# “A STUDY OF NEUROANATOMICAL VARIATIONS OF MEDIAN NERVE IN HUMAN CADAVERS”

**By**

**Dr. CHANNABASANAGOUDA**

Dissertation submitted to the
KLE University, Belgaum, Karnataka

In Partial Fulfillment
of the requirements for the degree of

M. D. (ANATOMY)

**Under the Guidance of**

**Dr. P. S. JEVOOR.** **MS**
**Professor and EX-H.O.D**

**DEPARTMENT OF ANATOMY,**
**JAWAHARLAL NEHRU MEDICAL COLLEGE,**
**NEHRU NAGAR, BELGAUM – 590 010, KARNATAKA**

**APRIL - 2010**

**KLE UNIVERSITY, BELGAUM, KARNATAKA**

# DECLARATION

I hereby declare that this dissertation entitled **"A STUDY OF NEUROANATOMICAL VARIATIONS OF MEDIAN NERVE IN HUMAN CADAVERS"** is a bonafide and genuine research work carried out by me under the guidance of **Dr. P. S. Jevoor** $_{MS}$ Professor and Ex-H.O.D of Anatomy, Jawaharlal Nehru Medical College, Nehru Nagar, Belgaum – 590 010.

Date: (Dr. Channabasanagouda)

Place: Belgaum

**KLE UNIVERSITY, BELGAUM, KARNATAKA**

# CERTIFICATE BY THE GUIDE

This is to certify that the dissertation entitled **"A STUDY OF NEUROANATOMICAL VARIATIONS OF MEDIAN NERVE IN HUMAN CADAVERS"** is a bonafide research work done by **Dr. Channabasanagouda** in partial fulfillment of the requirement for the degree of **M. D. (ANATOMY).**

Date:
Place:Belgaum

Dr. P. S. Jevoor. MS
Professor and Ex-H.O.D
of Anatomy,
J. N. Medical College,
Nehru Nagar,
Belgaum – 10

**KLE UNIVERSITY, BELGAUM, KARNATAKA**

# ENDORSEMENT

This is to certify that the dissertation entitled **"A STUDY OF NEUROANATOMICAL VARIATIONS OF MEDIAN NERVE IN HUMAN CADAVERS"** is a bonafide research work done by **Dr. Channabasanagouda** under the guidance of **Dr. P. S. Jevoor.** $_{MS,}$ Professor and Ex-H.O.D of Anatomy, J. N. Medical College, Nehru Nagar, Belgaum - 10.

Dr. V. S. Shirol $_{MS}$
Professor and Head,
Department of Anatomy,
J. N. Medical College,
Nehru Nagar, Belgaum – 10

Date:

Place: Belgaum

Dr. V. D. Patil $_{MD,DCH}$
Principal,
J. N. Medical College,
Nehru Nagar, Belgaum – 10

Date:

Place: Belgaum

**KLE UNIVERSITY, BELGAUM, KARNATAKA**

# COPYRIGHT

## DECLARATION BY THE CANDIDATE

I hereby declare that the KLE University, Belgaum, Karnataka shall have the rights to preserve, use and disseminate this dissertation in print or electronic format for academic / research purpose.

Date :

Place : Belgaum

(Dr.Channabasanagouda)

# ACKNOWLEDGEMENT

It is with great respect and privilege, I express my most sincere gratitude to my respected guide, **Dr. P. S. Jevoor** $_{\mathbf{MS}}$, Professor & Ex-H.O.D of Anatomy, J. N. Medical College, Belgaum for his caring attitude, able guidance, valuable suggestions, and constant encouragement throughout the study which facilitated the completion of this dissertation in time.

I express my heartfelt gratitude to **Dr. V. S. Shirol** $_{\mathbf{MS,}}$ Professor and Head of Department and **Dr. S. P. Desai** $_{\mathbf{MS,}}$ Professor, Department of Anatomy, J. N. Medical College, Belgaum, for all the help rendered me during the study. I thank all staff and my colleagues in the Department of Anatomy, J. N. Medical College, Belgaum, for their encouragement and help.

I thank **Dr. V. D. Patil** $_{\mathbf{MD,\ DCH,}}$ Principal, J. N. Medical College, Belgaum for permitting me to carry out this study.

I thank the Technical Staff and the Non Teaching Staff, who helped in various aspects to complete my study.

I thank all my friends and family members for their inspiration, moral courage and love during the study.

Finally I bow my head before God, the almighty.

Date: Dr. Channabasanagouda

Place: Belgaum

# LIST OF ABBREVIATIONS USED

| | |
|---|---|
| AIN | Anterior interosseous nerve |
| BB | Biceps brachii |
| cm | Centimeter |
| CTS | Carpal tunnel syndrome |
| CB | Coracobrachialis |
| FDS | Flexor digitorum superficialis |
| FCU | Flexor carpi ulnaris |
| MN | Median nerve |
| MCN | Musculocutaneous nerve |
| PT | Pronator teres |
| UN | Ulnar nerve |

# ABSTRACT


**Background and objectives**

Median nerve is called labourers' nerve. Comprehensive knowledge pertaining to its anatomical variations is extremely important in clinical and surgical procedures so as to avoid injury to it. The objectives of the study were to know about the variations of median nerve in its formation course, branching pattern and termination.

**Methods**

Dissection method was employed and 50 upper limbs were studied for anatomical variations of median nerve obtained from the department of Anatomy.

**Results**

The median nerve was found to be formed by two roots in 37(74%) and by three roots in 13 (26%) specimens. It was found to be formed in axilla in 32 (64%), in the upper third of arm in 10 (20%), middle third of arm in 6 (12%) and lower third of arm in 2 (4%) specimens. The median nerve coursed lateral to brachial artery in 47 (94%) and medial to brachial artery in 3 (6%) specimens. In one specimen high division of brachial artery in the middle third of the arm was observed along with formation of median nerve at the same level. Formation of median nerve was lateral to axillary artery in 42 (84%) specimens, anterior to axillary artery in 5 (10%) specimens, medial to axillary artery in 3 (6%) specimens. Absence of musculocutaneous nerve was noted in 6 (12%) specimens and it was bilateral in one cadaver. In two out of these six specimens where absence of musculocutaneous nerve was noted, there were concomitant variations in the formation of median nerve as

well. In both of these specimens the median nerve was formed by three roots. In one specimen there was extremely thin normal lateral root and abnormally very thick second lateral root of median nerve. In another specimen apart from three roots there was vascular variation as well. Vena comitans was coursing within the loop formed by the two lateral roots of the median nerve.

The median nerve passed between two heads of pronator teres in 44 (88%) specimens, deep to the muscle in 2 (4%), through ulnar head in 2 (4 %) and the nerve passed deep to humeral head the ulnar head being absent in 2 (4%) specimens. The median nerve passed deep to flexor digitorum superficialis in 48 (96%) and piercing the muscle in 2 (4%) specimens. The median nerve becoming superficial in middle third of the forearm was noted in 10 (20%) specimens. Palmaris longus was absent in 2 (4%) specimens. Communications between median nerve and musculocutaneous nerve were observed in 6 (12%) specimens. In one specimen along with communication between median and musculocutaneous nerve in middle third of arm there was a concomitant arterial variation as well. In that specimen high division of axillary artery was observed.

Communications between median and ulnar nerve in forearm and hand were seen in 4 (8%) each. The median nerve was found to terminate in the palm into 3-5 branches in 5 (10%) specimens.

**Conclusion and interpretation**

We are optimistic that the data obtained in our study would be helpful for the clinicians. It is probable that the differences observed as compared to other studies may be due to differences in the sample size.

The present study concludes that, the different types of variations in cadavers which have been studied would be of immense help for successful clinical and surgical procedures.

The present study may provide additional information as such neurovascular variations encountered here are important to be noted during surgical procedures as these are more prone to iatrogenic injuries.

**Key words**

Neuroanatomical; variations; median; nerve;

# CONTENTS

# LIST OF TABLES

# LIST OF HISTOGRAMS

# LIST OF PHOTOGRAPHS

# INTRODUCTION

Normal and anomalous position of the arteries and veins may be determined preoperatively by angiographic studies but in case of nerves it is not possible to detect such an anomaly. Only at the time of surgery the surgeon is exposed to such variations.[1] Prior knowledge of the possible variations is thus very much essential.

The anatomical variations of the peripheral nervous system, often form the basis of unexpected clinical signs and symptoms. Descriptions of nerve variations are useful in clinical and surgical practice, as an anatomical variation can be the cause of a nerve palsy syndrome due to different relation of a nerve and a related muscle. In most of these cases, an appropriate surgical procedure can lead to a rapid recovery of nerve function.[2]

Hence, anatomical variations of peripheral nerves constitute a potentially important clinical and surgical issue. Precise knowledge of variations, particularly of median nerve may prove valuable in trauma of upper limbs as well as in plastic and reconstructive repair operations.[3]

Sound knowledge of the branching patterns of the median nerve is very important for understanding the various presentations of median nerve entrapment. In the arm, the most common median nerve variation relates to the "delayed" contribution of the lateral cord. In 24% of cases the lateral cord gives very small proximal contribution but the musculocutaneous nerve sends a branch to the median nerve in the proximal arm. The medial and lateral roots can pass posteriorly to the axillary artery to form the median nerve, which subsequently takes a posterior course to reach the medial aspect of the brachial artery. The external anomalies of the nerves like communication between nerves and unusual branching patterns of nerves are also extremely important with respect to compressive neuropathies of the upper extremity.

These are significant sources of misdiagnosis; for instance, a proximal injury of the nerve may cause weakness of a muscle that it does not usually innervate. Alternatively, one may only see "partial" nerve lesions of muscles supplied by another "uninjured" nerve.[4]

Although communications between the nerves in the arm are rare, the communications between median nerve and musculocutaneous nerve were described from nineteenth century onwards. Such variations have clinical importance especially in post-traumatic evaluations and exploratory innervations of the arm for peripheral nerve repair. The knowledge of the variations of this communication between median nerve and musculocutaneous nerves in the distal third of the arm is also important in the anterior approach for treatment of the fracture of the humerus.[5]

Also, it is important to bear a good knowledge of the variations in innervations of the palmaris longus as it is preferred for cosmetic, plastic and reconstructive surgeries. Many surgeons agree that the palmaris longus tendon is the first choice as a donor tendon because it fulfils the necessary requirements of length, diameter and availability and can be used without causing any functional deficit.[6] Complete knowledge of innervation of palmaris longus is required for the operating surgeon, to avoid post operative complications and for maintaining the required actions in operations such as Camitz opponensplasty. [7]

Intercommunications between peripheral nerves deserve special attention in view of their clinical significance. If the surgeon finds it necessary to isolate and trace the median nerve and musculocutaneous nerves distally, it is essential to be alert to communications that may occur between them. The clinical relevance of such variations might be correlated to entrapment syndromes. Entrapment of musculocutaneous nerve is rare and has its origin either in physical activity or in violent passive movements of arm and forearm. If this situation coexists with communication of musculocutaneous nerve with median nerve, it may give rise to symptoms of median nerve neuropathy. This knowledge may prove useful for clinicians in order to avoid an unnecessary carpal tunnel release.[8]

Variant anatomy recognized during routine cadaver dissection has an important learning potential, as it provides a framework to review the embryogenesis of the structure in question and an insight into its surgical, medical and radiological implication. Moreover it imparts the concept of patient uniqueness and subsequent individualization of medical and surgical therapies.[9]

Impairment of function of forearm muscles and thenar muscles affects not only prospects of employment but also a whole range of everyday tasks. It is therefore extremely important clinically to preserve the functions of forearm and hand. Yet, forearm and hand can be frequently injured, precisely because upper limb is used in exploring and handling tools.

Median nerve is called labourers' nerve, as it is responsible for powerful coarse hand movements. Muscles supplied by the median nerve are concerned with pronation of the forearm, flexion and abduction at the wrist and flexion of the digits. The power of these movements is supplemented and modified by many small muscles in the hand, particularly thenar muscles which are supplied by median nerve. They act as a group and help in flexion, abduction and opposition of the thumb, for efficient gripping by the hand.

From the clinical point of view, the hand is the one of the most important organs of the body. Without a normally functioning hand the patient's livelihood is often in jeopardy. From a purely mechanical point of view, the hand can be regarded as a pincer like mechanism between the thumb and fingers, situated at the end of a multijointed lever. The most important part of the hand is the thumb, and it is the physician’s responsibility to preserve the thumb, or as much of it as possible, so that the pincer like mechanism can be maintained. The pincer like action of the thumb largely depends on its unique ability to be drawn across the palm and opposed to the other fingers. This movement alone, although important, is insufficient for the mechanism to work effectively. The opposing skin surfaces must have tactile sensation. The most serious disability in median nerve injuries is the inability to oppose the thumb to the other fingers. In such a condition the delicate pincer like action of hand will be affected.[10]

Most of the previous studies pertaining to median nerve were confined to the different parts of upper limb such as the axilla or arm or forearm or hand or to a combination of two adjacent regions. Keeping in view the clinical significance of diagnosis and treatment in neurosurgical cases and for the reasons cited above, a detailed study of neuroanatomical variations of median nerve was taken up as this kind of study was not carried out in this part of Karnataka.

# OBJECTIVES

To study the neuroanatomical variations of median nerve pertaining to its

1) Formation

2) Course

3) Branching pattern

5) Termination

4) Communications

# REVIEW OF LITERATURE

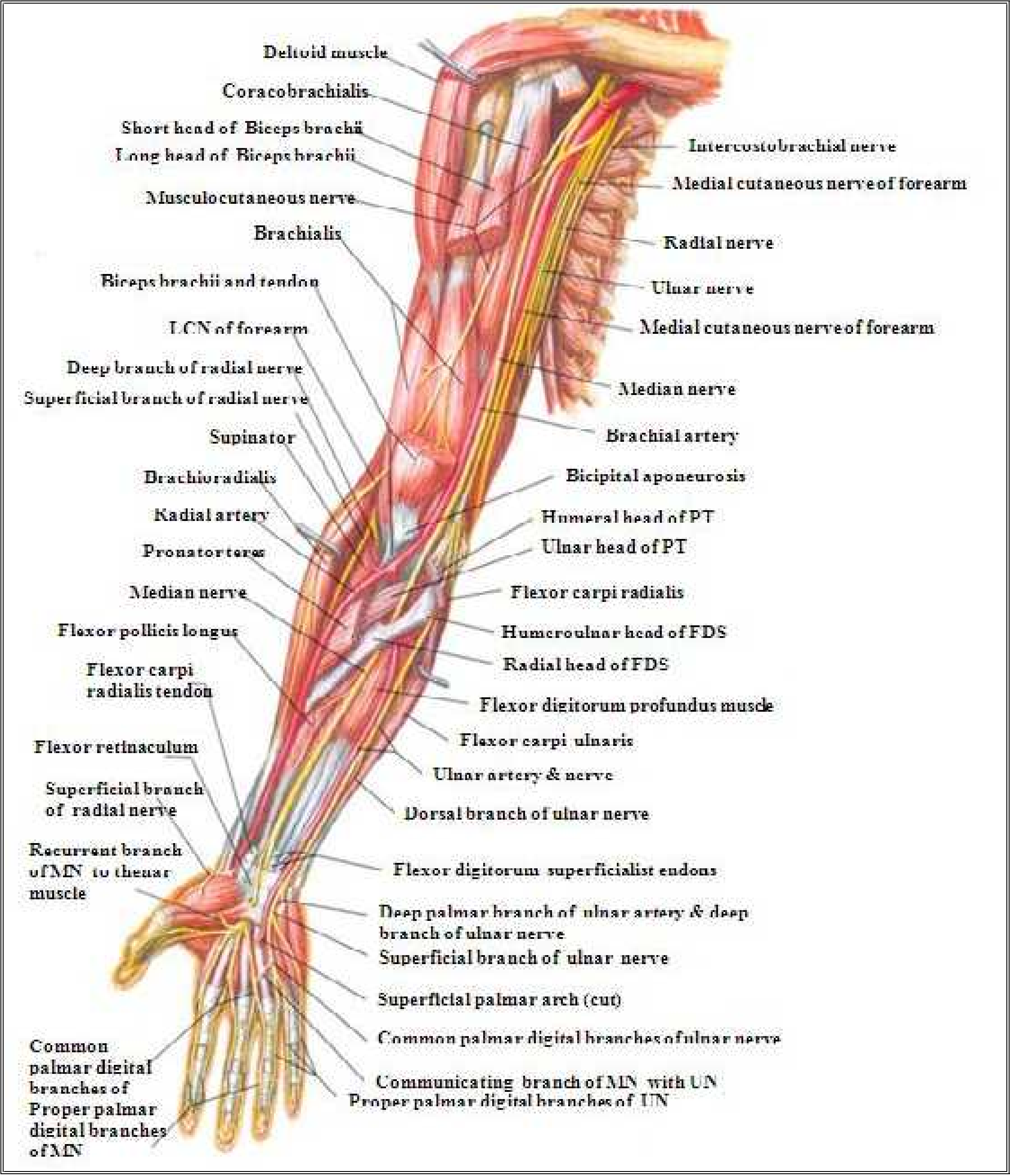
In the normal pattern, the median nerve is formed in the axilla by the union of medial and lateral roots. The medial root is derived from the medial cord of brachial plexus and conveys the fibers from C8 and T1. It crosses downward and laterally in front of the third part of axillary artery and joins the lateral root. The lateral root is the continuation of lateral cord of brachial plexus and conveys fibres from C5, C6, and C7.[11]

The median nerve enters the arm lateral to the brachial artery. Near the insertion of coracobrachialis it crosses in front of brachial artery, descending medial to it to the cubital fossa where it is posterior to the bicipital aponeurosis and anterior to brachialis, separated by the latter from the elbow joint. It gives off vascular branches to the brachial artery and usually a branch to pronator teres, at a variable distance proximal to the elbow joint.[12]

In the cubital fossa the median nerve lies medial to brachial artery, deep to the bicipital aponeurosis and anterior to brachioradialis.[13]

The median nerve enters the forearm between superficial (humeral) and deep (ulnar) heads of pronator teres. It crosses to the lateral side of the ulnar artery. It is separated from the ulnar artery by the deep head of pronator teres. Then it passes behind a tendinous bridge between the humero ulnar and radial heads of flexor digitorum superficialis and descends in the forearm posterior and adherent to flexor digitorum superficialis and anterior to flexor digitorum profundus. About 5cm proximal to flexor retinaculum, it emerges from behind the lateral edge of flexor digitorum superficialis, and becomes superficial just proximal to the wrist. Here it lies between the tendons of flexor digitorum superficialis and flexor carpi radialis, projecting laterally from beneath the tendon of palmaris longus.[12]

**Normal pattern of nerves and arteries of the upper limb**



Anterior interosseous nerve branches posteriorly from median nerve between the two heads of pronator teres, just distal to origin of its branches to the superficial forearm flexors and proximal to the point at which the median nerve passes under the tendinous arch of flexor digitorum superficialis. With the anterior interroseous artery it descends anterior to interosseous membrane, between and deep to flexor pollicis longus and flexor digitorum profundus. It supplies flexor pollicis longus and lateral part of flexor digitorum profundus. Terminally, the anterior interosseous nerve lies posterior to pronator quadratus, which it supplies via its deep surface. It also supplies articular branches to the distal radio-ulnar, radiocarpal and carpal joints.[12]

Muscular branches are given off near the elbow to all the superficial forearm flexors except flexor carpi ulnaris, i.e. to pronator teres, flexor carpi radialis, palmaris longus and flexor digitorum superficialis.

Articular branches, arising at or distal to the elbow joint, supply the joint and the proximal radio-ulnar joint. The palmar cutaneous branch which arises just above the flexor retinaculum supplies skin of central part of palm and adjacent part of thenar eminence.

Median nerve enters the palm by passing under the flexor retinaculum, in the carpal tunnel. Distal to the retinaculum the nerve divides into lateral and medial branches. The lateral branch gives off a recurrent muscular branch to supply the three thenar muscles and then subdivides into three proper palmar digital nerves to supply two sides of the thumb and radial side of the index finger; the branch to the index finger gives a branch to the first lumbrical. The medial branch subdivides into two common palmar digital nerves, lateral and medial. The lateral common palmar digital nerve gives a branch to second lumbrical and subdivides to supply adjacent sides of index and middle fingers. The medial common palmar digital nerve subdivides to supply adjacent sides of middle and ring fingers.[11]

In the stages of development, the sensory and motor neurons of the brain become interconnected in functional patterns, and axons grow out of the CNS and ganglia to innervate appropriate target organs (end organs). Axons travel to their target structures through the active locomotion of an apical structure called a growth cone. The growth cone, which moves by means of filopodia, guides the axon to its destination by sensing molecular markers that designate the correct route. This activity of the growth cone is called pathfinding. Once the growth cone reaches its target, it halts and forms a synapse. Somatic motor and sensory fibres synapse directly with their end organs.[14]

Numerous mechanisms have been proposed to explain the ability of the neurons to establish correct connections with each other and with end organs. It has been suggested, that at the appropriate time during development the end organs secrete either a tropic substance [netrin-1 and netrin-2] that attracts the correct growth cones or a trophic substance [brain-derived neural growth factor (BDNF) and insulin-like growth factor (IGF)] that supports the viability of the growth cones that happen to take the right path. It is also likely that the first or pioneer growth cones to traverse a route establish a pathway that is used by later growing axons. This mechanism would account for the formation of nerves, in which many axons travel together.[14]

The base of the early limb bud is relatively broad in comparison with the length of the body, and lies at the level of a greater number of somites than it does after further growth occurs. Since the segmentation of spinal nerves is dependent upon that of the somites, the limb bud develops at the level of a number of spinal nerves, typically those from the C5 to T1. The ventral branches of these spinal nerves join each other to form a plexus, and the plexus divides into dorsal and ventral parts, corresponding to the division of premuscle mass into extensor and flexor parts. The nerves from these divisions grow out with the developing limb, the dorsal or extensor portion of the plexus (largely the posterior cord and its branches) supplying the corresponding part of the premuscle mass, ventral or flexor portion (medial and lateral cords) supplying the developing anterior or flexor muscles.[15]

Among common clinical manifestations is median nerve injury resulting from a perforating wound in the elbow region results in loss of flexion of the proximal and distal interphalangeal joints of the 2nd and 3rd digits (hand of benediction). The ability to flex metacarpophalangeal joints of these digits is also affected because digital branches of the median nerve supply the 1st and 2nd lumbricals. The recurrent branch of the median nerve supplying the thenar muscles lies superficially and may be severed by relatively minor lacerations involving the thenar eminence. Severance of the recurrent branch of the median nerve paralyses the thenar muscles, and the thumb loses much of its usefulness.[16]

Carpal tunnel syndrome consists of a burning pain or “pins and needles” along the distribution of the median nerve to the lateral three and a half fingers and weakness of the thenar muscles. It is produced by compression of the median nerve within the tunnel. The exact cause of the compression is difficult to determine, but thickening of the synovial sheaths of the flexor tendons or arthritic changes in the carpal bones are thought to be responsible in many cases. No paresthesia occurs over the thenar eminence because this area of skin is supplied by the palmar cutaneous branch of median nerve, which passes superficial to the flexor retinaculum. The condition is dramatically relieved by decompressing the tunnel by making a longitudinal incision through the flexor retinaculum.[10]

Pronator syndrome is another condition, wherein uncommon entrapment neuropathy of the median nerve occurs in the elbow region. Entrapment can occur typically at four sites. Firstly, at the site of ligament of Struthers. This ligament represents an anatomical variant and when present, connects a small supracondyloid spur of bone to an accessory origin of Pronator teres. The median nerve can be compressed as it passes under this ligament. Secondly as it passes deep to bicipital aponeurosis; thirdly the aponeurotic edge of the deep head of Pronator teres, fourthly tendinous aponeurotic arch forming the proximal free edge of the radial attachment of flexor digitorum superficialis.[12]

The peripheral nervous system acts as a link between the individual organs and systems with central nervous system. For normal working, the impulses have to be transmitted through these nerves to effector organ. Hence, the knowledge of the exact peripheral innervation of muscle is of greater clinical use. This is because most of the injuries to the nerves involve some part of their long peripheral course.

Hippocrates (130-200 AD) provided one the first known references that stressed the importance of nerves, warning physicians to avoid injuring the nerves within the dislocated shoulders of soldiers during repair. Sushruta (600 B.C.) through the observation of different injuries and their results was able to describe the function of many components of the peripheral nervous system. Galen (129-216 AD) differentiated nerves from tendons and reported the successful repair of nerves by other physicians, although no record exists that he attempted any repairs. In the 7$^{th}$ century, Paulus Aegineta was the first to report the use of suture and agglutination to repair nerves. Other physicians who performed early work with nerves and their repair include Rhazes and Avicenna in the 9$^{th}$ century, Ali Abu Ibn Sina in Persia during the 10$^{th}$ century, and Ferrara in Italy in the 17$^{th}$ century.[17]

Chauhan R and Roy TS (2002), in their study on 200 cadavers noted in the right upper limb of a female cadaver that, the median nerve (MN) had three roots; one each coming from the lateral cord, medial cord and the musculocutaneous nerve (MCN). A thick lateral root originated from the lateral cord and joined the medial root to form the main trunk of the MN on the medial side of the axillary artery, 2.6 cm distal to the tip of the coracoid process. The ulnar nerve arose independently from the medial cord of the brachial plexus, which continued for some distance with the medial root of the MN and separated from the latter. The MN formed had the same diameter as the ulnar nerve. MCN was found to be communicating with the MN at two sites. A third root of the median nerve emerged from the MCN, which joined the MN 12.3 cm distal to the tip of the coracoid process, below the level of insertion of the coracobrachialis muscle. The third root received a communicating branch from the MCN, 9.9 cm distal to the tip of coracoid process. The third root of the MN and its communicating branch crossed the brachial artery superficially. The most frequent variation is the presence of a communicating branch that bifurcates from the MCN and goes distally to join the MN, an anastomosis observed in the lower third of arm. If this branch is given off in upper third of the arm, it is generally considered as third (double lateral) root of the median nerve. The upper limb dissected by them revealed that a branch of the MCN appeared in upper third of the arm, passed medially downwards and joined the MN in the lower third of the arm. This branch was of the same diameter as the lateral root. Therefore, this was considered as the third root of median nerve or second lateral root. They reported in addition to communication with the MN, the communicating third root also received a branch from the main trunk of the MCN. Also, the third root passed superficial to the brachial artery. These kinds of variations are important, as they are more prone to injury in surgical operations of the axilla and upper arm.[18]

Concurrent variations of median nerve, musculocutaneous nerve and biceps brachii muscle were found by Nayak S et al.(2006) in the anterior compartment of the arm of an adult male cadaver. The variations found were unilateral. The biceps brachii had a third head. This head originated from the lower part of the shaft of the humerus and the medial intermuscular septum. Its origin surrounded the median nerve and brachial artery. The third head joined with the rest of the muscle and had a common insertion with them. It was supplied by a branch of musculocutaneous nerve. The median nerve was formed just below the midpoint of the arm. The medial and lateral roots of the median nerve and the lateral cord were very long. Both medial and lateral roots of median nerve crossed the brachial artery from lateral to medial side and median nerve was formed just medial to the brachial artery. The median nerve, along with brachial artery passed through a tunnel formed by the third head of the biceps. Further course and distribution of the median nerve was normal. The origin of the musculocutaneous nerve was also low. The nerve did not pierce coracobrachialis. It passed between the short head and the third head of biceps. Its further course and distribution was normal. The coracobrachialis was supplied directly by a branch of the lateral cord. The cases of low origin of median and musculocutaneous nerves may lead to confusions in surgical procedures and difficulties in nerve block anesthesia. The passage of median nerve and brachial artery through the third head may lead to compression of these structures, which in turn may lead to neurovascular symptoms below the level of elbow. The medial and lateral roots of median nerve crossing the brachial artery from lateral to medial side, can lead to the compression of the brachial artery.[3]

An unusual case report showed multiple bilateral neuroanatomical variations of the nerves of the arm in both upper limbs of an adult male cadaver. On the left side, there were two roots of the median nerve, a thin lateral root and a medial root. The thin lateral root crossed the third part of axillary artery and joined the medial root, thus the median nerve was formed medial to the third part of the axillary artery and it continued medial to the brachial artery and anterior to the ulnar nerve. After supplying the coracobrachialis muscle, the musculocutaneous nerve descended lateral to the brachial artery without piercing the coracobrachialis muscle. At 12 cm from the coracoid process, the musculocutaneous nerve communicated with the median nerve and then supplied the remaining muscles, biceps brachii and the brachialis muscle and then continued as lateral cuaneous nerve of forearm. On the right side, a thin lateral root crossing the third part of axillary artery joined the medial root of the median nerve. The musculocutaneous nerve gave a branch to coracobrachialis, fused with the median nerve for 2 cm and then, it separated from the median nerve and without piercing the coracobrachialis muscle, it descended and supplied the muscles of the arm and continued as the lateral cutaneous nerve of forearm. The median nerve was medial to the brachial artery this side also. These are errors in the pathway (course) of some, inappropriately placed nerve fibers. In order for these nerve fibers to get to their proper end-point, the bundle of nerves fibers leave the inappropriate trunk and join the proper nerve trunk. Certainly a mystery, as seen in these ‘anastomoses’. Significant variations in nerve patterns may be a result of altered signalling between mesenchymal cells and neuronal growth cones or circulatory factors at the time of fusion of brachial plexus cords. Studies of comparative anatomy have observed the existence of such connections in monkeys and in some apes; the connections may represent the primitive nerve supply of the anterior arm muscles.[5]

An unusual formation of the median and musculocutaneous nerves was observed by Saeed and Rufai (2003), during routine dissection of the left upper limb of a 60-year-old male cadaver. The median nerve was formed by the fusion of three roots, two from the lateral cord and one from the medial cord of the brachial plexus. One of the branches arising from the lateral cord was the normal lateral root of the median nerve, where as the other was an abnormal contribution. This variant lateral root of the median nerve was slightly larger than the normal root and arose from the lateral cord about 2.5 cm proximal to the origin of the musculocutaneous nerve and joined the medial root 2.5 cm proximal to the union of medial and normal lateral root of the median nerve. The variant lateral root of the median nerve pursued an oblique course anterior to the third part of the axillary artery. The contribution of lateral roots to the median nerve was much larger than the medial root. The medial root of the median nerve, after receiving the variant lateral root, crossed anteriorly from medial to the lateral side of the axillary artery. The median nerve received its normal lateral root just lateral to the axillary artery and then coursed inferiorly lateral to it, maintaining the same relationship with the brachial artery in the arm. A communicating branch arose from the median nerve 13 cm distal to its formation and coursed downward and laterally for about 3 cm before joining the musculocutaneous nerve about 17 cm distal to its origin from the lateral cord. The communicating branch also provided a small branch to biceps brachii muscle. Injury to such a variant median nerve in the proximal arm may lead to paraesthesia along the preaxial border of the forearm, weakness of elbow flexion, in addition to other manifestations of median nerve injury. The existence of this kind of anomaly may be attributed to random factors influencing the mechanism of formation of limb muscles and peripheral nerves during embryonic life. It seems likely that nerve fibres from the $5^{th}$

and 6$^{th}$ cervical ventral rami hitch-hiked along the median nerve through its variant lateral root and rejoined the musculocutaneous nerve in the lower half of the arm. This may be the effect of "neurobiotaxis" occurring during fetal development.[9]

Pandey SK and Shukla VK (2002), studied the variations in formation, location, and courses of the cords of brachial plexus and the median nerve in 344 axillae of 172 cadavers ranging from 60 to 80 years of age. They found an abnormal formation, location, and course of the median nerve in 12 cadavers. The total prevalence was observed in 3.5% on the right side, 0.6% on the left, and 2.3% bilaterally. In eight of the twelve cases, the lateral root of the median nerve obliquely crossed axillary artery and joined with the medial root on the medial side of the artery to form the median nerve, which coursed medial to the artery. In four of the twelve variant cases, the two roots of the median nerve did not join in the arm and both roots coursed anteromedial to the axillary and brachial arteries. In such cases, the lateral root of the median nerve obliquely crossed axillary artery and the medial root received a communicating branch from the posterior cord. It was further observed that one or two communicating branches from the lateral cord joined the medial root of the median nerve. The communicating branch had a very close relationship with the axillary artery below the origin of the thoracoacromial trunk. They found the low fusion of two roots in 6 of 172 (3.5%) cadavers and bifid median nerve in 3 of 172 (1.7%) cadavers. The communicating branches passed either from one cord to the other or from one cord to one of the roots of the median nerve, or between two roots of the median nerve. These communicating branches mainly passed between the axillary artery and one of its branches.[19]

During the gross anatomy dissection of a 50-year-old male cadaver, Vijaya PS et al. (2006) noticed a rare variation of entrapment of the medial root of median nerve between the axillary artery and its anomalous branch. In this case, the medial root of median nerve passed posterior to the third part of the axillary artery and then between the axillary artery and the anomalous branch and united with the lateral root, due to which the medial root of median nerve may be compressed. This variation may be clinically important because symptoms of median nerve compression, arising from similar variations are often confused with more common causes such as radiculopathy and carpal tunnel syndrome.[20]

During dissection of a 45 year old male cadaver the authors noticed rare anatomic variations in the left upper limb. The variations were unilateral. On the left side, the brachial vein was passing between the medial and lateral roots of median nerve to drain into the axillary vein. The median nerve was formed by the fusion of three roots: two from the lateral cord and one from the medial cord of the brachial plexus. One of the branches arising from the lateral cord was the normal lateral root of the median nerve, whereas the other was an abnormal contribution. This variant lateral root of the median nerve came from the lateral cord proximal to the origin of the musculocutaneous nerve and joined the medial root, proximal to the union of medial and normal lateral roots of the median nerve. The anomalous lateral root of the median nerve pursued an oblique course anterior to the third part of the axillary artery. A communicating branch arose from the median nerve 12 cm distal to its formation and coursed downward and laterally for about 3 cm before joining the musculocutaneous nerve. The course and branches of the median nerve in the forearm and hand were normal. The lateral antebrachial cutaneous nerve showed a loop through which a perforating vein was passing.[21]

Ahamat Uzun and Sait Bilgic (1999), carried out a study on 130 brachial plexuses of 65 newborn. They observed variation in the formation of the median nerve in 4 of 130 plexuses. The median nerve was formed by fusion of three branches; two of them coming from the normal medial and lateral cords and one from the branch of the anterior division of the middle trunk. These findings were symmetrical in two cadavers. In 14 of the 130 plexuses (10.77 %), a connection between the medial root of the median nerve and the ventral division of the middle trunk was noted.[22]

An anomaly in the formation of the median nerve with additional anastomotic branches between the musculocutaneous and median nerves were noted by Uzun et al. (2001) in the left upper extremity of a 66 year old male cadaver, wherein the nerve was formed by the fusion of the four branches, three of them coming from the lateral cord and one from the medial cord. One of the branches coming from the lateral cord was the normal lateral root of the median nerve. One of the unusual branches originated 1.6 cm distal to the origin of the musculocutaneous nerve and joined with the median nerve in the proximal arm. The musculocutaneous nerve, at the level of the lateral border of the coracobrachialis muscle, gave off another branch that also joined the median nerve. The fusion of this communicating branch with the median nerve was 20 cm above the intercondylar line of the humerus.[23]

A rare variation of the formation of the median nerve posterior to the third part of axillary artery was reported by an author. The two roots of the median nerve joined behind the axillary artery to form the median nerve. The lateral root coursed between the axillary artery and anterior circumflex humeral artery to join the medial root posteriorly. Then the median nerve coursed posterior to the brachial artery to reach the medial aspect of the brachial artery in the cubital fossa.[24]

Inter-communications between median and musculocutaneous nerves with dual innervation of brachialis muscle were observed by Arora et al. (2003), during routine dissection of left upper limb of a 60 year old male cadaver. The MCN and MN had inter-communications at two sites. The proximal communicating trunk was 2.5cm in length and was given off by the musculocutaneous nerve (MCN) before the latter pierced the coracobrachialis (CB) muscle. This trunk coursed distally to join the MN 4.6 cm from the coracoid process. The length of distal communicating branch was 10.7 cm. It emerged from the MN, 12.4 cm from the coracoid process, and coursed distally to join the MCN after the latter had pierced the CB and had supplied branches to biceps brachii. From the site of union of the distal communicating branch and the MCN, branches were given off to the brachialis muscle. The MCN continued distally as the lateral cutaneous nerve of the forearm.[8]

R. Chitra (2007), conducted a study on 50 upper limb specimens of 25 cadavers. In this analytical study of various types of intercommunications between musculocutaneous and median nerves she observed the communications between the two nerves in 13 arms. The observations of communications between musculocutaneous and median nerves were compared with various classifications suggested by other authors.[25]

During routine dissection of left upper limb of 35 year adult male cadaver the authors noticed various anomalies in the same limb. There were numerous communications in the various terminal branches of the cords of brachial plexus. However the median nerve was formed by the union of two lateral roots and one medial root. The proximal lateral root arose from the anterior division of the middle trunk while the distal lateral root was the usual terminal branch of the lateral cord.[26]

There was an unusual unilateral variation between the median and musculocutaneous nerves that was found by Ibrahim et al. (2005) during the dissection of arm of 48 years old male cadaver. The median nerve was originating normally from the brachial plexus but on its way to the cubital fossa it received an accessory branch from the musculocutaneous nerve. The communicating branch was about 2.5 cm long and had an oblique course between the two nerves. The course and branches of the two nerves in the arm, forearm and hand were normal in every aspect, as were the courses and branches of the median and musculocutaneous nerves of the contralateral side. In this case, the lateral root of median nerve from the lateral cord was significantly normal and the abnormal communicating branch was significantly thick. It is not particularly uncommon to find out a nerve trunk of considerable size leaving the musculocutaneous nerve and passing distally and medially to join the median nerve. This is a result of median nerve fibers from the lateral cord passing into the musculocutaneous nerve rather than into the lateral root of the median nerve and then rejoining the median nerve at a lower level. When this occurs, the lateral root of the median nerve is typically abnormally small. After a trauma to the arm, signs of median nerve injury could be observed in a patient with an intact median nerve if such a variation is present and the fibers coursing in the musculocutaneous nerve are damaged. Result of an exploratory intervention of the arm for peripheral nerve repair in a patient with this kind of variation can be successful only if the surgeon is aware of such variations of peripheral nerves and specifically looks for their presence. During flap dissections, unexpected nerve damages could arise especially by surgeons who are familiar with routine course of peripheral nerves and their relationship with neighboring structures but inexperienced in variations. Any injury to musculocutaneous nerve, in a patient with this kind of variation, presents as double nerve injury, which makes the diagnosis more problematic.[27]

D. Venierator and S. Anagostopoulou (1998), carried out a study on 79 human cadavers (44 females and 35 males).Their study was concerned with the incidence of communications between the musculocutaneous nerve and median nerve, and the sites of occurrence with respect to the coracobrachialis muscle. 158 brachial plexuses were dissected. In 16 cadavers, 22 communications were found between the musculocutaneous and median nerves (13.9%). In six subjects they were present bilaterally. There were three types, based on the sites of communication. Type I: The communication was proximal to the entrance of the musculocutaneous nerve into coracobrachialis. They observed such communications in 9 specimens; Type II: The communication was distal to the muscle. Such communications were found in 10 specimens; Type III: The nerve as well as the communicating branch did not pierce the coracobrachialis muscle. This type was found in 3 specimens. Bilateral communications were not necessarily of the same type.[28]

A unilateral variation in the pattern of formation of brachial plexus was observed by Oluyemi et al. (2007), in the left arm of an adult cadaver. This brachial plexus had only two cords (medial & lateral) with three abnormal communications. A branch was observed to originate from the posterior aspect of medial cord. It ran for about 2cm before it divided into the axillary and radial nerves. The two branches followed normal courses. The lateral cord sent an abnormal communication to the medial cord as the latter gave off the medial root of median nerve. This abnormal branch fused with the branch from medial cord to form the medial root of median nerve. The lateral cord also gave the lateral root of median nerve. An abnormal communication was observed between the musculocutaneous and median nerves. The abnormal branch of the musculocutaneous nerve was found originating at the junction of the superior and middle thirds of the left brachium. It coursed inferiorly between the accessory head of biceps brachii and brachialis muscles for about 9.2 cm and joined the median nerve 15.5 cm below its origin and 5.5 cm above the base of the cubital fossa. Giving its accessory branch and the nerve to the biceps brachii and brachialis muscle, the musculocutaneous nerve coursed normally as lateral cutaneous nerve of forearm. In this case of a brachial plexus with only two cords (medial & lateral), the axillary and radial nerves originated from what seems like posterior cord from the posterior aspect of medial cord. This informs us that the three posterior divisions of upper, middle and lower trunks that were supposed to form the posterior cord were fused with the medial cord. The communication between the medial and lateral cords is unusual. There was an abnormal branch from the lateral to medial cord. This branch fused with the medial root of median nerve. This is probably due to some fibres of medial cord running in lateral cord leaving it later to join the medial cord. Because each peripheral nerve is a collection of nerve fibres bound together by connective tissue, it is understandable that the median nerve, for instance, may have two medial roots instead of one, which means the nerve fibres are simply grouped differently. This results from the fibres of the medial cord of the brachial plexus dividing into three branches, two forming the median nerve and the third forming the ulnar nerve. In the present case though the median nerve has two medial roots, one of them came from the lateral cord and fused with the medial root from the medial cord.[29]

Z Ash Aktan et al. (2001), conducted a study on 48 upper limbs of 24 cadavers with an age range of 50-80 years. All the cadavers were male. Connections between the musculocutaneous nerve and median nerve were found in five arms. Three of them were in the left arm. The connections were not bilateral in any cadaver. They left the musculocutaneous nerve about 1 cm from the formation of this nerve. The point of entering the median nerve was about 10 cm from the formation of the median nerve. The mean length of these interconnections was 3-8 cm. In one cadaver there was a branch from the median nerve extending to the brachial artery. It is said that if the lateral root of the median nerve is small, the musculocutaneous nerve connects with the median nerve but in their study in one arm out of 48, the lateral root was not small. The connections were near, but before the origin of the coracobrachialis muscle. These connections between the nerves may provide alternate motor and sensory innervation during a defect in these nerves after a trauma. A branch to the brachial artery from the median nerve was seen in the right arm of a cadaver. It was thought that it could be a thick sympathetic branch.[30]

Choi D et al. (2002) , carried out a study on 276 arms of 138 cadavers (66 male, 72 female) with an age range of 64-101 years. Variations of musculocutaneous and median nerves in the arm were seen in 64 cadavers (46.4%) of the whole sample of 138 cadavers. The findings were bilateral in 9 (14.1%) cadavers that means total 18 arms and unilateral in 55 (85.9%) comprising 26 right and 29 left arms. Of these 73 variant arms (26.4%), 42 were male and 31 female. There were no statistically significant differences in prevalence of variations by gender and side. But there was a significantly higher prevalence of unilateral, rather than bilateral variation. They classified these variations in three general patterns based on the number of connecting branches or the fusion of both the nerves as follows.

Pattern 1. Musculocutaneous and median nerves were fused. This pattern occurred in14 arms (19.2%) of the 73 variant arms. The length of the common trunk varied between 2 and 13.8 cm. In one arm, musculocutaneous nerve pierced the coracobrachialis muscle lower than normal, whereas it did not pierce in 13 cases. The musculocutaneous nerve separated from the median nerve and gave branches to the biceps brachii muscle, in four cases, distal to its separation. In two cases, a branch to the biceps brachii originated proximal to fused segment, and in eight cases from the common trunk itself. In all cases, branches to the brachialis muscle originated from the musculocutaneous nerve.

Pattern 2. There was a connecting branch between the musculocutaneous and median nerves. It occurred in 53 (72.6%) of the 73 variant arms. This group was further subdivided into two categories based on the number of branches from the musculocutaneous nerve that joined to form one connection to the median nerve. Thus Pattern 2a was defined as a single branch contributing to the single connection between the musculocutaneous and median nerves, and included 51 cases, (69.9%). Pattern 2b consisted of two cases (2.7%) in which the connection was formed from two or three branches from the musculocutaneous nerve, joining to form one anastomotic branch to the median nerve.

Pattern 3. In this pattern, two connecting branches between the musculocutaneous and median nerves were present. It occurred in 5 (6.8%) of the 73 variant arms. In three arms the connecting branches passed in both directions. In two cases, the branches were parallel, descending from the musculocutaneous nerve to the median nerve.[31]

Oluyemi KA et al. (2007) studied forty-eight upper extremities to investigate the communication between median and musculocutaneous nerves. Communications were observed in two of the left arms. In one of the cadavers, the abnormal branch of the musculocutaneous nerve was found to be originating approximately at the mid-point of the brachial region distal to the insertion of the coracobrachialis muscle. It coursed inferiorly between the biceps brachii and brachialis muscles for about 4.2 cm and joined the median nerve 8.7 cm superior to the base of the cubital fossa. Giving its accessory branch and the nerve to the biceps brachii and brachialis muscle, the musculocutaneous nerve coursed normally as a lateral cutaneous nerve of the forearm. On the other cadaver, the abnormal branch of the musculocutaneous nerve was found to be originating at the junction of the upper and middle thirds of the left brachium, about 3 cm before the insertion of the coracobrachialis muscle. It coursed inferiorly between the accessory head of biceps brachii and brachialis muscles for about 9.2 cm and joined the median nerve 15.5 cm below its origin and 5.5 cm above the base of the cubital fossa. In this brachium, the biceps brachii had an accessory head originating from the anterior surface of the left humerus.[32]

Niedenfuhr et al. (2002) studied 140 upper limbs of 70 human cadavers (31 male, 39 female). They proposed a new classification of the Martin-Gruber anastomosis, a neural connection between the median and ulnar nerves in the forearm. The Martin-Gruber anastomosis was found in 16 (22.9%) of the 70 cadavers, being bilateral in 3 (18.7%) and unilateral in 13 (81.3%), 5 right and 8 left forearms. It occurred in 8 (25.8%) of the 31 male cadavers and in 8 (20.5%) of the 39 females. Therefore, the anastomosis was found in 19 (13.6%) of the total 140 forearms. Pattern I was seen in 17 (89.5%) cases, the anastomosis was made by only one branch, whereas Pattern II was seen in 2 (10.5%) cases, it was made by two branches. Pattern I was classified into three types based on the level at which the anastomotic branch arose from the median nerve or one of its branches. The individual branches were classified as Types a, b, and c based on the nature of their origin from the median nerve. Type A (47.3%) arose from the branch to the superficial forearm flexor muscles, Type B (10.6%) from the common trunk, and Type C (31.6%) from the anterior interosseous nerve. The anastomotic branch took an oblique or arched course before joining the ulnar nerve, undivided in 15 cases, but divided into two branches in 4 cases. The anastomosis passed in front of the ulnar artery in four cases, behind it in six, and in nine cases it was related to the anterior ulnar recurrent artery.[33]

Niedenfuhr et al. (2002) in another study on 236 upper limbs of 118 human cadavers (55 male, 63 female) investigated the incidence and morphology of the intramuscular Martin-Gruber anastomosis. The Martin-Gruber anastomosis was found in 25 (21.2%) of the 118 cadavers. It occurred in 11 (20%) of the 55 male cadavers (4 bilateral, 7 unilateral; 5 left and 2 right) and in 14 (22.2%) of the 63 female cadavers (2 bilateral, 12 unilateral; 8 left and 4 right). Therefore, the Martin-Gruber anastomosis was found in 31 (13.1%) of the 236 upper limbs. According to a recent classification (Rodríguez-Niedenführ et al., 2000), pattern I was found in 29 cases (93.5%), corresponding to Type A in 13 (41.9%), Type B in 3 (9.7%) and Type C in 13 (41.9%), whereas pattern II was found in 2 cases (6.5%), both being a duplication of Type IC. Intramuscular Martin-Gruber anastomosis was a single anastomosis that originated in all cases from the anterior interosseous nerve (pattern IC) and then passed through a muscle bundle of the flexor digitorum profundus and behind the ulnar artery to join the ulnar nerve as a single connecting branch. It did not send branches to the flexor digitorum profundus. This intramuscular course was observed in 3 of the 13 cases of Type C anastomosis (23.1%) or 3 cases out of 31 Martin-Gruber anastomoses (10%).[34]

Interestingly, nerve fibres that normally run with the ulnar nerve may sometimes leave the brachial plexus in the median nerve, and vice-versa. Such fibres may stay with their abnormal carrier all the way to the muscle, for which they are destined, in which case that muscle has an anomalous innervation from the “wrong” nerve. More frequently, these fibres cross from the abnormal carrier to their proper carrier somewhere below the elbow. The most common form of such a median / ulnar communication is called the Martin- Gruber anastomosis, which consists of fibres that should have left the brachial plexus with the ulnar nerve to innervate certain muscles of the hand, but instead leave with the median nerve. In the forearm these misdirected fibres cross from the median nerve to join the ulnar nerve. The significance of this anomalous pathway is that injury to the median nerve proximal to the anastomoses may lead to symptoms more normally seen when the ulnar nerve is damaged.[35]

Beheiry EE (2004) studied 60 arms of 30 preserved human cadavers, ranging in age from 30 to 67 years. The median nerve was studied pertaining to its abnormal branches, distribution and communication with other nerves especially the musculocutaneous and/or ulnar nerves. In one limb out of 60 (1.7%), the median nerve gave off muscular branches to the brachialis muscle as well as a branch from its lateral root to supply both heads of the biceps brachii muscle. Concomitantly the musculocutaneous nerve was absent. In the same limb it was noticed that, a branch from the lateral cord of the brachial plexus supplied the coracobrachialis muscle. Three limbs (5%) showed a communicating branch between the median and the musculocutaneous nerves. These observations should be considered when a high median nerve paralysis is shown to originate in the axilla or proximal arm in a patient presenting with weakness of forearm flexion and supination. Similarly, it can explain weakness of the flexor muscles of arm, in thoracic outlet syndrome with median nerve affection.[36]

Abhaya et al. (2003), observed a variation wherein the lateral root of median nerve emerged from the anterior aspect of the coracobrachialis muscle 10.2 cm. from the tip of coracoid process and joined the medial root of median nerve arising from the medial cord of brachial plexus at 15.5 cm to form the main trunk of median nerve while the musculocutaneous nerve emerged from the lateral side of coracobrachialis muscle, lateral to the exit of lateral root of median nerve at 11 cm from the tip of coracoid process. On exploring the passage of lateral cord within the coracobrachialis muscle it was found that it split into musculocutaneous and lateral root of median nerve 9.6 cm from coracoid process and the branch to the coracobrachialis muscle arose from musculocutaneous nerve 9.8 cm from the tip of the coracoid process. The lateral root of median nerve did not give any branch within the muscle and no communication was observed between musculocutaneous and lateral root of median nerve within the coracobrachialis muscle or in the later course of these two nerves.[37] Coracobrachialis is a flexor muscle of the arm and is vulnerable to the injury from the retractors placed under the coracoid muscles as required during shoulder reconstructive surgery. The operative management by coracoid graft transfers in the recurrent dislocations of shoulder and shoulder arthroscopies could be the source of lesions to the structures piercing the muscle.[38] Coracobrachialis muscle has been suggested for possible use as flap for coverage in infraclavicular defects of exposed axillary vessels, especially in postmastecomy reconstructive surgery.[39]

Absence of the musculocutaneous nerve was noted by Sud and Sharma (2000) wherein the lateral cord gave a lateral pectoral nerve just below the outer border of the first rib to the pectoralis major muscle. Instead of giving musculocutaneous nerve, there were two lateral roots joining the median nerve. The first root and the second root given to the median nerve were 5 and 10 cm from the outer border of the first rib respectively. Both these roots were observed to join the median nerve in front of the axillary artery. From the lateral side of the median nerve, 6 cm from the outer border of the first rib, a branch was given to the corocobrachialis. Another branch was given to biceps brachii from its lateral side at a distance of 16.5 cm from the outer border of the first rib. The lateral cutaneous nerve of the forearm was also given from the lateral side of the median nerve about 17 cm from outer border of the first rib. The lateral cutaneous nerve of the forearm gave a branch 20cm from the outer border of the first rib to the brachialis muscle. This branch, after supplying the brachialis, pierced its substance and emerged to supply the biceps brachii.[40]

A rare variant of a muscular branch of the brachial artery that penetrated the median nerve in the lower part of the arm was observed by another author. After its origin from the posteromedial surface of the brachial artery, the muscular branch of brachial artery passed through a nervous loop in the median nerve to enter and supply the brachialis muscle. On histological examination, at the site of arterial penetration, the nerve displayed perineural thickening and increased number of fascicles. An increase in the interfascicular connective tissue was also noted. Three small branches of the artery supplied the nerve fascicles. They did not observe nerve compression or muscular changes, but the possibility of altered clinical symptoms produced by irritation from arterial pulsation cannot be ruled out. This variation may be clinically important because symptoms of median nerve compression arising from similar variations are often confused with more common causes, such as radiculopathy and carpal tunnel syndrome.[41]

Median nerve and brachial artery in the arm are not usually overlapped by any structure. Connective tissue bands and muscular slips draping or enclosing this neurovascular bundle have been reported, which may produce clinical symptoms of nerve compression and vascular changes. There was a case report of an unusual musculoaponeurotic band by Wadhwa et al. (2004), which originated as the ligament of Struthers but terminated as the brachiofascialis muscle of Wood and in the process might have entrapped both the median nerve and brachial artery. The nerve to pronator teres originated from the median nerve within this tunnel. On histological examination the nerve was flattened and showed some perineural thickening. In view of the flexor function of brachialis muscle, this anomalous musculoaponeurotic band might be considered as a clinically important entity in the causation of idiopathic neurovasculopathy in the hand.[42]

In the left forearm and hand of an adult male cadaver it was observed by another author that the muscle belly of palmaris longus received a branch from the median nerve in the proximal third of the forearm near the elbow joint. With further progress of the dissection it was noticed that another branch emerged from the median nerve, and ramified into a number of branches to innervate the distal most part of the tendon and the proximal part of the palmar aponeurosis from its dorsal aspect. These branches further passed through the aponeurosis to become cutaneous nerves. Palmar cutaneous branch of the median nerve emerged proximal to the branch for the palmaris longus tendon. Palmaris longus, a muscle with small belly and long thin tendon is becoming popular in reconstructive surgeries. Its presence in 75% population[43] and its superficial location makes the procedure relatively safe.[44] It is the most common donor material for tendon and joint reconstructive surgeries.[45] Palmaris longus is completely developed at birth, while fascia lata, which is also used for reconstructive surgeries, is not so well developed at that age. All these factors facilitate harvesting of palmaris longus as the donor material in all age groups.[7]

Beris AE et al. (2008) have demonstrated incidental intraoperative findings of variations of the standard median nerve anatomy. They found intraoperatively, variations of median nerve at the wrist in 11 of 110 consecutive patients operated with open release of the transverse carpal ligament in CTS. In three patients, there was an aberrant sensory branch arising from the ulnar side of the median nerve and piercing the ulnar margin of the transverse carpal ligament. In three patients motor branch of median nerve originated beneath the flexor retinaculum and then curved over it proximally to the thenar muscles. Two patients had bifid median nerve. In two patients, the motor branch took off from ulnar side of the median nerve. In one patient, the sensory palmar cutaneous branch of median nerve, separated from the radial aspect of the nerve few millimeters distal to the proximal border of the transverse carpal ligament and pierced shortly after, the mid substance of the ligament. Surgeons should be aware of anomalous branches, which should be recognized and separately decompressed if needed.[46]

In an adult female cadaver, a right bifid median nerve was observed by Tubbs and Salter (2006). The bifurcation of this nerve occurred 6 cm distal to the medial epicondyle. The ulnar part of this split nerve pierced the flexor digitorum superficialis (FDS) to enter the carpal tunnel along with the radial part of this nerve that travelled in a normal median nerve course. These two parts traveled through the carpal tunnel separately and communicated in the palm. The ulnar part of this split nerve ended by supplying digital cutaneous branches to the radial one half of the fourth digit. Radial part of this split nerve supplied the skin of the digits adjacent to the second web space and first digit, the 1$^{st}$ and 2$^{nd}$ lumbricals, and muscles of the thenar eminence. The FDS was innervated by both parts of this split nerve.[47]

A rare variation of median nerve was noted by Sundarum et al. (2008), wherein the median nerve was split 5 cm proximal to the flexor retinaculum. This split portion of the median nerve continued distally as a common palmar digital nerve, which passed anterior to the long flexor tendons and just proximal to the web space between middle and ring finger, divided into two proper palmar digital nerves, one medial and one lateral in position. The lateral branch split again into two and the common palmar digital branch of ulnar artery passed through the gap between them. Just before reunion a branch was given off, which supplied the medial side of the middle finger. Further distally both rami reunited and from the reunited portion a branch was given off, to supply the medial side of the middle finger. Lateral side of the ring finger was supplied by medial branch of the proper palmar digital nerve. In this case the superficial palmar arch was found to be incomplete. The main trunk of the nerve gave off two common palmar digital nerves that presented a normal course and distribution.[48]

Vollala VR and Potu BK (2007) observed an additional belly for the flexor carpi ulnaris (FCU) in a cadaver, which was taking origin from the medial side of the coronoid process and inserted into the tendon of FCU. The additional belly was innervated by a branch coming from the median nerve, where as the normal FCU was supplied by ulnar nerve. The insertion of the tendon of the FCU was normal.[49]

The flexor carpi ulnaris is a useful local muscle flap in the forearm and elbow. It is, however, an important palmar flexor and ulnar deviator of the wrist and functional loss may arise from the use of this muscle in its entirety. The flexor carpi ulnaris is made up of two distinct neuromuscular compartments. This arrangement allows for splitting of the muscle and the potential use of the larger ulnar compartment as a local muscle flap while maintaining the humeral compartment as an ulnar deviator and palmar flexor of the wrist.[50]

Alves N et al. (2004) conducted a study on eighteen forearms to study the innervation of the pronator teres and the relationship of the median nerve to the pronator teres. The number of the median nerve branches to pronator teres muscle varied from 1 to 3. The most proximal origin was located 4.0 cm above the elbow articular line, and the most distal origin was 1.0 cm below the line. 93.3 % of the branches originated at the distal third of the arm and 6.7 % of the branches originated in the forearm. The muscles responsible for pronation of forearm are pronator teres and pronator quadratus. Knowledge of the anatomical distribution of nerves to these muscles makes the treatment of pronator syndrome easier.[51]

# METHODOLOGY

## Materials

The present descriptive study was carried out by dissecting the human cadaveric upper limbs available in the Department of Anatomy. Total of 50 specimens (25 right upper limbs and 25 left upper limbs) were studied in the present work. Trauma, surgery and amputation of part of upper limb were the exclusion criteria.

## Methods

Dissection method was employed as per Cunningham's manual of practical anatomy. Pectoralis major and minor muscles were cut and reflected. Cords of brachial plexus were disposed. Median nerve was identified. Its formation and any variations in it were noted. To note the level of formation, the arm length was measured from tip of acromian process to lateral epicondyle by using measuring tape and the same was divided into upper, middle and lower third. Connecting branch from musculocutaneous nerve to median nerve in axilla or upper third of arm was considered as second lateral root and in middle or lower third of arm as communication. The course of the median nerve was observed by tracing the median nerve distally in the arm. Any variation in its course in relation to brachial artery was noted. Absences of musculocutaneous nerve and, in such cases, the branches given by median nerve to muscles of flexor compartment of arm were also noted. Presence of communications between median nerve and musculocutaneous nerves in arm as said above, were looked for. The further course of the median nerve was traced in forearm and hand till its termination. Pronator teres was cut at its insertion and the superficial flexor tendons were also cut proximal to flexor retinaculum. Variations of the median nerve pertaining to its course, branches, termination, and communications with ulnar nerve in forearm and hand were noted. Photographs were taken under good lighting, using zoom camera. Schematic diagrams were drawn. Photographs were labeled. The data collected in the present study was recorded, tabulated, analyzed and compared with that of the previous studies.

The following parameters were looked for in the present study of median nerve, in

**Formation**

1. Number of roots and level of formation of median nerve
2. Formation of median nerve in relation to axillary artery

**Course**

3. Course of median nerve in upper part of arm in relation to brachial artery
4. Course of median nerve in relation to pronator teres
5. Course of median nerve in relation to flexor digitorum superficialis
6. Level of median nerve becoming superficial in forearm

**Branching pattern**

7. Muscles of anterior compartment of arm innervated by median nerve and MCN
8. Number of branches of MN to superficial muscles of forearm
9. Level of origin of MN branches to superficial muscles of forearm in relation to elbow joint and distance from the lateral epicondyle
10. Level of origin of anterior interosseous nerve in relation to lateral epicondyle and site of origin
11. Level of origin of palmar cutaneous branch in relation to flexor retinaculum
12. Origin of recurrent muscular branch to thenar muscles
13. Origin of accessory muscular branch to thenar muscles

**Termination**

14. Level and mode of termination of median nerve

**Communications**

15. MN Communications with Musculocutaneous and ulnar nerves.

**Statistical analysis**

The data were tabulated and analysed. Rates and ratios were calculated.

# RESULTS

The data obtained on different parameters were tabulated and recorded as follows.

**Table – 1: Number of roots and level of formation of median nerve**

| Level of formation of median nerve | Number of specimens | |
|---|---|---|
| | with 2 Roots | with 3 Roots |
| Axilla | 26 | 6 |
| Upper third of arm | 3 | 7 |
| Middle third of arm | 6 | - |
| Lower third of arm | 2 | - |

Connecting branch from musculocutaneous nerve to median nerve either in axilla or upper third of arm was considered as second lateral root and in the middle or lower third of arm as communication.

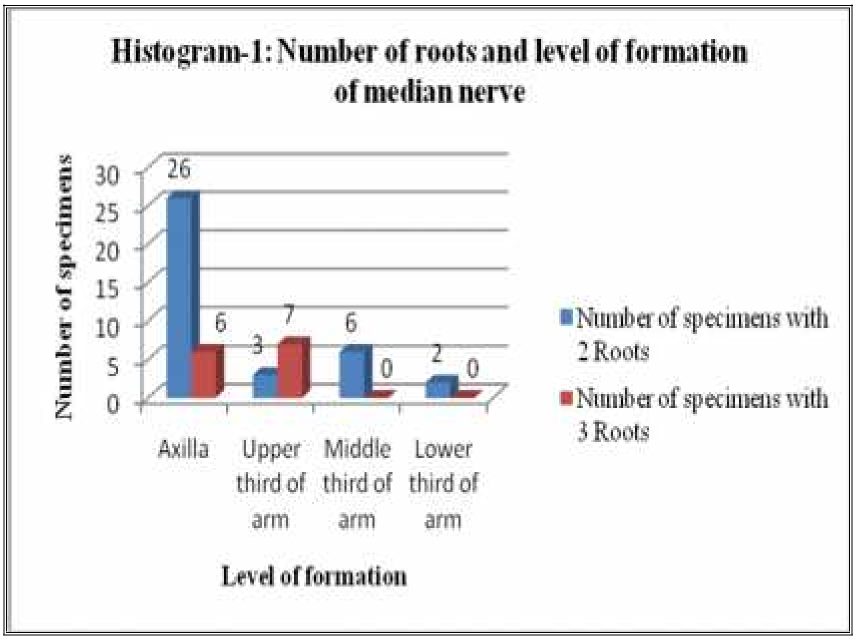


**Table – 2: Formation of median nerve in relation to axillary artery**

| Formation of median nerve | Number of specimens |
|---|---|
| Lateral to axillary artery | 42 |
| Anterior to axillary artery | 5 |
| Medial to axillary artery | 3 |

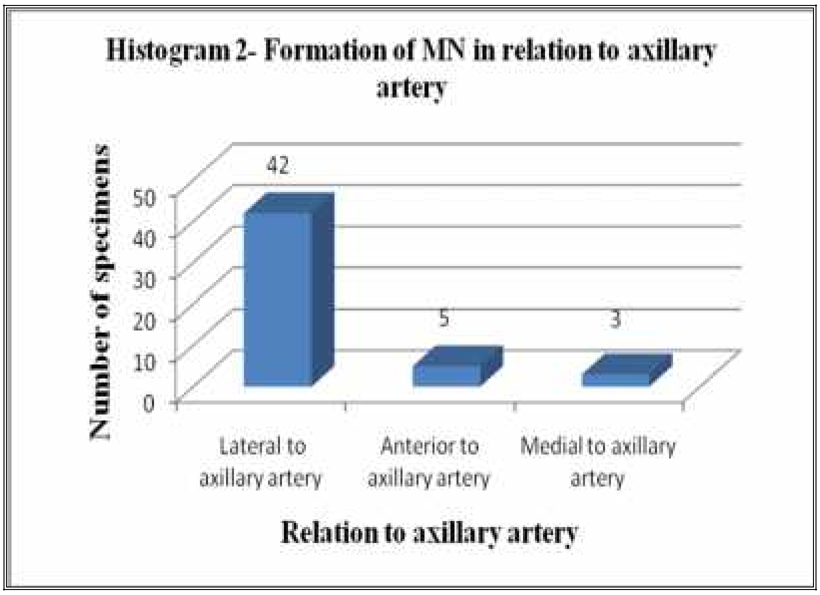



**Table - 3: Course of MN in upper part of the arm in relation to brachial artery**

| Course of median nerve | Number of specimens |
|---|---|
| Lateral to brachial artery | 47 |
| Medial to brachial artery | 3 |

**Table – 4: Course of median nerve in relation to pronator teres muscle**

| MN relation to pronator teres muscle | Number of specimens |
|---|---|
| Between two heads | 44 |
| Deep to muscle | 2 |
| Through the ulnar head | 2 |
| Deep to humeral head, ulnar head being absent | 2 |

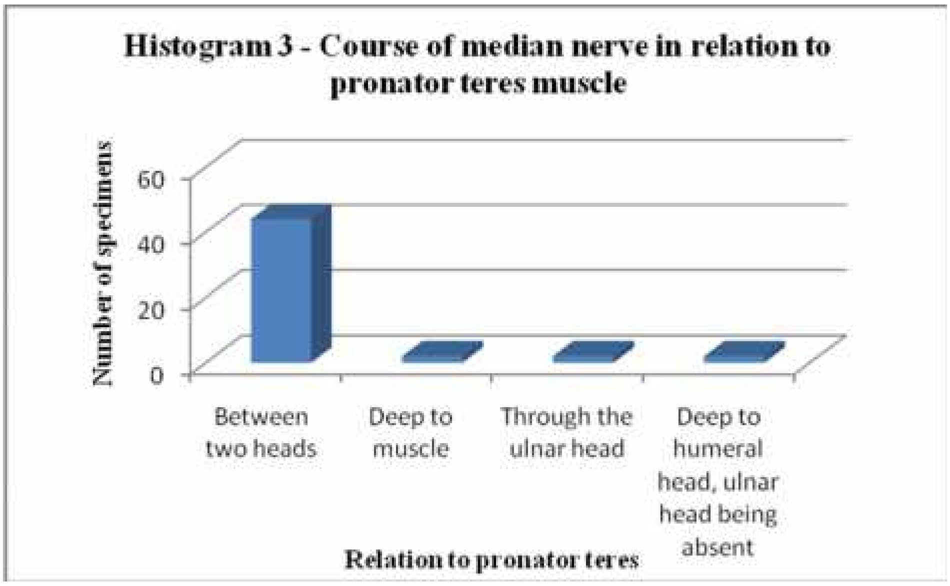


**Table – 5: Course of median nerve in relation to the FDS muscle**

| Relation of median nerve to F D S | Number of specimens |
|---|---|
| Deep to F D S | 48 |
| Piercing the F D S muscle | 2 |

**Table – 6: Level of median nerve becoming superficial in the forearm**

| MN becoming superficial in | Number of specimens |
|---|---|
| Lower third of forearm | 40 |
| Middle third of forearm | 10 |

**Table - 7: Innervation of muscles of anterior compartment of arm by MN and MCN**

| Nerve of anterior compartment of arm | Number of specimens |
|---|---|
| Median nerve | 6 |
| Musculocutaneous nerve | 44 |

Absence of MCN was noted in six specimens

**Table – 8: Number of branches of median nerve to superficial muscles of forearm.**

| Superficial muscles of forearm | Number of specimens | | |
|---|---|---|---|
| | with 1Branch | with 2 Branches | with 3 Branches |
| Pronator teres | 38 | 10 | 2 |
| Flexor carpi radialis | 49 | 1 | - |
| Flexor digitorum superficialis | 20 | 18 | 12 |
| Palmaris longus | 48 | - | - |

Palmaris longus was absent in two specimens.

**Table – 9: Level of origin of MN branches to superficial muscles of forearm in relation to elbow joint and distance from the lateral epicondyle**

| Superficial muscles of forearm | Level of origin of MN branches to muscules from the lateral epicondyle | | | |
|---|---|---|---|---|
| | <5cm Proximal to elbow joint | <5cm Distal to elbow joint | 5-10cm Distal to elbow joint | >10cm Distal to elbow joint |
| Pronator teres | 26 | 14 | 10 | - |
| Flexor carpi radialis | 16 | 30 | 4 | - |
| Flexor digitorum superficialis | 10 | 32 | - | 08 |
| Palmaris longus | 2 | 24 | 22 | - |

Palmaris longus was absent in two specimens.

**Table – 10: Level of origin of anterior interosseous nerve in relation to lateral epicondyle and site of origin**

| Anterior interosseous nerve | | Number of specimens |
|---|---|---|
| Level of origin from lateral epicondyle | <5 cm | 12 |
| | 5-7 cm | 38 |
| Site of origin from MN | Posterior | 42 |
| | lateral | 8 |

**Table – 11: Level of origin of palmar cutaneous branch in relation to flexor retinaculum**

| Origin of palmar cutaneous branch | Number of specimens |
|---|---|
| Just proximal to flexor retinaculum | 40 |
| 5-7 cms proximal to flexor retinaculum | 10 |

**Table - 12: Origin of recurrent muscular branch to thenar muscles**

| Recurrent muscular branch | Number of specimens |
|---|---|
| Distal to flexor retinaculum | 50 |

In all the specimens recurrent muscular branch originated distal to flexor retinaculum

**Table - 13: Origin of accessory muscular branch to thenar muscles**

| Accessory muscular branch | Number of specimens |
|---|---|
| Proximal to flexor retinaculum | 8 |
| Distal to flexor retinaculum | 6 |

Accessory muscular branch was found in 14 specimens

**Table - 14: Level and mode of termination of median nerve**

| Level of termination of MN | Mode of termination of MN | |
|---|---|---|
| | 2 branches (medial and lateral) | 3-5 branches |
| Forearm | 2 | - |
| Hand | 43 | 5 |

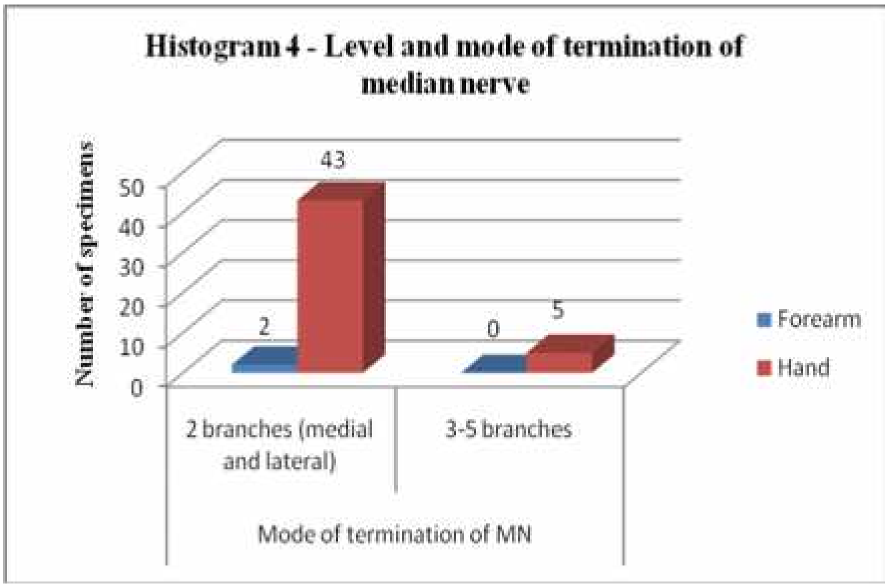
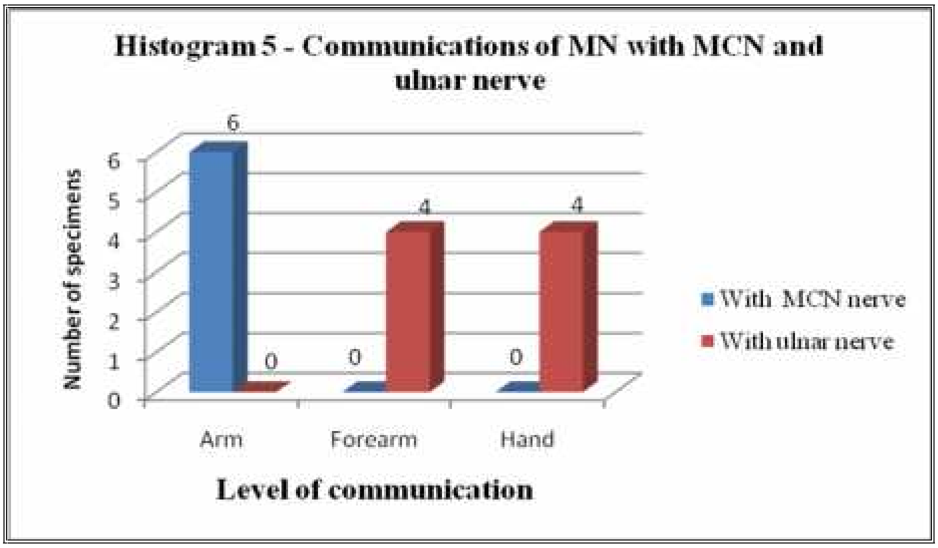


**Table - 15: Communications of M N with M C N and ulnar nerve**

| Level of communication | With MCN nerve | With ulnar nerve |
|---|---|---|
| Arm | 6 | - |
| Forearm | - | 4 |
| Hand | - | 4 |

Connecting branch from musculocutaneous nerve to median nerve either in middle or lower third of arm was considered as communication.



# DISCUSSION

Previous research studies have reported the fact that the variant median nerve with abnormal formation, course and distribution is more prone to accidental injuries and entrapment neuropathies. During surgical procedures carried out on an upper limb, a surgeon is exposed to the topographical anatomy of the neural structures and awareness of such variations may be of immense clinical help. Knowledge of such anomalies is also important during treatment of fractures. Better understanding and correct interpretation of clinical neurophysiology can only be possible with prior academic knowledge. Accordingly, a view of previous studies at different levels of median nerve, along with observations made in the present study is assessed through following important parameters.

**Formation**

**1. Number of roots and level of formation of median nerve**

Eglseder and Goldman (1997) have found that median nerve to be formed of three roots in 14% of their specimens.[53]

Uzun A and Bilgic S (1999), in their study of 130 brachial plexuses noted variation in the formation of the median nerve (10.77%), with fusion of three branches. [22]

Uzun A et al. (2001) have reported a variation in the formation of median nerve wherein the median nerve was formed by the fusion of four branches. [23]

Mohammed HM Badawoud (2003) in his study of 48 upper limbs, found median nerve to be formed by four roots in 1 specimen (2.1%) and by three roots in 3 specimens (6.3%).[52]

Fazan VPS et al. 2003 in their study of 54 upper extremities found median nerve to be formed by three roots in 28 (52%) limbs.[2]

Gupta M et al. (2005) have noted that the median nerve formation by the union of two lateral roots and one medial root.[2]

In the present study the median nerve was found to be formed by two roots in 37 (74%) specimens and three roots in 13 (26%) specimens (Photograph-2). In four specimens the normal lateral root of median nerve was thin and abnormal or second lateral root was thick. In nine specimens both the lateral roots were of equal thickness.

Fazan VPS et al.2003 in their study of 54 upper limbs noticed formation of median nerve distally in the arm in 4 (7%) limbs.[2]

Nayak S et al. (2006) have reported formation of median nerve below the midpoint of arm just medial to brachial artery.[3]

Pandey SK and Shukla VK (2007) in their study of 344 specimens have observed median nerve formation at lower level in 6 (1.7%) limbs.[19] However the authors have not mentioned the exact level of formation.

In the present study the median nerve was found to be formed in the axilla in 32 (64%) specimens, in the upper third of arm in 10 (20%), in middle third of arm in 6 (12%) and in lower third of arm in 2 (4%) specimens (Photograph-6). In one specimen wherein the median nerve was formed in the middle third of arm, there was high division of brachial artery at the same level (Photograph-5).

**2. Formation of median nerve in relation to axillary artery**

Johnson D and Ellis H (2005) mentions that the formation of median nerve is either anterior or lateral to third part of axillary artery.[12]

Chitra R (2007) has reported a case of formation of median nerve medial to axillary artery bilaterally [5] and in another case she reported formation of median nerve posterior to third part of axillary artery.[24]

Pandey SK and Shukla VK (2007) in their study of 344 axillae have reported formation of median nerve, medial to axillary artery in 8 (2.3%) cases.[19]

In the present study formation of median nerve was lateral to axillary artery in 42 (84%), anterior to axillary artery in 5 (10%), medial to axillary artery in 3 (6%). Formation of median nerve posterior to the axillary artery was not found in any of the specimens. Of the three specimens where the median nerve was formed medial to axillary artery, in two specimens both the lateral roots crossed the axillary artery from lateral to medial to join the medial root (Photograph-3).

**Course**

**3. Course of median nerve in upper part of the arm in relation to brachial artery**

Nayak S et al. (2006) have reported median nerve to descend medial to brachial artery.[3]

R Chitra (2007) has reported median nerve to descend medial to brachial artery bilaterally and in another case, posterior to brachial artery.[5, 24]

In the present study median nerve coursed lateral to brachial artery in 47 (94%) specmens, medial to brachial artery in 3 (6%) specimens (Photograph-3) and posterior to brachial artery in none of the specimens.

**4. Course of median nerve in relation to pronator teres**

Beaton and Anson (1939) in their study of 240 arms found the median nerve to pass between the two heads of pronator teres in 82.5 %, deep to the two heads in 6.3 %, through humeral head in 2.5 % and in 10.8% the nerve passed deep to humeral head, the ulnar head being absent.[57]

Bergman RA et al. (2002) have noted the median nerve wherein it passed superficial or deep to two heads or pierced the humeral head of pronator teres.[58]

In the present study the median nerve passed between the two heads of pronator teres in 44 (88 %) specimens (Photograph-11), deep to the two heads in 2 (4%) specimens, through ulnar head in 2 (4 %) specimens (Photograph-12) and in 2 (4%) specimens the nerve passed deep to humeral head the ulnar head being absent (Photograph-13).

**5. Course of median nerve in relation to flexor digitorum superficialis**

Many authors like Hollinshead WH (1958), Last RJ (1999) and Johnson D and Ellis H (2005) have mentioned that the median nerve passed deep to flexor digitorum superficialis almost to the wrist.[12, 13, 15]

Bergman RA et al. (2002) have noted the median nerve passing superficial to flexor digitorum superficialis and also passing through the muscle belly.[58]

In the present study the median nerve passed deep to flexor digitorum superficialis in 48 (96%) specimens and was found to pierce the muscle in 2 (4%) specimens.

**6. Level of median nerve becoming superficial in forearm**

Hollinshead WH (1958) has mentioned that the median nerve becomes superficial in the forearm proximal to flexor retinaculum and lies between the tendons of flexor digitorum superficialis and flexor carpi ulnaris.[12]

Bergman RA et al. (2002) have observed the median nerve becoming superficial 2.5 cm proximal to the wrist.[58]

According to Johnson D and Ellis H (2005), the median nerve becomes superficial 5 cm proximal to flexor retinaculum.[15]

In the present study it was observed that the median nerve appeared superficial in lower third of forearm in 40 (80%) specimens and in middle third of forearm in 10 (20%) specimens (Photograph-10).

**Branching**

**7. Muscles of anterior compartment of arm innervated by median nerve and MCN**

Le Minor (1990) has reported absence of musculocutaneous nerve where in the lateral cord of brachial plexus gave muscular branches to coracobrachialis and biceps brachii.[55]

Gumusburun E and Adiguzel E (2000) have noted bilateral absence of musculocutaneous nerve. Two branches from the lateral cord innervated the coracobrachialis muscle. The median nerve innervated the biceps brachii and brachialis muscles.[56]

Sud M and Sharma A (2000) have also reported absence of musculocutaneous nerve.[40]

Beheiry EE (2004) has noted absence of musculocutaneous nerve in one limb (1.7%) out of 60 upper limbs studied.[36]

Guttenberg and Ingolotti M (2009) in their study of 56 upper limbs have noticed absence of musculocutaneous nerve in 2 (3.6%) limbs.[59]

In the present study absence of musculocutaneous nerve was noted in 6 (12%) specimens and it was bilateral in one cadaver. The branches either from lateral roots of median nerve or directly from median nerve innervated the biceps brachii, coracobrachialis and brachialis muscles in all the specimens (Photograph-7).

In two out of these six specimens where absence of musculocutaneous nerve was noted, the median nerve was formed by three roots. In one specimen there was an extremely thin normal lateral root and a significantly thick second lateral root of median nerve (Photograph-8). In another specimen vena comitans was coursing within a loop formed by the two lateral roots of the median nerve (Photograph-4).

**8. Number of branches of MN to superficial muscles of forearm**

**Pronator teres**

Alves N et al. (2004) in their study of 18 forearms have mentioned 1 to 3 branches to pronator teres.[51]

In the present study there was one branch to pronator teres in 38 (76%) specimens, two branches in 10 (20%) and three branches in 2 (4%) specimens.

**Flexor carpi radialis**

In the present study flexor carpi radialis was supplied by one branch in 49 (98%) specimens and two branches in 1 (2%) specimen.

**Flexor digitorum superficialis**

In the present study flexor digitorum superficialis was supplied by one branch in 20 (40%) specimens, and two branches in 18 (36%) and three branches in 12 (24%) specimens.

**Palmaris longus**

Thompson NW et al. (2001) in their population study of 300 Caucasian subjects to assess the incidence of absence of palmaris longus by clinical inspection noticed unilateral absence of palmaris longus in 49 (16%) subjects and bilateral in 26 (9%) subjects.[6]

Keith L Moore (2002) and Richard Snell (2004) have mentioned the absence of palmaris longus both unilaterally and bilaterally.[16, 10]

Sebastin SJ et al. (2005) their study of 329 Chinese men and women, found palmaris longus to be absent unilaterally in 3.3%, and bilaterally in 1.2%, with an overall prevalence of absence in 4.6% of subjects.[62]

In the present study the palmaris longus was absent in 2 (4%) specimens. Palmaris longus in remaining 48 (96%) specimens received one branch.

**9. Level of origin of MN branches to superficial muscles of forearm in relation to elbow joint and distance from the lateral epicondyle**

Tetro AM (2007) has mentioned that, all the muscular branches arising from the median nerve in the forearm are from the medial or posteromedial aspect of the nerve.[4]

In the present study lateral epicondyle was taken as reference point for measurement of level of origin of muscular branches.

**Pronator teres**

Alves N et al. (2004) in their study of 18 forearms have mentioned regarding origin of branches to pronator teres that most proximal origin was 4.9 cm above the elbow articular line whereas the most distal origin was 1.6 cm below the elbow articular line.[51]

In the present study, in 26 (52%) specimens branches arose above the elbow joint in 10 (20%), distal to elbow joint but less than 5 cm in 14 (28%), distal to elbow joint but within 5 to 10 cm from the elbow joint. The branches to pronator teres were less than 5 cm from lateral epicondyle in 40 (80%) and 5-10 cm from lateral epicondyle in 10 (20%) specimens.

**Flexor carpi radialis**

In the present study branches to flexor carpi radialis arose above the elbow joint in 16 (32%) specimens, distal to elbow joint but less than 5 cm in 30 (60%) specimens, distal to elbow joint but within 5 to 10 cm from the elbow joint in 4 (8%) specimens. The branches to flexor carpi radialis were less than 5 cm from lateral epicondyle in 46 (92%) and 5-10 cm from lateral epicondyle in 4 (8%) specimens.

**Flexor digitorum superficialis**

In the present study branches to flexor digitorum superficialis arose above the elbow joint in 10 (20%) specimens, distal to elbow joint but less than 5 cm in 32 (64%) specimens, distal to elbow joint but more than 10 cm from the elbow joint in 8 (16%) specimens.

The branches to flexor digitorum superficialis were less than 5 cm from lateral epicondyle in 42 (84%) and more than 10 cms from lateral epicondyle in 8 (16%) specimens.

**Palmaris longus**

Thompson NW et al. (2001) in their population study of 300 Caucasian subjects to assess the incidence of absence of palmaris longus by clinical inspection noticed unilateral absence of palmaris longus in 49 (16%) subjects and bilateral in 26 (9%) subjects.[6]

In the present study the palmaris longus was absent in 2 (4%) specimens. Palmaris longus in remaining 48 specimens received one branch. In 2 (4%) specimens branches to palmaris longus arose above the elbow joint, distal to elbow joint but less than 5 cms in 24 (50%) specimens, distal to elbow joint but within 5 to 10 cms from the elbow joint in 22 (46%) specimens. The branches to palmaris longus were less than 5 cms from lateral epicondyle in 26 (54%) specimens and 5-10 cms from lateral epicondyle in 22 (46%) specimens.

**10. Level of origin of anterior interosseous nerve in relation to lateral epicondyle and site of origin**

Johnson D and Ellis H (2005) have mentioned that anterior interosseous nerve arises from the median nerve between the two heads of pronator teres just distal to the origin of branches to superficial flexors.[12]

According to Tetro AM and Pichora DR (2007) the anterior interosseous nerve arises in the pronator teres muscle, from the posterolateral aspect of median nerve at a point approximately 5-8 cm distal to medial epicondyle.[4]

The present study showed that the anterior interosseous nerve arose below the elbow joint but within 5 cm from lateral epicondyle in 12 (24%) specimens and below the elbow joint but within 5 to 7 cm from lateral epicondyle in 38 (76%) specimens.

The site of origin was from posterior aspect of median nerve in 42 (84%) specimens and from lateral aspect in 8 (16%) specimens.

**11. Level of origin of palmar cutaneous branch in relation to flexor retinaculum**

Johnson D and Ellis H (2005) and Bergman RA et al. (2002) have mentioned that palmar cutaneous branch is given just proximal to flexor retinaculum.[12, 58]

In the present study palmar cutaneous branch was given off just proximal to flexor retinaculum in 40 (80%) specimens and 5-7 cms proximal to flexor retinaculum in 10 (20%) specimens.

**12. Origin of recurrent muscular branch to thenar muscles**

Richard Snell (2004), Johnson D and Ellis H (2005), Hollinshead WH (1958) and Keith L Moore (2002) have mentioned that the recurrent muscular branch is given off just distal to the flexor retinaculum.[10, 12, 15, 16]

Imamura K (2001) noted the variations of the recurrent branch of the median nerve during operations to treat carpal tunnel syndrome in 129 subjects wherein he found extraligamentous type in 122 hands (94.6%), the subligamentous type in 2 hands (1.6%), and the transligamentous type in 5 hands (3.9%).[65]

Alp M et al. (2005) have observed the following variations in the thenar branch in their study of 144 hands. Origin of thenar branch was proximal to flexor retinaculum in 2%, distal to flexor retinaculum in 84% and between the borders of flexor retinaculum in 14%.[66]

In the present study recurrent muscular branch was given off just distal to the flexor retinaculum in all the 50 specimens.

**13. Origin of accessory muscular branch to thenar muscles**

Accessory muscular branches were found by Imamura K (2001) in 10 (7.8%) hands of 125 subjects during operation.[65]

Alp M et al. (2005) have found accessory muscular branch in 12 (8.3%) hands in their study of 144 hands. [66]

In the present study accessory muscular branch was found in 14 (28%) specimens, it arose proximal to flexor retinaculum in 8 specimens and distal to flexor retinaculum in 6 specimens.

**Termination**

**14. Level and mode of termination of median nerve**

Urban T and Krosman M (1992) have found terminal division of median nerve in proximal 1/3rd of forearm.[63]

Rader et al. (1992) have noted terminal division of median nerve in distal 1/3rd of forearm.[64]

Last RJ (1999) and Dutta AK (2004) have mentioned that the median nerve terminates in the palm by dividing into medial and lateral branches, which in turn give digital branches just distal to the flexor retinaculum.[13, 11]

Johnson D and Ellis H (2005) have mentioned that the median nerve terminates in the palm by dividing into variable number of branches.[12]

In the present study the median nerve was found to terminate in the forearm in 2 (4%) specimens by dividing into medial and lateral branches and in 48 (96%)

specimens it terminated in hand. Of the latter 48 specimens, in 43 it terminated in two branches and in 5 specimens in 3-5 branches.

**Communications**

**15. MN Communications with musculocutaneous and ulnar nerves.**

Chitra R (2007), Arora J et al. (2003), Chauhan R and Roy TS (2002), Ibrahim CH et al. (2005) and Oluyemi KA et al. (2007) have reported median nerve communications with musculocutaneous nerve.[5, 8, 18, 27, 29]

Venierator D and Anagostopoulou (1998), in their study of 158 upper limbs found median nerve communications with musculocutaneous nerve in 22 (13.9%) limbs. In 6 cadavers these were bilateral.[28]

Eglseder E and Goldman M (1997) in their study of 54 cadaver arms noticed interconnections between median nerve and musculocutaneous nerve in 36% cases.[53]

Aktan ZA et al. (2001) in their study of 48 limbs, have reported median nerve communications with musculocutaneous nerve in 5 (5%) limbs.[30]

Choi D et al.(2002) in their study of 276 upper limbs found median nerve communications with musculocutaneous nerve in 73 (26.4%) limbs. In 9 cadavers these were bilateral.[31]

Beheiry EE (2004) in his study of 60 cadaver arms noticed communications between median nerve and musculocutaneous nerve in 3 (5%) limbs.[36]

Guttenberg and Ingolotti M (2009) in their study of 56 upper limbs have reported median nerve communications with musculocutaneous nerve in 30 (53.6%) limbs.[59]

In the present study connecting branches between median nerve and musculocutaneous nerve either in the middle or lower third of arm were considered as communications and such communications were found in 6 (12%) specimens. In one specimen along with communication between median and musculocutaneous nerve in middle third of arm there was high division of axillary artery as well (Photograph-9).

In the forearm, communications between median nerve and ulnar nerve were first described by the Swedish anatomist Martin (1763) and later by Gruber (1870) and thus referred to as the Martin- Gruber anastomosis.[60]

Shu HS et al. (1999) in their study of 72 upper limbs found 17 (23.6%) limbs with Martin-Gruber communication.[61]

Niedenfuhr MR et al. (2002) in their study, found Martin- Gruber anastomosis in 19 (13.6%) of the 140 forearms.[33]

In another study by Niedenfuhr MR et al. in the same year found Martin-Gruber anastomosis in 31 (13.1%) of the 236 upper limbs.[34]

In the present study communications between median and ulnar nerve in forearm were seen in 4 (8%) specimens.

Riche (1897) and Cannieu (1897) independently, described a neural connection between ulnar and median nerve in the hand referred to as Riche-Cannieu anastomosis. Dogan NU et al. mention that it may be present in as many as 70%. [17, 60]

In the present study the communicating branches between median and ulnar nerve in hand were seen in 4 (8%) specimens (Photograph-14).

# CONCLUSION

A key to carry out therapeutic and diagnostic procedures successfully, on upper limbs depends on the knowledge of the possible variations of nerves and arteries which may be encountered. Such neurovascular variations are not only more prone to iatrogenic injuries but they interfere in the correct interpretation of clinical conditions as well. Some of the complications that have been reported include injuries to nerves, arteries, wrong diagnosis and unnecessary carpal tunnel release.

In the present study an attempt is made to know the possible variations of median nerve in its formation, course, branching pattern and termination so as to provide additional information which may help to decrease the risk of diagnostic and operative complications.

The present study concludes that, the different types of variations in cadavers which have been studied would be of immense help for successful clinical approaches. Of course, the small number of specimens was a limitation in our study. However our study has thrown up a number of avenues for further research studies. If our limitation is overcome in larger studies, we would have better guidelines for understanding the clinical conditions and for successful surgical procedures.

# SUMMARY

The present study was conducted to know the variations of median nerve in a total of 50 upper limbs obtained from the Department of Anatomy.

The median nerve was found to be formed by two roots in 37 (74%) and by three roots in 13 (26%) specimens. It was found to be formed in the axilla in 32 (64%), in the upper third of arm in 10 (20%), middle third of arm in 6 (12%) and lower third of arm in 2 (4%) specimens. In one specimen wherein the median nerve was formed in the middle third of the arm, there was a high division of brachial artery as well. Formation of median nerve was lateral to axillary artery in 42 (84%), anterior to axillary artery in 5 (10%), medial to axillary artery in 3 (6%) and posterior to axillary artery in none of the specimens. The median nerve coursed lateral to brachial artery in 47 (94%) and medial to brachial artery in 3 (6%) specimens. Absence of musculocutaneous nerve was noted in 6 (12%) specimens and it was bilateral in one cadaver. In two out of these six specimens where absence of musculocutaneous nerve was noted, there were concomitant variations in the formation of median nerve as well, which are very rare findings encountered in the present study and in these two specimens the median nerve was formed by three roots. In one of these two specimens there was an extremely thin normal lateral root and an abnormally thick second lateral root of median nerve and in another specimen vena comitans was coursing within the loop formed by the two lateral roots of the median nerve.

The median nerve passed between the two heads of pronator teres in 44 (88%), deep to the two heads in 2 (4%), through ulnar head in 2 (4 %) and the nerve passed deep to humeral head the ulnar head being absent in 2 (4%) specimens. The median nerve was found to pass deep to flexor digitorum superficialis in 48 (96%) and pierce flexor digitorum superficialis muscle in 2 (4%) specimens. The median nerve becoming superficial in middle third of the forearm in 10 (20%) specimens was a salient observation contrary to the description in most of the text books that it becomes superficial in lower third of the forearm.

Communications between median nerve and musculocutaneous nerve were observed in 6 (12%) specimens. In one of these six specimens, high division of axillary artery was observed along with communication.

Communications between median and ulnar nerve in forearm and hand were seen in 4 (8%) specimens each. The median nerve was found to terminate in the palm into 3-5 branches in 5 (10%) specimens which was again an important finding contrary to the description available in most of the text books that it terminates into two branches.

It is probable that some differences observed as compared to other studies may be due to differences in the sample size.

The present study provides additional information on neurovascular variations which are of importance to clinicians and surgeons.

# BIBLIOGRAPHY


1. Das S, Paul S. Anomalous Branching Pattern of Lateral Cord of Brachial Plexus. Int.J. Morphol. 2005; 23(4): 289- 92.
2. Fazan VPS, Amadeu AS, Caleffi AL, Rodrigues Filho OA. Brachial Plexus Variations in its Formation and Main Branches. Acta Cir. Bras. 2003; 18(5): 14-8.
3. Nayak S, Samuel VP, Somayaji N. Concurrent Variations of Median Nerve, Musculocutaneous Nerve and Biceps Brachii Muscle. Neuroanatomy. 2006; 5: 30-2.
4. Tetro AM, Pichora DR. High Median Nerve Entrapments. An Obscure Cause of Upper-Extremity Pain. [monograph on the internet]. New York: Simmons Orthopaedic & Spine Associates. 2007; [cited 2009 Aug 6]. Available from: http://www.simmonsortho.com/literature/ highmediannerve/highmediannerve.html
5. R Chitra. Multiple Bilateral Neuroanatomical Variations of the Nerves of the Arm. Neuroanatomy. 2007; 6: 43-5.
6. Thompson NW, Mockford BJ, Cran GW. Absence of the Palmaris Longus Muscle: A Population Study. The Ulster Med. J. 2001; 70(1) 22-4.
7. Chauhan, R. Atypical Innervation of Palmaris Longus-A Case Report. J. Anat. Soc. India. 2003; 52(2):171-3.
8. Arora J, Kapoor V, Suri RK, Khan RQ. Inter-Communications Between Median and Musculocutaneous Nerves With Dual Innervation of Brachialis Muscle-A Case Report. J. Anat. Soc. India. 2003; 52(1): 66-8.
9. Saeed M, Rufai AA. Median and Musculocutaneous Nerves: Variant Formation and Distribution. Clin. Anat. 2003; 16: 453-7.
10. Snell RS. Clinical Anatomy. 7th Ed. Bettysun Editor. Baltimore .Lippincott Williams and Wilkins. 2004. p. 455-590.

11. Dutta A.K. Essentials of Human Anatomy: Superior and Inferior Extremities. 3rd Ed. Calcutta. Current Books Int. 2004. p. 101-6.
12. Johnson D, Ellis H, Editors. Gray's Anatomy. The Anatomical Basis for Clinical Practice. 39th Ed: Elsevier Churchill Livingstone; 2005. p. 817-933.
13. Last RJ, Sinnatamby CS. Last's Anatomy Regional and Applied 10th ed. Inburgh. Churchill Livingstone. 1999. p. 35-105.
14. Larsen WJ. Development of the Peripheral Nervous System. In: Essentials of Human Embryology. 2nded. New York: Churchill Livingstone Inc; 1998. p. 69-79.
15. Hollinshead WH. Anatomy for Surgeons: Back and Limbs, Volume 3. 1st ed. New York, Paul Hoeber Inc. 1958. p. 207-580.
16. Moore KL, Agur AMR. Essential Clinical Anatomy 2nd ed. Philadelphia: Lippincott Williams & Wilkins, 2002. p. 405-97.
17. Gupta S. Hand, Nerve Injury Repair. [monograph on the internet].e-medicine; [cited 2009 Aug 6]. Available from: http://emedicine.medscape.com/article/128 7077/overview
18. Chauhan R, Roy TS. Communication between the Median and Musculocutaneous Nerve- A Case Report. J. Anat. Soc. India. 2002; 51(1): 72-5.
19. Pandey SK, Shukla VK. Anatomical Variations of the Cords of Brachial Plexus and the Median Nerve. Clin. Anat.2007; 20: 150-6.
20. Vijaya PS, Vollala VR, Mohandas R, Shetty S. A Rare Entrapment of Medial Root of Median Nerve Between Axillary Artery and its Anomalous Branch. The Internet J. Neuro. 2006; 5 (2). Available from: http://www.ispub.com/journal/ the_internet _ journal_of_neurology.

21. Vollala VR, Potu BK, Gorantla VR, Reddy S. Variant Median Nerve and Lateral Antebrachial Cutaneous Nerve associated with Anomalous Brachial Vein: Case Report. Neuroanatomy. 2008; 7: 28-32.

22. Uzun A, Bilgic S. Some Variations in the Formation of Braichal Plexus in Infants. Turk. J Med Sci.1999; 29: 553-77.

23. Uzun A, Leonard L, Seelig.Jr. A Variation in the Formation of the Median Nerve: Communicating Branch Between the Musculocutaneous and Median Nerves in Man. Folia. morphol. 2001: 60 (2): 99-101.

24. R Chitra. A Rare Variant Formation of the Median Nerve: A Case Report. The Internet. J. Neuro. 2007: 8(2). Available from: http://www.ispub.com/journal/the internet journal of neurology.

25. R. Chitra. Various Types of Intercommunications Between Musculocutaneous and Median Nerves: An Analytical Study. Ann. Indian. Acad. Neurol. 2007; 10: 100-4.

26. Gupta M, Goyal M, Harjeet. Anomalous Communications in the Branches of Brachial Plexus. J. Anat. Soc. India. 2005; 54(1):1-3.

27. Ibrahim CH, Adnan E, Cem DC. Variations Between Median and Musculocutaneous Nerves. The Internet J. Surg. 2005; 6(1). Available from: http://www.ispub.com/journal/the_internet_journal_of_surgery.

28. Venierator D, Anagostopoulou S. Classification of Communications Between the Musculocutaneous and Median Nerves. Clin. Anat.1998; 11:327-31.

29. Oluyemi KA, Adesanya OA, Ofusuri DA, Okwuonu CU, Ukwenya VO, Ominiabons FA, Odion BI. Abnormal Pattern of Brachical Plexus Formation: An Original Case Report. The Internet Journal of Surgery. 2007; 4(2). Available from: http://www.ispub.com/journal/the_internet_journal_of_surgery

30. Aktan ZA, Ozutruk L, Bilge O, Ozer MA, Pinar YA. A Cadaveric Study of the Anatomic Variations of the Brachial Plexus Nerves in the Axillary Region and Arm. Turk J Med. Sci.2001; 31: 147-50.
31. Choi D, Niedenfuhr MR, Vazquez T, Parkin I, Sanudo JR. Patterns of Connections Between the Musculocutaneous and Median Nerves in the Axilla and Arm. Clin. Anat.2002; 15: 11-7.
32. Oluyemi KA, Adesanya OA, Saalu CL, Okwuonu UC, Ofusori DA, Odion BI. Communication Between Median and Musculocutaneous Nerve and Accessory Head of Biceps Brachii: A Case Report. The Internet J. Surg. 2007; 2 (1). Available from: http://www.ispub.com/journal/the_internet_journal_of_surgery.
33. Niedenfuhr MR, Vazquez T, Parkin I, Logan B, Sanudo JR. Martin–Gruber Anastomosis Revisited. Clin. Anat. 2002; 15: 129-34.
34. Niedenfuhr MR , Vazquez T, Ferreira B, Parkin I, Nearn L, Sunudo JR. Intramuscular Martin – Gruber Anastomosis. Clin. Anat. 2002; 15: 135-8.
35. Stern JT. Upper limb. In: Essentials of Gross Anatomy. 1st ed. Philadelphia: Davis; 1988. p. 489-614.
36. Beheiry EE. Anatomical Variations of the Median Nerve Distribution and Communication in the Arm. Folia Morphol. 2004; 63 (3): 313-8.
37. Abhaya A, Khanna J, Prakash R. Variations of the Lateral Cord of Brachial Plexus Piercing Coracobrachialis Muscle. J. Anat. Soc. India 2003; 52(2): 168-70.
38. Flatow EL, Bigliani LU, April EW. An Anatomic Study of the Musculocutaneous Nerve and its Relationship to the Coracoid Process. Clin.Orthop.1989;244:166-71.
39. Hober PC, Rohrich RJ, Mickel TJ.The Coracobrachialis Muscle Flap for Coverage of Exposed Axillary Vessels: A Salvage Procedure. Plastic and Reconstructive Surgery.1990; 85 (5): 801-4.

40. Sud M, Sharma A. Absence of Musculocutaneous Nerve and the Innervation of Coracobrachialis, Biceps Brachii and Brachialis from the Median nerve. J. Anat. Soc. India. 2000; 49(2): 176-7.

41. Roy TS. Median Nerve Penetration by Muscular Branch of the Brachial Artery Clin. Anat. 2003; 16: 335-9.

42. Wadhwa S, Mehra S, Khan RQ, Kapoor V. Abnormal Musculoaponeurotic Tunnel in the Arm: Possible Entrapment of Median Nerve and Brachial Artery with High Origin of Nerve to Pronator Teres within the Tunnel. Clin. Anat. 2004; 17: 360-3.

43. Wehbe MA. Tendon Graft Donor Sites. J. Hand Surg. 1992; 17 : 1130-2.

44. Lam DSC, Ng JSK, Cheng GPM, Li RTH. Autogenous Palmaris Longus Tendon as Frontalis Suspension Material for Ptosis Correction in Children. Am. J. Ophthalmol. 1998; 126(1)**:** 109-15.

45. Milford L. Tendon Injuries. In: Crenshaw AH, Editor. Campbell's Operative Orthopaedics. Toronto. C.V. Mosby; 1987. p. 149-82.

46. Beris AE, Lykissas MG, Kontogeorgakos VA, Vekris MD, Korompilias AV. Anatomic Variations of the Median Nerve in Carpal Tunnel Release. Clin. Anat. 2008; 21: 514-8.

47. Tubbs RS, Salter EG. A Rare Finding of the Median Nerve in the Forearm. Clin. Anat.2006; 19: 704-5.

48. Sundarum SM, Kumar MSJ, Setupathi BB, Nayak SR, Krishnamurthy A. Split Median Nerve with Variation in its Common Digital Branch - A Case Report. Neuroanatomy. 2008; 7: 15-6.

49. Vollala VR, Potu BK. Additional Belly of Flexor Carpi Ulnaris Muscle Found in a South Indian Male Cadaver. The Internet Journal of Orthopaedic Surgery. 2007;

5(1). Available from:http://www.ispub.com/journal/the internet journal of orthopedic surgery.

50. Lingaraj K, Lim AY, Puhaindran ME, Kumar PV. The Split Flexor Carpi Ulnaris as a Local Muscle Flap. Clin. Orthop. Relat. Res. 2007; 455: 262-6.
51. Alves N, Candido PL, Frazao R. Innervation of the Pronator Teres Muscle. Int. J. Morphol. 2004; 22(3): 237-40.
52. Mohammed HM Badawoud. A Study on the Anatomical Variations of Median Nerve Formation. Bahrain Med Bull. 2003; 25(4).
53. Eglseder E, Goldman M. Anatomical Variations of the Musculocutaneous Nerve in the Arm. Am J Orthop 1997; 26(11):777-80.
54. Nakashima T. An Anatomic Study on the Martin-Gruber Anastomosis. Surg. Radiol. Anat.1993; 15(3): 193-5.
55. Le Minor, J M. A Rare Variation of the Median and Musculocutaneous Nerves in Man. Arch Anat Histol Embryol. 1990; 73: 33-42.
56. Gumusburun E, Adiguzel E. A Variation of the Brachial Plexus Characterized by the Absence of the Musculocutaneous Nerve- A Case Report. Surg. Radiol. Anat. 2000; 22(1): 63-5.
57. Beaton L E, Anson B J. The Relation of the Median Nerve to the Pronator Teres Muscle. Anat. Rec.1939; 75: 23-6.
58. Bergman RA, Afifi AK , Miyauchi R. Illustrated Encyclopedia of Human Anatomic Variation: Opus III: Nervous System: Plexuses Median Nerve. [updated 2001 Dec 4; cited 2009 Jan 9] Available from: http://medpro.smiletrain.org/library/images/vh094.htm

59. Guttenberg RAG, Ingolotti M. Classifying Musculocutaneous Nerve Variations. Clin. Anat. 2009; 22: 671- 83.

60. Dogan NU, Uysal II, Seker M. The Communications Between the Ulnar and Median Nerves in Upper Limb. Neuroanatomy. 2009; 8: 15-9.

61. Shu HS, Chantelot C, Oberlin C, Alnot JY, Shao H. Martin-Gruber Communicating Branch: Anatomical and Histological Study. Surg. Radiol. Anat. 1999; 21(2). Available from: http://www.springerlink.com/content/mw5074272753u3k3

62. Sebastin SJ, Puhaindran ME, Lim AYT, Lim IJ, Bee WH. The Prevalence of Absence of the Palmaris Longus – A Study in a Chinese Population and a Review of the Literature. J. Hand Surg.2005; 30 (5): 525-7.

63. Urban T, Krosman M. Variation of the Median Nerve in the Forearm and the Wrist. Folia. Morphol. 1992; 51 (1): 77-9.

64. Rader CP, Rehm KE, Koebke J. Anomalous Course and Anomalous Division of the Median Nerve in the Distal Forearm. Handchir Mikrochir Plast Chir. 1992; 24(5): 276-8.

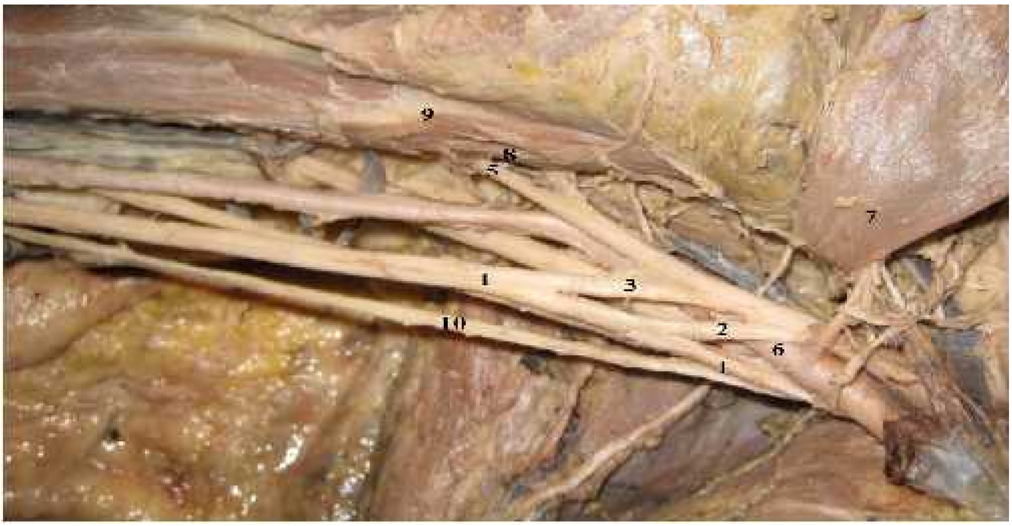
65. Imamura K. Anatomical Variations of the Recurrent Branch of the Median Nerve. J. Orthop. Traumatol. 2001; 50(1): 170-3.

66. Alp M, Marur T, Akkin SM, Yalcin L, Demirci S. Ramification Pattern of the Thenar Branch of the Median Nerve Entering the Thenar Fascia and the Distribution of the Terminal Branches in the Thenar Musculature: Anatomic Cadaver Study in 144 hands. Clin. Anat. 2005; 18(3): 195-9.

# ANNEXURE – 1

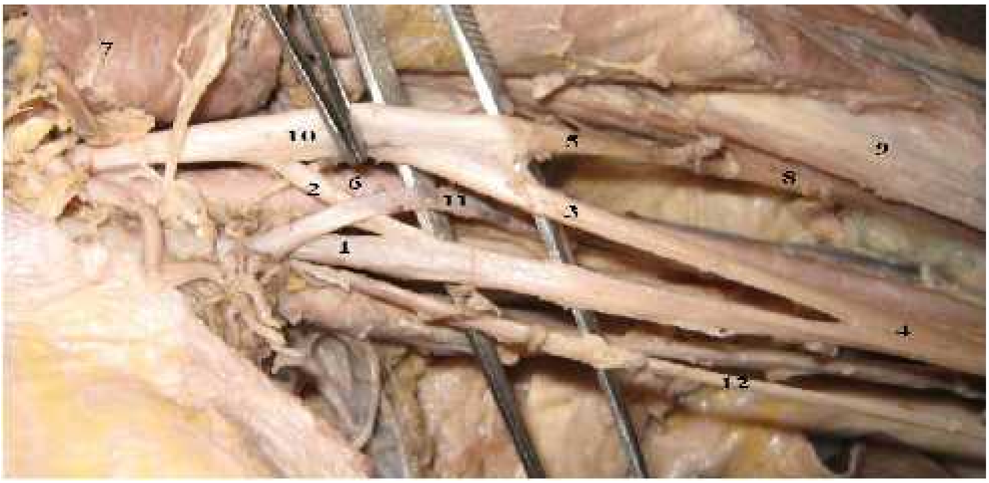
**Photograph- 1: Instruments used in the study**

**Photograph- 2: M N formation in axilla by three roots.**




1. Medial root of MN
2. Lateral root of MN
3. Second lateral root
4. Median nerve
5. MCN
6. Axillary artery
7. Pectoralis minor
8. Coracobrachialis
9. Biceps brachii
10. Ulnar nerve

**Photograph - 3: M N formation in upper third of arm by three roots and vena comitans passing through a loop formed by the two lateral roots.**



1. Medial root
2. Lateral root
3. Second lateral root
4. Median nerve
5. MCN
6. Axillary artery
7. Pectoralis minor
8. Coracobrachialis
9. Biceps brachii
10. Lateral cord
11. Vena comitans
12. Ulnar nerve

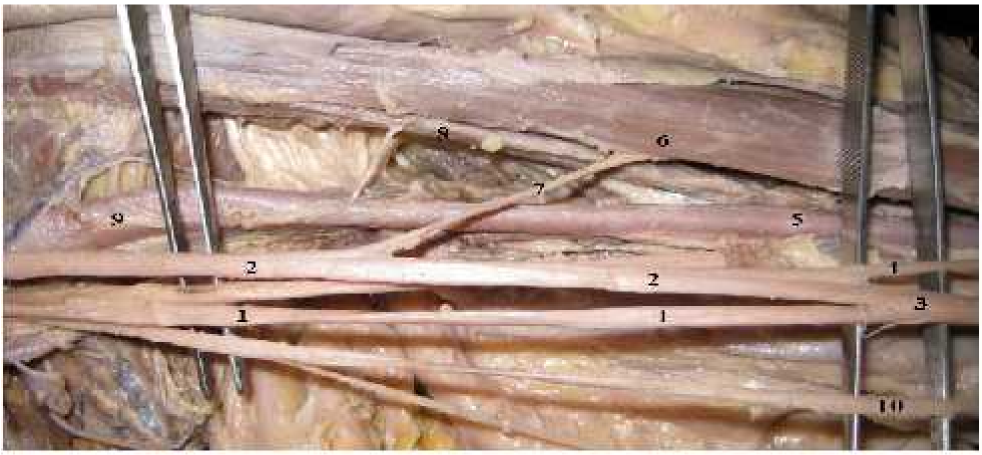
**Photograph- 4: Absence of MCN. Median nerve formation in upper third of arm by three roots and vena comitans passing through a loop formed by two lateral roots of MN.**

1. Medial root of MN
2. Lateral root of MN
3. Second lateral root
4. Median nerve
5. Axillary artery
6. Vena comitans
7. Nerve to C B
8. Biceps brachii
9. Lateral cord

**Photograph- 5: M N formation in middle third of arm and high division of brachial artery.**

| | |
|---|---|
| 1. Medial root of MN | 5. Ulnar nerve |
| 2. Lateral root of MN | 6. Brachial artery |
| 3. Median nerve | 7. Ulnar artery |
| 4. M C N | 8. Radial artery |

**Photograph- 6: M N formation in lower third of arm & absence of MCN. Nerve to B B and LCN of forearm given by lateral root of MN.**

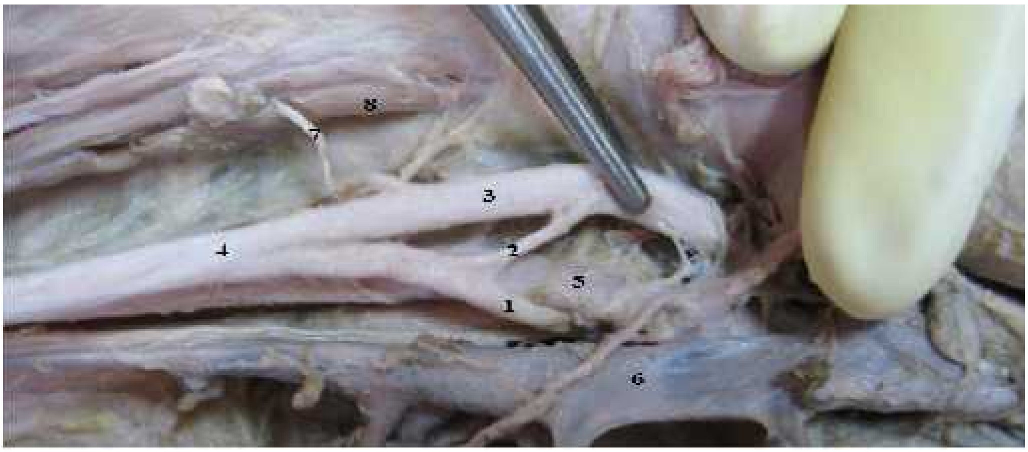


| | |
|---|---|
| 1. Medial root of MN | 6. Biceps brachii |
| 2. Lateral root of MN | 7. Nerve to B B |
| 3. Median nerve | 8. Coracobrachialis |
| 4. L C N of forearm | 9. Axillary artery |
| 5. Brachial artery | 10.Ulnar nerve |

**Photograph- 7: Absence of MCN. Biceps brachii, CB and brachialis muscles supplied by median nerve.**

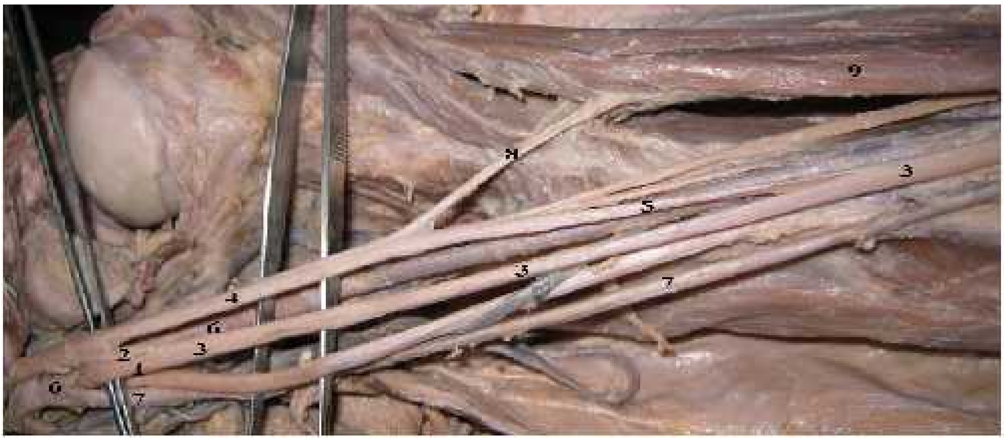
1. Medial root of MN
2. Lateral root of MN
3. Median nerve
4. Axillary artery
5. Biceps brachii
6. Coracobrachialis
7. Nerve to C B
8. Nerve to B B
9. Nerve to brachialis
10. Axillary vein

**Photograph- 8: Absence of MCN & formation of MN in axilla by three roots with very thin lateral root and significantly thick second lateral root.**



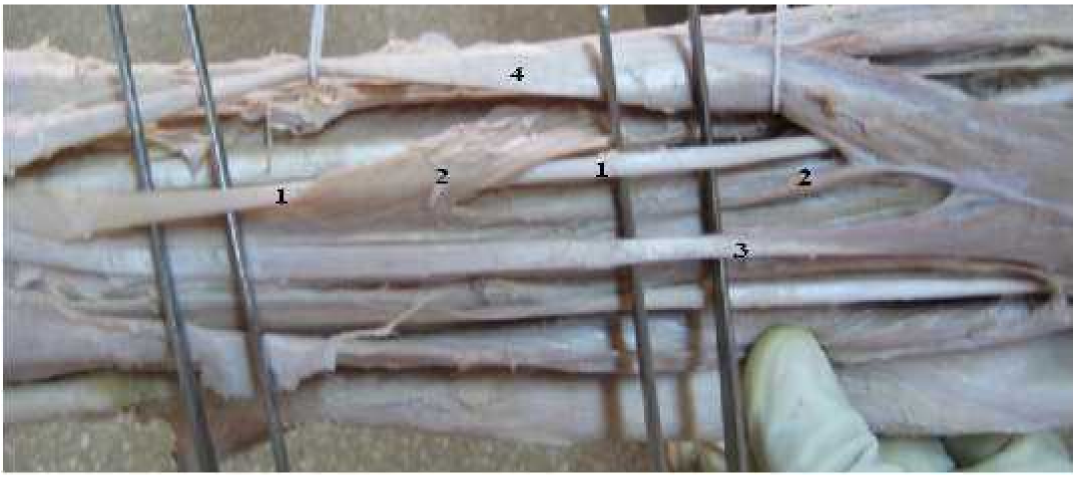
1. Medial root of MN
2. Lateral root of MN
3. Second lateral root of MN
4. Median nerve
5. Axillary artery
6. Axillary vein
7. Nerve to CB
8. Coracobrachialis

**Photograph- 9: Communication between MN and MCN and high division of axillary artery.**




1. Medial root of MN
2. Lateral root of MN
3. Median nerve
4. M C N
5. Communicating branch
6. Axillary artery
7. Radial artery
8. Nerve to B B
9. Biceps brachii

**Photograph- 10: M N appearing superficial in the middle third of forearm.**

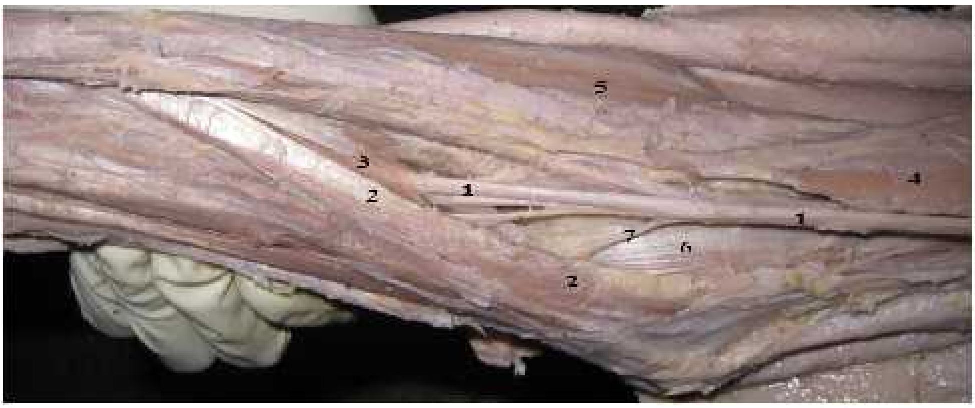



1. Median nerve
2. Flexor digitorum superficialis
3. Palmaris longus
4. Flexor carpi radialis

**Photograph- 11: M N passing between two heads of pronator teres.**

1. Median nerve
2. Humeral head of P T
3. Ulnar head of P T
4. Brachial artery
5. Ulnar artery
6. Radial artery
7. Brachialis
8. Brachioradialis

**Photograph- 12: M N passing through ulnar head of pronator teres.**

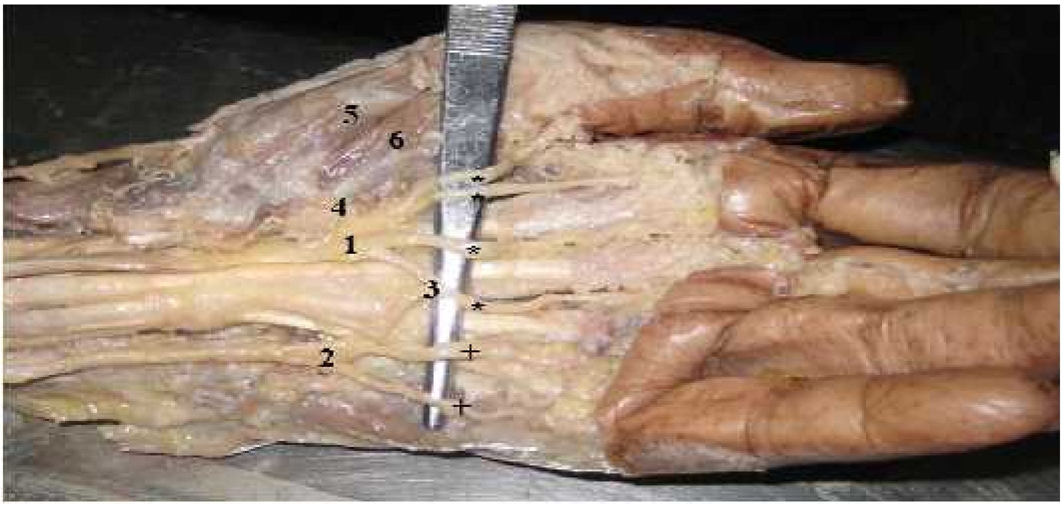


1. Median nerve
2. Humeral head of P T
3. Ulnar head of P T
4. Biceps brachii
5. Brachioradialis
6. Brachialis
7. Nerve to P T

**Photograph- 13: M N passing below humeral head of pronator teres, ulnar head being absent.**

| | |
|---|---|
| 1. Median nerve | 4. Nerve to P T |
| 2. Humeral head of P T | 5. Brachialis |
| 3. Flexor carpi radialis | 6. Brachioradialis |

**Photograph- 14: M N termination into 4 branches and communication with ulnar nerve**



| | |
|---|---|
| 1. Median nerve | 5. Opponens pollicis |
| 2. Ulnar nerve | 6. Flexor pollicis brevis |
| 3. Communication between M N& U N | * Digital branches of M N |
| 4. Recurrent muscular branch | + Digital branches of UN |

| Master chart showing the important parameters studied | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Sp. No.** | **Sex** | **Side** | **Formation** | **Course** | **Branching** | **Termination** | **Communication** |
| 1 | M | R | 3 Roots. Medial to Axillary artery | Medial to Brachial artery | Normal | Normal | With MCN |
| 2 | M | L | 2 Roots | Deep to PT | Normal | Normal | With UN in forearm |
| 3 | M | R | 2 Roots | Normal | Normal | Normal | Normal |
| 4 | M | L | 2 Roots | Normal | Normal | Normal | Normal |
| 5 | M | R | 3 Roots | Normal | Normal | Normal | With UN in forearm |
| 6 | M | L | 3 Roots | Normal | Normal | Normal | With MCN |
| 7 | M | R | 2 Roots | Normal | Normal | Normal | Normal |
| 8 | F | L | 2 Roots | Normal | Normal | Normal | Normal |
| 9 | F | R | 2 Roots | Normal | Normal | Normal | Normal |
| 10 | M | L | 2 Roots Medial to axillary Artery | Medial to Brachial artery | Normal | In hand by 4 branches | Normal |
| 11 | M | R | 3 Roots | Normal | Normal | Normal | Normal |
| 12 | M | L | 2 Roots | Normal | Normal | Normal | Normal |
| 13 | M | R | 2 Roots Anterior to Axillary artery | Piercing FDS | Normal | Normal | Normal |
| 14 | M | L | 2 Roots | Normal | Normal | Normal | Normal |
| 15 | M | R | 3 Roots | Normal | Normal | Normal | Normal |
| 16 | F | L | 2 Roots | Normal | Normal | Normal | Normal |
| 17 | F | R | 2 Roots. Middle third of arm | Normal | Normal | Normal | Normal |
| 18 | M | R | 2 Roots | Through Ulnar head of PT | # | In hand by 3 branches | With UN in hand |
| 19 | M | L | 2 Roots | Normal | Normal | Normal | Normal |
| 20 | M | L | 3 Roots. Upper third of arm | Normal | Normal | Normal | Normal |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 21 | M | R | 2 Roots | Normal | Normal | In forearm | With UN in forearm |
| 22 | M | R | 2 Roots | Normal | # | Normal | Normal |
| 23 | M | L | 2 Roots. Lower third of arm. | Medial to Brachial artery | #, brs were from lateral root of MN | Normal | Normal |
| 24 | M | L | 3 Roots | Normal | Normal | Normal | Normal |
| 25 | F | L | 2 Roots Anterior to Axillary artery | MN becomes superficial in middle third of arm. | Normal | Normal | With MCN |
| 26 | F | R | 2 Roots | Normal | Normal | Normal | Normal |
| 27 | M | R | 2 Roots | Normal | Normal | Normal | Normal |
| 28 | M | L | 3 Roots | Deep to PT | Normal | Normal | Normal |
| 29 | M | R | 2 Roots | Piercing FDS | Normal | Normal | With MCN |
| 30 | M | L | 2 Roots | Normal | Normal | Normal | Normal |
| 31 | M | R | 3 Roots | * | Normal | Normal | Normal |
| 32 | M | L | 2 Roots | Normal | Normal | In forearm | Normal |
| 33 | M | R | 2 Roots Anterior to Axillary artery | Normal | Normal | Normal | Normal |
| 34 | M | L | 3 Roots | Normal | Normal | Normal | With UN in forearm |
| 35 | M | L | 3 Roots | * | Normal | Normal | Normal |
| 36 | M | L | 2 Roots | Through Ulnar head of PT | Normal | Normal | With MCN |
| 37 | M | R | 2 Roots | Normal | Normal | Normal | Normal |
| 38 | M | L | 2 Roots | Normal | Normal | Normal | Normal |
| 39 | M | R | 2 Roots Anterior to Axillary artery | Normal | Normal | Normal | Normal |
| 40 | M | R | 3 Roots | Normal | # | Normal | Normal |
| 41 | M | R | 2 Roots | Normal | Normal | Normal | Normal |
| 42 | M | L | 2 Roots | Normal | Normal | Normal | Normal |
| 43 | M | R | 2 Roots | Normal | Normal | Normal | Normal |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 44 | M | L | 2 Roots | Normal | Normal | In hand by 4 branches | With UN in hand |
| 45 | M | R | 3 Roots | Normal | # | In hand by 5 branches | With UN in hand |
| 46 | F | L | 2 Roots | Normal | Normal | Normal | Normal |
| 47 | F | R | 2 Roots | Normal | Normal | Normal | Normal |
| 48 | M | L | 2 Roots | Normal | Normal | Normal | With MCN |
| 49 | M | L | 2 Roots | Normal | Normal | Normal | Normal |
| 50 | M | R | 2 Roots. Anterior to Axillary artery | Normal | # | In hand by 3 branches | With UN in hand |

* Deep to humeral head of pronator teres, ulnar head being absent.

#Branches to BB, CB & Brachialis given by MN. MCN being absent.

High division of Brachial artery was found in specimen no. 17.

High division of Axillary artery was found in specimen no. 25.