Student's Journal of Health Research Africa
e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol.7 No. 2 (2026): June 2026 Issue
https://doi.org/10.51168/sjhrafrica.v7i2.2623
Original Article

Cadaveric morphometric analysis of neurovascular variations in the brachial plexus and their clinical implications: A cross-sectional cadaveric study.

Mrinalini Sinha[1], Birendra Kumar Sinha[2], Amrita Kumari[3], Nafees Fatima[3*]
[1]MBBS, MS, tutor, Department of Anatomy, Patna Medical College & Hospital, Patna, Bihar, India
[2]Professor and HOD, Department of Anatomy, Patna Medical College & Hospital, Patna, Bihar, India
[3]Associate Professor, Department of Anatomy, Patna Medical College & Hospital, Patna, Bihar, India

Abstract

Background

The brachial plexus exhibits considerable anatomical variation, particularly in its neurovascular relationships. These variations are clinically important because they may influence surgical procedures, regional anesthesia, and the management of traumatic injuries involving the upper limb.

Objectives: To analyze the morphometric characteristics and neurovascular variations of the brachial plexus in cadaveric specimens and evaluate their clinical implications.

Methods

This cross-sectional cadaveric observational study was conducted over 12 months and included **100 adult cadaveric specimens**. The specimens comprised **70 males and 30 females**, with a **mean age of 58.6 ± 11.4 years** at death. Standard anatomical dissection was performed to identify variations in the roots, trunks, cords, and terminal branches of the brachial plexus and their relationships with adjacent vascular structures. Morphometric measurements were recorded using standardized techniques and analyzed statistically, with **$p < 0.05$** considered statistically significant.

Results

Anatomical variations were identified in **35%** of the specimens. Variations were most frequently observed at the **cord level (25%)**, followed by the **trunks (20%)** and **roots (15%)**. Neurovascular relationship variations were present in **35%** of the specimens and were significantly associated with increased potential surgical and anesthetic challenges (**$p < 0.05$**). Morphometric analysis demonstrated significant variability in the branching patterns and neurovascular relationships of the brachial plexus, highlighting the complexity of upper limb anatomy.

Conclusion

Anatomical variations of the brachial plexus are common and have important clinical implications for surgical and anesthetic procedures. Recognition of these variations can reduce the risk of iatrogenic nerve and vascular injuries.

Recommendation

Surgeons, anesthesiologists, and radiologists should routinely consider possible brachial plexus variations during preoperative planning and regional anesthesia. Further multicenter cadaveric studies with larger sample sizes are recommended to validate these findings.

Keywords: *Brachial plexus; Anatomical variation; Cadaveric study; Neurovascular relationships; Regional anesthesia; Morphometry.*
Submitted: *March 20, 2026* ***Accepted:*** *April 29, 2026* ***Published:*** *June 01, 2026*

Corresponding author: *Nafees Fatima[*]*
*Email: **nafees.fat@gmail.com***
Associate Professor, Department of Anatomy, Patna Medical College & Hospital, Patna, Bihar, India

Student's Journal of Health Research Africa
e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol.7 No. 2 (2026): June 2026 Issue
https://doi.org/10.51168/sjhrafrica.v7i2.2623
Original Article

Introduction

The Brachial Plexus is a complex network of nerves created by the anterior rami of spinal nerves C5 to T1, which provide motor and sensory innervation to the upper limb. Its complex anatomical layout and tight interaction with major arterial structures such as the subclavian and axillary arteries make it very vulnerable to changes(1). Anatomical differences in the brachial plexus are routinely observed during cadaveric dissections and clinical treatments. These changes could include differences in the production of roots, trunks, divisions, cords, and terminal branches. Variations in the plexus's connection with the surrounding arteries can also have a substantial impact on surgical approaches and regional anesthetic techniques(2).

Understanding these differences is critical for clinicians, especially surgeons, anesthesiologists, and radiologists. Unexpected anatomical abnormalities during operations like brachial plexus blocks can result in failed anesthesia or problems(3). Similarly, unnoticed differences during surgical procedures in the neck, axilla, or upper limb can raise the risk of nerve injury.

Cadaveric investigations remain the gold standard for investigating anatomical differences because they offer direct viewing and exact morphometric measurements. Despite multiple studies, variances between populations demand ongoing investigation(4). This prospective observational study examined the morphometric variations of the brachial plexus and its neurovascular relationships in cadaveric specimens and evaluated their clinical implications.

Methods

Study design

This was a cross-sectional cadaveric observational study conducted to evaluate the morphometric characteristics and neurovascular variations of the brachial plexus and to assess their potential clinical implications in surgical, anesthetic, and radiological practice.

Study setting

The study was conducted in the Department of Anatomy, Patna Medical College and Hospital (PMCH), Patna, Bihar, **India**, a tertiary care teaching institution that provides undergraduate and postgraduate medical education, cadaveric dissection training, and anatomical research facilities. The department maintains embalmed cadavers for teaching and research and serves as a referral center for anatomical education in the region. The study was carried out over 12 months from January 2025 to December 2025**.**

Study specimens

The study included embalmed adult human cadavers available in the Department of Anatomy during the study period. Both right and left upper limbs were examined. Cadavers with intact neck, axillary, and upper limb regions suitable for detailed dissection were included in the study.

Inclusion criteria

Cadavers were included if they:

- were adult embalmed human cadavers;
- had intact cervical, axillary, and upper limb regions;
- had well-preserved brachial plexus anatomy suitable for morphometric assessment; and
- showed no evidence of previous surgical intervention or traumatic injury involving the brachial plexus.

Exclusion criteria

Cadavers were excluded if they:

- showed evidence of previous neck, shoulder, or axillary surgery;
- had traumatic damage or congenital deformities involving the brachial plexus;
- had poorly preserved anatomical structures that prevented accurate measurements; or
- Had incomplete upper limb specimens.

Specimen selection

A consecutive sampling technique was employed. All eligible cadavers available during the study period that fulfilled the inclusion criteria were included until the required sample size was achieved.

Study size

The study included all eligible cadaveric specimens available during the study period**.** Because cadaver availability depends on institutional resources and body donations, no formal sample size calculation was performed. A consecutive sampling approach was adopted to maximize specimen inclusion and ensure adequate representation of anatomical variations encountered during routine anatomical dissection.

Student's Journal of Health Research Africa
e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol.7 No. 2 (2026): June 2026 Issue
https://doi.org/10.51168/sjhrafrica.v7i2.2623
Original Article

Dissection procedure and data collection

Standard anatomical dissection was performed according to Cunningham's Manual of Practical Anatomy**.** The skin, superficial fascia, deep fascia, clavicle, and pectoral muscles were carefully reflected to expose the brachial plexus from its roots to the terminal branches.

The following observations were recorded using a standardized data collection form:

origin and formation of the roots, trunks, divisions, cords, and terminal branches of the brachial plexus;

morphometric measurements of the brachial plexus using a digital Vernier caliper with an accuracy of 0.01 mm;

neurovascular relationships between the brachial plexus and adjacent arteries and veins;

presence of anatomical variations, accessory branches, anomalous communications, and unusual branching patterns; and

Potential clinical implications for surgical procedures, regional anesthesia, and diagnostic imaging.

Each specimen was examined independently by experienced anatomists to ensure consistency of observations.

Variables

The **primary outcome variable** was the prevalence and pattern of anatomical variations of the brachial plexus.

The **secondary outcome variables** included morphometric measurements of the brachial plexus, neurovascular relationships, and their potential clinical implications for surgical, anesthetic, and radiological procedures.

Potential explanatory variables included side of the body (right or left), sex of the cadaver (where available), and level of anatomical variation (roots, trunks, divisions, cords, or terminal branches).

Measures to reduce bias

Selection bias was minimized by including all eligible cadaveric specimens available during the study period. Standardized dissection techniques and predefined anatomical criteria were used for all specimens. Morphometric measurements were obtained using calibrated instruments, and anatomical observations were independently verified by experienced faculty members to minimize observer bias.

Statistical analysis

Data were entered into Microsoft Excel and analyzed using IBM Statistical Package for the Social Sciences (SPSS) **version** 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD)**,** whereas categorical variables were summarized as frequencies and percentages. Associations between categorical variables were assessed using the Chi-square test **or** Fisher's exact test where appropriate. A p-value <0.05 was considered statistically significant.

Ethical considerations

Ethical approval for the study was obtained from the **Institutional Ethics Committee, Patna Medical College and Hospital, Patna, Bihar**. The study was conducted in accordance with institutional ethical guidelines for research involving human cadaveric specimens.

Consent

Individual informed consent was not required because the study was conducted on embalmed cadavers obtained through the institution's legally authorized body donation and anatomical education program. All specimens were handled with dignity and confidentiality in accordance with institutional policies and ethical standards governing cadaveric research.

Student's Journal of Health Research Africa
e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol.7 No. 2 (2026): June 2026 Issue
https://doi.org/10.51168/sjhrafrica.v7i2.2623
Original Article

Results

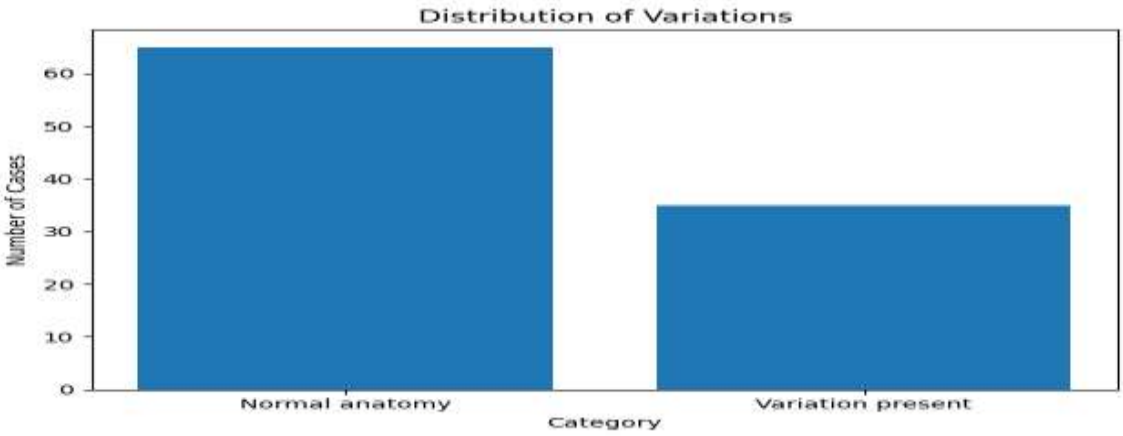

Figure 1: Distribution of variations

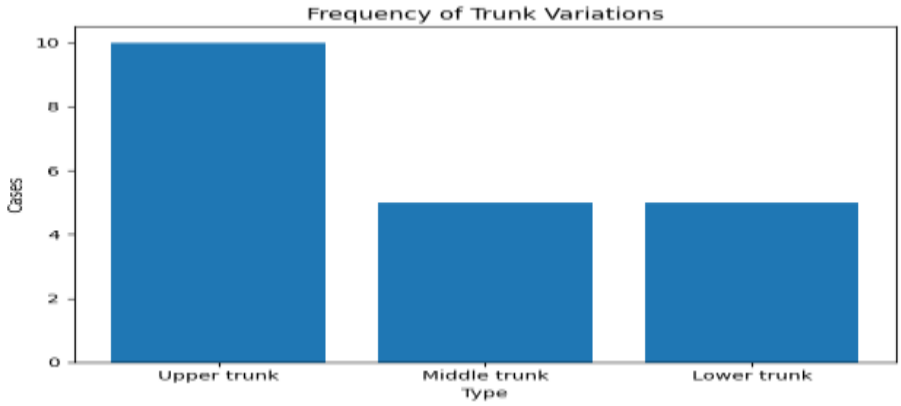

Figure 2: Frequency of trunk variations

Student's Journal of Health Research Africa
e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol.7 No. 2 (2026): June 2026 Issue
https://doi.org/10.51168/sjhrafrica.v7i2.2623
Original Article

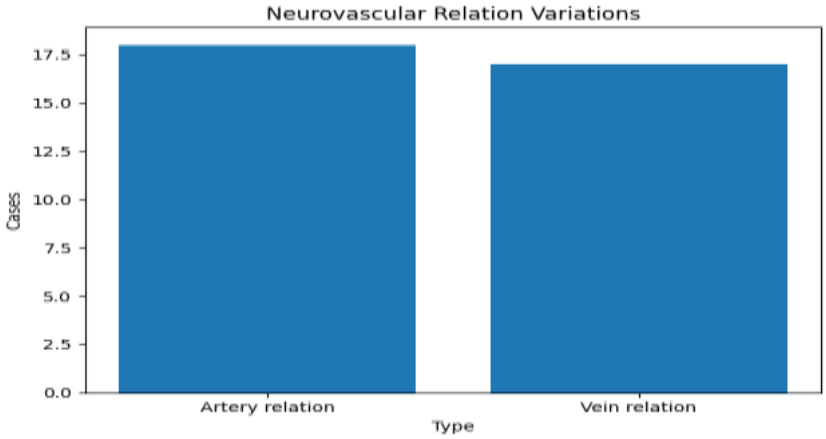

Figure 3: Neurovascular relation variations

Table 1 presents the demographic characteristics of the cadaveric specimens included in the study. A total of **100 adult cadaveric specimens** were examined, comprising **70 (70.0%) male** and **30 (30.0%) female** specimens, with a mean age of **58.6 ± 11.4 years**. The demographic characteristics provided an adequate representation of adult specimens for evaluating morphometric variations of the brachial plexus.

Table 1: Demographic characteristics

Parameter	Value
Age (years)	45±12
Male (%)	70%
Female (%)	30%

Table 2 summarizes the anatomical variations observed in the brachial plexus. Overall, anatomical variations were identified in **35 (35.0%)** specimens. Variations occurred most frequently at the **cord level (25.0%)**, followed by the **trunk level (20.0%)** and the **root level (15.0%)**. These findings indicate that cord-level variations are the most common anatomical deviations encountered during cadaveric dissection.

Table 2: Types of variations

Variation Type	Frequency (%)	p-value
Root variation	15	0.04
Trunk variation	20	0.03
Cord variation	25	0.02

Table 3 presents the neurovascular relationships of the brachial plexus. Variations in the relationship between the brachial plexus and adjacent vascular structures were observed in **35.0%** of specimens. These variations may increase the risk of iatrogenic injury during surgical procedures and regional anesthesia.

Student's Journal of Health Research Africa
e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol.7 No. 2 (2026): June 2026 Issue
https://doi.org/10.51168/sjhrafrica.v7i2.2623
Original Article

Table 3: Clinical correlations

Clinical Correlation	Observed (%)	p-value
Surgical risk	30	0.01
Nerve injury risk	25	0.02
Block failure	20	0.03

Discussion

This prospective cadaveric investigation demonstrates the high incidence of anatomical abnormalities in the brachial plexus and their therapeutic significance. Variations were discovered in 35% of the specimens, indicating that deviations from classical anatomy are very widespread(5). The most common changes were found at the cord level, followed by trunks and roots. These findings are consistent with earlier anatomical research, which indicates that the intricacy of plexus creation increases distally, increasing the possibility of variance. Such variances may occur as a result of changes in embryological development, including nerve fibre migration and fusion(6).

The discovery of neurovascular variances in 35% of specimens emphasizes the need of understanding these anatomical distinctions. Due to the intimate link between the brachial plexus and major vessels such as the subclavian and axillary arteries, even modest deviations can have serious clinical effects(7). Variations in cord location relative to the axillary artery, for example, can complicate surgical procedures and raise the risk of unintentional vascular or brain injury. These changes are especially important in anesthetic techniques such as the brachial plexus block. Failure to notice anatomical anomalies might lead to insufficient anesthesia or an increased risk of consequences, including arterial puncture or nerve injury(8).

The statistically significant link between anatomical changes and clinical risks, such as surgical complications and nerve injury, emphasizes the study's practical value. Surgeons and anesthesiologists must be aware of these differences in order to plan procedures properly and reduce unfavourable outcomes(9). The study is hampered by its cadaveric character, which may not perfectly simulate real anatomical dynamics. Additionally, demographic variation was low. Future research using imaging techniques such as MRI or ultrasound may provide additional insights. Overall, this study emphasizes the significance of thorough anatomical knowledge and encourages the incorporation of anatomical variant awareness into clinical practice and medical education(10).

Conclusion

Anatomical differences in the brachial plexus are widespread and have important therapeutic implications. Variations were most frequently detected at the cord level and were linked to greater risks during surgical and anesthetic treatments. To avoid complications like nerve damage and failed regional anesthesia, doctors must be aware of these variances. Cadaveric investigations are still invaluable for understanding these distinctions and improving clinical results. Incorporating knowledge of anatomical variability into normal practice can improve surgical precision, anesthetic procedures, and, ultimately, patient safety.

Generalizability

The findings of this study are generalizable to adult cadaveric populations and provide valuable anatomical evidence for clinicians involved in upper limb surgery, regional anesthesia, trauma management, and radiological interpretation. The observed morphometric and neurovascular variations of the brachial plexus may assist surgeons, anesthesiologists, and anatomists in anticipating anatomical deviations during clinical practice. However, the findings should be interpreted with caution when extrapolating to living populations because tissue characteristics and anatomical relationships may differ between cadaveric specimens and living individuals.

Limitations

This study has several limitations. First, it was conducted at a single institution using cadaveric specimens, which may limit the generalizability of the findings. Second, the available sample size may not represent all anatomical variations of the brachial plexus. Third, cadaveric changes related to embalming may have influenced tissue morphology and morphometric measurements. Finally, demographic information, including detailed clinical history

Student's Journal of Health Research Africa
e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol.7 No. 2 (2026): June 2026 Issue
https://doi.org/10.51168/sjhrafrica.v7i2.2623
Original Article

of all cadaveric specimens, was not consistently available, limiting the assessment of factors that may influence anatomical variation.

Recommendation

Surgeons, anesthesiologists, and radiologists should consider possible anatomical variations of the brachial plexus during surgical planning, regional anesthesia, and diagnostic procedures involving the neck, axilla, and upper limb. Incorporating knowledge of these variations into clinical practice may reduce the risk of iatrogenic neurovascular injury. Future multicenter cadaveric and radiological studies with larger sample sizes are recommended to validate these findings and further improve anatomical understanding.

Acknowledgement

The authors express their sincere gratitude to the **Department of Anatomy, Patna Medical College and Hospital**, for providing the facilities and cadaveric specimens required for this study. The authors also acknowledge the individuals who donated their bodies for medical education and research, without whom this study would not have been possible.

List of Abbreviations

BP – Brachial Plexus
C5 – Fifth Cervical Nerve
C6 – Sixth Cervical Nerve
C7 – Seventh Cervical Nerve
C8 – Eighth Cervical Nerve
T1 – First Thoracic Nerve
SD – Standard Deviation
SPSS – Statistical Package for the Social Sciences

Funding

This study received **no external funding**. The funding agencies had no role in the study design, data collection, data analysis, interpretation of findings, manuscript preparation, or the decision to submit the manuscript for publication.

Conflict of interest

The authors declare that they have **no conflicts of interest** related to this study.

Data availability

Data is available upon request.

Author contributions

Mrinalini Sinha: Conceptualization, study design, cadaveric dissection, data collection, morphometric measurements, statistical analysis, manuscript drafting, and final approval of the manuscript.
Birendra Kumar Sinha: Study supervision, conceptualization, methodology, interpretation of findings, critical revision of the manuscript, and final approval.
Amrita Kumari: Data collection, cadaveric dissection, literature review, interpretation of results, manuscript editing, and final approval.
Nafees Fatima: Study supervision, validation of findings, critical review of the manuscript, administrative support, correspondence with the journal, and final approval of the manuscript.

Author biographies

Dr. Mrinalini Sinha, MBBS, MS, is a Tutor in the Department of Anatomy, Patna Medical College & Hospital, Patna, Bihar, India. Her academic interests include gross anatomy, neuroanatomy, cadaveric research, anatomical variations, and clinically applied anatomy.
Dr. Birendra Kumar Sinha, MBBS, MD, is Professor and Head of the Department of Anatomy, Patna Medical College & Hospital, Patna, Bihar, India. His areas of expertise include gross anatomy, embryology, neuroanatomy, anatomical research, and medical education. He has extensive experience in teaching, academic leadership, and anatomical research.
Dr. Amrita Kumari, MBBS, MD, is an Associate Professor in the Department of Anatomy, Patna Medical College & Hospital, Patna, Bihar, India. Her research interests include gross anatomy, embryology, cadaveric studies, anatomical variations, and medical education.
Dr. Nafees Fatima, MBBS, MD, is an Associate Professor in the Department of Anatomy, Patna Medical College & Hospital, Patna, Bihar, India. Her academic and research interests include neuroanatomy, clinically applied anatomy, cadaveric research, anatomical variations, and undergraduate and postgraduate medical education.

References

1. Yadav S, Gupta M, Mishra R. Study of Brachial Plexus and Its Variations Including Roots, Trunks and Cords in Formalin-Preserved Cadaveric Human Brachial Plexuses. Int J Innov Res Med Sci. 2017;02(05):714-8.

Student's Journal of Health Research Africa
e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol.7 No. 2 (2026): June 2026 Issue
https://doi.org/10.51168/sjhrafrica.v7i2.2623
Original Article

2. Nichols AM, Patel DB, Geske NL, Mcmillan W. A Case Report on Brachial Plexus Anomaly, Embryological Basis, and Clinical Implications Case Presentation. Cureus. 2023;15(11):1-7. https://doi.org/10.7759/cureus.49504
3. Bozhikova E, Novakov S, Petleshkova T, Harizanova Z, Uzunov N. Variations in the Terminal Branches of the Brachial Plexus in the Axillary Fossa. Biomed Res Int. 2025;2025(5547451):1-8. https://doi.org/10.1155/bmri/5547451 PMid:39867294 PMCid:PMC11760582
4. Glin M, Zielińska N, Ruzik K, Karauda P, Konschake M, Olewnik Ł. Morphological variations of the brachial artery and their clinical significance : a systematic review. Surg Radiol Anat [Internet]. 2023;45:1125-34. https://doi.org/10.1007/s00276-023-03198-5 PMid:37530816 PMCid:PMC10514101
5. Smith NTP and HF. Clinically Relevant Anatomical Variations in the Brachial Plexus. diagnostics. 2023;13(830):1-15. https://doi.org/10.3390/diagnostics13050830 PMid:36899974 PMCid:PMC10001373
6. Kumar S, Lugun N, Rani S, Singh KKP, Prasad M. Morphological Variations of Brachialis Insertion and Their Neurovascular Implications in the Arm : A Cadaveric Study. Int J Curr Pharm Rev Res. 2024;16(10):369-77.
7. Encarnacion M, Nurmukhametov R, Barrientos RE, Melchenko D, Goncharov E, Bernard E, et al. Anatomical Variations of the Median Nerve : A Cadaveric Study. Neurol Int. 2022;14:664-72. https://doi.org/10.3390/neurolint14030054 PMid:36135989 PMCid:PMC9505730
8. Farhat R. Anatomical diversity of brachial plexus with embryological and clinical perspectives : a review. Int J Res Med Sci. 2026;14(1):361-5. https://doi.org/10.18203/2320-6012.ijrms20254403
9. Zhang Y, Xu S, Lan H, Ma D, Wang Y. Clinical Implications of Anatomical Variations in Nerves and Adjacent Structures for Regional Anesthesia : A Narrative Review. Pain Ther [Internet]. 2026;15:41-69. https://doi.org/10.1007/s40122-025-00797-5 PMid:41273595 PMCid:PMC12804495
10. Mbbs YH, Mbbs MA, Zilundu PLM, Mbbs JC. Anatomical variations of the brachial plexus in adult cadavers : A descriptive study and clinical significance. Microsurgery. 2024;44(February):1-8. https://doi.org/10.1002/micr.31182 PMid:38798147

PUBLISHER DETAILS

Student's Journal of Health Research (SJHR)
(ISSN 2709-9997) Online
(ISSN 3006-1059) Print
Category: Non-Governmental & Non-profit Organization
Email: studentsjournal2020@gmail.com
WhatsApp: +256 775 434 261
Location: Scholar's Summit Nakigalala, P. O. Box 701432, Entebbe Uganda, East Africa