Title: STUDY OF VARIATIONS IN THE FORMATION AND BRANCHING PATTERN OF BRACHIAL PLEXUS

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Abstract

Background: The brachial plexus, originating from cervical and thoracic spinal roots, is integral for upper limb function, supplying motor, sensory, and sympathetic fibres. Anatomical variations, notably the prefixed and postfixed types, influence neural architecture, with developmental defects contributing to diverse differences.

Aim: To investigate variations in the brachial plexus formation and branching patterns in adult human cadavers.

Methodology: The study at an Anatomy Department in a Medical College examined 46 upper limbs to observe variations in prefixed or postfixed brachial plexus formation during 2 years, cadaveric dissection involved reflecting skin in the posterior neck triangle, incision from the clavicle to the acromial end, exposing the plexus's origin, and meticulously cleaning connective tissue.

Results: The study involved dissecting 23 adult human cadavers, focusing on bilateral upper limbs to discern variations in establishing prefixed or postfixed brachial plexus types. Of the 46 specimens, 28 exhibited a prefixed type, while the rest showed contributions from C5 to T1. Musculocutaneous nerve lengths were measured, with a mean of 4.6 cm on the right and 4.4 cm on the left. The median nerve's maximal length was greater on the left (27.4 cm) than on the right (24.8 cm). Ulnar nerve lengths averaged 24.8 cm on the right and 26.8 cm on the left. Variations included median nerve formation distal to its origin and an additional branch between medial and lateral roots.

Conclusion: The study underscores the importance of integrating knowledge of brachial plexus variations into medical practices for enhanced patient care.

Keywords: Anatomical Variations, Brachial Plexus, Prefixed and Postfixed Types

Introduction

The brachial plexus, an intricate network of nerves originating from the cervical and thoracic spinal roots, is pivotal in supplying motor, sensory, and sympathetic fibres to the upper limbs (1). This anatomical marvel, coursing from the neck to the axilla, is formed by the harmonious union of roots spanning from C5 to T1, giving rise to three primary trunks: superior, intermediate, and inferior. The myriad branches that intricately weave through the upper limb emerge from these trunks, contributing to its complex neural architecture (2).

Variations within the brachial plexus are common and diverse, resulting in a spectrum of anatomical configurations significantly impacting its functionality. Among these variations, the prefixed and postfixed types are noteworthy, delineated by the specific union patterns of spinal roots. This complexity is further compounded as the trunks diverge into anterior and posterior divisions, ultimately forming cords such as the posterior, lateral, and medial cords. The connections within these cords create an intricate network of anastomoses, exerting a profound influence on the cutaneous and motor supply to various upper limb regions (3).

The prevalence of anatomical differences within the brachial plexus is striking, contributing to more than half of the documented variations in the human neural system. These deviations often stem from developmental defects in the trunks, divisions, and cords, which may be intricately linked to neuronal growth cones (4). Recognizing the brachial plexus not merely as a confluence of nerves but as a sophisticated routing mechanism is pivotal. It guides nerves with similar functions to their designated terminal destinations, ensuring seamless coordination of neural signals throughout the upper limb (5).

While a myriad of brachial plexus variants exists, none can claim representation for the majority of individuals. Cadaveric investigations have consistently unveiled significant anatomical variances, deviating from the conventional definitions. This revelation underscores the imperative need for medical practitioners to comprehend these intricacies thoroughly. Such understanding is indispensable for the precise administration of local anaesthetics and the meticulous execution of surgical procedures within the axilla and arms. (6)

Moreover, the awareness of these anatomical abnormalities is paramount in addressing challenges associated with nerve blocks and averting potential damage during surgical operations involving the axilla and upper arm (7). This study seeks to contribute to collective knowledge by systematically assessing cadaveric variations in the brachial plexus. Specifically, the focus is directed towards scrutinizing the lengths of cords, branches, and changes in origin.

A thorough grasp of these variations equips clinicians with the requisite knowledge to navigate successful surgical interventions, deliver effective treatments for upper limb-related issues, and accurately diagnose clinical manifestations within the intricate realm of the upper limbs. This study endeavours to illuminate the nuanced landscape of the brachial plexus, furthering our understanding of its intricate variations and clinical implications.

Methodology

The study, conducted at the Department of Anatomy, JSS Medical College, involved the examination of 46 upper limbs to observe variations in the formation of the prefixed or postfixed type of brachial plexus.

Cadaveric Dissection Procedure: With the skin's reflection in the neck's posterior triangle, an incision extended along the clavicle to the acromial end. The resulting flap exposed the brachial plexus's origin down to its roots, with subsequent tracing of supraclavicular and dorsal scapular nerves behind the trapezius muscle. Connective tissue and fascia covering the axillary artery, ulnar nerve, radial nerve, and branches were meticulously cleaned. Specific examinations and measurements were carried out on various branching patterns and nerves.

Root Examination: Determining the presence of C4 or T2 contributions (Prefixed or Postfixed).

Musculocutaneous Nerve Inspection: Observing its emergence from the lateral cord and entry into the coracobrachialis muscle.

Ulnar Nerve Identification: Tracing along its length to the hand and measuring. Noting the distance from the point of joining the lateral and medial cords to form the median nerve to the lower border of the pectoralis minor muscle.

Median Nerve Examination: Investigating variations in its formation, including any additional contributions, and measuring along its length up to the distal border of the flexor retinaculum.

Study Duration: The comprehensive study spanned 2 years.

Study Type: This research followed a cross-sectional study design.

Materials Utilized: The dissection and measurement processes were facilitated using vernier callipers, measuring tapes, scalpels, and forceps.

Results

The study encompassed the dissection of 23 adult human cadavers over two years, focusing on bilateral upper limbs to identify variations in establishing the prefixed or postfixed type of brachial plexus.

Prefixed or Postfixed:

The type of origin was categorized as prefixed when there was a significant contribution from the C4 nerve to the trunks. Conversely, a significant contribution from the T2 spinal root led to a postfixed origin. Of the 46 upper limb specimens, 28 were identified as prefixed, while the remaining specimens exhibited contributions from C5 to T1 shown in *Graph 1.*

Musculocutaneous Nerve:

The length of the musculocutaneous nerve, arising from the C5-C7 nerve roots as the last branch of the lateral cord, was measured on both sides. The mean length on the right side was 4.6 ±1.35 cm, with a maximum length of 8.5 cm, while the left side had a mean of 4.4 cm and a standard deviation of 1.23. Notably, the mean length was greater on the right side shown in *Table 1.*

Median Nerve:

The maximal length of the median nerve was noted, descending from the brachial plexus and following a course between the brachialis and biceps brachii muscles. On the left side, the maximum length was 36.5 cm, and on the right side, it measured 35.6 cm. The mean length on the right was 24.8 ±4.50 cm; on the left, it was 27.4 ±5.40 cm. Interestingly, the mean length was greater on the left side shown in *Table 2.*

Ulnar Nerve:

The ulnar nerve, formed by the nerve roots of C8 and T1 with additional fibres from C7, was measured. The average length was 24.8 ±4.50 cm on the right side and 26.8 ±5.40 cm on the left. The greatest length on the right side was 35.6 cm, while it measured 26.5 cm on the left in *Table 3.*

In addition to nerve measurements, various variations were observed:

In 8 upper limbs, the formation of the median nerve was noted distal to its point of origin. In 8 cadavers, an additional branch was observed between the formation of the median nerve from the median and lateral roots, shown in *Figure 1.*

Discussion

The brachial plexus, a complex network of nerves originating from the cervical and thoracic spinal nerves, plays a crucial role in the motor and sensory functions of the upper limbs. Variations in its anatomy can have profound implications, potentially leading to syndromes of nervous palsy due to the dynamic relationship between the nerves and the muscles they innervate (1). This knowledge is paramount in clinical and surgical practices, particularly during brachial plexus procedures.

Kerr et al. in their study, thoroughly reconstructed the human brachial plexus' anatomical structure and divided it into three main categories and seven subgroups. A few variants remained to be described even though the variations mentioned in their study were also observed in the present study at different percentages (likely due to the high number of cases analyzed in that study) (8). The various blocks administered to the brachial plexus used as a component of anaesthesia for upper limb surgeries throughout the past century may not function properly due to anatomical anomalies. Additionally, unexpectedly, certain variations result in plexus injury after surgeries involving neck dissections and other surgeries involving the axilla and arm (9). Anaesthesia-related effects of brachial plexus occlusion are utilized during operations and for postoperative analgesia. Knowing how the brachial plexus differs can help with nerve blockage, which is good for clinical practice and diagnosis of sensory losses (10–12).

In our study, communicating branches were seen arising between the medial and lateral roots of the median nerve. In our study, A contributing branch from the lateral cord in one of the upper limbs joined the lateral roots of the median nerve. Some authors also described this in their study. It indicates that due to an additional lateral root to the median nerves' proximity to the axillary artery during axillary surgery, this variation might cause harm and reduce blood supply to the arms by compressing the artery (13,14). The brachial plexus is completely formed by the 13th week of intrauterine life. Although the precise reason for prefixation or post-fixation is unknown, some scholars think it is a straightforward concordance between the limb buds' position along the embryo's rostrocaudal axis. Depending on when the limb buds mature,

the brachial plexus may show major differences in the nerves that cause it (15). The terms used to indicate whether a plexus is prefixed or postfixed have also varied.

Our study observed the occurrence of prefixed and postfixed brachial plexus. Among 23 human cadavers, giving a sample size of 46 upper limb samples for the study, 36% of the upper extremity had the prefixed type of arrangement for the brachial plexus, and the remaining 64% showed the postfixed type of arrangement. Compared to Uysal et al., who found a greater frequency of variants on the right side, Matejcik et al. discovered variants were more frequent on the left side (16,17). In general, Uysal et al. discovered more variance among women. It is widely acknowledged that prefixed plexuses can arise more prevalent than are postfixed (18). Though it is the data, it is clear that there is a large range of differences in the data.

In conclusion, this cadaveric study significantly contributes to understanding diverse anatomical variations within the brachial plexus, which is crucial for anatomists, radiologists, anesthesiologists, and surgeons. The prevalence of these variants in the peripheral nervous system explains unexpected clinical symptoms. Clarity on the embryological roots and clinical manifestations of median nerve abnormalities is essential, particularly during axilla exploration surgeries and nerve blocks. Surgeons must be aware of these variations, especially when dealing with neoplasm or trauma repair, as the median nerve's involvement may lead to sensory, motor, and trophic changes during orthopaedic procedures. This study highlights the clinical importance of integrating knowledge about brachial plexus variations into medical practices for improved patient care.

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Tables and Figures

Table 1: The table depicts the Mean length of the musculocutaneous nerve

Musculocutaneous Nerve	**Mean**	**Standard deviation**	**Maximum**	**Minimum**
Right	4.6	1.35	8.5	3.5
Left	4.4	1.23	7	2.9

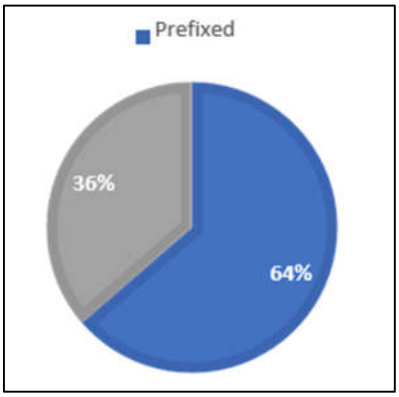
Table 2: The table depicts the Mean length of the median nerve

Median Nerve	**Mean**	**Standard deviation**	**Maximum**	**Minimum**
Right	24.8	4.50	35.6	18
Left	27.4	5.40	36.5	17

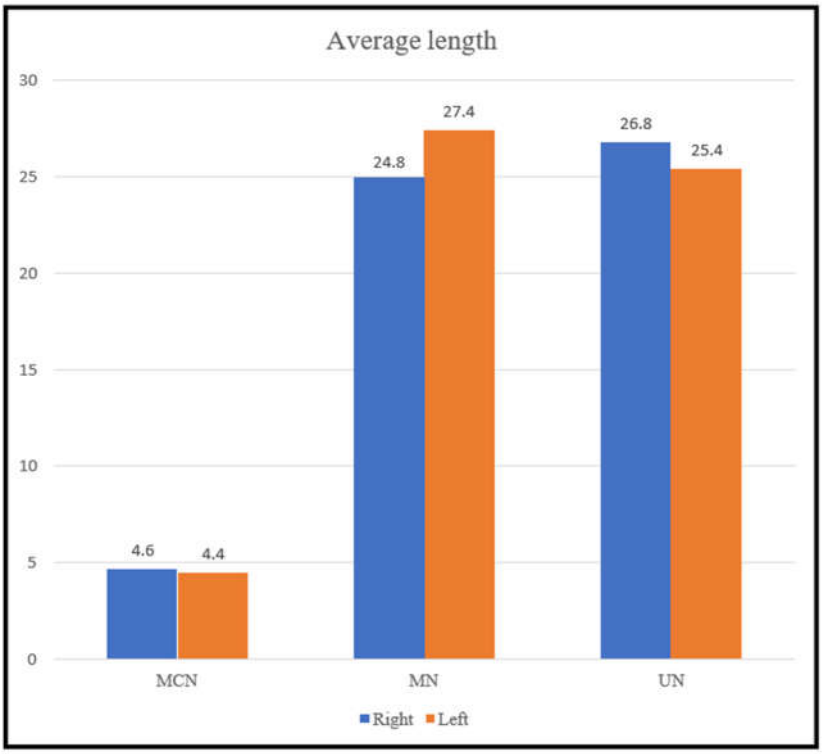
Table 3: The table depicts the Mean length of the ulnar nerve

Ulnar Nerve	**Mean**	**Standard deviation**	**Maximum**	**Minimum**
Right	26.8	2.41	31.2	23
Left	25.4	2.57	32	21

Graph 1: Graph illustrates the number of prefixed and normal formation brachial plexus



Graph 2: The Graph illustrates the average length of the nerves



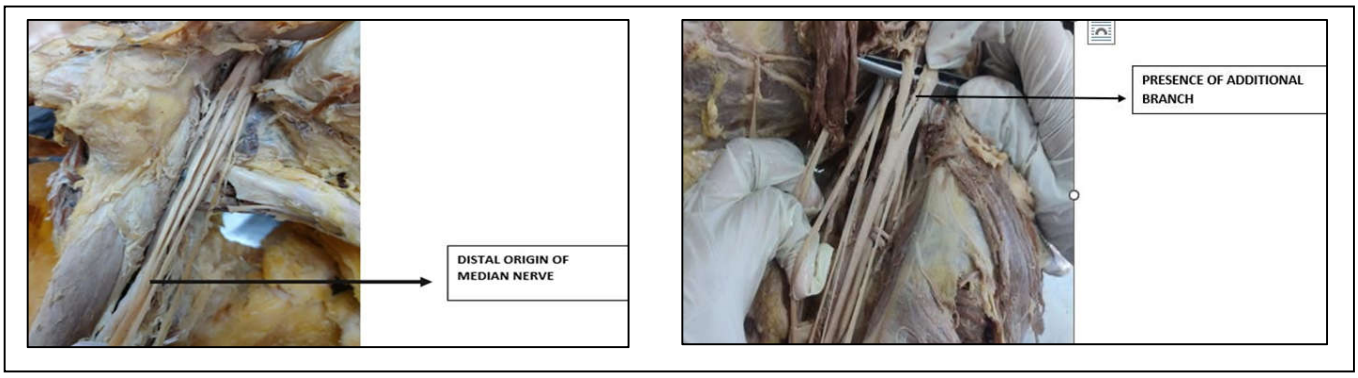


Figure 1: a) Origin of Median Nerve, b) Presence of additional branch

Figure 2: a) Measurement of Median Nerve, b) Measurement of Ulnar Nerve and c) Measurement of musculocutaneous nerve