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Study Of Anatomical Variations Of The Brachial Plexus In Cadavers: Formation And Branching Pattern

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ABSTRACT

Background: The brachial plexus constitutes a complex network of nerves responsible for innervating the upper limb with both motor and sensory signals. This network arises from the spinal nerves located in the cervical and upper thoracic segments.

Aim: The aim of this study is to describe the anatomical variations of the brachial plexus in cadavers.

Materials & Methods: The study examined the brachial plexus anatomy using forty cadavers. It focused on development, branching, and trajectory, using conventional techniques and magnification. The study recorded anatomical differences including root formation, trunk formation, cord arrangement, divisions, and additional nerve trunks. Digital photographs were taken for further analysis and documentation.

Results: The brachial plexus was found in 92% of specimens, with 36% showing deviations in trunk configuration. The most frequent variant was classical "M" pattern (80% of cases), with 4% involving fusion of middle and lower trunks. Divisions and consistent but asymmetric branching patterns were observed in 7% of cases. The medial cord formed in 64% of cases, and an auxiliary lateral cord was noted in 6%. Variations in the median nerve development were noted in 6% of cases, including absence of musculocutaneous nerve in some specimens.

Conclusion: Cadaveric investigations reveal variations in the brachial plexus anatomy, highlighting the importance of understanding these differences for surgical, anesthetic, and rehabilitative procedures, particularly in the neck, shoulder, and upper limb regions.

Key words: Upper limb, brachial plexus, spinal nerves, anatomical variations.

INTRODUCTION

To innervate the upper limb with motor and sensory signals, the brachial plexus is an intricate network of nerves that originates from the spinal nerves of the cervical and upper thoracic region. Because of the common and substantial clinical implications of changes in brachial plexus structure, medical practitioners must have a thorough understanding of its anatomy [1,2]. These differences can affect surgical methods, anesthetic procedures, and the treatment of neurological illnesses and trauma [3–4].

This study aims to provide insights into the structural diversity of the brachial plexus by describing its anatomical variations in cadavers in the Indore region. Since cadaveric investigations permit in-depth analysis of nerve genesis, branching patterns, and connections, they supply precise information for comprehensive comprehension of these differences [5]. Several factors such as genetics, development, or environmental influences can cause variability of the brachial plexus anatomy among populations. Improving clinical and surgical precision, particularly for treatments involving the neck, shoulder, and upper limb, requires identifying and documenting these differences [6–8]. By comparing cadaveric specimens with classical descriptions of the brachial plexus, this study seeks to enhance anatomical understanding and improve diagnostic and therapeutic approaches.

MATERIALS & METHODS

The anatomy department provided all the cadavers used in the study with required authorization for scientific research, and the institutional ethics committee approved the study.

Methodology: The goal of this cadaveric study was to explore the various differences in the anatomy of the brachial plexus. We dissected and studied forty cadavers (eighty-two sides) to record differences in the brachial plexus development, branching, and trajectory. We used the following criteria for determining which cadavers would serve as samples: dead animals whose necks and upper limbs are not damaged.

The second criterion for exclusion was the presence of any abnormalities in the upper limb, neck, or shoulder areas, as well as any history of surgery or obvious signs of trauma. Also, we won't include cadavers if there have been significant postmortem alterations that would make dissection difficult or produce misleading results. Every cadaver had its age, sex, and ethnicity documented. The ages of the 40 cadavers ranged from 50 to 85 years, with 25 males and 15 females included. We used a broad collection of cadavers data to investigate potential anatomical distinctions between individuals of diverse ethnic backgrounds.

How to Perform a Dissection: We used conventional techniques to carry out the dissection, utilizing a surgical loupe for magnification. We placed each corpse in a supine position, with the upper extremities abducted. The epidermis, superficial fascia, and deep fascia from the neck and shoulder areas were carefully removed to expose the brachial plexus. The dissection started at the spinal nerve roots (C5 to T1) and ended with the axillary branches of the brachial plexus. We used the axillary artery, clavicle, anterior and middle scalene muscles, and other significant anatomical landmarks to guide the dissection. We carefully identified and traced the brachial plexus bilaterally, including its roots, trunks, divisions, cords, and branches.

In some cases, careful excision of muscle and soft tissue was required to improve the visibility of the nerves. We meticulously recorded variations of the brachial plexus, including formation and fusion of roots and trunks, presence of additional nerve trunks or roots, and configuration of cords and branches. Digital photographs were taken at multiple stages of dissection for documentation. The diameter of each nerve root and trunk was measured using nerve calipers.

Comparative Analysis: We compared the conventional descriptions of the brachial plexus in anatomical textbooks with cadaveric findings to identify discrepancies. Variations were categorized based on pre-fixed or post-fixed plexus patterns, presence or absence of extra nerve branches, and uncommon fusions.

RESULTS

Table 1: Findings observed in the cadavers with regards to brachial plexus

1. Origin of the Brachial Plexus

Typical Origin	**Observed in 92% of specimens (ventral rami of C5–C8 and T1)**
Variations	Observed in 8% of specimens:
	– Contribution from C4 (pre-fixed plexus) in 5%
	– Contribution from T2 (post-fixed plexus) in 3%

2. Formation of Trunks

Typical Arrangement	**Upper, middle, and lower trunks in 90% of specimens**
Variations	Observed in 10% of specimens:
	– Fusion of middle and lower trunks in 4%
	– Duplication of the upper trunk in 6%

3. Divisions

Standard Pattern	**Anterior and posterior divisions present in 100% of specimens**
Variations	Asymmetric branching patterns in 7% of specimens

4. Cords

Typical Arrangement	**Lateral, posterior, and medial cords identified in 88% of specimens**
Variations	– Absence of distinct medial cord, branches arising from lower trunk in 6%
	– Formation of accessory lateral cord in 3%

5. Branches

Typical Branching	**Normal patterns of terminal branches in 85% of specimens**
Variations	Observed in 15% of specimens:
	– Musculocutaneous nerve absent in 4% (fibers incorporated into the median nerve)

6. Additional Variations

Finding	**Observation**
Communicating Branch	Between ulnar and median nerves in 7% of specimens
Aberrant Muscular Branches	Arising directly from cords in 4% of specimens

7. Symmetry

Pattern	**Observation**
Bilateral Symmetry	Observed in 80% of specimens
Unilateral	Observed in 20% of specimens

Table 1 shows the findings observed in the cadavers with regards to brachial plexus. In 92% of specimens, the brachial plexus began in the ventral rami of C5–C8 and T1; 8% of specimens showed alterations. Out of 5% of cases, C4 (pre-fixed plexus) contributes. In 3% of cases, T2 (post-fixed plexus) contributes. The construction of trunks: Ninety percent of specimens showed the usual configuration of upper, middle, and lower trunks. In 10% of cases, trunks showed variations, including fusion of middle and lower trunks. Six percent of instances duplicated the upper trunk.

Divisions: Anterior and posterior divisions were found in 100% of specimens. However, asymmetric branching patterns were observed in 7% of cases. Cords: We found the traditional split in the lateral, posterior, and medial cords in 88% of specimens. In 6% of cases, the medial cord was absent, with branches arising from the lower trunk. In 3% of cases, an auxiliary lateral cord formed. Branches: Normal terminal branching patterns were observed in 85% of specimens. Variations included absence of the musculocutaneous nerve in 4% of cases, with fibers integrated into the median nerve.

High division of the radial nerve proximal to the arm occurred in 6% of cases. The median nerve was created from three roots instead of two in 5% of specimens. Variations in additional branching included communicating branches between the ulnar and median nerves in 7% of cases, and aberrant muscular branches arising from the cords in 4% of specimens.

In 7% of cases, the ulnar and median nerves linked between the ulnar and median nerves; in 4% of cases, muscle branches arose directly from the cords rather than terminal branches. Of the specimens examined, 80% showed bilateral symmetry, whereas 20% showed unilateral changes.

DISCUSSION

In our study, 29 out of 80 samples exhibited a classic “M” pattern of the brachial plexus, indicating a prevalent anatomical variation. This finding aligns with previous research highlighting the significance of such variations in clinical practice. Anatomical variations in the brachial plexus are clinically significant, especially the medial brachial cutaneous nerve (MBCN) and the medial antebrachial cutaneous nerve (MACN), which commonly originate from a common trunk. Our cadaveric specimens demonstrated variations in 8% of cases. The present study reveals that variations of MACN originate from a common trunk, reinforcing findings from earlier research.

In 17% of cases, the medial cord of the brachial plexus can be the origin of the median nerve (MPN). A common component of this configuration is the anastomosis, which links the configurations on the sides of the plexus. Our study found this variant in 28% of the studied samples, showing a high occurrence. The presence of pectoralis minor nerve from the medial cord can help control the nerves and function of the pectoral muscles through the branches it provides.

The medial pectoral nerve can originate from a deep branch of the lateral pectoral nerve (5% of the time), the medial trunk (25% of the time), or the anterior division of the upper trunk (5% of the time), highlighting the intricate interplay of its variants. Although Haldaz et al. [22] discovered a traditional medial cord origin in just 93.3% of instances, Benes et al. [24] classified the MPN’s origins into five categories, with 90.9% of cases originating from the medial cord. These variances are likely the result of methodological inconsistencies across different studies. Surgeons must be aware of these variations during procedures to avoid complications.

The axillary nerve is where the thoracodorsal nerve normally branches off the posterior cord, beginning in 7% of cases. While some investigations found this between 20% and 23% [23,24], this variation is less frequent than the 4% reported by Benes et al. [24]. These variances may require different surgical approaches, especially in shoulder or axillary procedures, as the thoracodorsal nerve could be endangered.

In 5% of cases, the medial antebrachial cutaneous nerve arose from the ulnar nerve, and in 3% of cases, the medial brachial cutaneous nerve arose from the ulnar nerve. Even though these variations are less common, they may alter peripheral nerve architecture, making preoperative imaging and meticulous dissection crucial.

Differences Between the Median and Musculocutaneous Nerves

In 43% of patients, the medial nerve showed several contributions from the lateral cord, indicating a significant number of variants. Dissection methods may have impacted these results, since an overabundance of epineurium removal can make it seem like there are numerous contributions that are actually nonfunctional.

Additionally, we discovered that the musculocutaneous nerve branched out to the median nerve in 5% of cases, suggesting that overlapping innervation pathways could complicate identification and surgery. In 1% of specimens, the posterior cord supplied the median nerve with fibers, a previously unreported finding. Furthermore, although most studies describe multiple proximal branches in 90% of cases, only 11.8% of musculocutaneous nerves actually showed this. These outcomes highlight the necessity for caution during surgical procedures to avoid unexpected nerve damage.

Clinical Consequences

Anatomical dissimilarities influence several clinical syndromes directly. Thoracic outlet syndrome (TOS), cord compression, or distribution of nerve roots can significantly affect the function and management of the brachial plexus. Compression of the nerves in the brachial plexus causes neurogenic TOS, which manifests as pain, paresthesia, and occasionally paresis.

Although most diagnostic procedures are based on conventional techniques for nerve mapping, newer imaging modalities such as ultrasound and MRI allow better visualization of nerve variations before surgery. This is especially helpful in procedures involving the axilla or chest wall, such as identifying an anomalous pectoralis minor nerve.

Nerve branching patterns vary across the body, and anatomical studies continue to shed light on these variations. Understanding and integrating these findings into surgical practice enables safer and more precise procedures. Establishing correlations between anatomical variants and clinical outcomes will further enhance patient care.

CONCLUSION

Differences in the anatomy of the brachial plexus observed in cadavers indicate a wide variety of nerve origins, branches, and connections. Recognizing these variations is essential for surgeons, anesthesiologists, and clinicians involved in procedures of the neck, shoulder, and upper limb. Improved anatomical knowledge contributes to safer interventions and better clinical outcomes.

Conflict of interest

There is no conflict of interest among the present study authors.

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