Research Article ISSN 2689-1093

Surgical Research

The Brachial Plexus: Variations are The Rule

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Received: 24 March 2021; **Accepted:** 15 April 2021

Citation: Elzawawy EM. The Brachial Plexus: Variations are The Rule. Surg Res. 2021; 3(1): 1-8.

ABSTRACT

Anatomical variations of the brachial plexus are so common, it is crucial to look for them before surgical correction of the different injuries of the plexus and prior to supra or infraclavicular plexus block. This study was done to identify the variations of the brachial plexus and highlight their clinical significance.

The materials of this study included 20 cadaveric specimens obtained from the Faculty of medicine, University of Alexandria which were dissected to find the variations of the different parts of the plexus.

Variations were found in 90% of cases and involved all the stages of the plexus, prefixed pattern was found in 40% of cases, postfixed in 15% and both prefixed and postfixed in 5%. Anomalous formation of the trunks or cords as well as abnormal origin of the branches were detected. Communicating branches existed between the different parts of the plexus.

The brachial plexus is very variable, even in the same person the right and left sides may not be similar. Disagreement exists between different studies as regards the location and description of the variations. The anatomical basis of brachial plexus variations should be kept in mind, especially when interpreting clinical symptoms following trauma or tumor events.

The presence of variations can affect the decision and type of repair for brachial plexus injury.

Keywords

Trunks, Cords, Branches, Variations.

Introduction

The brachial plexus is a union of the lower four cervical and the first thoracic ventral rami with a small contribution from C4 or T2. These ventral rami are the roots of the plexus and vary in their mode of junction. Brachial plexus anatomical variations have been described by many authors, although such variations have not been extensively catalogued. Variations of the formation, location, course, and branches of the plexus are of great anatomical and clinical interest [1,2].

The various anomalies of the brachial plexus are important for the choice of surgical repair of the different injuries of the plexus [3]. Variations of the plexus are predisposing factors for thoracic outlet syndrome. They cause specific symptoms and require a different surgical approach in comparison with other causes of the syndrome [4].

Anatomical variations of the branches of the brachial plexus are so common that normal textbook parameters must be handled carefully, especially regarding surgical procedures. The more common variations occur at the junction or separation of individual parts [5,6]. The position of the main branches of the brachial plexus in the axilla and upper arm are variable and can be studied using high resolution ultrasonography before performance of infraclavicular plexus block [7,8].

The relations between the trunks, cords and branches of the plexus and the subclavian, axillary, and brachial arteries are very variable. These relations must be considered during vascular and neurological surgeries in the neck and axilla. Brachial plexus injuries represent a severe and difficult to handle traumatic event. Before surgical correction of brachial plexus or vascular injury in the neck, surgeons should be aware of the possible variations [9].

Aim of the Work

Was to identify the variations of the brachial plexus and highlight their clinical significance.

Materials and Methods

Twenty cadaveric specimens were dissected to study the formation, location and course of the roots, trunks, cords, and branches of the brachial plexus to show the most common variations. None of the dissected specimens had pathological lesions, traumatic lesions, or surgical procedures in the neck, thoracic or axillary regions. All specimens were fixed in 10% formaldehyde solution. The dissections included posterior triangle of neck, cervicoaxillary canal and axilla. The roots, trunks, divisions, and the brachial plexus branches were carefully dissected. This included the dissection of scalene muscles, pectoralis major and minor muscles. The clavicle was divided at its middle to expose the divisions of the plexus. Each finding was photographed and registered as usual or unusual according to classical textbooks description. The results were descriptive, and data was presented as absolute numbers and percentages.

Results

Overall variations were found in 90% of our series. The following brachial plexus patterns were found in this study:

1- The upper trunk was formed by C5 and C6 and joined by a branch from C4 (Prefixed pattern) in 40% (Figures 1A, B). The 2 roots forming the upper trunk may remain separate for about 2cm before joining together (Figure 2A).

2- The lower trunk was formed by C8 and T1and joined by a branch from T2 (postfixed pattern) in 15% (Figure 2A).

3- Prefixed and postfixed patterns in the same specimen in 5%, C8 and T1 join about 2cm from the lateral border of scalenus anterior, C8 is joined by a small branch from T2 about 1cm lateral to the muscle (Figure 3A).

4- In 5%, the upper and lower trunks were large; the middle trunk was small and divided into 2 branches that passed directly into the lateral and medial roots of the median nerve. These roots were joined by a branch from the anterior division of the upper trunk and a branch from the anterior division of the lower trunk respectively (Figures 4 A, B).

5- Absence of the lateral cord and the musculocutaneous nerve and the coracobrachialis and biceps muscles were supplied directly from the anterior division of the upper trunk in 5% (Figure 4B).

6- The lateral cord was formed by the anterior divisions of the upper and middle trunks and a branch from the anterior division of the lower trunk in 5% (Figure 3A).

7- Variations of the posterior cord:

- In 10% it was a small confluence of the posterior divisions of the three trunks and divided at once into: lower subscapular, axillary, radial and thoracodorsal nerves (Figure 3B).
- In 10% the posterior cord was formed by the posterior divisions of the upper and lower trunks only because the middle trunk did not give posterior division (Figure 4B).

8- Variations of the nerve to serratus anterior (long thoracic nerve):

- It originated by 2 roots, an upper one from the back of the joining between the upper and middle trunks (C5, C6, C7) and a lower one from the upper border of the lower trunk (C8). The union between the 2 roots was proximal as it took place in the neck (Figure 3C).

9- Variable branches from the upper trunk:

- The nerve to subclavius arose from the upper trunk in 20% (Figure 1A).
- The upper subscapular nerve arose from the upper trunk or its posterior division in 35% (Figure 3B).
- Suprascapular nerve took origin normally from the upper trunk in 50%. It arose from the ventral ramus of C4 in 15%, from the ventral ramus of C5 in 15%, from anterior division of upper trunk in 5%, from posterior division of upper trunk in 5%, from posterior cord in 10% (Figures 1,2,3).

10- Abnormal relations between the arteries and the plexus were found in 20% of cases. The suprascapular artery took origin from the third part subclavian artery and passed in front of the lower and middle trunks and deep to the upper trunk (Figure 1A). The lateral root of median nerve crossed in front of the axillary artery and the nerve was formed in front of the artery (Figure 2B). The lateral root of median nerve crossed in front of axillary artery and joined the medial root on the medial side of the artery (Figure 3A).

11- Communicating branches between the lateral cord and lower trunk were found in 80% (Figures 1A, 2A, 3A), between the trunks

Table 1: Origin of the branches of the brachial plexus

Nerve	Usual origin	Unusual origins
- Suprascapular nerve	Upper trunk 50%	- C4 in 15%, C5 in 15%, anterior or posterior division of upper trunk in 10% and the posterior cord in 10%.
- Upper subscapular nerve	posterior cord 55%	- Upper trunk in 20%, Posterior division of upper trunk in15% and axillary nerve 10%.
- Lower subscapular nerve	posterior cord 85%	- Axillary 5%, thoracodorsal 5%, and radial 5%.
- Thoracodorsal nerve	posterior cord 80%	- Radial 10% or axillary 10%.
- Long thoracic nerve	C5, C6, C7 40%	- C5 and C6 30%, C8 in 10%as a lower root and 20% as a contribution from the lower trunk
- Axillary nerve	posterior cord 75%	- Posterior division of upper trunk15%, radial nerve10%.
- Radial nerve	posterior cord 75%	- Upper trunk 10%, posterior division of upper trunk15%.
- Musculocutaneous nerve	lateral cord 75%	- Anterior division of upper trunk 10%, upper trunk 5%, 2 roots from the upper and middle trunks 10%.
- Nerve to subclavius	C5, C6 70%	-pper trunk 20%, C5 only10%.

in 5%, between the different cords in 10%, especially between the medial and posterior cords (Figure 2B).

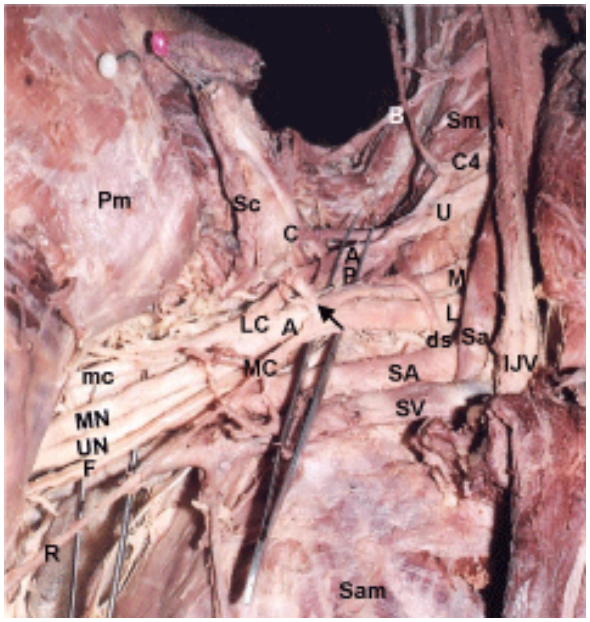

Figure 1 (A): A photograph of the right side of the neck and the right axilla showing the upper (U), middle (M) and lower (L) trunks of brachial plexus, the upper trunk takes a branch from C4 (prefixed pattern) which gives suprascapular nerve (B). The upper trunk gives nerve (c) to subclavius (Sc) and divides into anterior (A) and posterior (P) divisions, the middle trunk is small. The anterior divisions of the upper and middle (A) trunks form the lateral cord (LC) while the anterior division of the lower trunk forms the medial cord (MC). The branches of the cords are seen in the axilla: the musculocutaneous nerve (mc), the median nerve (MN), the ulnar nerve (UN) and the medial cutaneous nerves of the forearm (F) and arm (R). Note the subclavian artery (SA), the subclavian vein (SV), the internal jugular vein (IJV) and the scalenus anterior (Sa), scalenus medius (Sm) and serratus anterior (Sam) muscles. Pectoralis minor muscle (Pm) is cut and reflected laterally. The suprascapular artery (ds) arises from the third part subclavian artery and passes in front of the middle and lower trunks. There is a connection (marked by an arrow) between the lateral cord and the lower trunk.

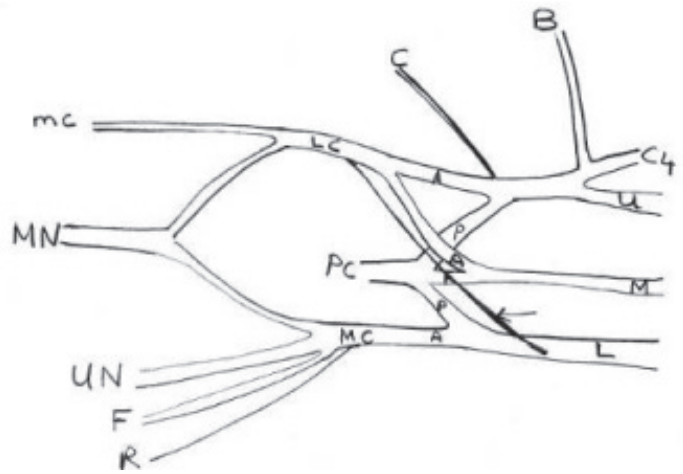

Figure 1 (B): Diagrammatic illustration of the same specimen.

Figure 2 (A): A photograph of the left brachial plexus showing the upper (U), middle (M) and lower (L) trunks. The 2 roots of the upper trunk (C5 and C6) remain separate for about 2cm before joining together to form the upper trunk which divides at once into suprascapular nerve (B), anterior (A) and posterior (P) divisions. The lower trunk is joined by a branch from T2 (postfixed pattern). The lateral cord (LC) is formed by the anterior divisions of the upper and middle trunks. A connection (pointed by an arrow) is seen between the lateral cord and the lower trunk. Note the medial cord (MC), the branches of the plexus: the median (MN), the ulnar (UN), the musculocutaneous (mc), the radial (RN), the axillary (AN) nerves and medial cutaneous nerve of forearm (F). The subclavian (SA), the axillary (AA) and the brachial (BA) arteries. The subclavian vein (SV) and the subclavius muscle (Sc) are cut and reflected.

Figure 2 (B): The same specimen; the upper trunk (U) is retracted upwards to show the posterior (P) divisions of the 3 trunks forming the posterior cord (PC) and its continuation the radial nerve (RN). The anterior division of the lower trunk (A) forms the medial cord which gives the medial cutaneous nerve of forearm (F), the ulnar nerve (UN) and the medial root (MR) of median nerve (MN). Note that the medial and the posterior cords are connected for a short distance before giving terminal branches. The 2 roots (LR, MR) of MN join in front of the axillary artery (AA).

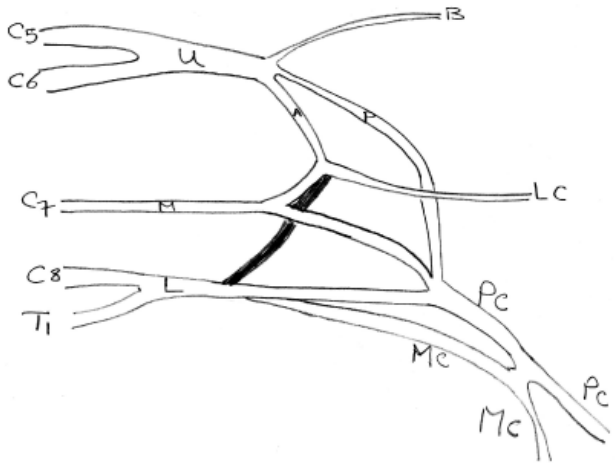

Figure 2 (C): Diagrammatic illustration of the same specimen.

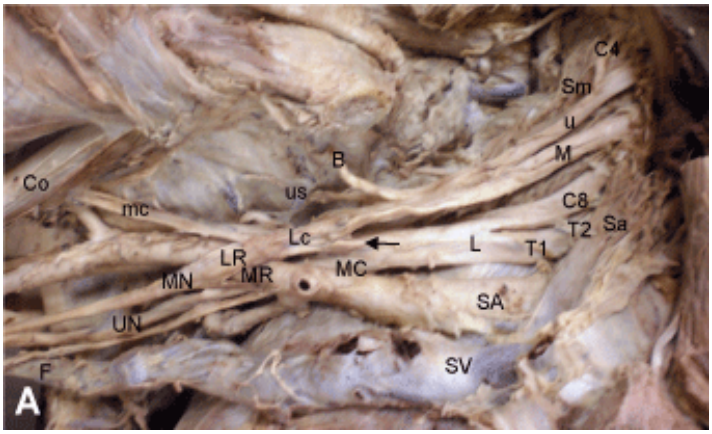

Figure 3 (A): A photograph of the right brachial plexus showing the upper (U), middle (M) and lower (L) trunks, the upper trunk receives a contribution from C4 (prefixed pattern) and gives suprascapular nerve (B) and upper subscapular nerve (us). The lateral cord (LC) is formed by the upper and middle trunks and a branch from the anterior division of lower trunk (pointed by arrow). There is a connection between the lateral cord and the lower trunk (pointed by arrow). The 2 roots (C8 and T1) forming the lower trunk are joined by a small branch from T2 (postfixed pattern) and then give the medial cord (MC) that gives the medial root (MR) which joins the lateral root (LR) to form the median nerve (MN). Note, the musculocutaneous nerve (mc), the ulnar nerve (UN), the medial cutaneous nerve of forearm (F), the subclavian artery (SA) and subclavian vein (SV), the scalenus anterior (Sa), scalenus medius (Sm) and coracobrachialis (Co) muscles.

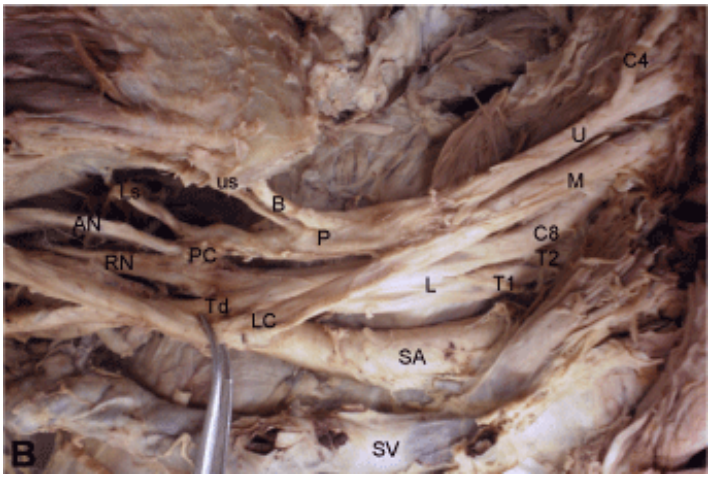

Figure 3 (B): A photograph of the same specimen after retracting the lateral cord (LC) downwards to show the posterior cord (PC) which is a small confluence of the posterior divisions of the trunks and divides at once into terminal branches: lower subscapular (Ls), axillary (AN), radial (RN) and thoracodorsal (Td) nerves, note the upper subscapular (us) and suprascapular (B) nerves arise from the posterior (P) division of the upper trunk before forming the posterior cord.

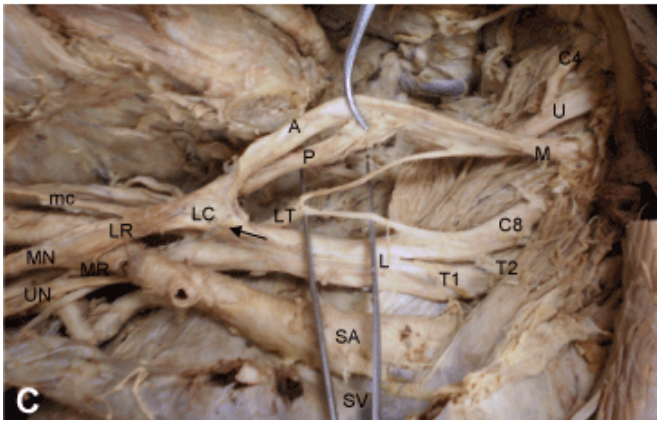

Figure 3 (C): A photograph of the same specimen after retracting the upper (U) and middle (M) trunks upwards to show the long thoracic (LT) nerve arising by two roots from the posterior aspect of the upper and middle trunks and the upper aspect of the lower trunk (L). The upper and middle trunks join before dividing into anterior (A) and posterior (P) divisions. The anterior division forms the lateral cord (LC) that has a connection (pointed by arrow) with the lower trunk.

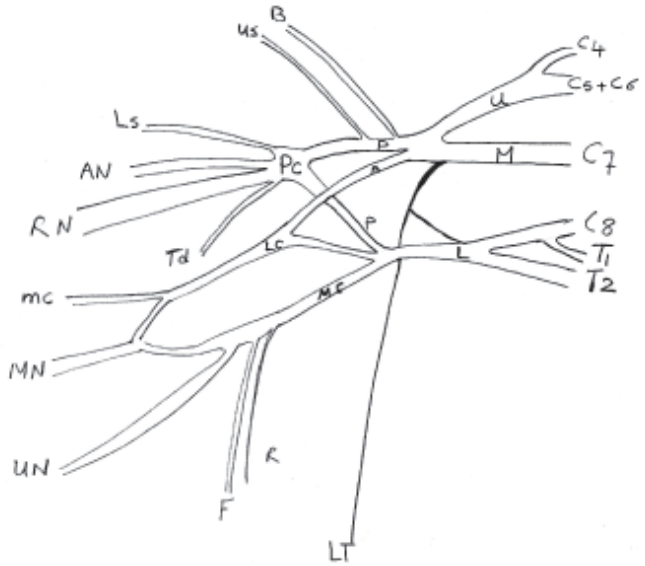

Figure 3 (D): Diagrammatic illustration of the same specimen.

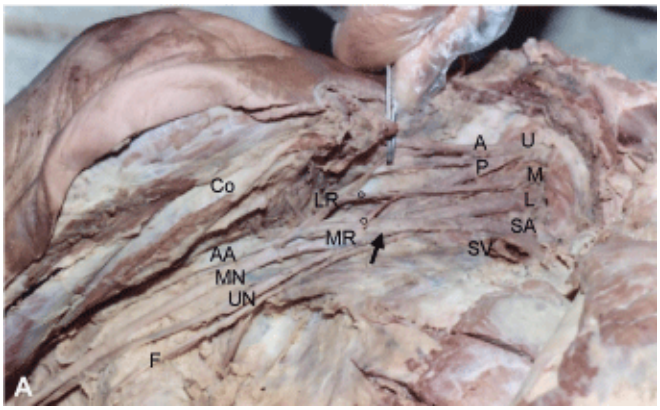

Figure 4 (A): A photograph of the right brachial plexus showing the upper (U), middle (M) and lower (L) trunks. The upper and lower trunks are large while the middle trunk is small and divides into 2 branches (°) that pass into the medial (MR) and lateral (LR) roots of the median nerve (MN). There is no lateral cord or musculocutaneous nerve, and coracobrachialis muscle (Co) is supplied directly from the anterior division (A) of the upper trunk. The lateral root of the median nerve is joined by a branch (retracted upwards by forceps) from the upper trunk and the medial root is joined by branch (pointed by arrow) from the lower trunk. Note the subclavian artery (SA), the subclavian vein (SV), the axillary artery (AA), the ulnar nerve (UN) and the medial cutaneous nerve of forearm (F).

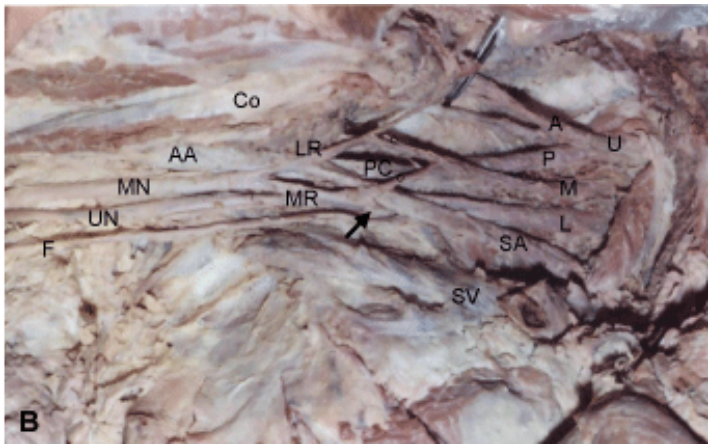

Figure 4 (B): A close up photograph of the previous specimen. The nerve supplying coracobrachialis appear at the tip of the forceps. The posterior cord (PC) is formed by the posterior divisions of the upper and lower trunks (P) only as the middle trunk does not give posterior division.

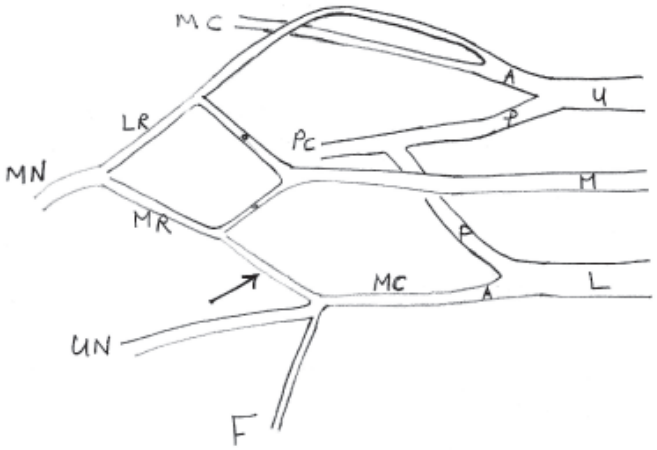

Figure 4 (C): Diagrammatic illustration of the same specimen.

Discussion

Variations of brachial plexus were reported by many authors as Ballesteros and Ramirez [10] who found variations in 47.1% of their series. Uysal et al. [11] reported variations in 53.5% of human fetuses especially in females and on the right side. However, Uzun and Seeling [12] and Fazan et al. [13] found no gender or side differences. What really matters is the type of variation as it can explain clinical syndromes and impact decisions of surgical repair after trauma. It seems that certain surgical treatment failures of brachial plexus lesions are related to these variations.

Prefixed pattern of brachial plexus was found in 40% of this series and postfixed pattern was cited in only 15% while prefixed and postfixed patterns were found in one specimen (5%). Previous studies show wide range of these variations, prefixed pattern in 28-62% and postfixed pattern in 16-73 % [14]. Uysal et al. [11] found prefixed pattern in 25.5% and postfixed pattern in 2.5% of cases, the lower trunk was not formed in 9% of their cases while the upper trunk was not formed in 1% of cases, the upper trunk was formed by C4 and C5 only in 0.5% and the lower trunk was formed by T1 and T2 in 0.5%. In this study, the upper and lower trunks were always present and C6 and C8 always shared in the formation of these trunks, respectively.

Bansal et al. [15] emphasize the importance of these variation during performance of the anesthetic blockade of brachial plexus as they could cause failure of this loco-regional anaesthesia. They advise all anesthesiologists to perform ultrasound-guided blocks to carefully evaluate the sonoanatomy of the plexus. They added that combination of nerve stimulation and ultrasound guidance is safer and better in the patients with anatomical variation.

Tubbs et al. [16] described different anomalies of the long thoracic nerve where C5, C6 and C7 join at different levels but they did not describe a long thoracic nerve having a root from C8 which was presented in this study. Ballesteros and Ramirez [10] described a distal union of the roots of the long thoracic nerve in 33.3% of cases. In this study, the union between the 2 roots was proximal. This can explain the partial symptoms when this nerve is injured during first rib resection, lung surgery, thoracotomy, and chest tube placement. A surgeon performing any of these procedures must bear in mind the possibility of distal or proximal upper and lower root union. A surgeon who counts on classical description of the nerve may cause damage of the nerve.

The suprascapular nerve is very variable; it can arise from C4 or C5, from the anterior or the posterior division of the upper trunk

and from the posterior cord. Normal description was found in 50% only in this study, and this disagrees with Ballesteros and Ramirez [10] who found normal suprascapular nerve in 82.4% and Fazan et al. [13] who found abnormal origins in 5.5% of cases. Emamhadi et al. [17] stated that the suprascapular nerve was formed from posterior division of the upper trunk in 21% of cases.

Upper subscapular nerve is very variable as it may arise from the upper trunk (20%) or its posterior division (15%) or the axillary nerve (10%) and this conforms with the results of Tubbs et al. [18], Chaware et al. [19] and Singhal et al. [20].

Variations of the lateral cord, musculocutaneous and median nerves are the most common of all brachial plexus variations [21]. The musculocutaneous may be doubled, unusually short or even absent. It may arise from the lateral cord, from the posterior cord, from median nerve or from 2 separate bundles from medial and lateral cords [22]. The roots of the median nerve may join in the distal part of the arm in 8.5% of cases, and a connection between the median and musculocutaneous nerves occur in 1% of cases [23].

In the present study, we recorded absence of the lateral cord, anomalous origin of musculocutaneous nerve from the upper trunk or its anterior division in 15% of cases or by 2 roots from upper and middle trunks in 10% of cases. In one case, the middle trunk divided into 2 branches that passed into the medial and lateral roots of the median nerve after joining branches from the medial and lateral cords, respectively. This is a rare anomaly that was reported previously by Huynh et al [24]. It can affect the relation between the median nerve and the axillary and brachial arteries.

We found abnormal relations between the roots of median nerve and the axillary artery and between the trunks of the plexus and the branches of the subclavian artery. Das and Paul [25] found an abnormal relation between the median nerve and axillary artery which can cause compression syndrome and ischemia. Safwat et al. [26] found suprascapular artery arising from the third part subclavian artery in 26.7% of their series and described it passing deep the upper and middle trunks in 53.3%, superficial to all trunks in 20% and superficial to the lower, middle, and deep to the upper trunks in 26.7%. Pandey and Shukla [27] described variations of the relations between the trunks, cords and branches of the brachial plexus and the axillary and brachial arteries in 12.8% of cases compared to 20% in this study.

Communicating branches between the lateral cord and lower trunk was a constant feature in this study. This is how C7 can reach the ulnar nerve.

Conclusion

Variations of brachial plexus are more the rule than the exception and knowledge of these variations is important to clinicians, especially in radiological diagnoses, local anesthesia, and surgical procedures. Being aware of the restrictiveness of this study's sample size, we have concluded that: 1- Most of the evaluated plexuses had anatomical variations (90%). 2- Variations include all the stages of the plexus. 3- Further studies are needed to confirm the existence of these variations in a larger sample of cadaveric specimens and to study gender and side differences.

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