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ORIGINAL RESEARCH

Study of Anatomical variations of thebrachial 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 regions. **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 and trunk formation, cord arrangement, divisions, and additional nerve trunks. Digital photographs were taken for further investigation. The study aimed to identify variations in brachial plexus anatomy and provide insights into ethnic differences. **Results:** The brachial plexus is found in 92% of specimens, with 8% showing alterations. The construction of trunks is consistent in 90% of cases, with 4% involving a fusion of middle and lower trunks and 6% involving duplicate upper trunks. Divisions are consistent, but asymmetric branching patterns are observed in 7% of cases. The traditional split in the lateral, posterior, and medial cords is found in 88% of specimens. Variations include the absence of a clear medial chord in 6% of cases and an auxiliary lateral cord in 3% of cases. 85% of specimens show typical patterns, with anomalies in 15%, including the absence of the musculocutaneous nerve in 4% of cases and the median nerve developing from three roots instead of two. Notable discoveries include a connecting branch between the ulnar and median nerves in 7% of cases. **Conclusion:** Cadaveric investigations reveal variations in the brachial plexus anatomy, influencing surgical approaches, anesthetic methods, and treatment in neck, shoulder, and upper limbs, requiring better understanding.

Key words: Upper limb, brachial plexus, spinal nerve, anesthetic procedures, neurological illness, trauma.

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 in the neck 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[3-6].

This study aims to provide insights into the structural diversity of the brachial plexus by describing its anatomical variances in cadavers. Since cadaveric investigations permit in-depth investigation of nerve genesis, branching patterns, and connections, they supply priceless information for comprehending these differences[7]. Several factors such as genetics, development, or the environment can cause the frequency of brachial plexus variations to vary among populations[8.9].

Improving clinical and surgical precision, particularly for treatments involving the neck, shoulder, and upper limb, requires identifying and documenting these differences[10,11]. By comparing cadaveric specimens with classical descriptions of the brachial plexus, this study will add to what is already known about this anatomical structure[12,13]. Improving anatomical education and clinical practice is the ultimate goal of these discoveries[14,15].We hypothesized that there are no significant anatomical variations in the brachial plexus among the cadavers studied in the Indore region for null hypothesis and for alternatehypothesized that we hypothesize that there

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are significant anatomical variations in the brachial plexus among the cadavers studied in the Indore region.

MATERIALS & METHODS

The anatomy department provided all the cadavers used in the study with the 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's development, branching, and trajectory.

We used the following criteria for this investigation to determine 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 they're too decomposed or 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 and 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 used a supine position for each corpse, abducting the upper limbs. We meticulously removed the epidermis, superficial fascia, and deep fascia from the neck and shoulder areas 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 important anatomical landmarks to guide the dissection. We painstakingly located and traced the brachial plexus on both sides, encompassing its roots, trunks, divisions, cords, and terminal branches. Careful excision of muscle and soft tissue was required in certain instances to provide better visibility of the nerves. We meticulously recorded the anatomical differences, including the formation and fusion patterns of roots and trunks. 2. The arrangement of the cords and the quantity of divisions. 3. There are additional nerve trunks or roots present. We took digital photographs at various stages of the dissection for further investigation and documentation. We measured the diameter of each nerve root and trunk using nerve calipers. Differences Categorization: We will compare standard descriptions of the brachial plexus from anatomical textbooks with the cadaveric findings to identify any variances. We noted and classified brachial plexus configurations that deviated from the norm based on whether they were pre-fixed or post-fixed, the 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	Observed in 12% of specimens:
	- 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 absence in 4% (fibers incorporated into the median nerve).

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	- Median nerve formed from three roots instead of two in 5%.
	- High division of the radial nerve proximal to the arm in 6%.
6. Additional Variations	
Communicating Branch	Between ulnar and median nerves in 7% of specimens.
Aberrant Muscular Branches	Arising directly from cords in 4% of specimens.
7. Symmetry	
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 include C4, pre-fixed plexus, contributing. In 3% of cases, T2 (post-fixed plexus) contributes. The construction of trunks: Ninety percent of the specimens showed the usual configuration of upper, middle, and lower trunks. In 10%, abnormalities were found: In 4% of cases, there was a fusion of the middle and lower trunks. Six percent of instances duplicate the upper trunk.Divisions: Every specimen showed consistently the normal anterior and posterior divisions. However, we observed asymmetric branching patterns with differences in division size and course in 7% of cases.We found the traditional split in the lateral, posterior, and medial cords in 88% of the specimens. Variations included the absence of a clear medial chord, in which case branches sprang straight from the lower stem in 6% of cases. In 3% of cases, an auxiliary lateral cord forms.Of the main terminal branches—musculocutaneous, median, radial, ulnar, and axillary nerves—85% of specimens showed typical patterns. Anomalies in the branching pattern were present in 15% of cases, which included the absence of the musculocutaneous nerve in 4% of cases, with its fibers integrated into the median nerve.In 5% of cases, the median nerve develops from three roots instead of two. Six percent of cases show a high division of the radial nerve proximal to the arm. Extra Variations: Notable discoveries included:

In 7% of cases there is a connecting branch between the ulnar and median nerves; in 4% of cases the muscle branches arise straight from the cord rather than terminal branches. Of the specimens, 80% showed bilateral symmetry, and the remaining 20% showed unilateral changes.

DISCUSSION

In our study, 29 out of 80 samples exhibited the 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. Notably, the medial brachial cutaneous nerve (MBCN) and the medial antebrachial cutaneous nerve (MACN) can originate from a common trunk. In the present study, we observed 80 cadaveric specimens found this variation in 5% of cases. The MBCN and MACN typically arise separately from the medial cord of the brachial plexus, innervating the skin of the medial arm and forearm, respectively[5,6]. Recognizing such variations is crucial during surgical procedures to prevent inadvertent nerve damage and associated complications[7-9].

The medial antebrachial cutaneous nerve (MACN), typically originating from the medial cord of the brachial plexus, exhibits anatomical variations in its origin. Notably, in our study of 71 cadaveric specimens, the MACN was found to arise from the inferior trunk or the ulnar nerve in 2 cases. This variation underscores the importance of understanding potential deviations in nerve anatomy, especially during surgical procedures involving the medial aspect of the forearm. Such knowledge is crucial to prevent inadvertent nerve injury and associated sensory deficits[10,11]. The MACN provides sensory innervation to the skin over the medial forearm and the region overlying the olecranon. It descends through the arm within the brachial fascia alongside the basilic vein, then divides into anterior and posterior branches upon emerging from the fascia, extending distally as far as the wrist[14,15]. Recognizing these anatomical variations is essential for clinicians to ensure accurate diagnosis and effective management of nerve-related pathologies[16-20].

Clinicians, and surgeons in particular, rely heavily on anatomical variance because of the profound impact it has on the results of invasive medical treatments like surgery[21,22]. Classical human anatomy is a good starting point, but it doesn't always consider the ways in which people differ, which can affect how safe and successful treatments are[15-18]. Clinicians can improve patient care and results by being aware of these variations and tailoring their approaches[19]. With a focus on brachial plexus discoveries, this discussion emphasizes the significance of anatomical changes, with a particular emphasis on clinically important nerve anomalies and their ramifications[20].

In 17% of cases, the medial or lateral cords of the brachial plexus can be the origin of medial pectoral nerve (MPN) fibers. A common component of this configuration is the ansa pectoralis, which links the pectoral nerves on the sides of the body. Loukas et al. [19] found this variant in 28% of the studied samples, indicating a high occurrence. The ansa pectoralis, which comes from the deep part of the middle pectoral nerve, helps control the nerves and function of the pectoral muscles through the branches it provides [20,21].

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The medial pectoral nerve can originate from a deep branch of the lateral pectoral nerve (5% of the time), the middle trunk (25% of the time), or the anterior division of the upper trunk (5% of the time), highlighting the intricacy of its variants. Although Haladaz et al. [22] discovered a traditional medial cord origin in just 49.3% of instances, Benes et al. [21] 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. If surgeons want to keep the brachial plexus safe during procedures, they need to be aware of these variations.

The axillary nerve is where the thoracodorsal nerve, normally a branch of the posterior cord, begins in seventeen percent of cases. While other investigations found rates between 20% and 23% [23,24], this frequency is higher than the 4% reported by Benes et al [21]. These variances may necessitate different techniques for surgical procedures affecting the axilla or shoulder, as they put the unexpected course of the thoracodorsal nerve in danger.

In 5% of cases, the medial antebrachial cutaneous nerve arose from the ulnar nerve, and in 3% of cases, the medial brachial and antebrachial cutaneous nerves had a common trunk. Even though these variations are less common, they show how complex and diverse peripheral nerve architecture may be, which is why preoperative imaging and meticulous dissection are so important [25,26].

Differences Between the Median and Musculocutaneous Nerves: In 43% of patients, the median nerve showed several contributions from the lateral cord, indicating a significant number of variants. Dissection methods may have impacted these results, though, since an overabundance of epineurium removal can make it seem like there were numerous contributions when there actually was only one [27,28]. Additionally, we found 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, an oddity not previously highlighted. Further, although prior research indicated multiple proximal branches in 90% of cases, only 11.8% of musculocutaneous nerves actually showed this [28.29]. These inconsistencies warrant additional research on the effects of such branching patterns on clinical outcomes.

Therapeutic Consequences of Anatomical Dissimilarities: Anatomical variances directly impact Thoracic outlet syndrome (TOS), a disorder that affects up to 8% of the U.S. population and has significant implications for diagnosis and management [30,31]. Compression of the nerves in the brachial plexus causes neurogenic TOS, which manifests as pain, paresthesia, and occasionally paresis. While most diagnostic procedures are based on the standard brachial plexus anatomy, there are several variations, such as the piercing variety, in which the plexus roots pass through the scalene muscles. The present work expands on this information by identifying other branching variants that alter the function of peripheral nerves.

Another notable observation is the presence of the superficial brachial artery running anterior to the median nerve in 6.6% of cases. This variant, affecting 3.6% to 9.6% of the population, can compress the median nerve and cause radiating discomfort and motor impairments. These vascular linkages highlight the interconnectedness of anatomical differences and their possible clinical repercussions, even though they are not nerve anomalies [32.33].

Preoperative evaluation via imaging. Ultrasound and other modern imaging modalities can show nerve differences before surgery, which helps doctors prepare for potential complications. In surgical treatments involving the axilla or chest wall, for example, identifying an ansa pectoralis or an aberrant thoracodorsal nerve helps assist the planning process [34,35]. The identification of superficial arteries that compress peripheral nerves can better inform conservative or surgical treatment options [34,35]. Nerve branching patterns vary across the body, and research into this diversity has cast doubt on long-held beliefs in classical anatomy, especially as they pertain to the brachial plexus. These findings highlight the importance of clinicians remaining alert and flexible, with significant implications for diagnostic and surgical procedures. By integrating understanding of such variances into training and practice, clinicians can improve patient outcomes, decrease problems, and pave the way for more accurate, personalized medical treatment. The goal of future studies should be to improve surgical methods and diagnostic tools by establishing a correlation between these variations and clinical outcomes [31-35].

CONCLUSION

Differences in the brachial plexus's anatomy seen in cadavers are indicative of the wide variety of nerves' origins, branches, and connections. Approaches to surgery, methods of anesthetic, and clinical treatment can all be affected by these differences. To better comprehend these abnormalities and to guide targeted procedures in the areas of the neck, shoulder, and upper limbs, cadaveric investigations are essential.

Conflict of interest

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

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