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# The Brachial Plexus: More and More Variations

**Ehab Mostafa Elzawawy***

*Professor, Department of Anatomy and Embryology, Faculty of Medicine, University of Alexandria, Egypt.*

***Correspondence:**

Ehab Mostafa Elzawawy, Professor, Department of Anatomy and Embryology, Faculty of Medicine, University of Alexandria, 21321, Egypt.

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## ABSTRACT

*The brachial plexus is so variable that most of dissected cases will show some form of anatomical variations. In the same person, the right and left sides are not the same. This study was done to identify the variations of the brachial plexus and highlight their clinical significance. The materials of this study included 10 cadavers dissected on both sides to find out the variations of the different parts of the plexus.*

*Variations were found in 85% of cases. Variations included all stages of the plexus. Phrenic nerve took origin from the upper trunk in 10%, while the lateral pectoral nerve took origin by 2 roots from the upper and middle trunks or from the lateral and medial cords in 40%. Abnormal communications were found between the trunks, cords, or branches. Abnormal relations were found between the trunks, cords, or branches and the subclavian or axillary arteries. It is essential to know the exact anatomy of the brachial plexus prior to surgical repair of brachial plexus injuries or prior to supra or infraclavicular plexus block.*

*Variations of brachial plexus are so common. Researchers have been trying for so long to assign specific patterns for brachial plexus. Their efforts were inutile and now is the time to acknowledge anatomical variations of brachial plexus as the rule.*

## Introduction

The brachial plexus is the nerve plexus that supplies the upper limb. The location of the plexus makes it vulnerable to damage by different types of traumas or by pathological conditions such as thoracic outlet syndrome [1]. The roots of the plexus are the ventral rami of the lower four cervical spinal nerves and the first thoracic spinal nerve. When the plexus receives a contribution from C4, it is called prefixed pattern. If the plexus receives a contribution from T2, it is termed postfixed pattern [2,3].

The formation of the cords, trunks, and divisions of the plexus as well as the terminal branching pattern are very variable [4]. They are so variable that some authors consider variations of the plexus as the rule [5]. Thorough knowledge of all possible variations can help neurologists explain signs of disease and reduce the neurological damage that can be caused by neurosurgical interventions [6]. Moreover, these variations can guide the choice of surgical intervention appropriate for repair following traumatic damage [7]. The relations of the brachial plexus to surrounding muscles or blood vessels is very complex. This complexity must be comprehensively understood by surgeons engaged in brachial plexus surgery [8].

Bansal et al. [9] emphasized the importance of brachial plexus ultrasound and nerve stimulation prior to supraclavicular block to ensure success of this local anesthesia in case of anatomical variation of the plexus.

## Aim of the Work

Was to identify the anatomical variations of the different stages of the brachial plexus and emphasize its clinical importance.

## Materials and Methods

Ten cadavers were dissected on both sides to study the formation, location of all the stages of brachial plexus including the roots, trunks, cords, and branches. All encountered variations were recorded. None of the dissected specimens had any pathological or traumatic lesions, or prior surgical procedures in the neck or axillary regions. All specimens were fixed in 10% formaldehyde solution. The roots, trunks, divisions, and branches of the plexus were carefully dissected. The clavicle was divided at its middle to expose the divisions of the plexus. The relation of the roots and trunks to the scalene muscles as well as the relation of the cords and branches to the axillary and brachial vessels were carefully investigated.

## Results

Overall variations were found in 85% of this series. The following brachial plexus variations were found:

1- The upper trunk was formed by C5 and C6 and joined by a branch from C4 (Prefixed pattern) in 10% (Figures 1A, B),

2- The lateral pectoral nerve arose by 2 roots from the anterior aspects of the upper and middle trunks (Figures 1A, B). The lateral pectoral nerve arose by 2 roots from the anterior aspects of the lateral and medial cords (Figure 2A).

3- The posterior cord was replaced by the posterior division of the upper trunk that gave axillary, upper subscapular and continued as the radial nerve (Figures 2A, B). The radial nerve received a connection from the lower trunk that conveyed C8 and T1 (Figures 2C, D). The lower subscapular and thoracodorsal nerves took origin from the radial nerve after it received the connecting branch from the lower trunk (Figures 2C, D).

4- The long thoracic nerve arose by 2 roots from the posterior aspects of the upper and middle trunks (Figures 1A, B). The long thoracic nerve took origin by a single root from the posterior aspect of the upper trunk, passed through scalenus medius muscle and behind the plexus to reach serratus anterior (Figures 3A, B, C).

5- The suprascapular nerve took origin normally from the upper trunk in 50% (Figures 1A, 4A). It took origin from the posterior cord in 10% (Figures 3B, C).

6- Phrenic nerve took origin from the upper trunk (Figures 4A, B).

7- There was a communicating branch between the medial root of median nerve and the ulnar nerve (Figures 1A, B). There was a communicating branch between the lateral cord and the lower trunk (Figure 3A). There was a communicating branch between the middle and lower trunks (Figures 4B, C).

8- The upper trunk divided into 5 terminal branches: suprascapular nerve, anterior and posterior divisions, upper subscapular nerve, and nerve to subclavius arranged in that order from above downwards (Figures 5A, B).

9- The median nerve was formed on the medial side of the axillary artery (Figures 1A, 2B, 3A). Multiple large pectoral branches of thoracoacromial artery passed in front of the cords of brachial plexus to supply pectoral muscles (Figure 4A).

## Discussion

Leonhard et al. [10] emphasized that brachial plexus branching variants are a great diagnostic challenge especially in cases of thoracic outlet syndrome. Ultrasound combined with nerve stimulation could be a reliable means of diagnosing this etiology. Early recognition of these anatomical variants is crucial for developing a successful treatment plan, as many of the current treatment modalities may exacerbate patient symptoms.

Yadav et al. [11] reported normally formed posterior cord in 63.3%. However, in 26.7% cases, the posterior division of common trunk was found to unite with posterior division of lower trunk. Further in 3.3% cases the posterior cord did not receive any contribution from the lower trunk. We found posterior cord formed by posterior division of upper trunk in 20% of cases but it received a connecting branch from the lower trunk in all cases. It is through this connection that C8 and T1 are conveyed to the posterior cord and through the radial, lower subscapular and thoracodorsal nerves.

Anatomical variations of the plexus are usually associated with corresponding anomalies of the axillary and brachial arteries. Carroll et al. [12] reported a single corded plexus associated with a superficial brachial artery. The relation of the axillary artery and median nerve is very variable as the nerve formed medial to the artery in 60% of our series. A variation that must be kept in mind whenever surgical access is needed to repair vascular or neurological lesion in that area. Moreover, the branches of thoracoacromial artery can pass in front and compress the cords of the plexus in the narrow tunnel between these branches and the pectoral muscles. A situation that can explain neurological signs of brachial plexus compression in cases of vascular anomalies.

**Table 1:** Variations of the branches of the brachial plexus.

| Nerve | Usual origin | Unusual origins |
|---|---|---|
| -Phrenic nerve | C3, C4, C5 90% | Upper trunk in 10% |
| -Lateral pectoral nerve | Lateral cord 60% | Upper and middle trunks in 20%, lateral and medial cords in 20% |
| -Long thoracic nerve | C5, C6, C7 by 2 roots 60% | C5 and C6 as a single root from upper trunk in 40% |
| -Suprascapular nerve | Upper trunk 60% | Anterior or posterior division of upper trunk in 20% and posterior cord in 20% |
| -Upper subscapular nerve | Posterior cord 50% | Upper trunk in 20%, posterior division upper trunk in 20%, axillary nerve 10% |
| -Lower subscapular nerve | Posterior cord 50% | Radial in 30%, axillary in 15% and thoracodorsal in 5% |
| -Thoracodorsal nerve | Posterior cord 70% | Radial in 20% and axillary in 10% |
| -Axillary nerve | Posterior cord 70% | Posterior division of upper trunk in 15% and radial in 15% |
| -Radial nerve | Posterior cord 80% | Posterior division of upper trunk in 20% |
| -Nerve to subclavius | C5, C6 70% | Upper trunk in 20%, C5 only in 10% |

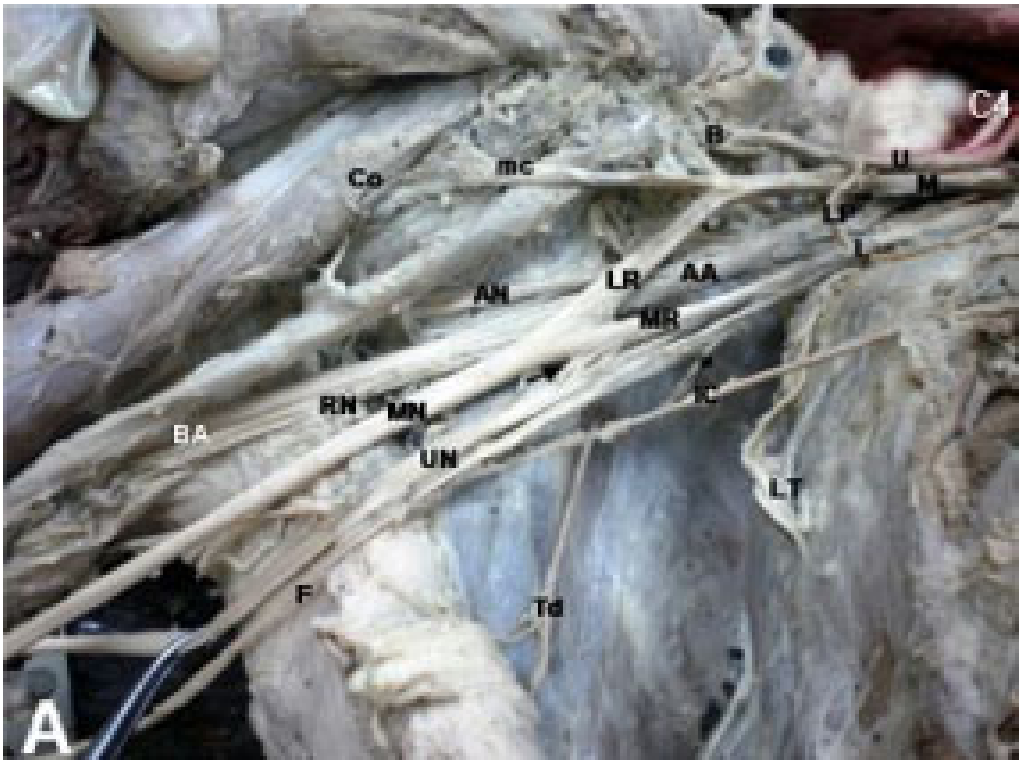


**Figure 1 (A)**: A photograph of right brachial plexus showing the upper trunk (U) that gives suprascapular nerve (B). The lateral pectoral nerve (LP) takes origin from the anterior aspects of the upper (U) and middle (M) trunks. The lower trunk (L) continues as the medial cord (MC) that gives the medial root (MR) of the median nerve (MN). A communication (pointed by an arrow) is seen between the medial root (MR) of the median nerve (MN) and ulnar nerve (UN). The 2 roots (MR) and lateral root (LR) of the median nerve join on the medial side of the axillary artery (AA). The branches of the posterior cord are seen: the axillary (AN), the radial (RN) and the thoracodorsal (Td) nerves. The medial cutaneous of forearm (F) sends a communicating branch (·) to the intercostobrachial nerve (IC). The long thoracic nerve (LT), musculocutaneous nerve (mc) and coracobrachialis muscle (Co) are seen.

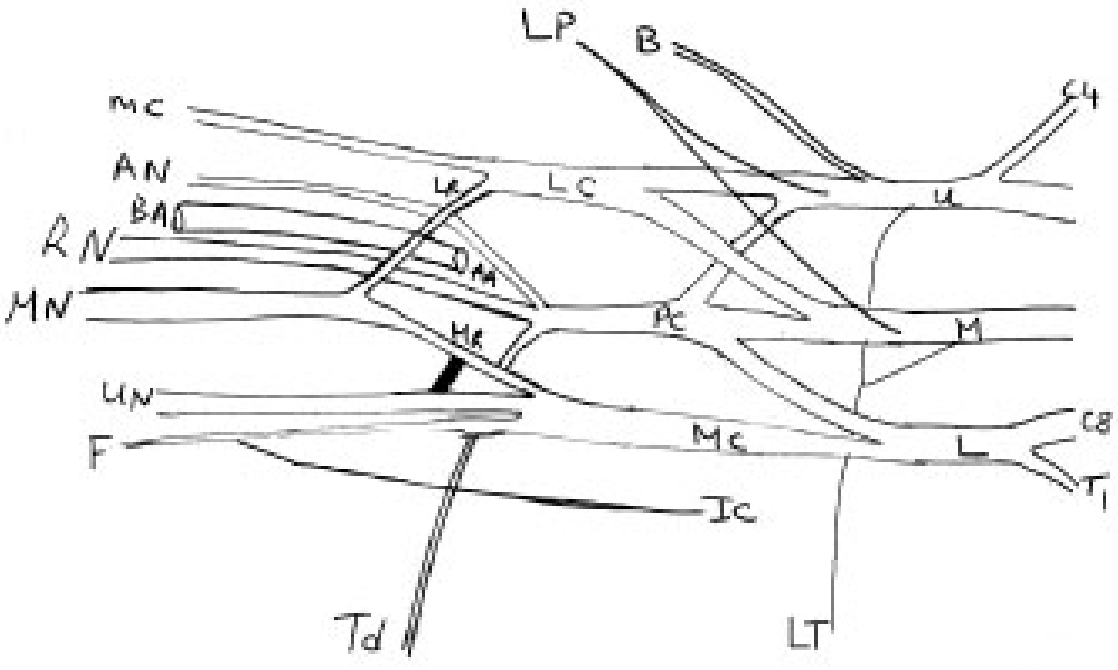


**Figure 1 (B)**: Diagrammatic illustration of the same specimen.

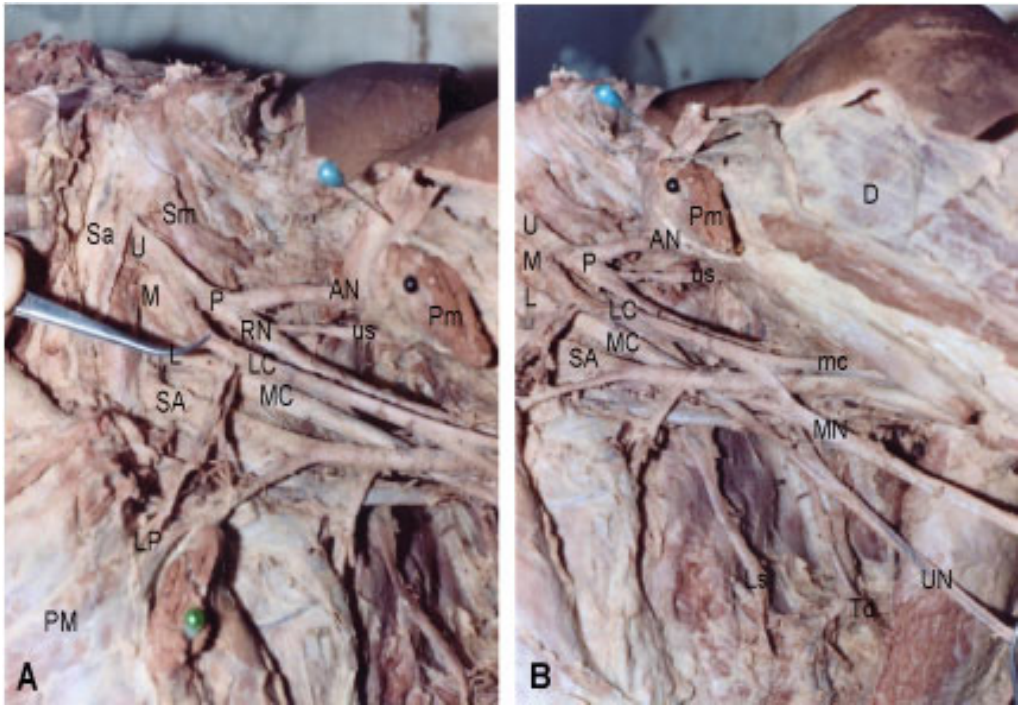


**Figure 2 (A):** A photograph of the left brachial plexus showing the upper (U), middle (M) and lower (L) trunks, the lateral (LC), medial (MC) cords. There is no posterior cord; it is replaced by the posterior division (P) of the upper trunk which gives the axillary nerve (AN), the upper subscapular nerve (us) and the radial nerve (RN). Note, the subclavian artery (SA), pectoralis minor (Pm), scalenus anterior (Sa) and scalenus medius (Sm) muscles. The lateral pectoral nerve (LP) arises by 2 roots from the lateral (LC) and medial (MC) cords and passes to pectoralis major (PM) muscle.

**Figure 2 (B):** A photograph of the distal part of the same specimen, it shows the musculocutaneous (mc), the median (MN), the ulnar (UN), the thoracodorsal (Td) and the lower subscapular (Ls) nerves and the deltoid muscle (D).

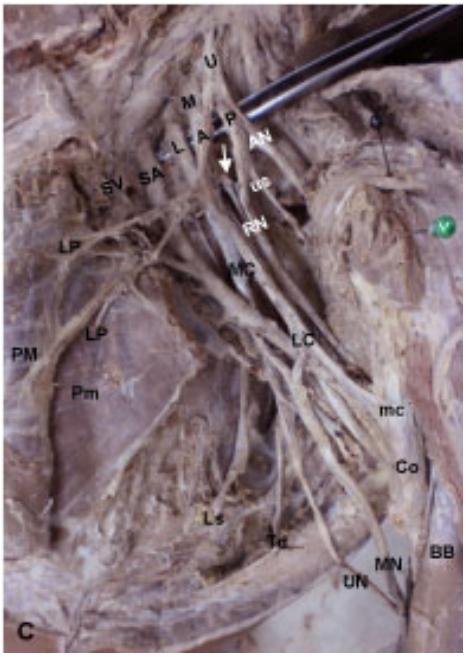


**Figure 2 (C):** A photograph of the left axilla of the previous specimen showing the upper (U), middle (M) and lower (L) trunks of the brachial plexus which are shorter than usual, the subclavian artery (SA) and subclavian vein (SV). The anterior division (A) of the upper trunk joins the middle trunk to form the lateral cord (LC) which gives the musculocutaneous nerve (mc). The posterior division (P) of the upper trunk replaces the posterior cord and gives: 1-the axillary nerve (AN) nerve, 2- the upper subscapular (us) nerve, 3- the radial nerve (RN) which is joined by a branch (pointed by arrow) from the lower trunk. The lower subscapular nerve (Ls) and the thoracodorsal nerve (Td) take origin from the radial nerve after it receives the branch from the lower trunk. Note, the lateral pectoral nerve (LP) supplying pectoralis major (PM) and pectoralis minor (Pm) muscles. The medial cord (MC) gives the ulnar nerve (UN). The median nerve (MN) is formed as usual by 2 roots from MC and LC. Note, the Biceps (BB) and coracobrachialis (Co) muscles.

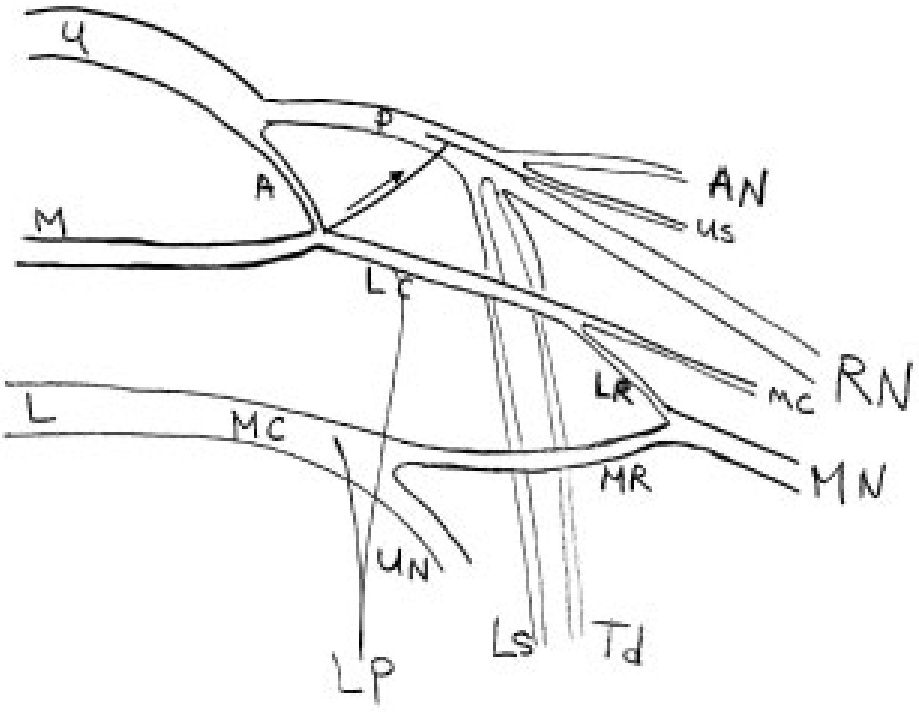


**Figure 2 (D):** Diagrammatic illustration of the same specimen

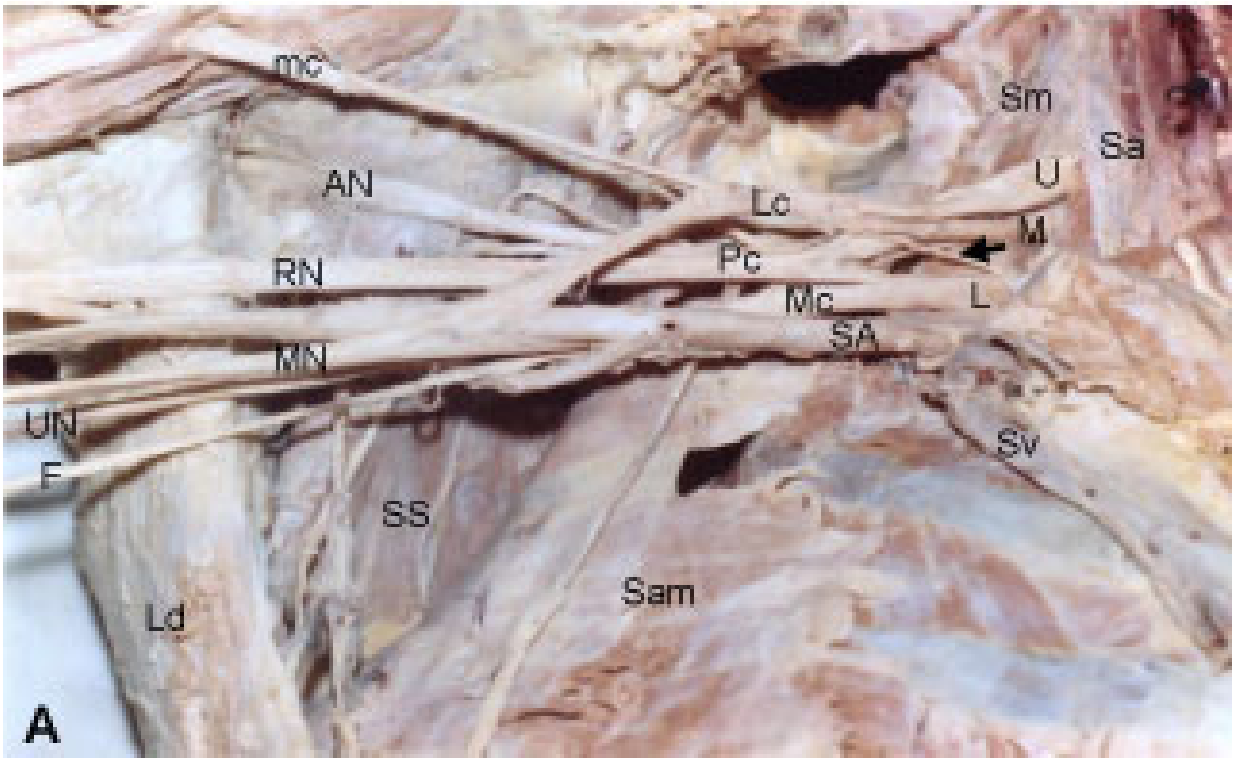


**Figure 3 (A):** A photograph of the right brachial plexus showing the upper (U), middle (M) and lower (L) trunks of the plexus and the 3 cords; lateral (LC), medial (MC) and posterior (PC). There is a connection (pointed by arrow) between the lateral cord and the lower trunk. Note the subclavian artery (SA), the subclavian vein (SV), scalenus anterior (Sa) and scalenus medius (Sm) muscles, the musculocutaneous nerve (mc), the axillary nerve (AN), the radial nerve (RN), the median nerve (MN), the ulnar nerve (UN), the medial cutaneous nerve of forearm (F), the serratus anterior muscle (Sam), the subscapularis muscle (SS) and latissimus dorsi muscle (Ld).

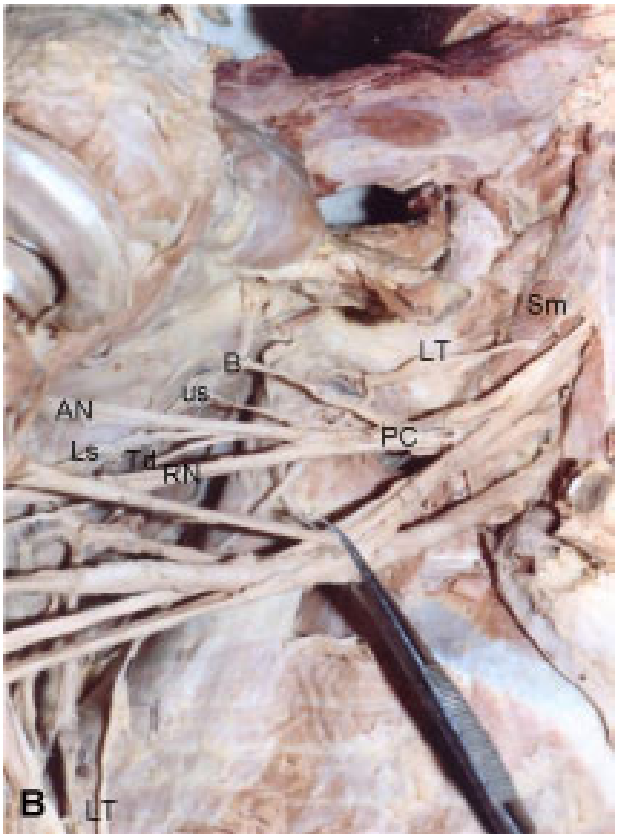


**Figure 3 (B):** A photograph of the same specimen after downward retraction of the lateral and medial cords to show the long thoracic nerve (LT) arising solely from the upper trunk and passing through scalenus medius (Sm) and behind the plexus to reach serratus anterior. The posterior cord of the plexus gives suprascapular nerve (B), upper subscapular nerve (us) and axillary nerve (AN) which gives lower subscapular (Ls) and thoracodorsal (Td) nerves and the cord terminates as the radial nerve (RN) which is the largest branch from it.

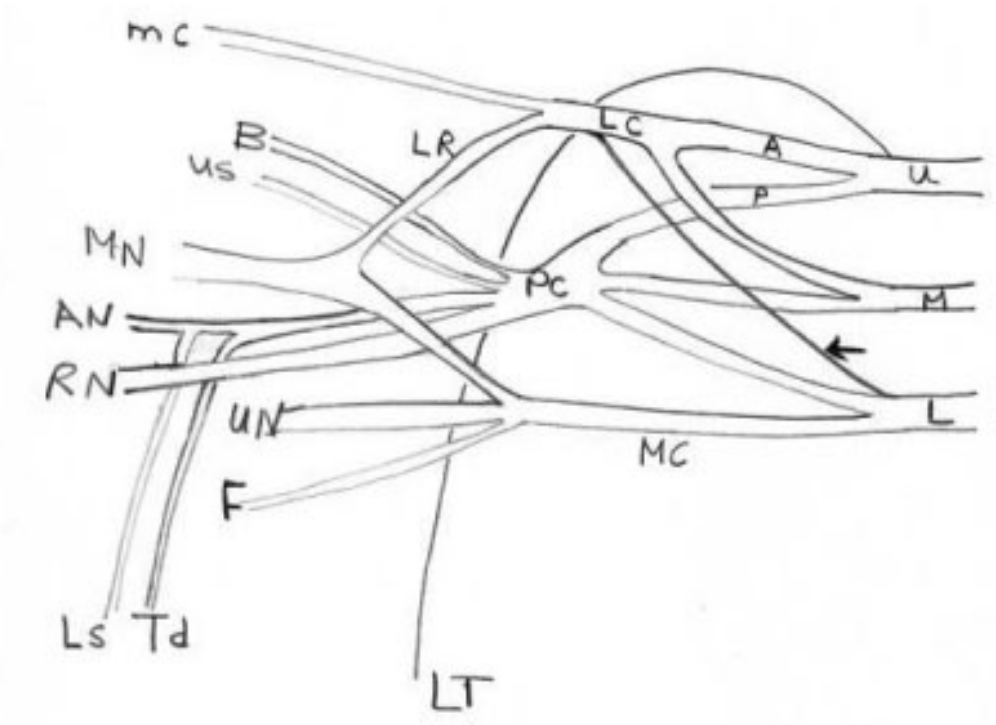


**Figure 3 (C):** Diagrammatic illustration of the same specimen.

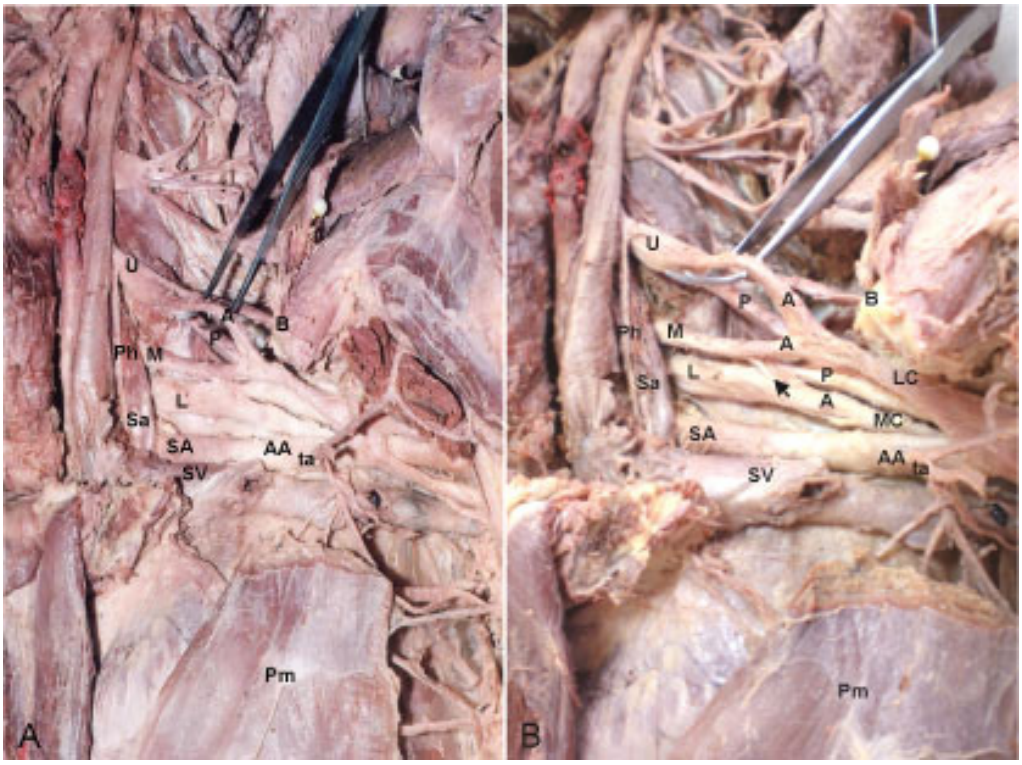


**Figure 4 (A):** photograph of the left side of the neck showing the upper trunk (U) of the brachial plexus giving the suprascapular nerve (B) and giving anterior (A) and posterior (P) divisions, the middle (M) and lower (L) trunks can be seen. The phrenic nerve (Ph) took origin from the upper trunk and runs on scalenus anterior (Sa) muscle, also note the subclavian artery (SA) and subclavian vein (SV). The pectoralis minor (Pm) muscle is cut to the show the cords of the plexus. The thoracoacromial artery (ta) arises from the second part axillary artery (AA) and gives pectoral branches that pass in front of the cords of the plexus to supply pectoralis minor.

**Figure 4 (B):** A close up photograph of the previous specimen to show the lateral cord (LC) formed by the anterior divisions (A) of the upper and middle trunks and the medial cord (MC) formed by the anterior division of the lower trunk. Note the connection between the middle and lower trunks (pointed by arrow).

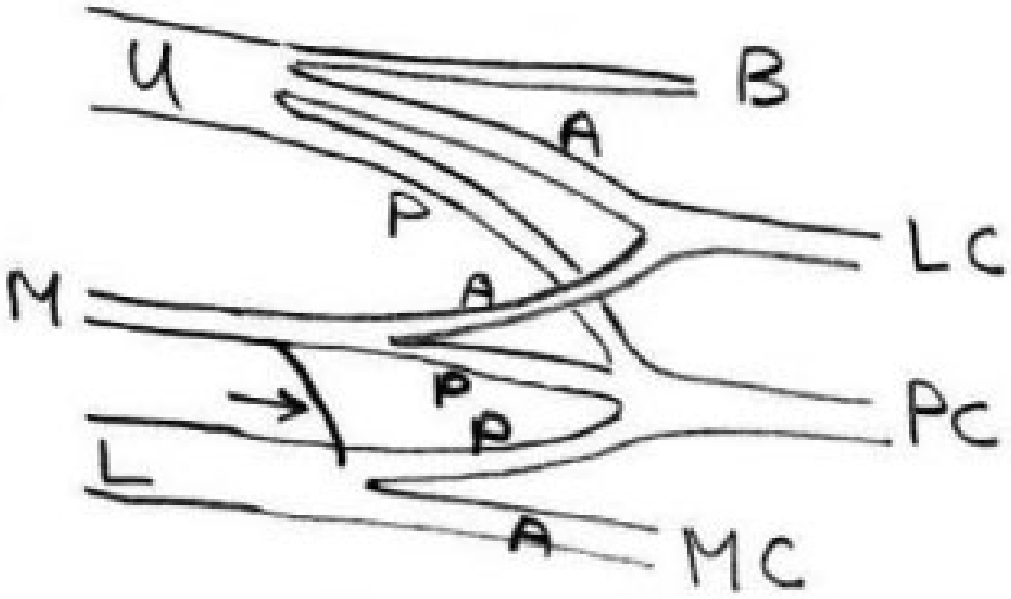


**Figure 4 (C):** Diagrammatic illustration of the same specimen.

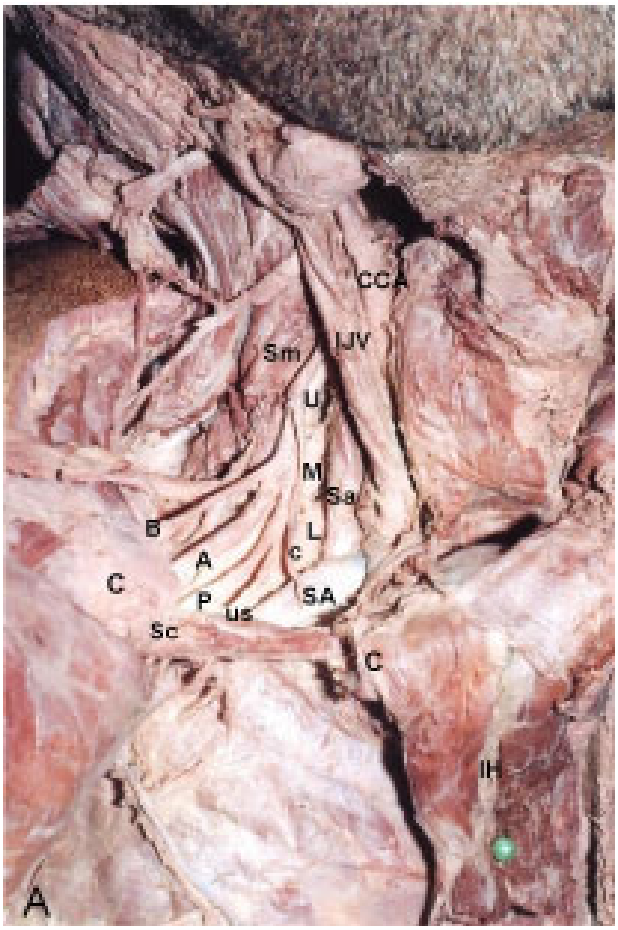


**Figure 5 (A):** A photograph of the right side of the neck. The middle part of the clavicle (C) was cut and removed. The upper trunk of the brachial plexus (U) gives 5 branches: the suprascapular nerve (B), the anterior division (A), the posterior division (P) that joins the posterior cord of the plexus, the upper subscapular nerve (us) and nerve (c) to subclavius (Sc). Note the middle (M) and lower (L) trunks of the plexus, the subclavian artery (SA), the common carotid artery (CCA), the internal jugular vein (IJV), scalenus anterior (Sa) and scalenus medius (Sm) muscles. The infrahyoid muscles (IH) can be seen retracted downwards.

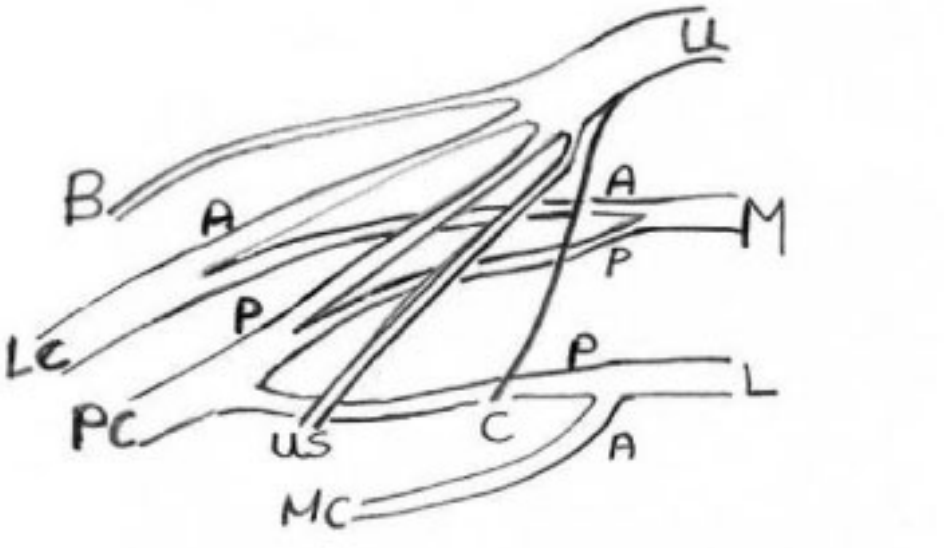


**Figure 5 (B):** Diagrammatic illustration of the same specimen.

Keet and Louw [13] reported presence of a C5 root piercing the anterior scalene in15% especially on the right side in females. We found long thoracic nerve arising by a single root from upper trunk (C5, C6) and piercing middle scalene to pass posterior to the plexus on its way to serratus anterior. A condition that can explain partial or complete paralysis of serratus anterior in C5 or scalene muscles lesions. Williams and Smith [14] reported that long thoracic nerve dysfunction in the absence of any reported trauma suggests the presence of anatomical variation as entrapment of the nerve within the scalene muscles.

The origin of phrenic nerve from the upper trunk is an unrecognized potential threat for life. This can explain Rizeq et al. [15] report of diaphragmatic paralysis in cases of upper trunk avulsion in neonates. The phrenic nerve took origin from the upper trunk in 10% of our series. Golarz and White [16] describe anomalies of phrenic nerve and brachial plexus that can cause postoperative complications following supraclavicular decompression for neurogenic thoracic outlet syndrome.

Abnormal origins of radial and axillary nerves were previously reported by Singhal et al. [2] who found radial nerve arising from the posterior divisions of the middle and lower trunks, the upper trunk gave no contribution, and this is the reverse of the findings of this study where the radial nerve took origin from the posterior division of the upper trunk in 20% of cases.

In this study, the thoracodorsal nerve originated from the posterior cord in 70%, from the radial nerve in 20% and from the axillary nerve in 10%. This can explain paralysis of latissimus dorsi in cases of radial or axillary nerve injuries. Moucharafieh et al. [17] stated that nerve transfers are the gold standard for repair of brachial plexus branches injuries. Repair of these cases requires attention to re-innervation of latissimus dorsi in addition to muscles supplied by radial or axillary nerves.

Gupta et al. [18] described the lateral pectoral nerve arising by one root from the lateral cord or from the posterior division of the upper trunk or by 2 roots from the anterior divisions of the upper and middle trunks. Similar variations were found in this study, the lateral pectoral nerve took origin by 2 roots from the medial and lateral cords in 20% and from the upper and middle trunks in 20%. This explains partial affection of pectoral muscles in upper trunk or lateral cord lesions.

Unusual clinical findings such as apparent involvement of the ulnar nerve in cases of injury to the lateral cord or apparent involvement of the median nerve in cases of injury to the musculocutaneous nerve can be explained by communicating branches between these nerves that represent anatomical variants [19]. Communicating branches were a constant feature in this study. They were found between the medial root of median nerve and the ulnar nerve, between the lateral cord and the lower trunk or between the middle and lower trunks. These branches are essential to convey C7 to flexor carpi ulnaris through ulnar nerve.

Sharif-Askary et al. [20] documented that congenitally short upper trunk can lead to persistent upper extremity weakness after trauma. Early diagnosis and treatment are essential for optimizing outcomes of surgical repair after brachial plexus injury and preventing irreversible muscle disability. A short upper trunk that divides immediately into 5 branches was found in 10% of this study. Unawareness of such variation can delay interpretation of signs of brachial plexus injury and can lead to faulty surgical intervention that worsens signs.

Leijnse et al. [21] ask a philosophic question about brachial plexus: what is anomalous and what is not? Trying to answer the question, they designed a model of standardized plexus based on a thorough literature review. Within the model, the major plexus morphological determinant is the embryological origin and position of the subclavian artery.

## Conclusion

Now is the time to quit trying to assign brachial plexus to specific patterns. It is time to accept that variation is the rule and start dealing with brachial plexus lesions on individual basis and not according to specific patterns.

Surgical choice for repair of brachial plexus injury is limited by anatomical variations as absence of one of the cords, trunks, or abnormal branching pattern of the plexus.

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