



CADAVERIC STUDY OF VARIATION IN THE FORMATION OF TRUNKS OF BRACHIAL PLEXUS, EMBRYOLOGICAL BASIS AND ITS CLINICAL SIGNIFICANCE.

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ABSTRACT

Brachial plexus is the plexus of nerves that supplies the upper limb. Variations in the branches of brachial plexus are common but variations in the roots and trunks are very rare. Here, we report one of such rare variations in the formations of the upper trunk, middle trunk, and lower trunk of the brachial plexus in the right and left upper limb of a male and female cadaver. In the present study 1 limb (1.6%), there was absence of the upper trunk on the left side of a male cadaver with approximate age of 20 years. And In 1 limb (1.6%), upper trunk of the brachial plexus was found unilaterally on the right side of a male cadaver aged approximately 55 years. the upper trunk was present in 2 limbs (3.3%), both on the right side of male cadavers with approximate age of 55 and 50 years. In both cases, C5 and C6 roots were split in anterior and posterior divisions (Figure No. 5). Both anterior divisions joined to give origin to an "anterior superior trunk" and both posterior divisions joined to give origin to a "posterior superior trunk". These trunks joined to give origin to the superior (upper) trunk. In 2 limbs (3.3%) The middle trunk was absent. in the right upper limb (1.6%) of a male cadaver with approximate age of 35 years the lower trunk was formed by the union of ventral rami of C7, C8 and T1 nerve roots..

KEYWORDS: Brachial plexus, Upper trunk, Middle trunk, Lower trunk.

INTRODUCTION

The brachial plexus, normally is formed by lower four cervical ventral rami (C5, C6, C7, C8) and greater part of the first thoracic ventral ramus (T1). It consists of roots, trunks, divisions and cords (lateral cord, medial cord and posterior cord).^[1] Sometimes C4 roots joins with C5, when plexus is called pre-fixed type. On occasions T2 roots joins with T1 with disappearance of C4 roots; this forms the post-fixed type of plexus. Branches of the brachial plexus are divided into supraclavicular and infraclavicular branches, supraclavicular branches are four (dorsal scapular nerve C5, a branches to join the phrenic nerve C5, long thoracic nerve C5, C6, C7, muscular branches to longus colli and scalene) from roots and two from upper trunk (nerve to subclavius and suprascapular nerve); In the inferior part of the neck, the roots of the brachial plexus unite to form three trunks:

- A upper trunk, from the union of the C5 and C6 roots.
- A middle trunk, which is a continuation of the C7 root.
- An lower trunk, from the union of the C8 and T1 roots.

Each trunk of the brachial plexus divides into anterior and posterior divisions as the plexus passes through the cervicoaxillary canal posterior to the clavicle. Anterior divisions of the trunks supply anterior (flexor) compartments of the upper limb and posterior divisions of the trunks supply posterior (extensor) compartments.

The divisions of the trunks form three cords of the brachial plexus:

- Anterior divisions of the superior and middle trunks unite to form the lateral cord.
- Anterior division of the inferior trunk continues as the medial cord.
- Posterior divisions of all three trunks unite to form the posterior cord.

infraclavicular branches are three from lateral cord (lateral pectoral nerve, musculocutaneous nerve and lateral root of median nerve), five from medial cord (medial pectoral nerve, medial cutaneous nerve of forearm, medial cutaneous nerve of arm, ulnar nerve C7,C8,T1 and medial root of median nerve) and five from posterior cord (upper subscapular nerve C5,C6, thoracodorsal nerve C6,C7,C8, lower subscapular nerve

C5, C6, axillary nerve C5, C6 and radial nerve C5, C6, C7, C8, T1).^[2]

The anomalous formation can be explained on the basis of embryological development.

The upper limb buds lie opposite the lower five cervical and upper two thoracic segments. As soon as the buds form, the ventral primary rami of the spinal nerves penetrate into the mesenchyme of limb bud. Immediately the nerves enter the limb bud, they establish intimate contact with the differentiating mesodermal condensations and the early contact between nerve and muscle cells is a prerequisite for their complete functional differentiation.^[2-4]

The growth as well as the pathfinding of nerve fibres towards the target is dependent upon concentration gradient of a group of cell surface receptors in the environment.^[3] Several signalling molecules and transcription factors have been identified which induce the differentiation of the dorsal and ventral motor horn cells.³⁻⁵

Misexpression of any of these signalling molecules can lead to abnormalities in the formation and distribution of particular nerve fibres.³

The high percentage of anomalies as mentioned above emphasizes the complexities and irregularities of this anatomic region with regard to surgical approaches.^[4] Knowledge of such variations is important for surgeons to perform surgical procedures in the axillary region and arm.^[5]

Considering the high percentage of anomalies in the formation of trunk and its paramount clinical importance, the present variations are documented and an attempt has been made to explain these variations in the light of embryological development.

MATERIALS AND METHODS

The study comprised of 60 upper limbs which belonged to 30 adult human cadavers of known sex (male: female ratio 28:02), obtained from mortuary of the Department of Anatomy, College of Medical Sciences and Teaching Hospital, Bharatpur, Chitwan, during the period between March 2009 to October 2012. The cadavers used in the current study were serialized from 1-30 with the suffixes 'M' for male, 'F' for female, 'R' for right and 'L' for left. Ethical approval was granted by the (Institutional Review Committee) of College of Medical Sciences and Teaching Hospital, Bharatpur, Chitwan.

The limbs of all cadavers were meticulously dissected (axilla, arm, cubital fossa, forearm and palm). The brachial plexus was dissected and exposed according to the methods described by Romanes in Cunningham's Manual of Practical Anatomy. All its roots, trunks, divisions, cords and branches were cleaned and the mode

of their formation, branching pattern and relations with major blood vessels of upper limbs (especially axillary and brachial arteries) were observed and noted. In each cadaver, both the upper limbs were dissected to note whether the variation, if any, was present unilaterally or bilaterally. The distances were measured at different branches of posterior cord of brachial plexus from origin of the parent cord; a thread was kept along the length of that part and was marked with Indian ink at designated points. The thread which was thus marked was lifted off the dissection area and spread along a graduated metric scale to measure the length in centimeters scale. All findings with regard to the variations in the formation of trunks and cords of brachial plexus, distribution of the branches derived from the cords and their branches with major blood vessels of the upper limb were documented and recorded. Statistical analysis was done wherever applicable.

RESULT

In the present study, variations in the formation of trunks of brachial plexus were noted in 12 limbs. Out of these, variation in the formation of upper trunks were noted in 4 (6.6%) limbs, middle trunks in 4 (6.6%) and lower trunks in 1 (1.6%) limbs (Chart No. 6).

1. **In 3 limbs (5%), there were 4 trunks** instead of the usual 3 and these were numbered craniocaudally as trunk I, II, III and IV (Figure No. 3). All these variations were noted in the left side, two in female (with approximate age of 30 & 45 years) and one in male (with approximate age of 30 years) cadavers.
2. **Variation in the formation of the upper trunk of brachial plexus**
 - a. In 1 limb (1.6%), variation in the formation of upper trunk of the brachial plexus was found unilaterally on the right side of a male cadaver aged approximately 55 years. The upper trunk was formed by the union of ventral rami of C5, C6 and C7 spinal nerves (Figure No. 4). The middle trunk was absent and the lower trunk was formed by the union of ventral rami of C8 and T1 spinal nerves (Figure No. 4).
 - b. Another type of variation in the formation of the upper trunk was present in 2 limbs (3.3%), both on the right side of male cadavers with approximate age of 55 and 50 years. In both cases, C5 and C6 roots were split in anterior and posterior divisions (Figure No. 5). Both anterior divisions joined to give origin to an "anterior superior trunk" and both posterior divisions joined to give origin to a "posterior superior trunk". These trunks joined to give origin to the superior (upper) trunk (Figure No. 5).
 - c. In 1 limb (1.6%), there was absence of the upper trunk on the left side of a male cadaver with approximate age of 20 years (Figure. No. 3 & 6). The ventral rami of C5 and C6 did not join to form the superior trunk but the formations of the other

trunks were normal and the suprascapular nerve originated exclusively from the C5 nerve root. After receiving a small contributing branch from C4, C5 independently bifurcated into an anterior and posterior division. The ventral ramus of C6 also independently split into anterior and posterior divisions (Figure No. 3 & 6).

3. Variation in the formation of the middle trunk of brachial plexus

- a. Middle trunk was absent in 2 limbs (3.3%). In each case, it was in the right side of a male cadaver with approximate age of 50 years (Figure No. 4).
- b. The middle trunk received a communicating branch from C8 on the left side in one male limb (1.6%) with approximate age of 40 years and a communicating branch from the inferior trunk on the right side in one male limb (1.6%) with approximate age of 60 years (Figure No. 7).

4. Variation in the formation of the lower trunk of brachial plexus

Formation of the lower trunk of the brachial plexus was abnormal in the right upper limb (1.6%) of a male cadaver with approximate age of 35 years. The lower trunk was formed by the union of ventral rami of C7, C8 and T1 nerve roots. The middle trunk was absent. Upper trunk formation was normal (Figure No. 7).

DISCUSSION

Out of 60 upper limbs dissected in present study, the variation in formation of brachial plexus was found in 20 limbs (33.3%), out of which 12 limbs (20%) were having variation in formation of the trunks and 8 limbs (13.3%) having variation in formation of the cords. Remaining 40 limbs (66.6%) were normal regarding the formation of brachial plexus.

Common variations in the formation of brachial plexus, prefixed and postfixed plexuses, have been well documented.^[62-65] Variations in the formation of the trunks of the brachial plexuses have been reported.^[65] An extensive study by Uysal et al., (2003) showed superior trunk not being formed in 1% of cases, inferior trunk not being formed in 9% of cases and formation of superior trunk by C4 and C5 roots and formation of inferior trunk by T1 and T2 roots.^[8]

Formation of upper trunk of brachial plexus by C5, C6 and C7 roots is very rare. This will be associated with absence of the middle trunk. We can also put this case as anatomical fusion of upper and middle trunks. One such case has been reported so far where the fusion between upper and middle trunks was bilateral.^[65] In the previous studies, the variations in the supra or infraclavicular part of brachial plexus were more frequent in the left side,^[65] but in our case the variation found was on the right side. The knowledge of variations in the formation of brachial plexus is very useful for the neurosurgeons. It will help

in the surgical treatment of tumors of nerve sheaths such as schwannomas and neurofibromas.

The absence of the inferior trunk characterized by the nonunion of C8 and T1 nerve roots has been reported.^[8,62] The absence of the middle trunk has also been observed. The ventral rami of the C5, C6 and C7 nerve roots have been found to form the superior trunk at the expense of an absent middle trunk.^[62, 66, 67] The C7, C8 and T1 nerve roots have been shown to form the inferior trunk with the absence of the middle trunk.^[62] Unilateral upper trunk variations similar to the one observed in the present study has been reported.^[8, 62] A studies by Uysal et al. revealed that the absence of the superior trunk was less common than the absence of the inferior trunk. The superior trunk was not formed in two plexuses (1%) while the inferior trunk was not formed in eighteen plexuses (9%).^[8]

The trunk variation presented in the current study did not result in abnormalities of the terminal branches of the brachial plexus distal to the level of the cords. Therefore, it is unlikely that the variation would negatively affect the normal function of the upper limb although this cannot be proven with certainty. The variation of the superior trunk corrected itself at the level of the cords to preserve the usual nerve root fiber arrangement of the posterior, medial and lateral cords. Although normal function of the upper limb was likely preserved with this variation, there were clinical implications that may apply.

The absence of the superior trunk may increase the chance of nerve root avulsion due to traction injury of the brachial plexus. A downward traction force of the upper limb can cause a breaking strain expended on the brachial plexus from above and result in a lesion of the C5 nerve root.^[51] Thus, a blow from above on the neck or shoulder may cause the integrated cord to be stretched and this stress to be transmitted to the sites of cord attachment. One of these risk sites is where the nerve roots meet the spinal cord. In an article by Stevens, it was described that five cords combined as one will withstand a greater amount of strain than the same cords divided. Thus, in a normal brachial plexus, a portion of the stress applied to the lateral cord will be transferred back to the spinal cord where it would then be disseminated to both C5 and C6 by way of the superior trunk. This division of force decreases the strain on C5 and may prevent an avulsion. Absence of the superior trunk results in the full force of strain being applied to the C5 nerve root. As a result, a similar force that does not cause a C5 avulsion in a normal plexus may cause an avulsion in a plexus without a superior trunk.^[51]

Formation of lower trunk of brachial plexus by C7, C8 and T1 roots along with absence of the middle trunk, as noted in the present study is very rare. The variation in the formation of brachial plexus as observed in the current study is the result of developmental anomaly.

The reason behind this variation may be the result of factors influencing the development of the limb muscles and the peripheral nerves during the embryonic life.

The development of forelimb muscles by regional expression of five Hox D genes occurs from the mesenchyme of paraxial mesoderm in the fifth week of the intrauterine life. The growth cones of the motor axons arrive at the base of the limb bud to form the brachial plexus and continue in the limb bud.^[68, 69]

The guidance of the developing axons is regulated by the expression of chemo-attractants and chemo-repellents in a highly coordinated site specific fashion. Trophic substances such as brain-derived neurotrophic growth factor, *neutrin-1*, *neutrin-2*, *c-kit ligand* etc. attract the correct growth cones that happen to take the right path.^[5] The significant variations in nerve pattern may be the result of altered signaling between the mesenchymal cells and the neuronal growth cones or circulatory factors at the time of fusion of brachial plexus cords.^[68, 69]

Satheesha nayak et al reported absence of middle trunk and variation in the formation of upper trunk by union of C5, C6 and C7 spinal nerves.^[70]

An extensive study by Usyal et al showed superior trunk not be formed in 1% of cases, inferior trunk not be formed in 9% of cases and formation of superior trunk by C4 and C5 roots and inferior trunk by T1 and T2 roots.^[8]

The knowledge of variations in the formation of brachial plexus is very useful for the anatomists, radiologists, anesthesiologists, neurosurgeons and orthopedic surgeons.^[35]

The knowledge of variations in the formation of brachial plexus is very useful for the neurosurgeons. It will help in the surgical treatment of tumors of nerve sheaths such as schwannomas and neurofibromas.^[70]

This type of knowledge is mainly helpful for anesthesiologist and surgeons for improved guidance during infraclavicular block procedures, surgical approaches for brachial plexus region tumors. Orthopedic treatment of the cervical rib also needs a thorough knowledge of normal and abnormal formation of brachial plexus.^[71]

Finally in image process three dimensional volumes rendered magnetic nuclear resonance scan allows visualization of the entire brachial plexus within a single composite image which is important in computer imaging in diagnostic medicine.^[72]

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