

# Variations in the Formation of the Median Nerve and Its Clinical Correlation

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## ABSTRACT

**Introduction:** The median nerve is commonly formed by the fusion of two roots, i.e., the lateral root arises from the lateral cord and the medial root from the medial cord. These roots embrace the axillary artery (third part) and then unite with each other slightly below the level of pectoralis minor, just anterior or anterolateral to the axillary artery. It is associated with different variations like origin from more than two roots, splitting of the nerve and abnormal connections with neighbouring nerves like musculocutaneous or ulnar nerve.

**Objectives:** To explore the different anatomical variations in the formation of the median nerve in the North Indian population.

**Materials and methods:** We studied different variations in the formation of the median nerve during routine dissection classes of the upper limb which was for the undergraduate medical students at the Department of Anatomy of Indira Gandhi Institute of Medical Sciences, Patna, Bihar, India. The present study was conducted on a total of 84 upper limbs, of 42 formalin-preserved cadavers, of which 28 belonged to males and 14 to females.

**Results:** We observed several variations in the formation of the median nerve. Three roots contributed to the formation of the median nerve in 25% of male subjects, among which the third root arose from the lateral cord of the brachial plexus in 16.07% of cases, and from the musculocutaneous nerve in 8.93% of cases. In females, three roots were found in 21.42% of cases, among which the root arose from the lateral cord of the brachial plexus in 14.28% of cases and from the musculocutaneous nerve in 7.14% of cases. Four roots were found in 5.36% of male cases, while in females they were found in 7.14% of cases. The formation of the median nerve occurred in the arm in 11.91% of cases (8.33% belonging to males and 3.58% to females), while in the axilla, it is formed anterior to the axillary artery in 4.76% of cases (3.57% belonging to males and 1.19% to females), medial to the axillary artery in 2.38% of cases (1.19% were found in both male and female cadavers). We also observed an abnormal connection between the median nerve and musculocutaneous nerve in two upper extremities (2.38% of cases) in one male and one female cadaver and one upper extremity of a female cadaver (1.19% of cases) in which the median nerve is present lateral to the brachial artery at the level of the cubital fossa.

**Conclusions:** The knowledge about variations in the formation of the median nerve is relevant to both anatomists and surgeons. It is useful during different surgical procedures around the axilla and also helps

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*in reducing the failure rate of nerve blocks around the infraclavicular part of the brachial plexus during surgeries involving this area.*

**Keywords:** median nerve, anatomical variations, brachial plexus, axillary artery, brachial artery, anaesthesia.

## INTRODUCTION

The median nerve, which is also known as the labourer's nerve, is formed by the union of the lateral and medial roots, which originate from the lateral and medial cords of the brachial plexus, respectively. The lateral cord conveys the fibers from C5, C6, and C7, and the medial cord carries the fibers from C8 and T1 (1, 2). These roots embrace the axillary artery (third part) and then unite with each other slightly below the level of pectoralis minor, just anterior or anterolateral to the axillary artery. Consequently, the trunk of the median nerve is formed, which descends on the lateral side of the axillary artery in the axillary fossa (3). In the upper arm, the relation of the median nerve with the brachial artery remains the same as the axillary artery, *i.e.*, it lies on the lateral side. At the middle of the arm, approximately at the level of the insertion of the coracobrachialis muscle, the median nerve passes anterior to the brachial artery to lie on its medial side in the cubital fossa (4). Formations and anomalies of the different nerves of the upper extremities have been well described by many authors (5, 6). However, in the present study, we report multiple variations of the median nerve that were observed by us during routine dissection classes. Understanding these anatomical variations of the median nerve will add to the existing knowledge, explaining its morphological and clinical significance.

The objectives of the present study were to document the different variations in the formation of the median nerve and the relation with the axillary artery in the axilla and the brachial artery at the cubital fossa in cadavers from Bihar, Jharkhand, West Bengal and Uttar Pradesh states of North India. □

## MATERIALS AND METHODS

The present descriptive study has been carried out on 84 upper limbs of 42 embalmed adult

cadavers, of which 28 belonged to males and 14 to females, during the routine dissection classes which was for the undergraduate medical students at the Department of Anatomy of Indira Gandhi Institute of Medical Sciences, Patna, Bihar, India. Among the 42 cadavers, five were procured from body donation and the remaining ones were obtained as unclaimed dead bodies from the hospital administration. The embalming of cadavers was done according to a method of Woodburne & Lawrence (7, 8) using a solution prepared by their formula number one. The age of all of cadavers varied between 35–68 years, and the age range was 35–68 years, with a mean of  $51.57 \pm 10.68$  years, in male cadavers, and 37–64 years, with a mean of  $45 \pm 8.80$  years, in female cadavers.

According to Cunningham's Manual of Practical Anatomy (9), all cadavers were dissected on both sides of the upper extremity. The skin, superficial fascia, and deep fascia have been separated, along with the muscles, to observe the formation of the median nerve and its variations. Cadavers with deformed or traumatized or any sign of surgery on the skin of cervical, axillary, and arm regions of upper limbs were excluded from the study. Visual observations were captured and preserved by digital photography. The present study was approved by the institutional ethical committee (ID No.: 1757/IEC/IGIMS/2020) and it was conducted from October 2020 to July 2022. The statistical analysis of data was done by the software Graph Pad Prism version 9 and the Chi-square test. □

## RESULTS

The macroscopic examination of the dissected brachial plexus was done to observe the pattern of formation of the median nerve among 84 upper extremities of both male and female cadavers. Two roots were reported in 69.64% of male cases and 71.44% of female cases. Three roots were found in 25% of male cases, among

TABLE 1. Variations in the formation of the median nerve in males and females

	Two roots	Three roots		Four roots	Total
		From LC	From MCN		
Males	39 (69.64%)	From LC	From MCN	3 (5.36%)	56 (100%)
		9 (16.07%)	5 (8.93%)		
		14 (25%)			
Females	20 (71.44%)	From LC	From MCN	2 (7.14%)	28 (100%)
		4 (14.28%)	2 (7.14%)		
		6 (21.42%)			

LC=lateral cord; MCN=musculocutaneous nerve

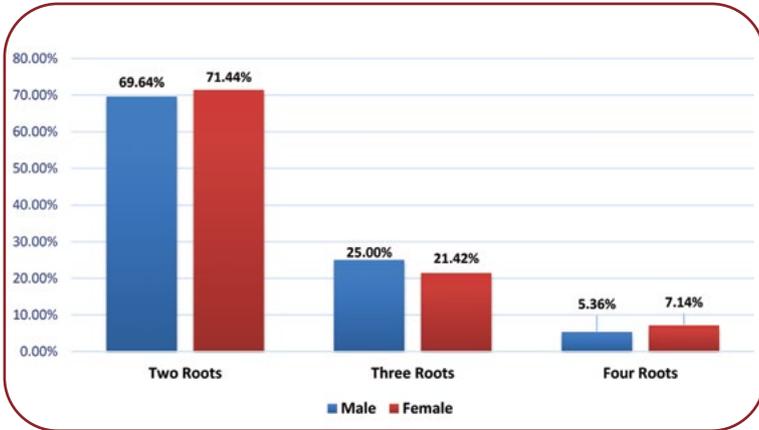


FIGURE 1. Pattern of formation of the median nerve in males and females

which the third root arose from the lateral cord of the brachial plexus in 16.07% of cases and from the musculocutaneous nerve in 8.93% of cases. In females, three roots were found in 21.42% of cases, among which the third root arose from the lateral cord of the brachial plexus in 14.28% of cases and from the musculocutaneous nerve in 7.14% of cases. Four roots were found in 5.36% of male cases and 7.14% of female cases (Table 1, Figure 1). The difference in incidences of formation of the median nerve by

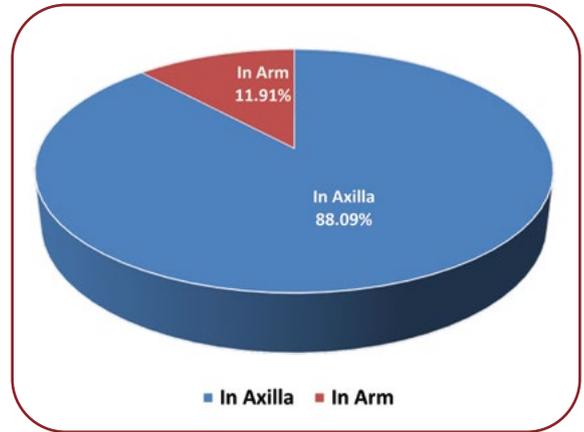


FIGURE 2. Site of formation of the median nerve



FIGURE 3. Formation of the median nerve by three roots, in which an additional root comes from the musculocutaneous nerve: 1) axillary artery; 2) medial root of the median nerve; 3) lateral root of the median nerve; 4) median nerve; 5) additional root coming from the musculocutaneous nerve; 6) musculocutaneous nerve; 7) ulnar nerve; 8) medial cutaneous nerve of the forearm

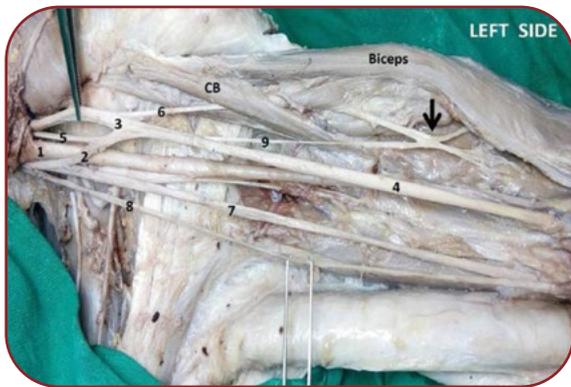
two, three or four roots among male and female specimens was not statistically significant (P-value > 0.05) (Table 2).

TABLE 2. Comparison of the formation of the median nerve in males and females

	Two roots	Three roots	Four roots	Total	Chi-square X <sup>2</sup> (2, N=84)	P-value
Males	39	14	3	56	0.208	0.901
Females	20	6	2	28		
Total	59	20	5	84		

TABLE 3. Site of formation of the median nerve

Site of formation of the median nerve		In males	In females	Total	
1. In the axilla	Lateral to axillary A	35 (41.67%)	33 (39.28%)	68 (80.95%)	
	Medial to axillary A	1 (1.19%)	1 (1.19%)	2 (2.38%)	
	Anterior to axillary A	3 (3.57%)	1 (1.19%)	4 (4.76%)	
2. In the arm		7 (8.33%)	3 (3.58%)	10 (11.91%)	



**FIGURE 4.** Formation of the median nerve by three roots, in which an additional root is coming from the lateral cord, along with an additional connection between the musculocutaneous and median nerve in the mid-arm: 1) axillary artery; 2) medial root of the median nerve; 3) lateral root of the median nerve; 4) median nerve; 5) additional root coming from the lateral cord; 6) musculocutaneous nerve; 7) ulnar nerve; 8) medial cutaneous nerve of forearm; 9) additional connection in between musculocutaneous and median nerve in the mid-arm



**FIGURE 5.** Formation of the median nerve by three roots, in which an additional root is coming from the lateral cord, with an additional connection between the musculocutaneous and median nerve in the lower arm: 1) axillary artery; 2) lateral cord of brachial plexus; 3) medial cord of brachial plexus; 4) lateral root of the median nerve; 5) medial root of the median nerve; 6) additional root of median nerve coming from the lateral cord; 7) median nerve; 8) musculocutaneous nerve; 9) ulnar nerve; 10) medial cutaneous nerve of arm; 11) medial cutaneous nerve of forearm; 12) lateral cutaneous nerve of forearm; 13) additional connection in between musculocutaneous and median nerve in lower arm

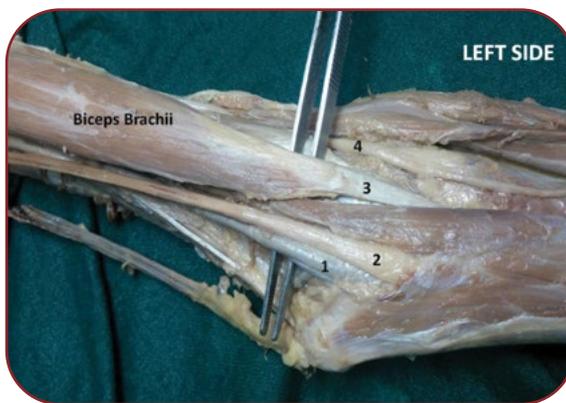
The formation of the median nerve was observed in the axilla in 88.09% of cases and in the arm in 11.91% of cases. Median nerve formation occurs at the arm level in 8.33% of male cadavers and 3.58% of female cadavers. In the axilla, this was formed lateral to the third part of the



**FIGURE 6.** Formation of the median nerve by four roots, in which additional roots come from the lateral cord and the musculocutaneous nerve: 1) axillary artery; 2) medial root of the median nerve; 3) additional root from the lateral cord; 4) lateral root of the median nerve; 5) additional root from the musculocutaneous nerve; 6) median nerve; 7) musculocutaneous nerve; 8) ulnar nerve; 9) medial cutaneous nerve of the forearm

**TABLE 4.** Course of the median nerve in relation to the brachial artery at the level of the cubital fossa

The course of the median nerve in relation to the brachial artery	No. of cases (%)
Medial	83 (98.81%)
Lateral	01 (1.19%)
Total	84 (100%)



**FIGURE 7.** The median nerve lies lateral to the brachial artery in the left cubital fossa: 1) brachial artery; 2) median nerve; 3) tendon of biceps brachii muscle; 4) radial nerve

axillary artery in 80.95% of cases, with 41.67% of cases belonging to males and 39.28% to females. It was formed anterior to the third part of the axillary artery in 4.76% of cases, with 3.57% of cases belonging to males and 1.19% to females. It formed medially to the third part of the axillary artery in the axilla in only 2.38% of cases,

of which 1.19% involved both male and female cadavers (Table 3, Figure 2). We also observed an abnormal connection between the median nerve and musculocutaneous nerve in two upper extremities (2.38% of cases) at the level of the mid-arm and lower arm in one male and one female cadaver (Figures 4 and 5). We also saw an abnormal position of the median nerve in relation to the brachial artery in one upper extremity of a female cadaver (1.19% of cases) in which the median nerve was present lateral to the brachial artery at the level of the cubital fossa (Table 4, Figure 7). □

### DISCUSSION

Formations and anomalies of the nerves of the upper limb have been globally described by many authors (10-16). In the present study, we documented different unusual patterns in the formation of the median nerve by three and four roots. We found that the additional roots taking part in the formation of the median nerve either came from the lateral cord or the musculocutaneous nerve. Such cases of the anomalous origin of the median nerve may lead to confusion in surgical procedures and nerve block anaesthesia. While Ghosh B *et al* (14) reported that the additional roots taking part in the formation of the median nerve were aroused from the posterior cord of the brachial plexus.

We found that three roots contributed to the formation of the median nerve in 25% of male cases, while in females they were found in 21.42% of cases of the upper limbs. Median nerve formation by three roots was also reported by Ghosh B *et al* (14) in 21.7% of cases, Pattanshetti SV *et al* (17) in 11.66% of cases, Budhiraja V *et al* (10) in 22.4 % of cases, Passey J *et al* (18) in 15 % of cases, Priya A *et al* (19) in 13.33 % of cases and Hada S *et al* (20) in 20% of cases. Mat Taib CN *et al* (21) found three roots in 36.4% of the left and 18.2% of the right upper limbs, as well as median nerve formation from one root that was directly coming from the medial cord in 4.5% of cases.

We found that four roots contributed to the formation of the median nerve in 5.36% of male cases and 7.14% of female cases. Median nerve formation by four roots was also reported by Ghosh B *et al* (14) in 5% of cases, Budhiraja V *et al* (10) in 3.57% of cases, Hada S *et al* (20) in

2% of cases, and Mat Taib CN *et al* (21) in 4.5% of cases. Priya A *et al* (19) observed the absence of the musculocutaneous nerve in 5% of cases. In its absence, the muscles of the anterior compartment of the arm were supplied by the median nerve.

We observed that the formation of the median nerve occurred in the axilla in 88.09% of cases and in the arm in 11.91% of cases, among which 8.33% cases belonged to male cadavers and 3.58% to female cadavers. The formation of the median nerve in the arm was reported by Budhiraja V *et al* (10) in 17.3% of cases and Hada S *et al* (20) in 8% of cases, while Pattanshetti SV *et al* (17) reported that among cases in which the median nerve was formed by the union of two roots, the nerve was formed in the axilla in 68.33% of cases, in the upper third of the arm in 13.33% of cases, and in the middle third of the arm in 6.67% cases; the latter also documented that it is formed by the union of the three roots too – in the axilla in 8.33% of cases and in the upper third of the arm in 3.33% of cases. Normally, the median nerve runs on the lateral side of the axillary artery. The medial root of the nerve crosses the axillary artery to join the lateral root. We observed that the formation of the median nerve occurred anterior to the third part of the axillary artery in 4.76% of cases and medially to the third part of the axillary artery in only 2.38% of cases. Pattanshetti SV *et al* (17) reported the formation of the median nerve anterior to the third part of the axillary artery in 20% of cases and medial to the third part of the axillary artery in only 3.33% of cases, Budhiraja V *et al* (10) reported its formation anterior to the axillary artery in 1.53% of cases and medial to the axillary artery in 6.12% of cases, Passey J *et al* (18) reported its formation medial to the axillary artery in 2.5% of cases and Mat Taib CN *et al* (21) reported that the median nerve was running posterior to the axillary artery in 13.6% cases and medial to the axillary artery in the left upper limb in 4.5% cases, while on the right side the median nerve was running medial to the axillary artery in 13.6% cases and posterior to it in 4.5% cases. In addition, Pandey and Shukla (22) conducted a study on 344 axillae and documented that the formation of the median nerve occurred medially to the axillary artery in 4.7% of cases. Knowledge of such variations has immense clinical importance, especially in the case of post-

traumatic evaluations and peripheral nerve repair.

We also observed additional communication between the median nerve and musculocutaneous nerve in 2.38% of cases. Ghosh B *et al* (14) reported additional communication between the median nerve and musculocutaneous nerve in 3.3% of cases. Pattanshetti SV *et al* (17) also reported additional communication between these two nerves in 11.67% of cases, and Priya A *et al* (19) reported abnormal connections between these nerves in 13.33% of explored cases. Mat Taib CN *et al* (21) reported additional communication between the median nerve and musculocutaneous nerve in 13.6% of cases and abnormal connections between the median nerve and ulnar nerve in 4.5% of cases belonging to the right side.

We found a single case in which the median nerve was present lateral to the brachial artery at the level of the cubital fossa, while Pattanshetti SV *et al* (17) reported two such cases in their study (in 3.33% of cases), and Nayak S *et al* (23) described a case in which the median nerve was descending to the medial of the brachial artery.

### Embryological explanation

The upper limb buds are situated just opposite the lower five cervical as well as the upper two thoracic segments. The ventral principal rami of the spinal nerves enter the mesenchyme of the limb bud as soon as buds begin to form and make close contact with differentiating mesodermal condensations. For their complete functional differentiation, the prerequisite is early contact between the nerve as well as the muscle cells (10, 24, 25). The variances may result from circulation concerns when the brachial plexus cord fused. During the fifth week of embryonic development, the forelimb muscles in humans grow from the mesenchyme of the paraxial mesoderm. The spinal nerve axon extends distally to the mesenchyme of the limb bud. The

motor and sensory neuron's peripheral processes grow in the mesenchyme in various directions. Once formed, any developmental differences would obviously persist after birth. As the guidance of the developing axons is regulated by the expression of chemo-attractants and chemo-repellents in a highly coordinated site-specific fashion, any alteration in signaling between mesenchymal cells and neuronal growth cones can lead to significant variations (26).

### Limitations of the study

The main limitations of our study include the lower number of female specimens compared to that of male specimens and the small sample size. Hence, the current study may be further extended on a large sample size and an equal number of male and female specimens. □

## CONCLUSIONS

Variations in the median nerve are very common in our population. They are of great interest to anatomists, radiologists, and surgeons. Nerve variations of the upper limb are very important in routine surgeries, post-traumatic evaluations, peripheral nerve repairs, and during radical neck dissections where these variations are more prone to iatrogenic injury. This awareness can be helpful to prevent injuries during surgical and anaesthetic procedures around the axilla and the arm. These variations may also help in the interpretation of nerve compression causing unexplained clinical symptoms. □

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