

Anatomical Variations of the Brachial Plexus in Adult Cadavers: A Cadaveric Descriptive Study**Rashmi Kumari¹, Pallavi Priyavadini², Seema Tabassum³, Sudhir Kumar Karn⁴**¹Tutor, Department of Anatomy, Darbhanga Medical College and Hospital, Laheriasarai, Darbhanga, Bihar, India²Tutor, Department of Anatomy, Darbhanga Medical College and Hospital, Laheriasarai, Darbhanga, Bihar, India³Professor, Department of Anatomy, Darbhanga Medical College and Hospital, Laheriasarai, Darbhanga, Bihar, India⁴Professor and HOD, Department of Anatomy, Darbhanga Medical College and Hospital, Laheriasarai, Darbhanga, Bihar, India

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Abstract:**Background:** The brachial plexus shows frequent anatomical variations that may complicate diagnosis, regional anesthesia, and upper-limb surgery, potentially leading to incomplete nerve block or iatrogenic injury.**Aim:** To document the anatomical variations of the brachial plexus in adult cadavers and determine the frequency of common and uncommon patterns.**Methodology:** A descriptive cross-sectional cadaveric study was conducted on 20 adult cadavers (40 upper limbs). Bilateral dissections were performed following standard protocols, and variations at roots, trunks, divisions, cords, and terminal branches were recorded and analyzed using descriptive statistics.**Results:** The usual root pattern was observed in 85% of limbs; variations included prefixed plexus (12.5%) and postfixed plexus (2.5%). Trunks and divisions showed no variation (100%). Cord variations occurred in 10%, including communications and a two-cord pattern. Branch variations were seen in 10%, including absence of the musculocutaneous nerve and communicating branches with the median nerve. Variations were most frequent at the roots and branches.**Conclusion:** Although the classical pattern predominated, clinically significant variations were common at roots, cords, and terminal branches. Awareness of these patterns is essential to improve surgical safety and anesthetic success.**Keywords:** Brachial Plexus, Anatomical Variation, Cadaveric Study, Musculocutaneous Nerve, Prefixed Plexus, Regional Anesthesia.**DOI:** 10.25258/ijpqa.17.2.40

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Introduction

The understanding of the structure of nerves in the limbs is of paramount clinical significance as injuries to upper limb are frequent and can give rise to a serious functional disability [1]. The neural structures of the shoulder and arm are common in trauma, compression neuropathies, fractures, dislocations, tumors, and iatrogenic surgical injuries. Since these structures control motor and sensory inception, any slight damage to the brain can seriously affect the day-to-day routine like grasping, lifting, writing and well-coordinated movement. Clinicians therefore need to have a good knowledge of neural anatomy in diagnosis, regional anesthesia, reconstructive and rehabilitation planning. In the neurological injuries, there is hardly any room to make mistakes in treating them and in the case that variations occur, it

becomes more challenging to treat and may slow down the surgical procedure thereby lowering the quality of the outcomes [2,3].

Anatomical differences of brachial plexus are not as infrequent as the practicing clinician might assume. In fact, over half of the nerve system anatomical variations have been noted to be brachial plexus based [4]. It is due to this high frequency that the unexpected revelations of surgical exploration, nerve block surgery, or radiological imaging are not unusual. Ignoring these differences can lead to incomplete anesthesia, interpretation of imaging studies, and inability to repair nerves or postoperative neurological impairments.

The upper limb is nourished by the brachial plexus containing both motor and sensory innervation. It is composed of anterior rami of the 5th cervical (C5) to the 8th cervical (C8) and the first thoracic spinal nerve (T1). The plexus originates in the lower cervical area, originating at the neck and then spreading laterally to the apex of the axilla and then enters the anterior arm compartment [5]. The brachial plexus contains five roots, three trunks, six divisions, three cords, five terminal branches. C5, C6, C7, C8, and T1 have their roots leaving the spinal canal under their respective levels. The trunks are created as a result of the fusion of C5 and C6 to form upper trunk, C7 constitutes middle trunk and C8 and T1 constitute lower trunks. The trunks have their anterior and posterior division, and a combination of these divisions makes the cords.

In this way, the three posterior divisions create the posterior cord and include the fibers of all the segments whereas the anterior divisions of the upper and middle trunks that contain C5-7 roots merge to create the lateral cord. The continuation of the anterior division of lower trunk with C8 and T1 roots is known as the medial cord. The five terminal branches are formed by the cords: the lateral cord proceeds to become the musculocutaneous nerve, the medial cord to be the ulnar nerve and the posterior cord to be the radial nerve. The lateral and medial cords communicate with each other (median nerve) [6] between them. This typical example signifies the pattern of the textbook, but almost always there are various deviations, which touch on roots, trunks, divisions, cords, and terminal branches.

As demonstrated by the neuronal growth cones [7], anatomical differences in the pattern of the brachial plexus could be attributed to developmental defects of the trunks, divisions or cords and be explained by variations among neurons. Motor axons during embryological development differentiate in the distal direction of limb buds under the action of chemo-attractant and chemo-repellent molecular signals. Any small changes in these signaling pathways can lead to persistence, vanishing or abnormal fusion of nerve fibers. Such developmental anomalies ultimately appear as prefixed or postfixed plexuses, abnormalities in communication between nerves, in accessory branches, failure of anticipated nerves to develop, or variations in branching. Hence, differences are not developmental anomalies but normal developmental options.

Some 50% of the individuals exhibit some slight change in the pattern of the brachial plexus, prefixed brachial plexus being one of the more frequent changes [8]. With a prefixed plexus, approximation changes towards the upper end only (C4-C8) and with a postfixed plexus the approximation changes towards the lower end only (C6-T2). Such changes can modify patterns of dermatomes and nerve injury clinical manifestation. As an example, when a

prefixed plexus exists, the symptoms that are likely to occur due to a C5 lesion might occur in a different pattern. It has also been reported regularly that variations in the branches of the cords occur. Among the common findings are communications between musculocutaneous and median nerves, abnormal origin of radial nerves, nerve duplication and abnormal sequences of the branches.

Due to these differences, special care techniques like the brachial plexus block anesthesia have to be performed with an anatomical expertise. Anesthesiologists are based on the ability to predict the relationships between various nerves and structures, but a variation in the relationship may lead to incomplete nerve blockage or a blood vessel being punctured [9] inadvertently. Correspondingly, orthopedic surgeons that repair humeral fractures, neurosurgeons that graft nerves, and plastic surgeons that undergo reconstructive surgery have to determine which nerve routes to avoid so as not to cause harm unknowingly. Radiology MRI and ultrasound MRI and ultrasound interpretations also require an anatomical understanding of normal and variant anatomy.

The frequency of variations in the brachial plexus has been found to have much variability worldwide, with regional variations also being reported. Population specific patterns may be a result of genetic, environmental and developmental factors. Thus, local cadaveric research is also needed to record local anatomical features and advance clinical practice. Despite some case reports and a few surveys with regard to the variability of the brachial plexus have been done in India, further descriptive cadaveric studies are required to capture the rare variants and determine the frequency of common variants, hence complementing the existing information [10].

Cadaveric dissection has always been the gold standard of understanding the anatomy of the peripheral nerves as it is able to give direct visualization of structures and relationships which cannot necessarily be seen through imaging alone. Cadaveric studies are documented in detail, a reliable source of anatomical information to clinicians, educators as well as researchers. Furthermore, the knowledge of normal variation will enable one to differentiate pathology and anatomical variation in the course of surgical and diagnostic practice.

Thus, the current cadaveric descriptive research examined the anatomical difference of the brachial plexus of adult cadavers, uncommon patterns, as well as the prevalence of common patterns. This research aims to increase the safety of surgery, the success of regional anesthesia and add to the anatomical literature that has a practical clinical implication.

Methodology

Study Design: This research was conducted as a descriptive, cross-sectional cadaveric study aimed at

observing and documenting the anatomical variations of the brachial plexus in adult human cadavers. The study focused on identifying deviations from the classical anatomical pattern at different levels of the brachial plexus.

Study Area: The study was carried out in the Department of Anatomy at Darbhanga Medical College and Hospital, Laheriasarai, Darbhanga, Bihar, India.

Study Duration: The study was conducted over a period of six months from April 2025 to September 2025.

Sample Size: The total sample size consisted of 20 adult cadavers (N = 20), providing 40 upper limbs for detailed examination of the brachial plexus.

Sample Population: The study population comprised formalin-preserved adult human cadavers available in the Department of Anatomy during the study period. These cadavers were utilized for routine dissections by undergraduate medical students (2021 and 2022 batches) and allied health science students (2021 batch). All cadavers had been preserved in formalin for at least three months prior to dissection to ensure adequate fixation and tissue integrity.

Data Collection: Upper limb dissections were performed according to the standardized dissection protocol described in Grant's Dissector. The dissections were carried out under the supervision of anatomy faculty members who served as investigators in the study. Each brachial plexus was examined bilaterally at the levels of roots, trunks, divisions, cords, and terminal branches. The distal course of branch nerves beyond their origin was not further assessed. All observed anatomical variations were carefully documented, systematically recorded in structured data sheets, and photographed for academic and research purposes.

Inclusion Criteria

- Adult human cadavers available during the study period
- Well-preserved formalin-fixed cadavers
- Cadavers with intact upper limbs and undisturbed axillary regions

Exclusion Criteria

- Cadavers with evidence of prior upper limb surgery
- Cadavers with traumatic injuries or deformities involving the neck, axilla, or upper limb

- Poorly preserved or damaged specimens
- Cadavers with previously dissected or disturbed brachial plexus regions

Procedure: The skin, superficial fascia, and deep fascia of the neck and axillary region were carefully removed to expose the underlying structures. The muscles of the posterior triangle of the neck and axilla were reflected systematically to visualize the brachial plexus. The roots arising from spinal nerves C5 to T1 were identified and traced to their formation into trunks, divisions, cords, and terminal branches. Any deviation from the classical anatomical description was identified, categorized, and recorded. Bilateral comparisons were made where applicable to assess symmetry or asymmetry of variations.

Statistical Analysis: The collected data were entered into Microsoft Excel and analyzed using descriptive statistical methods. Frequencies and percentages were calculated for each observed anatomical variation. Bilateral symmetry and asymmetry were also documented. The findings were presented in tabular and graphical formats where appropriate. As the study was descriptive in nature, no inferential statistical tests were applied."

Result

Table 1 presents the variations observed in the brachial plexus among 40 upper limbs (N = 40). At the root level, the usual pattern was seen in 34 limbs (85%), while variations occurred in 6 limbs (15%), including prefixed plexus with C4 contribution in 5 limbs (12.5%) and postfixed plexus with T2 contribution in 1 limb (2.5%). The trunks and divisions showed no variations (100% usual pattern). In the cords, the normal arrangement was present in 35 limbs (87.5%), whereas variations were seen in 4 limbs (10%), including communication between lateral and medial cords in 2 limbs (5%), lateral cord communicating with the medial root of the median nerve in 1 limb (2.5%), and the presence of only two cords in 1 limb (2.5%). Regarding branches, 32 limbs (80%) had the usual pattern, while 4 limbs (10%) showed variations such as absence of the musculocutaneous nerve in 2 limbs (5%) and a communicating branch from musculocutaneous to median nerve in 2 limbs (5%). Overall, variations were most frequent at the root level and least common in trunks and divisions.

Part of the Plexus	Number with Usual Pattern n (%)	Number with Variations n (%)	Variation
Roots	34 (85%)	5 (12.5%)	Prefixed brachial plexus (C4 contribution)
		1 (2.5%)	Postfixed brachial plexus (T2 contribution)
Trunks	40 (100%)	0 (0%)	No variations observed
Divisions	40 (100%)	0 (0%)	No variations observed
Cords	35 (87.5%)	2 (5%)	Communication between lateral and medial cords
		1 (2.5%)	Lateral cord communicating with medial root of median nerve
		1 (2.5%)	Only two cords present (posterior and combined anterior cord)
Branches	32 (80%)	2 (5%)	Absence of musculocutaneous nerve
		2 (5%)	Musculocutaneous nerve giving communicating branch to median nerve

Discussion

The current cadaveric research showed that most brachial plexuses still had classical structure, 85 percent of these had the normal root structure and 15 percent had variations. A prefixed plexus was found in 12.5% and a postfixed plexus in 2.5% of limbs among them. The observed prevalence rates are similar to global prevalence rates of about 9-11 per cent of prefixed and 1-3 per cent of postfixed plexuses that have been previously reported (Guday et al., 2017; Leonhard et al., 2016) [8,11]. This somewhat elevated prefixed incidence of our material could be due to population-based anatomical variation in that meta-analysis studies indicate regional discrepancies in the morphology of the brachial plexus (Benes et al., 2021) [12] [12]. Just as root differences were rare in the prior cadavers, root differences in our sample were more conservative than distal ones, which supports the idea that neural patterning in the proximal areas is more conserved than the distal ones during embryonic development (Emamhadi et al., 2016) [6].”

The current study did not show any anomalies in trunk or division as all limbs had the typical arrangement. This is contrary to the previous radiological and cadaveric results that revealed anomalies of the trunk in the range of 8-16 percent and anomalies of division in the range of 2-4 percent of cases (Cooke et al., 1988) [5]. Our sample size may not have been enough, or the ethnic homogeneity may have caused the lack of trunk and division variations. However, the same lack has sometimes been observed in local cadaveric research, indicating that the organization of upper plexus is relatively stable as compared to cords and terminal branches (Emamhadi et al., 2016) [6]. This consistency is clinically important as blocks to the trunks and divisions, i.e., supraclavicular blocks can have more predictable effects than in accords that are infraclavicular and more variable.

In the current study, the percentage of limbs that had a cord-level variation was 12.5%. Lateral to medial

cord communication was present in 5% of cases, lateral cord to medial root of median nerve in 2.5% of cases as well as two cords only. Similar messages between cords have been reported before in 310% of specimens (Goel et al., 2014; Emamhadi et al., 2016) [9,6]. Combined anterior cord is, however, much rarer and has been reported infrequently. These abnormal morphologies could change the topography of traumatic sensory injuries and could be the reason behind the unusual nerve conduction results during electrophysiological investigations. Surgically, unexpected cord communications heighten the chances that nerve blockade is not achieved adequately and the accidental damage to nerves occurs during the performance of axillary clearance surgeries (Padur et al., 2016) [10].

In our study, terminal branches variations were most common and only 80% of the variations had the classical branching pattern. In 5% of the limbs, there was no musculocutaneous nerve and in another 5% there were communicating branches between musculocutaneous and median nerves. Past anatomy literature indicates that terminal branch variability is found in about a quarter of people (Moore and Dalley, 1992) [13] which is similar to our results. Amputation of the musculocutaneous nerve with replacement of the median nerve is described as a rather uncommon but clinically significant anomaly (Parchand & Patil, 2013; Aydin et al., 2006) [14,15]. We have a 5% incidence which is quite a bit higher than several reports of incidence between 1 and 3, which could also be due to population variation. The aberration is especially crucial when carrying out nerve transfer surgeries and repairing humeral fracture, as the damage to the median nerve can also result in a reduction in the elbow flexion in the absence of musculocutaneous nerves.

The variation of communication between musculocutaneous and median nerve is Type II as outlined by Le Minor (1990) [16]. Previous cases stated 3-15 percent (Emamhadi et al., 2016) [6]. The fact that we discovered 5% is in this range. Neurological

impairments can be hidden by such communication, e.g., damage to the median nerve can still permit partial flexion of the forearm as a result of cross-innervation. Thus, the assessment of traumatic lesions or neuropathies should be reviewed with caution by surgeons and neurologists by interpreting motor weakness.

Generally, the current outcomes allow us to confirm the popular pattern that the least common variation can be found in trunks and divisions, more common at the root level, and most common in terminal branches. The systematic reviews have also highlighted similar hierarchical distribution (Benes et al., 2021) [12]. Embryologically, the later and more prone to change axonal guidance of distal segments, which is why the variation frequency is more frequent at the extremes (Snow, 2014) [7]. This is clinically important because infraclavicular and axillary methods of anesthesia or exploration must be done with increased attention as opposed to supraclavicular methods.

Overall, we find that our results are quite generally consistent with already available anatomical research studies but reveal a slightly larger variation rates of roots and terminal branches. Such disparities are probably due to anatomical variation in the regions and not a difference in methodology. Such differences need to be known to avoid misdiagnosis, unsuccessful nerve blocks, and iatrogenic injuries, especially in reconstructive, orthopedic, and neurosurgical works on the upper limb.

Conclusion

This current cadaveric research proves that the most common arrangement of the brachial plexus is in accordance with the classical anatomical pattern but, there exist significant differences, which are mostly at the roots, cords, and end branches. Root level changes were made of prefixed and postfixed configurations with the trunks and divisions kept fixed. Cord-level variations were characterized by abnormal communications and unusual fusions of anterior elements, which gave an abnormal cord formation in rare cases. Absence of musculocutaneous nerves and communication between musculocutaneous and median nerves was seen among the terminal branches. These results indicate that the overall structure of the brachial plexus can be largely maintained but clinically significant variations are not rare that can make surgeons, anesthesiologists, and clinicians to pay attention to anatomy details to help to prevent diagnostic errors and avoid iatrogenic nerve damages in cases of regional anesthesia and upper limb surgery.

References

1. Brunelli G, Brunelli F. Brachial plexus injuries Lamb DW, Hooper G, Kuczynski K (Eds.), The Practice of Hand Surgery (second ed.),

- Blackwell Scientific publications, Boston (1989), pp. 218-227.
2. Haghparast-Ghadim-Limudahi Z. Survey of 2582 cases of acute orthopedic trauma. *Trauma Mon.* 2014; 19(4):e16215.
3. Shin AY, Spinner RJ, Steinmann SP, Bishop AT. Adult traumatic brachial plexus injuries. *J Am Acad Orthop Surg.* 2005 Oct;13(6):382-96.
4. Peter L. Williams. *Gray's Anatomy.* 40th ed. Great Britain: Churchill Livingstone; 2008. P. 1266-74.
5. Cooke J, Cooke D, Parsons C. The anatomy and pathology of the brachial plexus as demonstrated by computed tomography *Clin. Radiol.*, 39 (1988), pp. 595-601.
6. Emamhadi M, Chabok SY, Samini F, Alijani B, Behzadnia H, Firozabadi FA, Reihanian Z. Anatomical Variations of Brachial Plexus in Adult Cadavers; A Descriptive Study. *Arch Bone Jt Surg.* 2016 ;4(3):253-8.
7. Snow DM. Neuronal growth cones and regeneration: gridlock within the extracellular matrix. *Neural Regen Res* 2014; 9:341–342.
8. Guday E, Bekele A, Mucche A. Anatomical study of prefixed versus postfixed brachial plexuses in adult human cadaver. *ANZ J Surg.* 2017;87(5):399–403.
9. Goel S, Rustagi SM, Kumar A et-al. Multiple unilateral variations in medial and lateral cords of brachial plexus and their branches. *Anat Cell Biol.* 2014;47 (1): 77-80.
10. Padur AA, Kumar N, Shanthakumar SR, Shetty SD, Prabhu GS, Patil J. Unusual and unique variant branches of lateral cord of brachial plexus and its clinical implications – a cadaveric study. *J Clin Diag Res.* 2016; 10: AC01-04.
11. Leonhard V, Smith R, Caldwell G, Smith HF. Anatomical variations in the brachial plexus roots: Implications for diagnosis of neurogenic thoracic outlet syndrome. *Ann Anat* 2016; 206:21–26.
12. Benes M, Kachlik D, Belbla M, Havlikova S, Kunec V, Whitley A, Kunca V. A metaanalysis on the anatomical variability of the brachial plexus: Part I—Roots, trunks, divisions and cords. *Ann Anat.* 2021; 238:151751.
13. Moore KL, Dalley AF. *Clinically Oriented Anatomy* (fourth ed.), Lippincott, Williams and Wilkins., Philadelphia (1992), pp. 714- 715.
14. Parchand MP, Patil ST. Absence of musculocutaneous nerve with variations in course and distribution of the median nerve. *Anat Sci Int.* 2013; 88(1):58-60
15. Aydin ME, Kale A, Edizer M, Kopuz C, Demir MT, Corumlu U. Absence of the musculocutaneous nerve together with unusual innervation of the median nerve. *Folia Morphol (Warsz).* 2006; 65(3):228.

16. Le Minor IM. A rare variation of the median and musculocutaneous nerves in man Arch Annt Histol Embryul, 1990:73; 33-42.