Original article

Variations in the branching pattern of brachial plexus with their embryological and clinical correlation

Sinha, RS.[1], Chaware, PN.*[2], Pandit, SV.[2] and Motewar, Sapana S.[3]

[1]Grant Medical College, byculla, Mumbai, Maharashtra, India (Anatomy Department), 400008 Mumbai, Índia
[2]Shri Vasantrao Naik Government Medical College, Yavatmal, Maharashtra (Anatomy Department), 445001 Yavatmal, Índia
[3]SRTR Government Medical College, Ambajogai, Dist-Beed (Physiology department), 431517 Ambajogai, Índia
*E-mail: prashantnchaware@gmail.com

Introduction: As per the medical and surgical aspects, nerve supply of upper limb is very important which is provided by brachial plexus. The aim of this study was to provide concise and relevant information about the variations in branching pattern of the brachial plexus. **Material and methods**: The material for the present study comprised of 40 upper limbs which belonged to 20 adult human cadavers of known sex. These were serialized and dissected according to the methods described in Cunningham's Manual. **Results**: In the present study, 35[87.50%] cases showed normal branching pattern of cords of brachial plexus and in 5[12.5%] cases, variant branching pattern was observed. Out of five variant cases, in first case we found two upper subscapular nerves, axillary nerve and lower subscapular nerve arose from posterior division of upper trunk and the nerve to latissimus dorsi arose from posterior division of middle trunk and not from posterior cord. In the second case upper subscapular nerve and axillary nerve arose from posterior division of upper trunk. In other three cases median nerve was observed to form by three roots, fibres of C7 root to ulnar nerve which are seldom visualised were observed and a communicating branch by musculocutaneous nerve to median nerve was seen. **Conclusion**: The findings of the present study will be of fundamental importance to the physicians, surgeons, radiologists and of course this knowledge is very important for anatomists during routine classroom dissection.

Keywords: anatomic variant, brachial plexus, median nerve, posterior cord, ulnar nerve.

1 Introduction

The brachial plexus is a network of nerves located in the neck and axilla, composed of the anterior primary rami of C5 to C8 and T1 and supplying the chest, shoulder, and arm. The ventral primary rami of C5 to C8 and T1 are the roots of brachial plexus (GRAY, 2005). These roots of brachial plexus join with each other to form three trunks, each of which bifurcates into anterior and posterior divisions. These divisions reorient themselves to form lateral, medial and posterior cords and these cords give rise to different nerves for the upper limb. Variations in the formation and branching of the brachial plexus are common and have been reported by several investigators (GRAY, 2005; GUPTA, GOYAL and HARJEET, 2005; MILLER, 1934). The brachial plexus has complex structure and has close relationship to the important anatomical structures. So variations in the brachial plexus have significant clinical and surgical importance. Brachial plexus variations are frequently reported. Such variations usually remain asymptomatic and are detected only during surgery, autopsy or cadaveric dissection but rarely may they present clinically with gross functional alterations. Since the emergence of newer diagnostic tools such as computed tomography and magnetic resonance imaging anatomical variations are more frequently encountered and have much clinical significance.

Variations of peripheral nerves of the limbs are revealed better by dissection of limb than by investigative procedures since better exposure of the part provides ready accessibility for detailed morphometry. The aim of this study was to provide concise and relevant information about the variations in branching pattern of the brachial plexus.

2 Material and methods

The present study was conducted at Department of Anatomy, Shri Vasantrao Naik Government Medical College, Yavatmal. The material for the present study comprised of 40 upper limbs which belonged to 20 adult human cadavers of known sex [male:female ratio 18:02], which were obtained from the Department of Anatomy, Shri Vasantrao Naik Government Medical College, Yavatmal. These were serialized from 1-20 with the suffixes 'M' for male, 'F' for female, 'R' for right and 'L' for left. The brachial plexus in each upper limb was dissected and exposed according to the methods described by Romanes in Cunningham's Manual of Practical Anatomy (ROMANES, 1964). All roots, trunks, divisions, cords and branches of brachial plexus were cleaned and the pattern of its formation and branching was seen.

3 Observations and results

3.1 Pattern of formation

In all 40 [100%] cases, the roots of the brachial plexus were given by anterior primary rami of C5 to C8 and T1. C5 and C6 joined to form upper trunk, C7 formed middle trunk and C8 and T1 joined to form lower trunk. All these trunks divided into upper and lower divisions. Anterior divisions of upper and middle trunks united to form lateral cord, anterior division of lower trunk formed medial cord and posterior divisions of upper middle and lower trunks united to form posterior cord.

3.2 Branching pattern

In all 40 [100%] cases, long thoracic nerve arose from C5, C6 and C7 roots, dorsal scapular nerve from C5. In all cases, upper trunk gave rise to suprascapular nerve and nerve to subclavius. Out of 40, in 35 [87.50%] cases branching pattern of cords of brachial plexus was normal i.e. lateral cord gave lateral pectoral nerve, musculocutaneous nerve and lateral root of median nerve, medial cord gave medial root of median nerve, medial pectoral nerve, medial cutaneous nerve of arm, medial cutaneous nerve of forearm and ulnar nerve while upper subscapular nerve, lower subscapular nerve, axillary nerve, nerve to latissimus dorsi and radial nerve arose from posterior cord. In 5 [12.5%] cases, variant branching pattern was observed. The variations were as follows:

1) Case No.[7-Fe-R] (Figure 1): There were variations in the branching pattern of posterior cord. There were two upper subscapular nerves. These two upper subscapular nerves, axillary nerve and lower subscapular nerve arose from posterior division of upper trunk and not from posterior cord. The nerve to Latissimus dorsi arose from posterior division of middle trunk and not from posterior cord. The only branch from posterior cord was radial nerve.

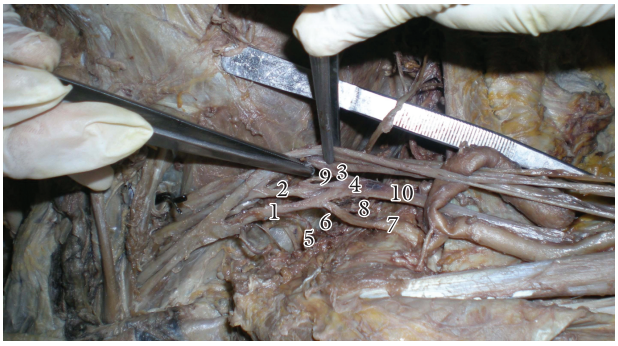

Figure 1. Variant branching pattern of posterior cord. (1) posterior division of upper trunk, (2) posterior division of middle trunk, (3) posterior division of lower trunk, (4) posterior cord, (5) upper subscapular nerve-1, (6) upper subscapular nerve-2 (7) axillary nerve, (8) lower subscapular nerve, (9) nerve to latissimus dorsi, (10) radial nerve.

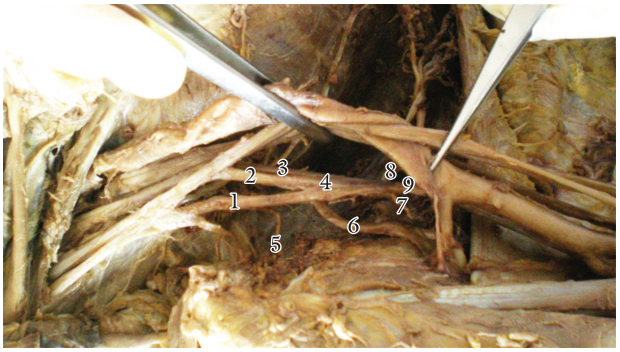

Figure 2. Variant branching pattern of posterior cord. (1) posterior division of upper trunk, (2) posterior division of middle trunk, (3) posterior division of lower trunk, (4) posterior cord, (5) upper subscapular nerve, (6) axillary nerve, (7) lower subscapular nerve, (8) nerve to latissimus dorsi, (9) radial nerve.

2) Case No.[18-M-R] (Figure 2): In this case also there were variations in the branching pattern of posterior cord. The upper subscapular nerve and axillary nerve arose from posterior division of upper trunk and not from posterior cord. The other branches i.e. lower subscapular, nerve to Latissimus dorsi and radial nerve arose from posterior cord.

3) Case No.[10-M-R] (Figure 3): Here variation was seen in relation with median nerve. It was found that the median nerve was formed by three roots, two coming from lateral cord and one from medial cord of brachial plexus. The uppermost or highest root was noted to be at the level of origin of coracobrachialis muscle. The second root was found to be immediately below the first one. These two roots were found to be passing obliquely in front of second and third part of axillary artery and joining individually with the medial root of median nerve and forming median nerve trunk, in front of third part of axillary artery. Further distribution of the anomalous median nerve in the arm, forearm and palm was normal.

4) Case No.[14-M-R] (Figure 4): In this case, the variations were found in relation with median and ulnar nerve. Middle trunk divided into anterior and posterior divisions. Anterior division of middle trunk joined with anterior division of upper trunk to form lateral cord. Anterior division of middle trunk gave a communicating channel which joined with medial root–1 of median nerve to form medial root–2 of median nerve with possible root values C7, 8, T1. Then this medial root–2 of median nerve travelled towards the arm and in the arm, anteromedial to

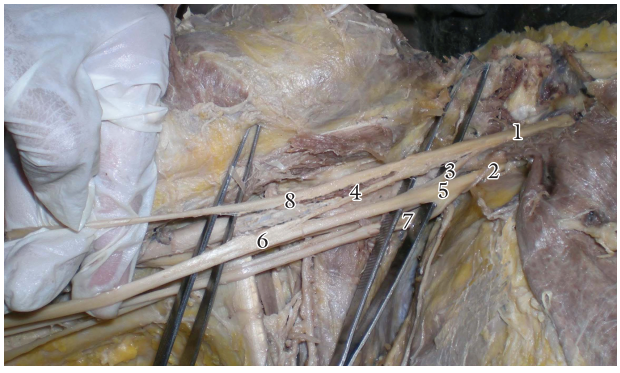

Figure 3. Three roots of median nerve. (1) lateral cord, (2) medial cord, (3) lateral root-1 of median nerve, (4) lateral root-2 of median nerve, (5) medial root of median nerve, (6) median nerve, (7) ulnar nerve, (8) musculocutaneous nerve.

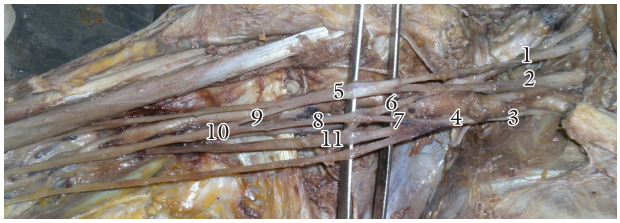

Figure 4. Variant formation of median and ulnar nerves. (1) upper trunk, (2) middle trunk, (3) lower trunk , (4) medial cord, (5) lateral cord, (6) communicating channel from middle trunk, (7) medial root – 1 of median nerve, (8) medial root – 2 of median nerve, (9) lateral root of median nerve, (10) median nerve, (11) ulnar nerve.

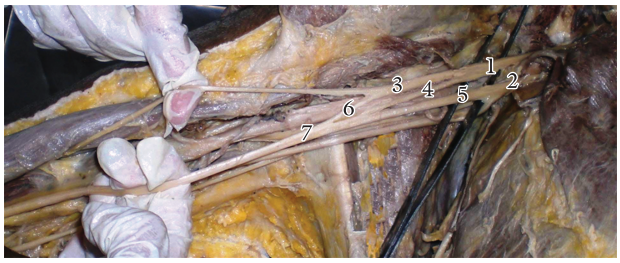

Figure 5. Communication between musculocutaneous nerve and median nerve. (1) lateral cord, (2) medial cord, (3) musculocutaneous nerve, (4) lateral root of median nerve, (5) medial root of median nerve, (6) musculocutaneous nerve's communicating branch to median nerve, (7) median nerve.

distal portion of 3rd part of axillary artery, it was joined by lateral root of median nerve given by lateral cord to form median nerve with possible root values C5, 6, 7, 8 and T1. Ulnar nerve arose from medial cord. The communicating channel from middle trunk, after contributing fibres to medial root–2 of median nerve, also gave fibres which joined ulnar nerve. Hence we clearly visualised fibres of C7 ramus joining the ulnar nerve which are seldom seen in routine dissection.

5) Case No.[16-M-R] (Figure 5): The musculocutaneous nerve arose normally from the lateral cord of brachial plexus. The median nerve was formed by the union of a lateral root coming from lateral cord and a medial root coming from medial cord, in front of the third part of axillary artery. The musculocutaneous nerve, after a very short course gave communicating branch to median nerve.

4 Discussion

Numerous variations have been described by different authors in the formation and in branching pattern of the brachial plexus. In the present study, we found variations in branching pattern of all the three cords.

Normally posterior cord gives rise to upper subscapular nerve, lower subscapular nerve, axillary nerve, nerve to latissimus dorsi and axillary nerve. In case No.[7-Fe-R], we found two upper subscapular nerves along with lower subscapular nerve and axillary nerve, arising from posterior division of upper trunk and nerve to latissimus dorsi arose from posterior division of middle trunk instead of posterior cord. In case No.[18-M-R], upper subscapular nerve and axillary nerve arose from posterior division of upper trunk. Earlier, various authors had come across with such variant origin in their dissection (CHAUDHARY, SINGLA, KALSEY et al., 2011; KERR, 1918; FAZAN, AMADEU, CALEFFI et al., 2003). Chaudhary, Singla, Kalsey et al. (2011) and Fazan, Amadeu, Caleffi et al. (2003) reported these variations to be more common in males and on left side. But we found above mentioned variations on right side of one female and one male cadaver which makes this study significant. Presence of two upper subscapular nerves is also mentioned in Grays Anatomy (GRAY, 2005).

Median nerve is formed by contribution from medial as well as lateral cord; one root coming from each of the two. In case no.[10-M-R], median nerve was formed by three roots, two coming from lateral cord and one from medial cord of brachial plexus. In the recent past, some authors got similar findings (SATYANARAYANA, REDDY, SUNITHA et al., 2010; BUDHIRAJA, RASTOGI and ASTHANA, 2011).

The nerves supplying upper limb are having their specific root values. But all these roots cannot always be traced during routine dissection. Ulnar nerve has root values C7, 8 and T1. Presence of C7 root in ulnar nerve is seldom visualised in the routine dissection. It has been documented that C7 root of ulnar nerve emerges from lateral cord, either through roots of median nerve (GRAY, 2005) or as an independent fascicle, the lateral root of ulnar nerve in axilla (SONTAKKE, TARNEKAR, WAGHMARE et al., 2011). Our finding of communicating channel of middle trunk (case No.[14-M-R]) which contributed fibres to medial root-1 of median nerve and then joined ulnar nerve can be conveniently considered as lateral root of ulnar nerve. We found, communicating channel of middle trunk joined with medial root-1 of median nerve to form medial root-2 of median nerve which later joined in the arm by lateral root of median nerve to form median nerve slightly distal to its usual location. Similar findings were observed by Sontakke, Tarnekar, Waghmare et al. (2011). But their report differed from our study as they found that the fascicle contributing fibres to ulnar nerve and median nerve arose from lateral cord and in our case, it started as a branch from anterior division of middle trunk.

In case No.[16-M-R] we found musculocutaneous nerve gave communicating branch to median nerve. Similar finding is mentioned by research workers like Thomas, Potu, Bhat et al. (2010) and Sachdeva and Singla (2011). Anastomosis between the musculocutaneous nerve and the median nerve is by far the most common and frequent of all the variations that are observed among the branches of the brachial plexus. It varies between a wide range of 1.4% to 63.5 % (SACHDEVA and SINGLA, 2011).

Variations in the branching pattern of brachial plexus can be due to abnormal formation in the development of trunks, divisions and cords (MILLER, 1934). Explanation of anatomical variations of brachial plexus can be traced by understanding its normal embryological development. Its development starts at 34th to 35th day of intrauterine life and definitive adult pattern is evident by 46th to 48th day of intrauterine life (MOORE and PERSAUD, 2004). Axillary artery has an important association to the divisions of the cords (MILLER, 1939). Thus during development, if axillary artery had variant relation to brachial plexus, the divisions of the cords would be modified.

The presence of such variations may be attributed to random factors influencing the mechanism of formation of limb muscles and the peripheral nerves during embryonic life. As described in textbook of human embryology (HAMILTON, BOYD and MOSSMAN, 1978), the paraxial mesoderm in developing embryo differentiate into myotome, dermatome and sclerotome. Myotome gives origin to muscles. During development, the cells of myotome usually elongate in a direction parallel to long axis of the embryo. Myotome enlarges rapidly both dorsally, flanking the neural tube and ventrally, where it extend into the somatopleure. At this time the fibres of ventral roots of spinal nerve, growing out of the neural tube make contact with the cells of appropriate myotome. This connection once established is permanent one. Between fifth and sixth week,

the myotome become divided by a slight constriction into a dorsal epaxial portion and ventro-lateral portion(hypomere). The nerve likewise become split into a dorsal primary ramus and ventral primary ramus connected to corresponding portions of the myotome. During further development, the nerve actually grows to the muscle and follows it during any subsequent migration. As the guidance of the developing axons is regulated by expression of chemoattractants and chemorepulsants in a highly coordinated site specific fashion, any alteration in the signalling between mesenchymal cells and neuronal growth cones can lead to significant variations (SANNES, REH and HARRIS, 2000). Chauhan and Roy (2002) commented that although it is unclear why neuronal processes assemble to form a mixed nerve, in this complex developmental event, there are multiple possibilities for the route taken by developing axons and thus for their arrival at the main trunk. They suggested the consideration of the phylogeny for the interpretation of the nerve anomalies of the arm. Considering the different variations of brachial plexus as a remnant from the phylogenetic or comparative anatomical point of view and that the ontogeny recapitulates the phylogeny, they mentioned the variations could be the result of the developmental anomaly. Studies of comparative anatomy have observed the existence of such connections in monkeys and in some apes; the connections may represent the primitive nerve supply of the anterior arm muscles (MILLER, 1934).

Thus, the complex developmental processes govern the formation of brachial plexus. So it is not surprising that anatomical variations of the brachial plexus are common. While many of these variations have little functional significance, they nevertheless need to be borne in mind while performing surgery in the axillary region.

Variant nerves, in terms of unusual beginning, course or distribution, are usually prone for injuries and entrapment neuropathies (SONTAKKE, TARNEKAR, WAGHMARE et al., 2011). Precise knowledge of such variations helps clinicians in correct interpretation of unusual clinical findings, clinical neurophysiological tests and radiological images. It also helps anesthetists in proper planning of brachial plexus blocks and orthopaedic surgeons for routine and reconstructive operations in the arm. The close relationship of the variant lateral root of the median nerve with the axillary artery may result in arterial compression leading to ischaemic pain or arterial insufficiency during certain postural manouevers of the shoulder joint (SONTAKKE, TARNEKAR, WAGHMARE et al., 2011). So knowledge of these variations in branching pattern of the brachial plexus is useful for surgeons, physicians, anaesthetists, radiologists and of course this knowledge is very important for anatomists during routine classroom dissection.

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