Research Article

Branching Patterns Of The Posterior Cord Of The Brachial Plexus In Human Fetuses: A Morphological Study With Anatomical And Surgical Significance

Dr. Lakshmi Kiruba N[1] , Dr. Surekha Waghanna[2] , Dr. Swapna Parate[3] , Dr. Dnyandeo Chopade[4] , Dr. Amit Naik[5], Dr. Kumar Satish Ravi[6]

[1]PhD scholar, Department of Anatomy, National Institute of Medical Sciences and Research, Nims University Rajasthan, Jaipur. lakshmikiruba1@gmail.com
[2]Assistant Professor, Department of Anatomy, National Institute of Medical Sciences and Research, Nims University Rajasthan, Jaipur. drsurekha.patil11@yahoo.com
[3]Professor & Head, Department of Anatomy, SMBT IMS & RC, Nashik, Maharashtra. drswapna.sorte@gmail.com
[4]Professor, Department of Anatomy, SMBT IMS & RC, Nashik, Maharashtra. drchopade@geneticsindia.com
[5]Professor and Head, Department of OBGY, SMBT IMS & RC, Nashik, Maharashtra. drnaikamit@gmail.com
[6]Professor & Head, Department of anatomy, National Institute of Medical Sciences and Research, Nims University Rajasthan, Jaipur. drksravi.jipmer@gmail.com
Corresponding author: Dr. Surekha Waghanna, Assistant Professor, Department of Anatomy, National Institute of Medical Sciences and Research, Nims University Rajasthan, Jaipur. drsurekha.patil11@yahoo.com

Abstract

Background: The posterior cord supplies muscles of posterior wall of axilla and extensor compartments of the upper limb. Variations in the Branching pattern may increase the risk of iatrogenic injury during axillary surgery, nerve blocks, and neurotization. This study aims to describe the developmental morphology and variations in branching pattern of the posterior cord of the brachial plexus in human fetuses and to assess their surgical relevance
Methods: Thirty upper limbs from 15 human fetuses (20–40 weeks gestation) were dissected. Posterior cord Branching patterns were documented and photographed. Statistical associations between laterality and variations were analyzed using Fisher's exact test via IBM SPSS 28.0 ($P<0.05$).
Results: Variations were observed in 47% (14/30) of limbs and 67% (10/15) of fetuses. These variations were more prevalent on the right side (64%) and were more frequently unilateral (60%) than bilateral (40%). The most common variation was a common trunk for the axillary nerve (AN) and lower subscapular nerve (LSN), occurring in 57% (8/14) of variant limbs. Other significant patterns included the AN or upper subscapular nerve arising from the posterior division of the upper trunk (4/14), various common trunks involving the thoracodorsal nerve, and instances of triple subscapular nerves.
Conclusion: Fetal posterior cord branching exhibits significant morphological variability. Awareness of these anatomical patterns is essential to prevent iatrogenic nerve injury during pediatric axillary surgery, neurotization, and regional anesthesia

Keywords: Brachial plexus; Human fetus; Anatomical variation; Nerve Block; Surgical anatomy; Regional anesthesia; Nerve Transfer; Axillary nerve.

Introduction

The brachial plexus provides essential motor and sensory innervation to the upper limbs. Classically, its posterior cord gives rise to the upper subscapular, thoracodorsal, lower subscapular, and axillary nerves before terminating as the radial nerve [1]. However, this standard pattern is observed in a minority of cases, with significant population-based variations occurring [1,2]. Understanding these variations is of immense clinical relevance. Its unprotected location makes the plexus highly susceptible to trauma, including obstetric brachial plexus palsy (OBPP) caused by excessive traction during complicated deliveries [3,4]. For surgeons operating in the axillary and neck regions, a detailed understanding of the anatomy is crucial to prevent iatrogenic nerve injury and to facilitate nerve transfer and neurotization techniques [2,5] Furthermore, recognizing these variants via ultrasound is essential for the safe and effective administration of targeted brachial plexus blocks in modern anesthesia [6]. Therefore, this research study investigates the developmental morphology and branching variations of the posterior cord in human fetuses via anatomical dissection to underscore their clinical significance for current surgical and regional anesthetic techniques.

Materials and Methods

Study Design and Setting

This observational morphological study was conducted in the Department of Anatomy, SMBT Institute of Medical Sciences and Research Centre (SMBTIMSRC), Dhamangoan, Nashik, Maharashtra, India. Bilateral dissections were performed on 15 aborted human fetuses [11 male (73.33%) and 4 female (26.66%)], yielding 30 upper limb specimens for analysis.

Inclusion and Exclusion Criteria

Fetuses with gestational age ≥20 weeks and no gross congenital malformations of the upper limbs or neck were included. Specimens exhibiting postmortem autolysis and visible deformity of upper limb were excluded.

Dissection Procedure

the fetuses were preserved in tanks containing 10% formalin solution. Bilateral dissection of the pectoral, axillary, and arm regions was done to expose the cords and branches of the brachial plexus. The branching patterns of the posterior cord were carefully traced from their origin. Any variations in the origin, number, or course of the subscapular, thoracodorsal, axillary, and radial nerves were documented and photographed for morphological analysis. All dissections were carried out systematically according to the standard guidelines outlined in Cunningham's Manual of Practical Anatomy, Volume 1. (6)

Data Collection and Classification

Variations were classified as:

1. Root contributions (normal C5-T1, prefixed C4-T1, postfixed C5-T2)
2. Branching patterns (normal anatomy vs. common trunks and anomalous origins)
   Data were recorded using a predesigned proforma capturing fetal demographics and anatomical findings.

Statistical Analysis The collected data were categorized by laterality (right vs. left) and sex. Statistical analysis was performed using IBM SPSS Statistics 28.0. Associations between laterality and the frequency of variations were analyzed using Fisher's exact test, with further evaluation of odds ratios and relative risks. A p-value of <0.05 was considered statistically significant.

Sample Characteristics and Brachial Plexus Root formation

The study population comprised 30 upper limbs from 15 human fetuses, with a male-to-female ratio of 2.75:1. Gestational age ranged from 20 to 40 weeks and was stratified into five groups (Table 1). Normal C5–T1 root formation was the most prevalent pattern (76.67%), while variations including prefixed and combined pre- and post-fixed plexuses were observed in 23.33% of limbs. Statistical analysis demonstrated that root origin patterns occurred independently of laterality (p = 0.385; Table 2)

Table 1: Demographic and Gestational Characteristics of the Study Population

Variable	Subgroup	Fetus Count (N=15)	Limb Count (N=30)	Percentage (%)
Sex	Male	11	22	73.33
	Female	4	8	26.67
Laterality	Right	-	15	50.00
	Left	-	15	50.00
Gestational Age	20–<24 weeks	4	8	26.67
	24–<28 weeks	2	4	13.33
	28–<32 weeks	2	4	13.33
	32–<36 weeks	4	8	26.67
	36–<40 weeks	3	6	20.00

Table 2: Distribution of Brachial Plexus Root Formation

Root Formation Pattern	Right (n=15)	Left (n=15)	Total (N=30)	Percentage (%)	p-value
Normal (C5–T1)	10	13	23	76.67	0.385
Prefixed	4	2	6	20.00	
Combined Pre- & Post-fixed	1	0	1	3.33	
Total	**15**	**15**	**30**	**100.00**	

Fisher's exact test for association between laterality and root pattern: **p = 0.385** (Not Statistically Significant).

Prevalence and Distribution of Posterior Cord Variations

The classical anatomical branching pattern of the posterior cord was observed in 53.33% (n = 16/30) of the evaluated upper limbs, whereas 46.67% (n = 14/30) exhibited morphological variations. At the individual fetus level, branching variations were identified in 66.67% (n = 10/15) of the specimens. Among these variant fetuses, unilateral presentations were more prevalent (60.00%, n = 6/10) than bilateral occurrences (40.00%, n = 4/10).

Anatomical variations were observed more frequently in the right upper limbs (60.00%, n = 9/15) compared to the left (33.33%, n = 5/15). However, statistical analysis revealed that this side-to-side difference was not significant (Fisher's exact test, p = 0.272; Odds Ratio = 3.00, 95% CI: 0.65–13.82). This indicates that morphological variations of the posterior cord occur independently of laterality.

Posterior cord branching pattern variation

Among the 14 upper limbs displaying variations, five distinct anatomical branching patterns were identified. And shown in the table 2

Table 2: Prevalence of variations in Branching Patterns of the Posterior Cord

Branching Pattern / Variation	Proportion of Variations (n = 14)	Prevalence in Total Sample (N = 30)
*Classical branching pattern	—	16 (53.33%)
#Common trunk for AN & LSN	8 (57.14%)	8 (26.67%)
^AN & USN from PD of Upper Trunk	3 (21.43%)	3 (10.00%)
^USN from PD of Upper Trunk	1 (7.14%)	1 (3.33%)
**Common trunk for AN, TDN & LSN	1 (7.14%)	1 (3.33%)
^^Common trunk for TDN & LSN	1 (7.14%)	1 (3.33%)
#Three subscapular nerves (USN, MSN, LSN)	1 (7.14%)	1 (3.33%)

Note: AN-Axillary nerve, LSN – Lower subscapular nerve, USN – Upper subscapular nerve, PD – Posterior division, TDN- Thoracodorsal nerve, MSN- Middle Subscapular nerve

*Reference Fig no 1 # Reference Fig no. 2 ^ Reference Fig no. 3 **Reference Fig no.4 ^^ Reference Fig no. 5

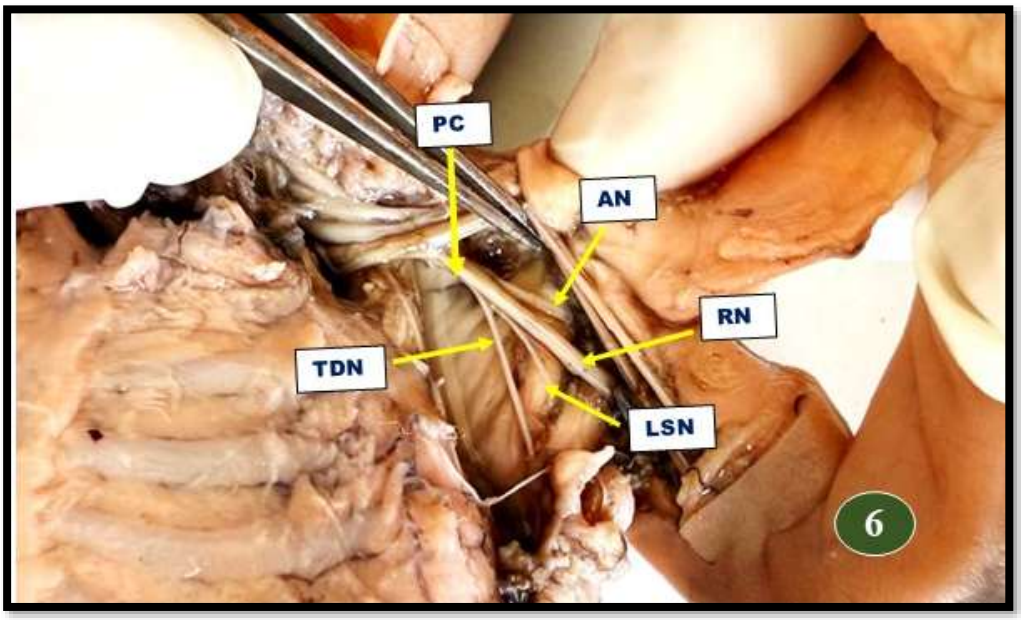

Fig.No.1 Normal Branching pattern of Posterior cord

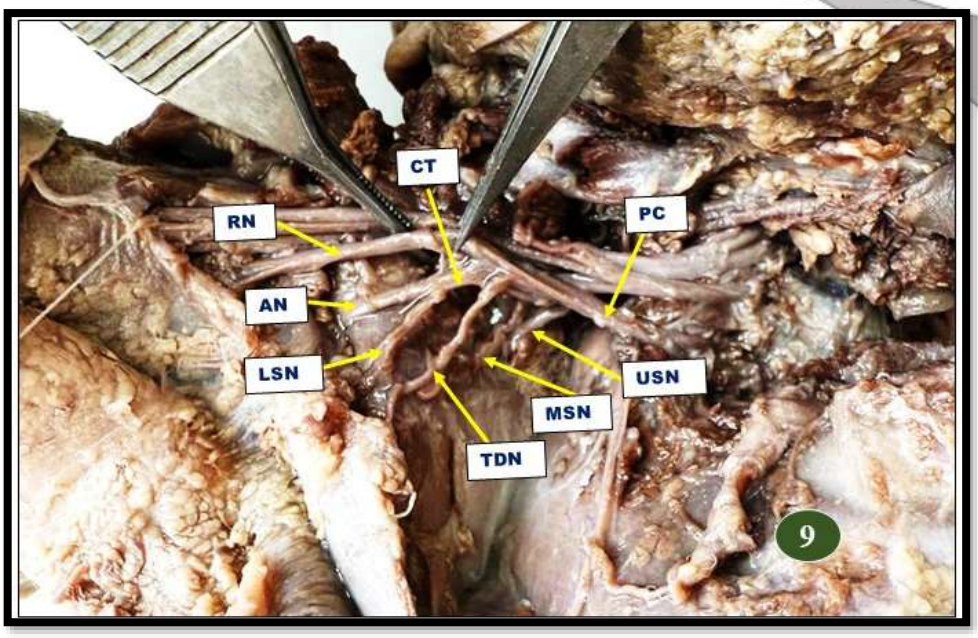

Fig. No.2 Common trunk (CT) for Axillary nerve and Lower subscapular Nerve from posterior cord of brachial plexus with 3 Subscapular nerves (USN, MSN, LSN)

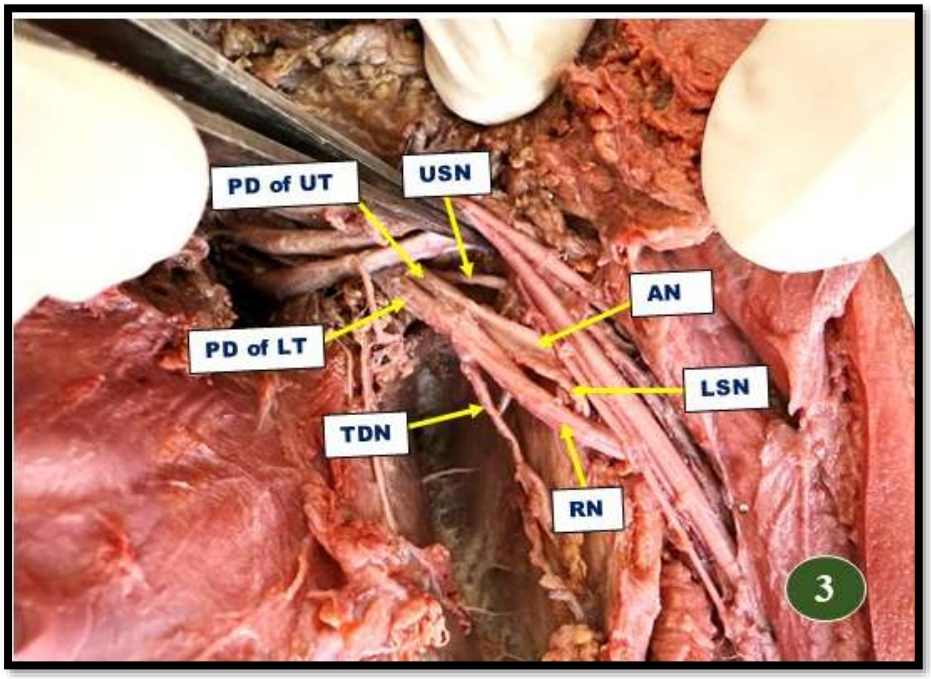

Fig.No.3 Axillary nerve and Upper subscapular Nerve from Posterior division of Upper trunk of Brachial Plexus

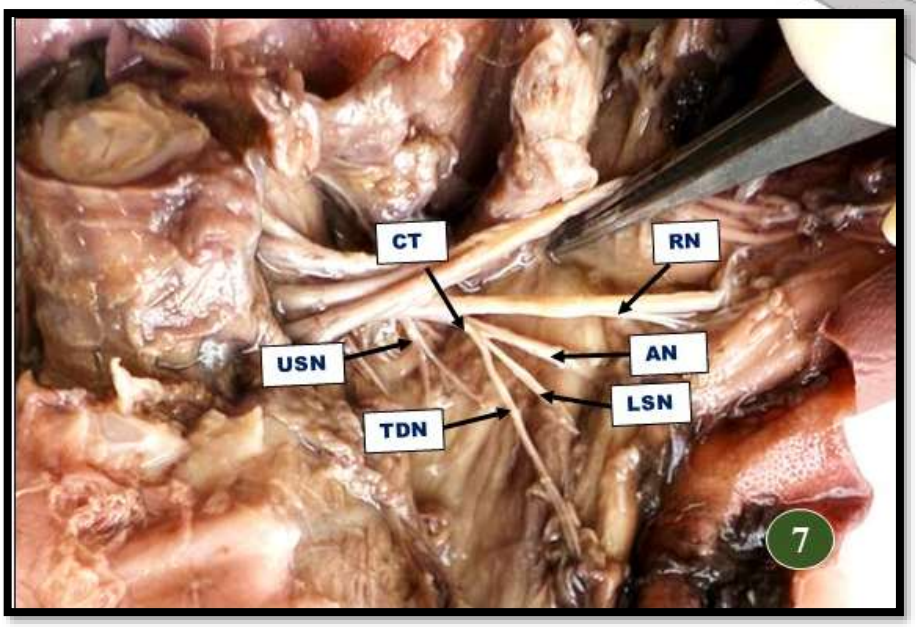

Fig.No.4 Shows Common trunk (CT) for Axillary nerve(AN) Thoracodorsal nerve (TDN) and Lower subscapular Nerve (LSN) from Posterior cord of Brachial Plexus

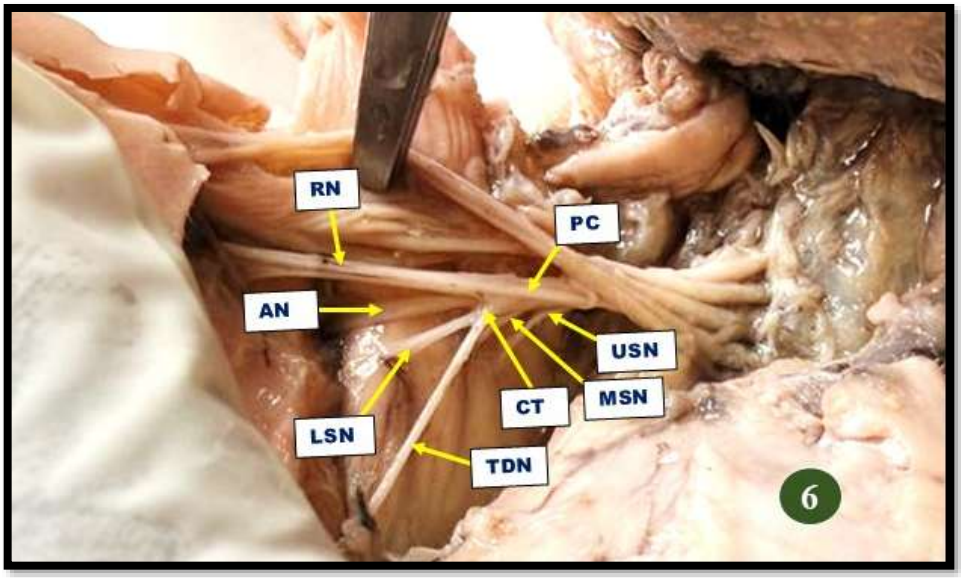

Fig.No.5 Shows Common trunk (CT) for Thoracodorsal nerve (TDN) and Lower subscapular Nerve (LSN) from Posterior cord of Brachial Plexus

Association Between Root Formation and Posterior Cord Branching

Of the 30 upper limbs analyzed, 76.67% (n = 23/30) demonstrated normal brachial plexus root formation, while 23.33% (n = 7/30) exhibited variations in root formation (prefixed or combined pre- and post-fixed). Posterior cord branching variations were observed in 57.14% (n = 4/7) of plexuses with variant roots, compared to 43.48% (n = 10/23) of plexuses with normal roots. Fisher's exact test revealed no statistically significant association between variations in root formation and variations in posterior cord branching patterns (p = 0.675; OR = 1.73, 95% CI: 0.31–9.57. Although posterior cord branching variations were observed more frequently in plexuses with atypical root formation.

Table 3: Association Between Brachial Plexus Root Formation and Posterior Cord Branching Variations

Brachial Plexus Root Formation	Classical Branching Pattern	Posterior Cord Variation	Total Limbs (N = 30)	p-value
Normal Root Formation	13 (56.52%)	10 (43.48%)	23 (76.67%)	**0.675**
Variant Root Formation	3 (42.86%)	4 (57.14%)	7 (23.33%)	
Total	**16 (53.33%)**	**14 (46.67%)**	**30 (100%)**	

Discussion

This study demonstrates that anatomical variability of the posterior cord branching pattern is common, with variations observed in 66.67% of fetuses (10/15) and 46.67% of plexuses (14/30), consistent with Muthoka JM et al who reported classical branching in only 10.7% (8/75) of posterior cords [2].

This high frequency supports the concept that the infraclavicular brachial plexus architecture is still undergoing active developmental rearrangements and a substantial proportion of "variant" configurations may represent persistence of transient morphological patterns.

Muthoka JM et al. (2011) reported the lower subscapular nerve arising from the axillary nerve in 57.3% (43/75) upper limbs, consistent with the 26.67% (8/30) incidence observed in the present study [1].

Rastogi et al. (2013) reported the axillary nerve arising from the posterior division of the upper trunk in 10.8% (8/74) upper limbs, comparable to the 10% (3/30) incidence observed in the present study [1].

Three subscapular nerves were observed in 3/30 upper limbs, indicating segmentation variability within the subscapular nerve group. Such multiplicity may be asymptomatic but is surgically relevant because accidental injury to small branches during axillary dissection can cause subtle weakness of medial rotation and adduction or alter scapulohumeral mechanics. Subscapular branches may also be used for neurotization, most often to reinnervate the axillary nerve and restore deltoid function after birth-related injury [5].

Rare common-trunk patterns involving the axillary, thoracodorsal, and/or lower subscapular nerves (each 1/14) are surgically important because injury to a single stem may compromise both deltoid and latissimus dorsi/teres major function and complicate selective neurotization in neonatal brachial plexus palsy [6,7].

The alteration of longitudinal tension dynamics associated with prefixed roots and variant posterior cord configurations significantly increases the susceptibility of the brachial plexus to severe stretch injuries or avulsions during traction-related deliveries, underscoring the necessity for clinical awareness of these morphological patterns to accurately interpret atypical presentations and optimize the diagnostic and therapeutic management of neonatal paralysis [8].

Embryological basis for morphological variations: As soon as limb buds form, the ventral primary rami of spinal nerves penetrate the mesenchyme and establish intimate contact with differentiating mesodermal condensations. Early contact between nerve and muscle cells is a prerequisite for their complete functional differentiation; any alteration in signaling between mesenchymal cells and neuronal growth cones can lead to significant variations [9].

These structural variations result from predictable embryological mechanisms: outgrowing axons must navigate physical constraints, such as the humeral cartilaginous precursor, and spatial conflicts with the subclavian artery and traversing veins [10]. Notably, in fetuses aged 12 to 20 weeks, the plexus often presents as a single cord that divides into discrete trunks only posterior to the clavicle [3]. This developmental process frequently results in anomalies, such as the thoracodorsal and lower subscapular nerves originating from a common trunk with the axillary nerve [1,2].

Fetal dissection studies offer a unique window into the developmental determination of brachial plexus pattern. It reveals the primary embryologic pattern with minimal postnatal or post-mortem distortion, and prior studies (Uysal 2003; Woźniak 2013; Cunha 2020) report overall variation rates of 13%–50% with inconsistent focus on posterior cord formation and branching [11,12,3].

The absence of a statistically significant association between brachial plexus root formation and posterior cord branching patterns suggests that morphological variations at these distinct levels likely arise from independent developmental constraints during fetal growth [10, 11]. Consequently, the presence of a variant root formation cannot reliably serve as a predictive marker for distal branching anomalies, necessitating a comprehensive anatomical assessment of the entire plexus to accurately manage its diverse morphological presentations [10, 12].

Conclusion

This study thereby contributes population-specific fetal anatomical data that enriches the global understanding of brachial plexus variability, with particular relevance to Indian obstetric and surgical practice. Furthermore,

knowledge of specific variations affecting nerves is beneficial in: Neurophysiological assessments for diagnosing peripheral nerve lesions, nerve grafting.

Limitations of the Study

The limitations of this study include a relatively small sample size (n = 46) and a regional focus on Indian fetuses, which may limit the generalizability of the findings. Future studies with larger cohorts and correlation with imaging modalities are recommended to validate these observations.

Conflict of Interest

The authors declare that they have no conflicts of interest. The authors received no financial support or other benefits that could have influenced the conduct or reporting of this study.

Acknowledgements

The authors respectfully acknowledge the fetal specimen donors and their families for their invaluable contribution to anatomical science. The authors also extend their gratitude to the Department of Anatomy and the Department of Obstetrics and Gynecology for their support in specimen procurement and facilitation of the study.

Declaration of AI Use

The authors used the AI-powered writing assistant Perplexity by Perplexity AI to assist with paraphrasing and grammar correction of the manuscript. The tool was used solely to improve clarity, readability, and language accuracy. The intellectual content, data interpretation, and final text remain the sole responsibility of the authors.

Ethical Considerations

This study was approved by the Institutional Ethics Committee of the National Institute of Medical Sciences & Research, Nims University Rajasthan, Jaipur [NIMSUR/IEC/2024/870], and SMBT Institute of Medical Sciences & Research Centre, Nashik, Maharashtra [1401/SMBT/IMSRC/10/IEC/24/65]. Fetuses were obtained from the Department of Obstetrics and Gynecology with informed consent from legal guardians. All procedures were conducted in accordance with the principles of the Declaration of Helsinki.

References

1. Rastogi R, Budhiraja V, Bansal K. Posterior cord of brachial plexus and its branches: anatomical variations and clinical implications. ISRN Anat. 2012;2012:501813.
2. Muthoka JM, Sinkeet SR, Shahbal SH, Matakwa LC, Ogeng'o JA. Variations in branching of the posterior cord of brachial plexus in a Kenyan population. J Brachial Plex Peripher Nerve Inj. 2011;6:1.
3. Cunha MR, Dias AA, Brito JM, Cruz CS, Silva SK. Anatomical study of the brachial plexus in human fetuses and its relation with neonatal upper limb paralysis. einstein (São Paulo). 2020;18:eAO5051.
4. Pondaag W, Malessy MJ, van Dijk JG, Thomeer RT. Natural history of obstetric brachial plexus palsy: a systematic review. Dev Med Child Neurol. 2004;46(2):138-144.
5. Haninec P, Hradecky J, Ouzky M, Samal F, Mencl L. Nerve transfers for axillary nerve repair in brachial plexus injuries: results from 206 patients. J Neurosurg Spine. 2025;42(5):659-666.
6. Pester JM, Hendrix JM, Varacallo MA. Brachial plexus block techniques. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan- [updated 2023 Aug 4; cited 2026 Feb 20]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK470213/
7. Sing Huat L, Abdullah S, Soh EZF, Abd Jabar F, Sapuan J. The outcome of neurotization of brachial plexus injury in a tertiary centre: a nine-year review. Cureus. 2022;14(3):e23394.
8. Louden E, Marcotte M, Mehlman C, Lippert W, Huang B, Paulson A. Risk factors for brachial plexus birth injury. Children. 2018;5(4):46.
9. Larsen WJ. Human embryology. 6th ed. New York (NY): Churchill Livingstone; 2020.
10. Leijnse JN, de Bakker BS, D'Herde K. The brachial plexus - explaining its morphology and variability by a generic developmental model. J Anat. 2020;236(5):862-882.
11. Uysal II, Seker M, Karabulut AK, Büyükmumcu M, Ziylan T. Brachial plexus variations in human fetuses. Neurosurgery. 2003;53(3):676-684.
12. Woźniak J, Kędzia A, Dudek K. Variability of the trunks and divisions of the brachial plexus in human fetuses. Adv Clin Exp Med. 2013;22(3):309-318.