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Original article:

An evaluation of the system of classifications of the median and musculocutaneous nerves: A study in West Bengal population

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Abstract:

Introduction: Anomalies of the brachial plexus are of interest to academicians and clinicians. The present study provides an assessment concerning the present classification criteria of median & musculocutaneous nerve among the Eastern Indian population. The related causative factors, developmental background and clinical relevance have also been elaborated.

Methods: Meticulous dissection of brachial plexus was performed bilaterally on 54 embalmed adult human cadavers in selected Medical colleges in West Bengal as a part of the undergraduate medical curriculum.

Results: Among 41male cadavers (75.93%), 6 cases (14.63%) were found on the right side and 3 cases (7.32%) on the left side. Among the females, only 1 case (7.69%) was found on the right side. The average distances (±Standard Deviation) of formation of median and musculocutaneous nerves and nerve to coracobrachialis, biceps brachii, brachialis from tip of coracoid process were 2.83(±0.65)cm, 4.55(±1.41)cm, 4.27(±0.42)cm, 7.65(±0.43)cm and16.04(±1.04)cm respectively. Arterial relations as well as side and gender predisposition of the anomalies were also tabulated.

Conclusion: The median & musculocutaneous nerves as well as their different muscular branches in the arm vary considerably in levels of origin, location and course which have paramount clinical significance. The prevalent classification system may be revised in the background of distinctive new pattern of anomalies.

Key words: Brachial Plexus, Median Nerve, Musculocutaneous Nerve, Anatomical variations, Le Minor Classification.

Introduction:

The median nerve is formed in the axilla by the union of lateral and medial roots. The medial root originates from the medial cord of the brachial plexus. The lateral cord of the brachial plexus divides into the lateral root of the median nerve and the musculocutaneous nerve.[1, 2] After their origin from the brachial plexus, the median and musculocutaneous nerves pass through the anterior compartment of the arm without receiving any branch from any nerve in the neighbourhood.[1,2] In the arm, the musculocutaneous nerve passes through the coracobrachialis muscle and innervates the coracobrachialis, biceps brachii and brachialis muscles and continues as the lateral cutaneous nerve of the forearm without any communication with the median or other nerves.[1, 2]

This work has been designed to obtain data on the prevalence and pattern of anomalies from the native population of West Bengal, India. Though several isolated case reports have been presented earlier, no comprehensive analytical study has been so far undertaken in this unmapped population to explore the anatomical variations of median and musculocutaneous nerves with respect to their classification criterion, point of formation, course and entrance into brachial musculature, relation to axillary artery as well as gender and side predisposition. The developmental background, causative factors and clinical significance have also been elaborated in details.

Material & Methods:

To cover maximum of the population of West Bengal, India, a cross-sectional hospital based study was carried out in several medical colleges. Among a total of six Medical colleges in Kolkata, for feasibility, this study was conducted in Calcutta National Medical College, Medical College, Kolkata & Institute of Postgraduate Medical Education and Research with huge drainage areas of southern and eastern part of West Bengal. To cover the western and northern population of West Bengal, Bankura Sammilani Medical College and North Bengal Medical College situated in Darjeeling district were chosen. Routine dissection of brachial plexus was performed on 54 embalmed adult human cadavers at the Department of Anatomy of the selected Medical colleges in West Bengal during a study period of August 2007-October2011 as a part of the undergraduate medical curriculum. The brachial plexuses were dissected bilaterally and examined for any anatomical variations of the median nerve and musculocutaneous nerve formation. The gender and side of occurrence of the variations were carefully recorded. Level of formation and course of the median and musculocutaneous nerve with branches were dissected meticulously, traced and photographed.

The point of entrance of nerve to corachobrachialis, biceps brachii and brachialis were measured from the tip of coracoid process. The site of formation of median nerve was also measured separately from the tip of the coracoid process and from the midpoint of a line joining the epicondyles of humerus. To obtain an accurate measurement of the topographical variation of the nerves, the two designated points were marked by two pins and connected by a thread. The distance between the two pins were precisely measured along that thread with a metric scale to the nearest millimeter. [**Fig-1**] The obtained data was methodically charted in a Microsoft Excel worksheet and evaluated by standard statistical methods.

Moreover, the relationship with the axillary artery and intercommunications between the two nerves were also documented. According to Standring S et al., the lateral or anterior position of the median nerve in relation to the axillary artery is usually considered a normal anatomical entity.[1] Consequently, the formation of median nerve at the medial side of the axillary artery was only considered as an anomalous case.

Results:

Out of 54 cadavers, 41 cadavers (75.93%) were male and 13 cadavers (24.07%) were female. Most of the study population belonged to 70 years (16.7% cases) with a mean age of 61.76 years and standard deviation of 6.69 years (Range: 50-73 years). Out of 108 upper limbs, variations of were found in 10 cases (9.26%). Among the males, 6 cases (14.63%) were found on the right side and 3 cases (7.32%) on the left side. Among the females, only 1 case (7.69%) was found on the right side. In rest of the cases no abnormalities were found. No single case of bilateral variation was found in the present study.

In the 108 upper limbs following interesting variations were found unilaterally:

Case 1: Multiple neurovascular abnormalities were encountered on the right upper limb of a 65 years old male cadaver. Formations of upper, middle and lower trunks were normal (from C5-T1). Anterior division of the upper trunk continued as the musculocutaneous nerve distally. The lateral root of the median nerve was formed from the anterior division of the middle trunk instead of arising from the lateral cord. Anterior division of the lower trunk continued as medial cord which contributed to the formation of the medial root of the median nerve as usual but at a much higher level. Posterior divisions of all three trunks united to form the posterior cord which continued as radial nerve as usual. [**Fig-2**] The median nerve of right upper limb was formed at an unusual high level. Union of the lateral and medial root of the median nerve was found just below and behind the clavicle. At the level of formation, both the roots of median nerve and the nerve itself were medial to the first part of the axillary artery. Median nerve in its subsequent course was also medial to axillary artery. About 1.5 cm distal to its formation, the median nerve gave a branch which crossed the second part of the axillary artery and innervated the coracobrachialis muscle from its proximal part.

The branch of the median nerve supplying coracobrachialis was dissected very carefully with removal of epineurium and it was found that both roots of the median nerve [**Fig-3**] contributed fibres for its formation though major part of the contribution was from the lateral root of the median nerve. So, the coracobrachialis muscle was supplied by the musculocutaneous nerve and supplemented by an additional branch from the median nerve carrying fibres from C7, C8, and T1. [**Fig-3**] Other branches of different cords were normal.

Case 2: Routine undergraduate dissection of a 50 years male revealed a right sided anomaly of the musculocutaneous and the median nerve. The median nerve was joined by an intercommunicating branch from the musculocutaneous nerve about 9.8cm above the midpoint of a line passing through the epicondyles of humerus. Biceps brachii and brachialis muscles were supplied by the musculocutaneous nerve before its communication with the median nerve. [**Fig-4**]However, coracobrachialis was not pierced by the musculocutaneous nerve and was supplied by an unusual twig from the musculocutaneous nerve. [**Fig-5**]

Case 3: An exceptional neurovascular anomaly was observed during routine cadaveric dissection of a 62 years old female cadaver. Median nerve was formed by union of two roots at the medial side of axillary artery. The musculocutaneous nerve was seen to be absent in the right upper arm, associated with an unusual high origin of the radial artery 15.7cm from the midpoint of the same line passing through the epicondyles of humerus and unilateral anomalous bifurcation of the brachial artery into an ulnar branch and a prominent aberrant artery entering the brachioradialis in the forearm. The lateral cutaneous nerve of the forearm also arose from the median nerve in the forearm. [**Fig-6**]

Case 4: A similar anomaly was observed during routine cadaveric dissection of a 70 years old male cadaver in which the musculocutaneous nerve was absent in the right upper arm and the median nerve formed the stand in supply of the flexors of the arm and forearm, as well as for the lateral cutaneous nerve of forearm.[**Fig-7**]

Case 5: Another aberration was recorded during routine cadaveric dissection of a 65 years old male cadaver. The musculocutaneous nerve on the left side was formed by the union of two nerves arising from the lateral cord of brachial plexus. [**Fig-8**]

Case 6: A communicating branch between median and musculocutaneous nerve was found in the left upper limb of a 61 years old male cadaver distal to coracobrachialis muscle. The formation of median nerve took place at the medial side of axillary artery. [**Fig-9**]

Case 7: Another variation was observed in the right upper limb of a 65 years old male cadaver where the lateral cord continued distally as musculocutaneous nerve and the lateral root of median nerve branched out from the musculocutaneous nerve 5.2cm distal to the coracoid process. [**Fig-10**]

Case 8: Aberrations similar to the second case were observed in the left upper limb of a 58 years old male cadaver. The musculocutaneous nerve did not pass through the coracobrachialis muscle after its origin from the lateral cord and joined with the median nerve about 9.5cm distal to a line connecting the epicondyles of humerus. Muscular branch to coracobrachialis, biceps brachii and brachialis arose from the median nerve. [**Fig-11**]

Case 9: A case of anomalous origin of musculocutaneous nerve was found in the right upper limb of a 70 years old male cadaver where the nerve arose from the median nerve about 4.6cm distal to coracoid process and 0.3cm away from the site of formation of median nerve.The lateral cord of brachial plexus continued distally as lateral root of the median nerve which supplied the coracobrachialis muscle by two branches. The biceps brachii and brachialis muscles were supplied by the musculocutaneous nerve as usual. [**Fig-12**]

Case 10: In another case two distinct lateral roots of median nerve were observed on the right side of a 63 years old male cadaver, where the proximal root arose from the lateral cord as usual but the distal root branched out from the musculocutaneous nerve 4.5cm distal to the coracoid process. [**Fig 13**]

The mean topographical variation of the point of entrance of different muscular branches in the arm derived either normally from the musculocutaneous nerve or anomalously from the median nerve were measured distal to the tip of the coracoid process. According to our observations, the anatomical sequence of the innervations of the arm started proximally with that to the coracobrachialis and was followed distally by that to biceps brachii and brachialis muscles. The result of those measurements is depicted in **Table-I**.

The anatomy of the musculocutaneous nerve was also investigated separately to determine its relationship with the coracoid process. In the present study, musculocutaneous nerve pierced the coracobrachialis muscle in 105 upper limbs (97.22%). In these cases, the mean distance from the tip of the coracoid process to the point of entrance of the main trunk into the muscle was 4.33cm with standard deviation of 0.62cm (range 2.6-7.8 cm). Moreover, the average distance of origin of the musculocutaneous nerve from the tip of the coracoid process was 2.83 cm with standard deviation of 0.65cm (range: 1.7-4.2cm) and the commonest distance was 2.2cm (9.3% cases). The result is depicted in **Table-II** according to gender and side. A significant difference was observed in the mean distance of origin of the musculocutaneous nerve among males & females ($p<0.05$). Interestingly, in Case No: 7 the lateral root of the median nerve originated much lower [5.2cm] as against our highest recorded origin [4.2cm] of the musculocutaneous nerve and the lateral root of median nerve. Consequently, we considered the musculocutaneous nerve as a continuation of the lateral cord of brachial plexus and the lateral root as an anomalous branch of the musculocutaneous nerve. Another case of low origin was also recorded in Case No: 9 where the musculocutaneous nerve arose from the median nerve about 4.6cm distal to coracoid process.

In the present study the average distance of the site of formation of the median nerve from the coracoid process was 4.55cm with standard deviation of 1.41cm (range: 1.5-8cm) and in majority of the cases (13%) the distance was 4.5cm. According to Malukar and Rathava (2011) the mean distance from the coracoid process was 5.7cm which was higher than that of the present study.[3]

Formation of median nerve in relation to axillary artery was also observed and documented according to gender and side [**Table-III**] **[Fig 14]**. According to the present study lateral side was the commonest position while medial side was the least documented position.

Discussion:

Previous studies have been carried out amongst people of various countries and ethnicities and the results of the prevalence values of the anomalies have been noted to vary as wide as 6 – 68%, which is higher than that of the present study(4.6%).[4, 5] Moreover, a higher prevalence was noted for the males (4.9%) in comparison to females (3.8%) in this study in agreement to Choi et al. [6]However, unlike Choi et al, a higher prevalence of the variations were noted to occur more on the right arm (7.4%) than on the left (1.9%).The communications between median and the musculocutaneous nerves have been classified into five types according to Le Minor (1992).[7]

- Type I: No communication between the median and the musculocutaneous Nerve.

  In the present study, Type I variety of Le Minor classification was represented by all normal and aberrant anatomical configurations that did not show any intercommunication. [Fig 15]

- Type II: The fibres of the medial root of the median nerve pass through the musculocutaneous nerve and join the median nerve in the middle of the arm.

  In the present study, no representative case characterized the Type II variation.

  Type III: The fibres of the lateral root of the median nerve pass along the musculocutaneous nerve and after some distance leave it to form the lateral root of the median nerve.

  In the present study, Case No: 7& 10 somewhat signified the Type III variability. [Fig 16]

  However, this category is ambiguous as is does not clarify the specific point of emergence of the musculocutaneous nerve or the lateral root of median nerve. Thus consideration of the lateral root is often deceptive in most of the cases which is thought to represent Type III variety.

- Type IV: The Musculocutaneous nerve fibres join the lateral root of the median nerve and after some distance the musculocutaneous nerve arises from the Median nerve.

  In the present study, Case No: 9 mirrored the Type IV variability. [Fig 12]

- Type V: The Musculocutaneous nerve is absent and the entire fibres of the musculocutaneous nerve pass through the lateral root and fibres to the muscles supplied by musculocutaneous nerve branch out directly from the median nerve.

  In the present study, Case No: 3 & 4 represented the Type V variability. [Fig 17]

Interestingly, Case No: 8 could not be perfectly matched under any of the categories in this classification system. In this case, the musculocutaneous nerve originated independently and rejoined the median nerve in the middle third of the arm without any intercommunication. This formation is entirely distinct from the Type I configuration and may be regarded as a new category in the classification.

Venieratos and Anangnostopoulou (1998) described only three types of communications between the musculocutaneous nerve and median nerve in relation to the coracobrachialismuscle.[8]

- Type I: Communication between musculocutaneous nerve and median nerve is proximal to the entrance of the musculocutaneous nerve into the coracobrachialis.
- Type II: The communication is distal to the muscle. In the present study Case No: 6 characterized the type II variability. [Fig 9]
- Type III: Neither the nerve nor its communicating branch pierces the muscle.

In the present study Type III was represented moderately by Case No: 2 & 8. [Fig 18]

The Le Minor classification (1992) does not clarify the status of the nerves and their intercommunicating branches beyond their points of emergence. On the other hand Venieratos and Anangnostopoulou (1998) are silent on the anomalous cases in which coracobrachialis is absent or is not pierced by the musculocutaneous nerve. Hence both the classification systems may not be all inclusive and leaves a scope of revision by further documented studies to encompass all the variable cases.

Chauhan and Roy (2002) advocated the interpretation of the nerve anomalies of the upper limb and communication between the musculocutaneous and median nerve as a remnant from the phylogenetic point of view. [9]Comparative studies of primitive nerve supply of the anterior brachial muscles in monkeys and in some apes have observed the existence of such connections.[10]It is reported that there was only one trunk equivalent to the median nerve in the thoracic limb of the lower vertebrates (amphibians, reptiles and birds). In the context that ontogeny recapitulates phylogeny, it is possible that the cords of the brachial plexus in higher vertebrates originated from a single mother trunk and hence aberrant intercommunications involving the daughter branches are encountered in variable degrees.[9]

Alternatively, the variation could arise from circulatory factors at the time of fusion of the cords of the brachial plexus.[11]Variations in the brachial plexus in the neck and upper part of the axilla may reflect its relation to the subclavian and axillary arteries. This arterial stem is normally derived from the 7th segmental branch of the dorsal aorta, and therefore normally passes between the lateral and medial cords, representing 5th, 6th, and 7th cervical nerves on one hand and 8th cervical and 1st thoracic on the other. Sometimes, however the subclavian-axillary stem is derived from the 6th, 8th or the 9th segmental artery, and it then has abnormal relations to the brachial plexus, and the plexus is in turn modified by the presence of the abnormally placed artery.[2]

In man, the forelimb muscles develop from the mesenchyme of the para-axial mesoderm during fifth week of embryonic life.[12]The ventral ramus axons destined for the limbs apparently travel to the base of the limb bud by growing along permissive pathways. Once the motor axons arrive at the base of the limb bud, they mix in a specific pattern to form the brachial plexus. This zone thus constitutes a decision making region for the axons.[12]Once the axons have sorted out in the plexus, the growth cones continue into the limb bud in the general direction of the appropriate muscle compartment. Axon guidance is thought to involve multiple short range local guidance factors and long range diffusible signals.[1]Short range signals require factors which are displayed on cell surfaces or in the extracellular matrix while long range cues come from gradients of specific factors diffusing from distant targets, which cause neurons to turn their axons towards the source of the attractive signal. These forces are thought to act in vivo in a dynamic process to ensure the correct passage of axons to their final destinations and to mediate their correct bundling.[1]The motor neurons that innervate the limb bud develop in the lateral medial columns (LMC) within the neural tube in response to retinoic acid signaling from the paraxial mesoderm. The timing of subsequent in growth into the limb bud is determined by signals from the limb mesenchyme such as Ephrin and Semaphorin 3A.[12]As the guidance of the developing axons is controlled in a highly synchronized site specific fashion, any alterations in signaling between mesenchymal cells and neuronal growth cones can lead to major abnormalities.[9,13] Once formed, any developmental modifications would evidently exist in the adult life.[9,14]Such information is also important for suturing of intercostal nerve to motor branches of biceps and brachialis for elbow flexion in brachial plexus injuries.[15]

Damage to the brachial plexus could occur in cases of open or closed injuries to the arm, such as grievous injuries or surgeries on the axilla or arm. The level of formation of the median nerve and its relation with the axillary vessels is important defining the limits for axillary lymph node and radical neck dissection. In atypical neural presentations and communications, injury to the median nerve and/or the roots may occur, with subsequent debility of the brachial flexors. Lesions of the communicating nerve may give rise to incomprehensive patterns of weakness that may impose a diagnostic predicament e.g. lesion of musculocutaneous nerve proximal to the anastomotic branch between musculocutaneous nerve and median nerve may lead to atypical and infrequent presentation of paresis or paralysis of the flexor musculature and thenar muscles[9,16]Deviations in intercommunication between musculocutaneous and median nerve may also have some implication in diagnostic clinical neurophysiology.[9, 6]

Conclusion:

This study indicates that the median and musculocutaneous nerve vary considerably in levels of formation, location, relation, course and interc-ommunicating branch/branches which have param-ount anatomical, surgical and neurophysiological significance. This study has also made an original attempt to numerically define a specific point of origin of the musculocutaneous nerve and the lateral root of the median nerve, thereby highlighting the fallacies in the existing classification systems. The authors also propose a window for further research related to revision of the present classifications to include the new and distinctive category of nerve anomalies that have remained hitherto unrepresented as in the present study.

Fig-1: Method of measurement of distance between A & B by using a metric scale.

Fig-1:
A= At the tip of the coracoids process.
B= At the formation of median nerve.

Fig-2: shows musculocutaneous nerve as continuation of anterior division of upper trunk along with atypical formation of median nerve.

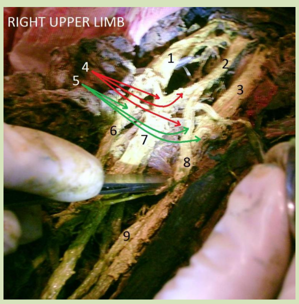


Fig-2:
1 = Upper trunk, 2 = Middle trunk, 3= Lower trunk, 4= Posteriordivisions of all trunks, 5= Anteriordivisions of all trunks, 6= Musculocutaneous nerve, 7= Posterior cord, 8= Median nerve, 9= Ulnar nerve.

Fig-3: shows double nerve supply of Coracobrachialis muscle from musculocutaneous nerve & an additional branch from median nerve.

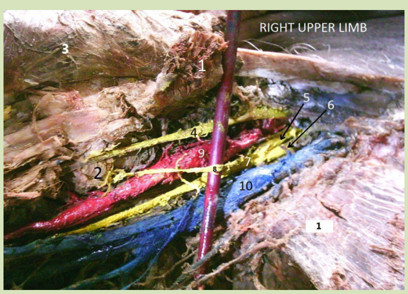


Fig-3:
1=Pectoralis minor muscle (cut ends), 2= Coracobrachialis, 3= Pectoralis major (reflected upwards), 4= Musculocutaneous nerve, 5=Lateral root of median nerve, 6=Medial root of median nerve,7= Median nerve, 8= Additional branch of median nerve supplying coracobrachialis, 9= Axillary artery, 10= Axillary vein.

Fig-4: shows intercommunicating branch between median and musculocutaneous nerves at the middle of the arm.

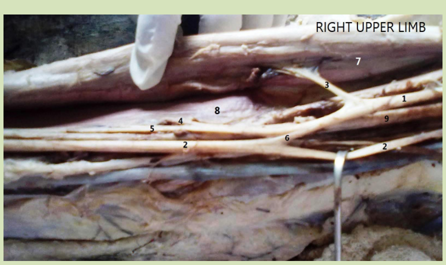


Fig-4:
1= Musculocutaneous nerve, 2= Median nerve, 3=Nerve supply to biceps brachii,4= Nerve supply to brachialis,5= Lateral cutaneous nerve of forearm,6=Communicating branch between median and musculocutaneous nerves,7=Biceps brachii,8=Brachialis,9= Axillary artery.

Fig-5: shows coracobrachialis muscle not pierced by musculocutaneous nerve.

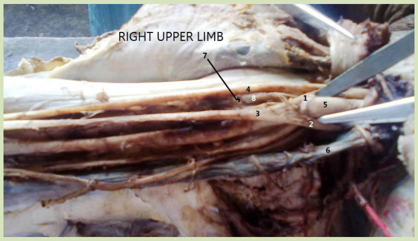


Fig-5:
1= Lateral root of median nerve, 2=Medial root of median nerve, 3= Median nerve, 4= Musculocutaneous nerve, 5= Axillary artery, 6= Axillary vein,7= Branch from musculocutaneous nerve supplying coracobrachialis, 8= Coracobrachialis muscle.

Fig-6: shows absence of musculocutaneous nerve.

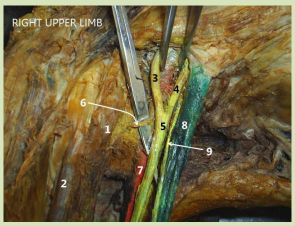


Fig-6:
1= Coracobrachialis, 2= Biceps brachii, 3= Lateral root of median nerve, 4=Medial root of median nerve, 5= Median nerve, 6=Nerve supply to coracobrachialis arising from the median nerve, 7=Axillary artery, 8= Axillary vein, 9= Medial cutaneous nerve of forearm.

Fig-7: shows absence of musculocutaneous nerve.

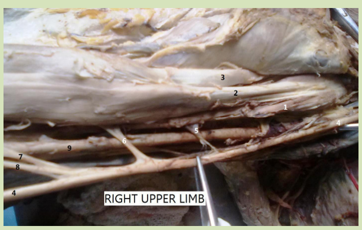


Fig-7:
1= Coracobrachialis, 2= Long head of biceps brachii, 3=short head of biceps brachii, 4= Median nerve, 5= Nerve supply to coracobrachialis, 6= Nerve supply to biceps brachii, 7= Nerve supply to brachialis, 8= Lateral cutaneous nerve of forearm, 9= Axillary artery.

Fig-8: shows formation of musculocutaneous nerve by union of two branches from lateral cord.

Fig-8:
1& 2=Branches of lateral cord forming musculocutaneous nerve, 3= Musculocutaneous nerve, 4= Lateral root of median nerve, 5=Medial root of median nerve, 6= Median nerve, 7= Axillary artery, 8= Axillary vein.

Fig-9: shows communicating branch between median and musculocutaneous nerves distal to coracobrachialis.

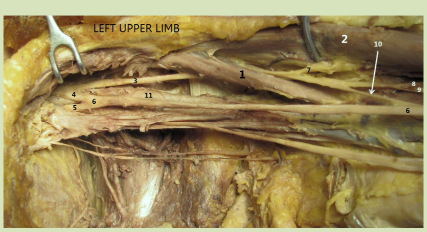


Fig-9:
1= Coracobrachialis, 2= Biceps brachii, 3= Musculocutaneous nerve, 4=Lateral root of median nerve, 5=Medial root of median nerve, 6= Median nerve, 7=Nerve supply to biceps brachii, 8= Nerve supply to brachialis, 9= Lateral cutaneous nerve of forearm, 10= Communicating branch between median and musculocutaneous nerves, 11= Axillary artery.

Fig-10: shows lateral root of median nerve arising from the musculocutaneous nerves

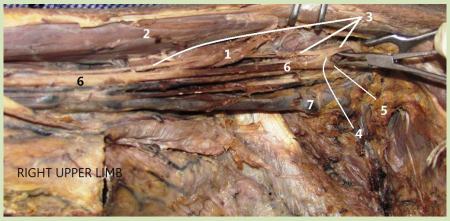


Fig-10:
1= Coracobrachialis, 2= Biceps brachii, 3= Musculocutaneous nerve, 4=Lateral root of median nerve, 5=Medial root of median nerve, 6= Median nerve, 7= Axillary vein.

Fig-11: shows union of median and musculocutaneous nerves in upper part of left arm.

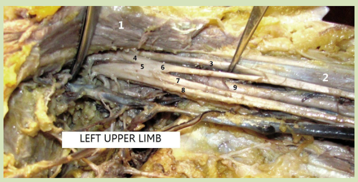


Fig-11:
1=Pectoralis major, 2= Biceps brachii, 3= Musculocutaneous nerve, 4=Lateral root of median nerve, 5=Medial root of median nerve, 6= Median nerve, 7=Ulnar nerve, 8=Medial cutaneous nerve of the forearm, 9= Axillary artery.

Fig-12: shows origin of musculocutaneous nerve from the median nerve.

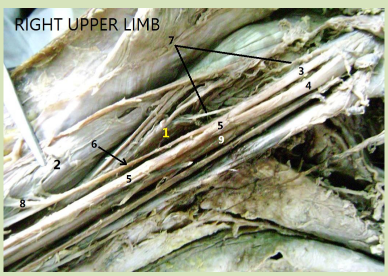


Fig-12:
1= Coracobrachialis, 2= Biceps brachii, 3=Lateral root of median nerve, 4=Medial root of median nerve, 5= Median nerve, 6= Musculocutaneous nerve, 7=Muscular branches to coracobrachalis from the lateral root of median nerve, 8=Nerve to biceps brachii, 9= Axillary artery.

Fig-13: shows additional lateral root of median nerve from the musculocutaneous nerve.

Fig-13:
1= Lateral cord, 2= Musculocutaneous nerve, 3= Lateral root of median nerve, 4=Medial root of median nerve, 5= Median nerve, 6= Additional lateral root of median nerve, 7= Ulnar nerve, 8= Axillary artery, 9= Axillary vein.

Fig 14: Column diagram shows gender and side distribution of the study population according to the formation of median nerve in relation to axillary artery.

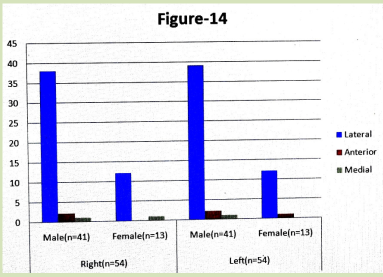


Fig-15: shows Le Minor Type I variation.

Fig-16: shows Le Minor Type III variation.

Fig-17: shows Le Minor Type V variation.

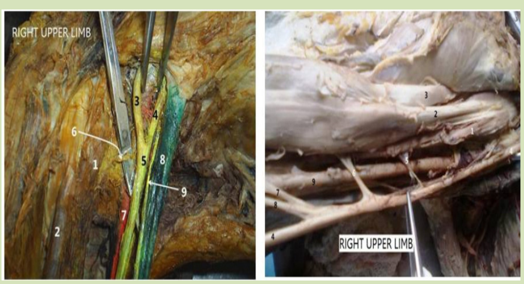
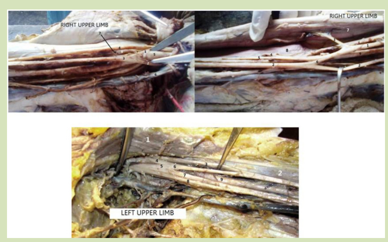


Fig-18: shows Venieratos and Anangnostopoulou Type III variation.



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