] After removal of skin and palmer aponeurosis transverse carpal ligament was identified and divided by a sagittal incision between thenar and hypothenar muscles. The median nerve was identified and its branches were traced till their termination in hand. The course of median nerve in the carpal tunnel and the distribution in hand including the branching pattern was recorded and photographed. Wherever necessary magnifying glass was used to identify small branches. The observations thus made were collected and subjected to analysis.

RESULTS

Out of total 50 hands studied, 25 (50%)

belonged to the right side and 25 (50%) to the left side. Textbook pattern of branching and distribution of median nerve, as described below, was observed in 15 out of 50 hands (30%). Out of 50 hands, 35 hands had varying number of variations. Left hands had more variations (20 of 35) as compared to right hands. In one peculiar hand five variations were observed. high division of median nerve, ulnar and subligamentous origin of thenar branch, two and half digital innervation pattern, multiple communicating branches at three levels between median and ulnar nerve.

Fifteen hands in which the distribution of median nerve was according to standard anatomical textbooks, the median nerve was passing deep to transverse carpal ligament (TCL) and the branching pattern was either bifurcation or trifurcation with single extraligamentous thenar branch with three and a half digital distribution. As far as communicating branches between median and ulnar nerve are concerned, only multiple communicating branches were considered a variation. Ten structures observed coursing through the carpal tunnel in these 15 hands included median nerve, four flexor digitorum superficialis tendons and four flexor digitorum profundus tendons, all ensheathed by the ulnar bursa, and the flexor pollicis longus, which was ensheathed by the radial bursa. The median nerve was the most superficial structure located within the carpal tunnel lying between ulnar and radial bursae in all except one hand. In this hand the median nerve was lying in front of the ulnar bursa.

In 49 hands median nerve was passing deep to TCL but in one it was passing through the TCL (transligamentous) in a fascial canal, which was six centimeters long. (Photograph 1) The extent of fascial canal was from the origin of palmar cutaneous branch upto the division of median nerve. Two patterns of branching of median nerve were identified. In 27 (54%) hands it was bifurcation (15 right hands and 12 left hands) and in 23 (46 %) hands it was trifurcation (10 right hands and 13 left hands). Bilateral symmetry in branching pattern was observed in 28 hands (14 cadavers) only. In bifurcating branching pattern median nerve was dividing at or just proximal to distal border of flexor retinaculum. The first branch arising from the main trunk of median nerve was thenar branch. Median nerve then divided into medial and lateral divisions. The lateral division provided digital branches to the pollex and the radial side of the index finger and medial division provided digital branches to adjacent sides of the index, middle and ring finger. The proper palmar digital nerve to the lateral side of the index also supplied the first lumbrical. The common digital nerve supplying the adjacent sides of index and middle finger supplied the second lumbrical. In trifurcating pattern both the divisions (medial and lateral) and thenar branch arose simultaneously from common stem at or just proximal to distal border of flexor retinaculum. (Photograph 2) The divisions gave digital branches in usual manner. But in one hand the trifurcation occurred 4 mm distal to the lower border of flexor retinaculum.

Bifid median nerve was observed in 4 hands in which the median nerve was dividing proximal to the upper border of transverse carpal ligament (high division). It was unilateral, in right hands of 3 cadavers and left hand of one cadaver. In two hands median nerve was dividing 5 mm above the proximal border of flexor retinaculum and in rest of the two cases it was dividing 10 mm above the proximal border of flexor retinaculum. Both the divisions were equal and did not pass through separate compartments.

In 33 hands (66%) one thenar branch was found to supply thenar muscles while in 17 hands (34%) multiple thenar branches were observed. Out of 17 hands with multiple thenar branches, 16 had two branches and in one very unusual instance seven branches were observed. (Photograph 3 and 4) Of the 16 hands with two thenar branches, in four hands a single thenar branch was bifurcating into two, right at its origin and in rest two branches were arising separately. In hand with seven thenar branches, except for the first branch all other branches arose distal to the lower border of the flexor retinaculum (extraligamentous). These all branches were entering FPB proximally three branches ended by supplying it and four supplied rest of the thenar muscles.

In hands with single thenar branch, thenar nerve was arising deep to the TCL (subligamentous) in 13 hands (39.39%); distal to TCL (extraligamentous) in 17 hands (51.51%) and in three hands (9.09%) it was piercing the TCL (transligamentous). In hands with two thenar branches (16 hands), 15 branches were extraligamentous (46.87%), nine were transligamentous (28.12%) and eight were subligamentous (25%).

In hands with single thenar branch, thenar branch was arising from the anterolateral aspect (volar radial) in 14 hands (42.42%), anterior aspect (volar) in 12 hands (36.36%) and anteromedial aspect (volar

Fig 1 : Transligamentous median nerve (Abbreviations: MN- median nerve, PCB- palmar cutaneous branch, FC- fascial canal, DIV lateral and medial divisions of median nerve). Please note that the median nerve got lifted in one of the cut edges of flexor retinaculum.

Fig 2: Trifurcation pattern of median nerve branching (Abbreviations: MN- median nerve, UN-ulnar nerve, FR- flexor retinaculum, TP- trifurcation pattern, MUC median ulnar communication, TB- thenar branch, LD and MD- lateral and medial division of median nerve)

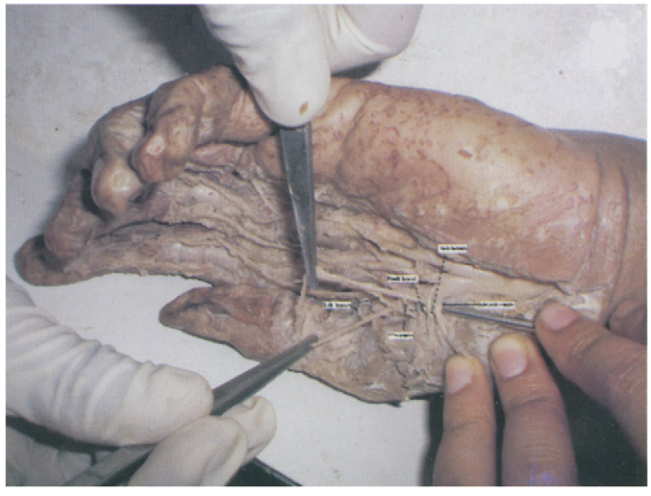

Fig 3: Multiple thenar branches (First and seventh branch has not been shown in this photograph since first was more proximal and seventh was broken during dissection)

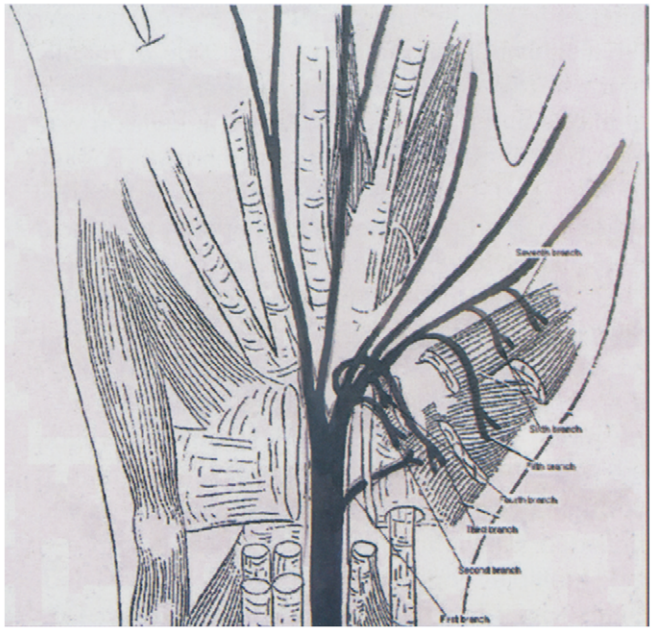

Fig 4: Line diagram of multiple thenar branches.

medial) in seven hands (21.21%). In hands with two thenar branches (16 hands), 19 branches were volar radial (59.37%), 10 branches were volar (31.25%) and three branches were volar medial (9.37%).

In all the 50 hands studied, median nerve supplied thenar muscles including flexor pollicis brevis, abductor pollicis brevis and opponens pollicis and lateral two lumbricals. In six hands third lumbrical was also supplied by median nerve. Of these six hands bilateral symmetry was observed in two cadavers (four hands). In the remaining two hands it was unilateral. Deep head of flexor pollicis brevis was innervated by ulnar nerve in all the hands except one, in which it was innervated by median nerve as well as deep branch of ulnar nerve.

Five digital branches were observed to arise from the divisions of median nerve in 47 hands (94%) supplying lateral three and a half digit (standard pattern). The classical innervation pattern with a neural watershed at the midline of the ring finger was observed in these hands. In two hands (4%) digital branches supplied lateral two and a half digits and in one hand (2%) they supplied lateral three digits. In one hand with median nerve supplying lateral three digits, lateral division provided proper palmar digital branches to the pollex and the radial side of the index finger and medial division supplied common digital branches to second interdigital cleft and one proper palmar digital branch for the medial side of middle finger. In two hands with median nerve supplying lateral two and a half digits, the lateral division was giving proper palmar digital branches to the pollex and the radial side of the index finger and medial division gave one common digital branch to second interdigital cleft which further divided into proper palmar digital branches for adjacent sides of the index and middle finger.

A communicating branch between median and ulnar nerves in the hand was observed in 10 hands (20%). The most common pattern of communication observed (90%) featured a communicating branch that originated proximally from the ulnar nerve and proceeded distally to join the median nerve. In one hand multiple communicating branches existed, arising from both median and ulnar nerves. One communicating branch was between the main trunks of median and ulnar nerves. The second communicating branch was between common digital branch of the two nerves and the third communicating branch was between proper palmar digital branches of median and ulnar nerves for the middle finger.

DISCUSSION

We observed anatomical variations of median nerve in 35 out of 50 hands (70%). Two to five variations per hand were found in 36 % of all hands and 34% had only one variation per hand. Frequency of variations has been extremely variable in literature. In operative studies on patients, the frequency of variations is relatively less compared to cadaveric studies, probably attributable to limited access in surgery. Barbe et al[3] examined 89 cadaveric forearm-hand hands. Twenty-nine percent of all hands examined had two to five anomalies/variations per tunnel, whereas another 27% had one anomaly or variation per tunnel. Lanz[2] observed 29 variations in the course of median nerve in 246 hands in which the carpal tunnel was explored at operation. Based upon Lanz classification[2], frequency of variations in present series was group 1: variation in the course of thenar branch. (58%), group 2: accessory branches at the distal portion of the carpal tunnel (34%), group 3: high divisions of the median nerve (8%) and group 4: accessory branches proximal to the carpal tunnel (nil). Lindley et al[6] studied the prevalence of anatomic variations encountered in elective carpal tunnel release. A total of 31 anomalies of median nerve, were documented in 30 hands (5.7%) during the course of 526 elective carpal tunnel releases.

We found median nerve passing through the TCL in a fascial canal (transligamentous) in one hand. To the best of our knowledge, there is no similar report in the published literature. Takami et al[7] reported an anomaly of the median nerve in which there was a division of median nerve into two branches (ulnar and radial) at the level of the distal third of the forearm and the ulnar division of the median nerve passed through a separate compartment within the transverse carpal ligament and it was necessary to decompress both branches of the nerve when releasing the carpal canal. In present study thenar branch was subligamentous in 13 hands (39.39%), extraligamentous in 17 hands (51.51%) and in three hands (9.09%) it was transligamentous in hands with single thenar branch. Falconer and Spinner[1] found transligamentous passage of the recurrent motor branch of the median nerve in six out of 10 hands. The existence of a transligamentous variation of thenar branch increases the susceptibility to injury during TCL incision for carpal tunnel decompression.

In present study, out of 17 hands with multiple thenar

branches, 16 had two branches and in one very unusual hand seven branches were observed. Akio9 studied variations of the branching of the median nerve and their variant course in a series of 147 hands in which the carpal tunnel was explored at operation. One hundred and fourteen hands had one thenar branch, 23 hands two and 10 hands three branches. To the best of our knowledge, there are no reports of seven thenar branches in the literature. Knowledge of multiplicity of thenar branches would help in avoiding inadvertent injury and incomplete decompression during carpal tunnel release.

In hands with single thenar branch, thenar branch was arising from the anterolateral aspect (volar radial) in 14 hands (42.42%), anterior aspect (volar) in 12 hands (36.36%) and anteromedial aspect (volar medial) in seven hands (21.21%). In the study by Akio[8], in 72 of the 114 hands the thenar branch arose on the volar radial aspect of the median nerve, in 40 on the volar medial aspect. Medial take off of the thenar branch is clinically important as it makes the nerve vulnerable during carpal tunnel release.

Bifid nerve was observed in four hands in which the median nerve was dividing proximal to the upper border of flexor retinaculum. Lanz[2] reported high division of the median nerve in seven out of 246 hands ((2.8%). Amadio[9] in a series of 275 carpal tunnel releases reported high bifurcation of median nerve in 3.3 % hands.

The median nerve usually supplies first and second lumbricals. The third lumbrical is commonly supplied by ulnar nerve but rarely it may be supplied by median nerve. In our series, third lumbrical was supplied by median nerve in six out of 50 hands. Mehta and Gardner[10] reported third lumbrical innervation by the median nerve in two out of 75 hands.

In two hands (4%) digital branches supplied lateral two and a half digits and in one hand (2%) they supplied lateral three digits. Linell[11] found one hand out of 20 having ulnar nerve distribution to both sides of the ring finger as well as to the little finger and three hands in which the ulnar nerve was distributed to the ulnar side of the middle finger (two and half distribution).

A communicating branch between median and ulnar nerves in the hand was observed in 10 hands (20%). In one hand multiple communicating branches existed, arising from both median and ulnar nerves. Bas et al[12] performed anatomic dissections under microscopic magnification of 30 fresh cadaveric hands to depict the course and interconnections of the sensory nerves to the digits. The communicating branches between the median and ulnar nerves in the palm were found in 20 of the 30 (67%) hands. Interconnecting nerves were located just distal to the TCL. These interconnections are at risk when releasing the distal aspect of the TCL during open or endoscopic carpal tunnel release. Aggressive retraction in this region and placement of the endoscope further distal to the TCL should both be avoided in order to prevent traction injury to these nerves resulting in paresthesia in the long and ring finger distribution.

Embryological basis of observed variations may be attributed to over or under expression of one or multiple transcription factors responsible for formation, relation and distribution of motor nerve fibres during their development. A group of cell surface receptors like neural cell adhesion molecule, L1 cell adhesion molecule and N-cadherin act as transcription factors which recognize and bind to components of extracellular matrix during neurite growth. Several trophic factors e.g. nerve growth factor, neurotrophin 3 and 4, released from the target tissue regulate expression of these cellular adhesion molecules. The axonal growth cones act as sensors to the concentration gradient of trophic factors in the environment and grow along the gradient towards the target e.g. Muscles.[13]

The most important highlights of this study are transligamentous passage of median nerve, high bifurcation of median nerve in four hands, seven thenar branches in one hand, two and a half digital innervation in two hands, third lumbrical being supplied by median nerve in six hands and multiple communicating branches between median and ulnar nerves in one hand. Anticipation of the frequency and multiplicity of anomalous/variant structures in the hand is of paramount importance to clinicians particularly hand surgeons.

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