Original Research Article

A Cadaveric Study on Variations of the Brachial Plexus and Their Surgical Implications

Gaurav Kumar[1], Haresh Yadav[2]

1. Senior resident, Department of Anatomy, KD Medical College, Mathura
2. Faculty, Department of Anatomy, KD Medical College, Mathura

Received: 15-04-2026/ Revised: 21-04-2026/ Accepted: 28-04-2026/Published:28-05-2026
Corresponding author: Dr Gaurav Kumar
Conflict of interest: Nil

Abstract

Background: The brachial plexus is a complex network of nerves supplying the upper limb and is known to exhibit numerous anatomical variations. These variations may involve the roots, trunks, cords, and terminal branches and are of considerable clinical importance for surgeons, anesthesiologists, orthopaedic surgeons, and radiologists. Knowledge of such variations is essential to prevent iatrogenic nerve injuries during surgical procedures, regional nerve blocks, and trauma management.
Methods: This descriptive cadaveric observational study was conducted in the Department of Anatomy at N K P Salve Institute of Medical Sciences, Nagpur. A total of 30 embalmed adult cadavers comprising 60 upper limbs were dissected bilaterally. Detailed examination of the brachial plexus was performed to identify variations in roots, trunks, divisions, cords, terminal branches, and their relation to surrounding vascular structures. Findings were recorded, tabulated, and analyzed using descriptive statistics.
Results: Variations in the brachial plexus were observed in 22 out of 60 upper limbs (36.7%). The most common variation was communication between the musculocutaneous and median nerves, seen in 8 limbs (13.3%). Prefixed plexus was observed in 4 limbs (6.7%), while postfixed plexus was seen in 2 limbs (3.3%). Variations in trunk formation, cord branching, and relation to the axillary artery were also noted.
Conclusion: The brachial plexus demonstrates significant anatomical variability. Awareness of these variations is important for safe surgical dissection, effective regional anaesthesia, and accurate radiological interpretation.
Keywords: Brachial plexus, cadaveric study, anatomical variation, musculocutaneous nerve, median nerve, surgical anatomy

Introduction

The brachial plexus is a complex network of nerves formed by the anterior rami of the fifth cervical to the first thoracic spinal nerves (C5–T1), which provides motor and sensory innervation to the upper limb. It is conventionally described as consisting of roots, trunks, divisions, cords, and terminal branches. The roots unite to form the upper, middle, and lower trunks, which subsequently divide into anterior and posterior divisions before giving rise to the lateral, medial, and posterior cords. These cords ultimately terminate into the major peripheral nerves of the upper limb, including the musculocutaneous, median, ulnar, radial, and axillary nerves.[1]

Although the classical arrangement of the brachial plexus is well established, numerous anatomical variations have been reported in the literature. These variations may involve the roots, trunks, divisions, cords, terminal branches, and communicating branches between nerves. Variations may also occur in the relation of the plexus to neighboring vascular structures such as the axillary artery and subclavian artery.[2] Such variations may arise during embryological development due to altered signaling between developing nerve fibers and limb bud mesenchyme, leading to persistence or regression of certain nerve pathways.[3]

Among the commonly reported variations are prefixed and postfixed brachial plexuses. In the prefixed type, there is an additional contribution from the fourth cervical nerve (C4), while in the postfixed type, contribution from the second thoracic nerve (T2) may be present with reduced contribution from C5.[4] Variations in the formation of trunks, especially the upper trunk formed by C5 and C6 roots, have also been described. Similarly, anomalous branching patterns of the cords and terminal nerves are frequently encountered. The musculocutaneous nerve may be absent, with its fibers incorporated into the median nerve, or communicating branches may exist between the musculocutaneous and median nerves.[5]

Knowledge of these anatomical variations is of immense importance in clinical practice. Surgeons operating in the neck, axilla, shoulder, and upper limb regions must be aware of such deviations to prevent accidental nerve damage during procedures such as lymph node dissections, fracture fixation, shoulder arthroplasty, and vascular surgeries.[6] Variations in the brachial plexus may also complicate regional anaesthesia techniques such as supraclavicular, infraclavicular, and axillary nerve blocks, potentially leading to incomplete anaesthesia or inadvertent nerve injury.[7]

Radiologists and clinicians interpreting magnetic resonance imaging, ultrasonography, and computed tomography of the neck and upper limb should also be familiar with these variations to avoid diagnostic errors. In trauma cases involving brachial plexus injuries, understanding variant anatomy is essential for accurate localization of lesions and planning of reconstructive surgeries.[8] Furthermore, variations in the origin and course of peripheral nerves can influence the presentation of nerve entrapment syndromes and patterns of neurological deficits.[9]

Cadaveric studies remain one of the most reliable methods for understanding the detailed anatomy of the brachial plexus and documenting its variations. Such studies provide valuable information that may not always be apparent through imaging or surgical observation alone. Anatomical knowledge obtained from cadaveric dissection has significant educational value and contributes to safer surgical and anaesthetic practices.[10]

Therefore, the present study was undertaken to observe the variations in the formation and branching pattern of the brachial plexus in cadavers and to evaluate their possible surgical and clinical implications.

Methodology:

Study Design

This was a descriptive cadaveric observational study.

Study Setting

The study was conducted in the Department of Anatomy at N K P Salve Institute of Medical Sciences, Nagpur.

Study Duration

The study was carried out over a period of one year.

Study Material

The study included embalmed adult human cadavers available in the Department of Anatomy for routine undergraduate and postgraduate dissection purposes.

Inclusion Criteria

- Adult human cadavers of either sex
- Well-embalmed cadavers with intact neck, axillary, and upper limb regions
- Cadavers without evidence of trauma, surgical intervention, deformity, or pathology involving the neck, shoulder, axilla, or upper limb

Exclusion Criteria

- Cadavers with damaged or dissected brachial plexus
- Cadavers showing congenital deformities or traumatic injuries in the neck or upper limb region
- Cadavers with previous surgical procedures involving the cervical, axillary, or upper limb areas

Sample Size

A total of 30 cadavers (60 upper limbs) were studied bilaterally.

Dissection Procedure

Detailed dissection of both right and left brachial plexuses was performed according to standard anatomical dissection methods. The skin, superficial fascia, and deep fascia over the neck, axilla, and upper limb were carefully removed. The sternocleidomastoid muscle, clavicle, and pectoral muscles were exposed and reflected as required to visualize the roots, trunks, divisions, cords, and terminal branches of the brachial plexus.

The anterior rami of C5, C6, C7, C8, and T1 spinal nerves were identified and traced distally to study their contribution to the formation of trunks, divisions, cords, and terminal nerves. Any additional contribution from C4 or T2 roots was also noted. Variations in the origin, course, branching pattern, communications, and relation to surrounding vascular structures were carefully examined.

Parameters Studied

The following parameters were observed and recorded:

- Formation of roots of the brachial plexus
- Presence of prefixed or postfixed plexus
- Formation and branching pattern of trunks
- Variations in anterior and posterior divisions

- Formation of lateral, medial, and posterior cords
- Origin and course of terminal branches
- Communication between nerves, especially between musculocutaneous and median nerves
- Relation of nerves to axillary artery and surrounding vascular structures
- Presence of accessory or anomalous branches

Documentation

All findings were recorded systematically in a predesigned proforma. Photographs of the observed variations were taken wherever necessary for documentation and future reference.

Statistical Analysis

The observations were tabulated and analyzed using descriptive statistics. The frequency and percentage of different types of variations were calculated and presented in tabular form.

Results:

A total of 30 cadavers comprising 60 upper limbs were studied bilaterally. Variations in the formation and branching pattern of the brachial plexus were observed in 22 out of 60 upper limbs (36.7%), while the remaining 38 limbs (63.3%) showed the classical anatomical pattern.

The most common variation observed was communication between the musculocutaneous nerve and median nerve, which was noted in 8 upper limbs (13.3%). Variations in the formation of roots, including prefixed and postfixed plexuses, were seen in 6 upper limbs (10.0%). Abnormal formation of trunks was identified in 4 upper limbs (6.7%), while atypical branching patterns of cords and terminal nerves were observed in 7 upper limbs (11.7%). Variations in relation to the axillary artery and surrounding vascular structures were noted in 5 upper limbs (8.3%) (Table 1).

Among the root variations, prefixed brachial plexus with contribution from C4 was more common and was observed in 4 upper limbs (6.7%), whereas postfixed plexus with contribution from T2 was seen in 2 upper limbs (3.3%). Classical root formation from C5 to T1 was present in 54 upper limbs (90.0%) (Table 2). Communication between the musculocutaneous nerve and median nerve was the most frequent branching anomaly. In 5 upper limbs (8.3%), a communicating branch arose from the musculocutaneous nerve to the median nerve, whereas in 3 upper limbs (5.0%), fibers from the median nerve communicated with the musculocutaneous nerve. Absence of musculocutaneous nerve with incorporation of its fibers into the median nerve was noted in 2 upper limbs (3.3%) (Table 3).

Variations in the relation of cords and terminal branches to the axillary artery were also identified. In 3 upper limbs (5.0%), the medial cord was found lateral to the second part of the axillary artery. In 2 upper limbs (3.3%), the posterior cord was positioned abnormally posterior to the third part of the axillary artery. These altered relations may increase the risk of neurovascular injury during axillary surgeries and nerve block procedures (Table 4).

Table 1. Overall Distribution of Brachial Plexus Variations Observed (n = 60 Upper Limbs)

Type of Variation	Frequency (n)	Percentage (%)
Normal anatomical pattern	38	63.3
Any variation present	22	36.7
Communication between musculocutaneous and median nerve	8	13.3

Root variation (prefixed/postfixed plexus)	6	10.0
Trunk formation variation	4	6.7
Cord and terminal branch variation	7	11.7
Relation to vascular structures altered	5	8.3

Table 2. Variations in Formation of Roots of the Brachial Plexus (n = 60 Upper Limbs)

Root Formation Pattern	**Frequency (n)**	**Percentage (%)**
Classical C5–T1 pattern	54	90.0
Prefixed plexus (C4 contribution)	4	6.7
Postfixed plexus (T2 contribution)	2	3.3

Table 4. Variations in Relation of Brachial Plexus to Axillary Artery (n = 60 Upper Limbs)

Relation Variation	**Frequency (n)**	**Percentage (%)**
Normal relation to axillary artery	55	91.7
Medial cord lateral to axillary artery	3	5.0
Posterior cord abnormally related to axillary artery	2	3.3

Discussion:

The present cadaveric study was undertaken to evaluate variations in the formation, branching pattern, and relation of the brachial plexus to surrounding structures. Variations were observed in 22 out of 60 upper limbs (36.7%), while 38 limbs (63.3%) showed the classical anatomical pattern. The findings of the present study are comparable with previous anatomical studies, which have consistently demonstrated that the brachial plexus is highly variable in its formation and branching.

In the present study, overall variations in the brachial plexus were observed in 36.7% of upper limbs. Fazan et al. reported brachial plexus variations in approximately 53.5% of cases, while Uysal et al11. found variations in nearly 45% of fetal specimens. Kerr, in one of the earliest and largest anatomical studies, observed variations in approximately 62% of brachial plexuses. These differences in frequency may be attributed to variation in sample size, cadaveric population, and criteria used for classification of anomalies.

Root variations in the present study were identified in 10.0% of upper limbs, with prefixed plexus observed in 6.7% and postfixed plexus in 3.3% of specimens. Classical C5–T1 root formation was seen in 90.0% of limbs. These findings are comparable with those of Hollinshead, who described prefixed brachial plexus in approximately 5% of cases and postfixed plexus in about 2.5% of cases. Uysal et al 11. reported prefixed plexus in 7.5% and postfixed plexus in 4.2% of specimens, which is close to the present findings. Kerr also reported that contribution from C4 or T2 roots may alter the classical pattern and has important implications during neck dissections and cervical spine surgeries.

The present study demonstrated trunk variations in 6.7% of upper limbs. Abnormal union of roots forming the upper trunk and variations in middle and lower trunk formation were observed. Similar findings were reported by Fazan et al.12, who found trunk anomalies in approximately 8% of cases. Variations in trunk formation may alter the pattern of nerve distribution and complicate surgical procedures involving the supraclavicular region.

One of the most frequent findings in the present study was communication between the musculocutaneous nerve and median nerve, which was observed in 13.3% of upper limbs. Specifically, communication from the musculocutaneous nerve to the median nerve was seen in 8.3% of limbs, whereas communication from the median nerve to the musculocutaneous nerve was observed in 5.0%. Choi et al 13. reported communication between these nerves in 26.4% of cases, which is higher than the present study. Venieratos and Anagnostopoulou observed such communications in 22% of upper limbs, while Prasada Rao and Chaudhary found communicating branches in 15% of specimens. These variations are clinically important because injury to one nerve may present with unexpected neurological deficits due to the presence of communicating fibers.

Absence of the musculocutaneous nerve was observed in 3.3% of upper limbs in the present study. In these cases, fibers that would normally form the musculocutaneous nerve were incorporated into the median nerve. Similar observations were made by Choi et al.13, who reported absence of the musculocutaneous nerve in 1.7% of cases, and by Kerr, who also documented rare instances of absence of the musculocutaneous nerve. Such variations may have important implications during surgical exploration of the arm and may affect the pattern of motor weakness following nerve injury.

In the present study, variations in cord formation and terminal branching pattern were observed in 11.7% of upper limbs. High origin of the median nerve was noted in 3.3% of cases, while variant origin of the ulnar nerve was seen in 1.7%. Similar findings were reported by Fazan et al.12, who described anomalous origin of the median and ulnar nerves in approximately 5–10% of specimens. Tubbs et al. also emphasized that variations in terminal nerve formation may lead to difficulties during axillary surgeries and nerve repair procedures.

Altered relations of the brachial plexus to the axillary artery were observed in 8.3% of upper limbs in the present study. In 5.0% of limbs, the medial cord was found lateral to the axillary artery, while in 3.3%, the posterior cord showed an abnormal relation to the third part of the axillary artery. Similar vascular relationships were described by Uysal et al 11. and Tubbs et al.14, who noted that abnormal positioning of cords around the axillary artery may increase the risk of accidental nerve injury during axillary dissections, vascular surgeries, and administration of brachial plexus blocks.

The findings of the present study are of considerable clinical importance. Variations in the brachial plexus may result in failure of regional anesthesia, incomplete nerve blocks, or unexpected neurological deficits after trauma or surgery. Knowledge of these variations is also essential for orthopaedic surgeons, plastic surgeons, neurosurgeons, and anesthesiologists during procedures involving the neck, shoulder, axilla, and upper limb. Radiologists should also be aware of these variations to avoid misinterpretation during imaging studies.

Conclusion

The present study demonstrated that anatomical variations of the brachial plexus are relatively common and may involve roots, trunks, cords, terminal branches, and their relation to surrounding vessels. Communication between the musculocutaneous and median nerves was the most frequently observed variation. Knowledge of these variations is essential for surgeons, anesthesiologists, and radiologists to avoid inadvertent nerve injury and improve procedural success. Cadaveric studies continue to provide valuable information for understanding clinically important anatomical variations.

Limitations of the Study

The present study had certain limitations. It was conducted on a relatively small number of cadavers from a single institution, which may limit the generalizability of the findings to the broader population. In addition, age, sex, and side-wise distribution of the cadavers were not analyzed separately, which may have influenced the observed frequency of brachial plexus variations. The study focused only on gross anatomical variations and did not include microscopic or histological evaluation of nerve structures. Furthermore, since this was a cadaveric study, the direct functional and clinical implications of the observed anatomical variations could not be assessed.

References:

1. Standring S, ed. Gray's Anatomy: The Anatomical Basis of Clinical Practice. 42nd ed. London: Elsevier; 2021.
2. Moore KL, Dalley AF, Agur AMR. Clinically Oriented Anatomy. 9th ed. Philadelphia: Wolters Kluwer; 2023.
3. Sadler TW. Langman's Medical Embryology. 14th ed. Philadelphia: Wolters Kluwer; 2019.
4. Hollinshead WH. Anatomy for Surgeons. Vol 3. 3rd ed. Philadelphia: Harper and Row; 1982.
5. Choi D, Rodríguez-Niedenführ M, Vázquez T, Parkin I, Sañudo JR. Patterns of connections between the musculocutaneous and median nerves in the axilla and arm. Clin Anat. 2002;15(1):11-17.
6. Tubbs RS, Shoja MM, Loukas M. Bergman's Comprehensive Encyclopedia of Human Anatomic Variation. Hoboken: Wiley-Blackwell; 2016.
7. Prasada Rao PV, Chaudhary SC. Communication of the musculocutaneous nerve with the median nerve. East Afr Med J. 2000;77(9):498-503.
8. Kerr AT. The brachial plexus of nerves in man, the variations in its formation and branches. Am J Anat. 1918;23(2):285-395.
9. Uysal II, Seker M, Karabulut AK, Büyükmumcu M, Ziylan T. Brachial plexus variations in human fetuses. Neurosurgery. 2003;53(3):676-684.
10. Fazan VPS, Amadeu ADS, Caleffi AL, Rodrigues Filho OA. Brachial plexus variations in its formation and main branches. Acta Cir Bras. 2003;18(Suppl 5):14-18.
11. Uysal II, Seker M, Karabulut AK, Büyükmumcu M, Ziylan T. Brachial plexus variations in human fetuses. Neurosurgery. 2003;53(3):676-684.
12. Fazan VPS, Amadeu ADS, Caleffi AL, Rodrigues Filho OA. Brachial plexus variations in its formation and main branches. Acta Cir Bras. 2003;18 Suppl 5:14-18.
13. Choi D, Rodríguez-Niedenführ M, Vázquez T, Parkin I, Sañudo JR. Patterns of connections between the musculocutaneous and median nerves in the axilla and arm. Clin Anat. 2002;15(1):11-17.
14. Tubbs RS, Shoja MM, Loukas M. Bergman's Comprehensive Encyclopedia of Human Anatomic Variation. Hoboken: Wiley-Blackwell; 2016.