

A STUDY OF MEDIAN NERVE AND ITS VARIATIONS - FORMATION, COURSE AND DISTRIBUTION

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Received : 15/12/2025
Received in revised form : 20/01/2026
Accepted : 07/02/2026

Keywords:
Anatomy, Brachial Plexus, Cadaver, Median Nerve, Peripheral Nerves, Upper Limb.

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DOI: 10.47009/jamp.2026.8.1.171

Source of Support: Nil,
Conflict of Interest: None declared

Int J Acad Med Pharm
2026; 8 (1); 887-891



ABSTRACT

Background: The median nerve shows variations in formation, course, branching, and relations, which are clinically important for surgery, nerve repair, and assessment of compression neuropathies, reducing complications, and improving diagnostic accuracy. This study aimed to focus on the formation, course, branching pattern, and variations of the median nerve, with particular emphasis on its relationship with the pronator teres, persistent median artery, and terminal distribution in the hand. **Materials and Methods:** This descriptive observational study was conducted on 50 embalmed adult human upper limb specimens at the Department of Anatomy, Madras Medical College, Chennai. Careful dissection was performed to trace the median nerve from its formation to the terminal branches. **Results:** The median nerve was formed by two roots from the medial and lateral cords in 43 specimens (86%), whereas trifurcate formation was observed in six specimens (12%). The most common site of formation was lateral to the axillary artery (84%). The musculocutaneous nerve was absent in seven specimens (14%), with the median nerve supplying the anterior compartment muscles. The pronator teres was supplied by a single branch in 36 specimens (72%), which commonly arose above the interepicondylar line (56%). The ulnar head of the pronator teres was absent in 10% of the specimens. A persistent median artery was observed in 6% of the cases. High division of the median nerve occurred in 4% of cases, whereas digital innervation to the lateral three and a half digits was constant. **Conclusion:** This study highlights the consistent anatomical patterns of the median nerve, along with important variations. Awareness of these findings is essential for safe surgical practice and accurate clinical assessment of upper-limb nerve disorders.

INTRODUCTION

Carpal tunnel syndrome is a common focal peripheral neuropathy caused by compression of the median nerve beneath the flexor retinaculum.^[1] Increased intracarpal pressure compromises neural conduction and microvascular perfusion, resulting in pain, paraesthesia, and motor weakness in the hand. Median nerve entrapment at the wrist is one of the most frequently encountered compression neuropathies in clinical practice. Repetitive wrist movements, fractures around the wrist, inflammatory arthropathies, space-occupying lesions, dialysis-related amyloidosis, and metabolic disorders are recognised causes, although idiopathic cases are frequent.^[1,2] These clinical entities emphasise the importance of understanding the normal anatomy and

anatomical variations of the median nerve at the wrist.

Pronator teres syndrome refers to median nerve compression as it passes through or around the pronator teres muscle.^[3] Entrapment may also occur proximally at the ligament of Struthers or due to anomalous muscles and vascular structures.^[4] Among these, the pronator teres muscle is a common site of median nerve compression in the proximal forearm. Variation in the relationship between the median nerve and the humeral or ulnar heads of the pronator teres directly influences symptom presentation and surgical exposure, making anatomical documentation essential.

The median artery arises from the anterior interosseous artery during early embryonic development and normally regresses by the eighth week of gestation.^[5] Failure of regression results in

persistence of the median artery within the forearm and carpal tunnel. Thrombosis or enlargement of this artery can compress the median nerve, producing acute neuropathic symptoms.^[6] Its presence represents an important developmental variation relevant to forearm dissection and carpal tunnel surgery.

Peripheral nerve entrapment commonly presents with pain, tingling, numbness, and weakness of the upper limb.^[7] Variability in the branching and innervation patterns of the median nerve accounts for differences in clinical manifestations, particularly in pronator teres syndrome. Accurate knowledge of nerve anatomy and its variations assists in lesion localisation and surgical planning and reduces the risk of iatrogenic injury.

The pronator teres plays a dual role as a forearm pronator and potential donor muscle in reconstructive procedures. It arises from the humeral and ulnar heads, with the median nerve typically passing between them. The muscle receives one or more branches from the median nerve, usually proximal to its entry between the heads of the muscle. Precise information regarding the number, origin, and length of these branches is critical for nerve transfer and neurotisation procedures in the cubital fossa.^[8]

Anatomical variations in the median nerve, including differences in its formation, relationship with the axillary artery, communication with the ulnar nerve, and terminal branching in the hand, are common. Systematic documentation of these variations through cadaveric studies provides an anatomical basis for interpreting nerve compression syndromes and guiding surgical interventions. Therefore, the present study focused on the formation, course, branching pattern, and variations of the median nerve, with particular emphasis on its relationship with the pronator teres, persistent median artery, and terminal distribution in the hand.

MATERIALS AND METHODS

This descriptive observational study was conducted on 25 embalmed adult human cadavers of either sex aged 50–80 years at the Institute of Anatomy, Madras Medical College, Chennai-03, over a period of 15 months from May 2018 to July 2019 during undergraduate training. Ethical approval was obtained from the institutional ethics committee, and informed consent was secured according to

institutional regulations for the use of embalmed cadavers in academic and research work.

Inclusion and Exclusion Criteria

Upper limb specimens obtained from adult and viable foetal human cadavers with no history or evidence of surgery in the hand region were selected for the study. Specimens showing obvious congenital abnormalities, signs of previous surgical procedures, or abnormal muscular structures within the carpal tunnel were excluded to prevent interference with anatomical observations.

Methods

Data were collected from embalmed, formalin-fixed upper limb specimens obtained from the dissection halls. This study focused on the formation, course, branching pattern, and variations of the median nerve, along with the related muscular and vascular structures. Measurements were taken using a thread and ruler, and photographs were taken using a 16-megapixel camera for documentation. Each dissected specimen was numbered, and the findings were noted systematically.

Dissection began with an incision from the nipple through the axilla to the anterior surface of the arm. The superficial and deep fasciae were dissected in layers, and fat, loose areolar tissue, and lymph nodes were removed to expose the axillary contents. The axillary vessels were identified, and the brachial plexus cords were traced. A longitudinal incision was made extending to the middle finger, and the forearm fascia was reflected. The flexor retinaculum was divided, and the palmar structures were carefully exposed. The thenar muscles and lumbricals were identified, and the median nerve was traced throughout its course to record its branches, relationships, and anatomical variations.

Data were analysed using SPSS v29. Data are presented as frequencies and percentages.

RESULTS

The median nerve was most commonly formed by two roots from the medial and lateral cords in 43 (86 %) specimens. Trifurcate formations were observed in six specimens (12%). The median nerve was formed lateral to the axillary artery in 42 (84 %) specimens. The musculocutaneous nerve was absent in seven specimens (14%), and in these cases, the median nerve supplied the muscles of the anterior compartment of the arm. [Table 1]

Table 1: Formation and proximal anatomical variations of the median nerve

Parameter	Observation	N (%)
Number of roots forming median nerve	Two roots (medial + lateral cords)	43 (86%)
	Three roots (trifurcate origin)	6 (12%)
	Two roots with musculocutaneous nerve contribution	1 (2%)
Source of additional root in trifurcation	From lateral cord	5 (10%)
	From medial cord	1 (2%)
Relation to axillary artery	Lateral to axillary artery	42 (84%)
	Medial to axillary artery	5 (10%)
	Anterior to axillary artery	2 (4%)
	Posterior to axillary artery	1 (2%)
Musculocutaneous nerve status	Present	43 (86%)
	Absent	7 (14%)
Innervation pattern when musculocutaneous nerve absent	All anterior arm muscles supplied by median nerve	6 (12%)
	Coracobrachialis supplied by lateral cord branch joining median nerve	1 (2%)

The median nerve most commonly supplied the pronator teres muscle through a single branch in 36 specimens (72%), and the branch usually arose above the intercondylar line in 28 specimens (56%). [Table 2]

Table 2: Branching pattern of the median nerve to pronator teres

Parameter	Observation	N (%)
Number of branches to pronator teres	One branch	36 (72%)
	Two branches	11 (22%)
	Three branches	3 (6%)
Level of origin of first branch	Above intercondylar line	28 (56%)
	At intercondylar line	4 (8%)
	Below intercondylar line	18 (36%)
Length of branch	Mean length	3.8 cm
	Range	2.2–5.4 cm

The ulnar head of the pronator teres muscle was present in most specimens (n = 45, 90%). The median nerve most commonly passed between the humeral

and ulnar heads of the pronator teres in 41 specimens (82%), whereas passage through the ulnar head was noted in 6 specimens (12%). [Table 3]

Table 3: Relation of median nerve to pronator teres muscle

Parameter	Observation	N (%)
Ulnar head of pronator teres	Present	45 (90%)
	Absent	5 (10%)
Relation of median nerve to pronator teres	Passing between humeral and ulnar heads	41 (82%)
	Passing through ulnar head	6 (12%)
	Passing below ulnar head	1 (2%)
	Passing deep to humeral head (ulnar head absent)	5 (10%)

No median–ulnar nerve communication was observed in any specimen (50, 100%), whereas a

persistent median artery was present in a small proportion of cases (3, 6%). [Table 4]

Table 4: Median–ulnar nerve communication and persistent median artery

Parameter	Observation	N (%)
Martin–Gruber anastomosis	Present	0
	Absent	50 (100%)
Persistent median artery	Present	3 (6%)
	Absent	47 (94%)
Origin of persistent median artery	From anterior interosseous artery	3 (6%)

The median nerve was divided distal to the flexor retinaculum in most specimens (48, 96%), and its digital branches supplied the lateral three and a half digits in all cases (50, 100%). [Table 5]

Table 5: Terminal division and digital distribution of the median nerve

Parameter	Observation	N (%)
Level of terminal division of median nerve	Distal to flexor retinaculum	48 (96%)
	Proximal to flexor retinaculum (high division)	2 (4%)
Digital innervation of median nerve	Lateral three and a half digits	50 (100%)

DISCUSSION

This study shows that two root formations of the median nerve dominated, with rare trifurcation. The nerve is usually formed laterally to the axillary artery. The pronator teres commonly receives a single branch arising proximally. Ulnar head absence and persistent median arteries were infrequent. Terminal division and digital supply were largely constant across specimens examined carefully

In this study, the median nerve usually formed from two roots, lay lateral to the axillary artery, and occasionally compensated for an absent musculocutaneous nerve. Similarly, Ashraf and Nasr reported trifurcate formation of the median nerve in 7 out of 60 specimens (11.7%), with the majority showing the usual two-root formation.^[9] Pattanshetti et al. observed trifurcation in 7 of 60 specimens (11.66%).^[10] Budhiraja et al. documented a higher incidence of three-root formation, reporting it in 42 specimens (24.1%).^[11] These findings support the predominance of two-root formation with occasional trifurcation.

In the present study, the median nerve was usually formed by two roots arising from the medial and lateral cords, whereas formation with three roots was



Figure 1 Muscular branches to Pronator teres muscle

uncommon. Similarly, Ashraf and Nasr reported trifurcate formation in 7 of 60 specimens (11.7%), with the majority showing classical two-root formation.^[9] Pattanshetti observed trifurcation in 7 of 60 specimens (11.66%), and in all cases, the additional root arose from the lateral cord.^[10] These studies support our findings by confirming that two-root formation is the predominant pattern and that trifurcation represents an anatomical variation.

In the present study, the median nerve was most often formed laterally to the axillary artery, whereas medial formation was observed less frequently. Comparable findings were reported by Budhiraja et al. found (10.3%) and Kumari et al. found (8.49%), who documented similar rates of medial formation.^[12]

Ashraf and Nasr reported anterior formation in 8.3% of specimens, which was higher than the present observation (4%).^[9] These findings support the predominance of lateral formation while highlighting minor population-based variations.

Our study demonstrated the absence of the musculocutaneous nerve in 14% of specimens, with the median nerve supplying the muscles of the anterior compartment of the arm in such cases. Similarly, Kaur et al. reported an absence in 13% of specimens, with similar compensatory innervation by the median nerve.^[13] Jamuna and Amudha and Namking et al. reported lower incidences of 6% and 1.71%, respectively.^[14,15] These studies support our findings by confirming that the absence of the musculocutaneous nerve is uncommon but consistently associated with median nerve substitution.

In this study, the pronator teres muscle was usually supplied by a single branch of the median nerve, which most often arose proximal to the interepicondylar line. Similarly, Basanagouda reported a single branch in 75.9% of specimens, with most branches arising above the interepicondylar line.³ These findings support the consistency of this branching pattern across populations.

The ulnar head of pronator teres was absent in 10% of specimens, comparable to Sharma et al. (13%) and Olewnik et al. (14%).^[16,17] The median nerve most frequently passed between the humeral and ulnar heads (82%), similar to reports by Basanagouda (87%) and Vymazalova et al. (86.8%).^[3,18] These findings confirm that the classical relationship predominates, with occasional variations.

In the present study no Martin–Gruber anastomosis was observed, contrasting with reports by Cavalheiro et al. (27%) indicating marked anatomical variability.^[19] Persistent median artery was observed in 8% of specimens, comparable to Raviprasanna and Dakshayani found (8%) and lower than Nayak (15.4%), supporting its infrequent but clinically relevant occurrence.^[20]

In this study the median nerve divided distal to the flexor retinaculum in most specimens (96%), with high division observed in 4%, consistent with reports by Mizia et al. (5%) and Agarwal et al. (11.53%).^[21,22] Digital innervation of the lateral three and a half digits was observed in all specimens, in agreement with Narayanan et al. confirming the stability of terminal distribution patterns.^[23]

This study provides detailed cadaveric evidence of median nerve variations, supporting surgical safety, anatomical accuracy, and improved clinical understanding.

Limitations

This study was limited by its small sample size and lack of clinical correlation. Cadaveric changes may alter anatomy, and the age range of specimens may influence observed variations, limiting the generalisation of findings.

Clinical implications

These findings aid in surgical planning and nerve repair by improving anatomical awareness. Future studies should include larger samples and imaging-based correlations in living subjects.

CONCLUSION

The median nerve shows consistent anatomical patterns with notable variations in its formation, branching, and trajectory. Two-root formation was the most common, whereas trifurcation and other variations were less frequent. Variations related to the pronator teres muscle and the presence of a persistent median artery were observed in a small number of specimens. The terminal division and digital distribution of the median nerve were largely constant. These findings highlight the importance of detailed anatomical knowledge in reducing surgical complications and improving outcomes in procedures involving the upper limb.

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