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An Insight into the Brachial Plexus and Related Anomalies: the Asian Scenario

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Abstract: Brachial plexus has been elaborately described in all conventional anatomy textbooks. Unfortunately, there is paucity of description of the variations related to brachial plexus in conventional textbooks of anatomy. Hence, the research reports are the only source of information. The present review was conducted by searching databases such as Pubmed, Science Direct and Google. All studies and reports pertaining to live humans and cadavers in the Asian region were selected for the review. It was mandatory for all studies to be published in any international English medium journal irrespective of the region where the study was performed. All brachial plexus anomalies reported from outside the Asian continent were excluded. The knowledge of brachial plexus anomalies is important for anatomy teaching and proper clinical diagnosis. The present review discusses the clinical implications of brachial plexus anomalies in the Asian continent.

Key words: Brachial Plexus · Nerve · Anatomy · Anomaly · Variation · Abnormality · Asia

INTRODUCTION

Brachial Plexus Anatomy: The anterior rami of C5-C8 and T1 nerves form the root of the brachial plexus. The root of the brachial plexus traverses a course between the anterior and middle scalene muscles. At the inferior part of the neck, there is formation of three trunks by the roots. The union of C5 and C6 roots form the superior trunk, C7 continues as middle trunk whereas union of C8 and T1 forms the inferior trunk [1]. Each trunk divides into anterior and posterior divisions. As a general rule, the anterior division innervates the anterior or flexor compartment of the upper limb whereas the posterior division innervates the posterior or the extensor compartment [1].

The anterior divisions of the superior and the middle trunk join to form the lateral cord whereas the anterior division of the inferior trunk continues as medial cord. The posterior division of all the three trunks join to form the posterior cord [1]. The lateral cord gives off three branches i.e. lateral root of median, lateral pectoral nerve and musculocutaneous nerves. The medial cord gives off five branches *i.e.* medial pectoral nerve, medial root of median, medial cutaneous nerve of arm, medial cutaneous arm of forearm and the ulnar nerves. The posterior cord gives off upper and lower suprascapular nerves, thoracodorsal nerve, axillary and radial nerves.

Anomalies Related to the Trunk of Brachial Plexus: There are reports of middle trunk were formed by union of C7 and C8 roots and lower trunk was formed by only T1 root [2]. The same study observed the upper and lower trunk to be fused in one specimen. There are reports of formation of upper trunk formed by C5, 6, 7 while C8,T1 formed the lower trunk with the middle trunk being absent [3]. Fusion of the upper and middle trunk has been also reported in another Indian study [4]. Another study reported that fusion of the trunks may be more common than even thought of Toshio *et al*. [5].

Anomalies Related to the Formation of Cords of Brachial Plexus: An earlier study conducted in the Japanese population found the upper trunk to be formed by the anterior primary division of C5 and C6 and a thin branch (0.5 mm in diameter) from C4, while the middle trunk was formed by the C7 and the inferior trunk was formed as usual by C8 and T1 [6]. Japanese researchers observed the union of anterior division of the medial cord with

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medial root of the medial nerve [7, 8]. A Korean study found the entire lateral cord to be joined to the median nerve with an associated anomaly of absence of musculocutaneous nerve [8].

Median Nerve: A root from the lateral (C5, 6, 7) and medial (C8,T1) embrace the third part of the axillary artery form the median nerve [9]. The median nerve first enters the arm lateral to the brachial artery, thereby crossing the insertion of corcobrachialis either anterior or posterior to the artery. It then descends to the cubital fossa where it traverses a course posterior to the bicipital aponeurosis and anterior to the brachialis [9]. The median nerve passes between the two heads of pronator teres muscle. The anterior interosseous nerve is given off from the median nerve posteriorly between the heads of the pronator teres muscle. Its branches innervate the flexor muscles of the forearm. In the wrist, it passes deep to the flexor retinaculum.

Anomalies Related to the Median Nerve: An earlier study reported the median nerve to be formed by the contribution of two lateral roots and one medial root [10]. In this case, the median nerve innervated the biceps and brachialis which are otherwise innervated by the musculocutaneous nerve. Another study also reported the median nerve to be formed by contribution of two roots from the lateral cords and one from the medial cord [11]. There are reports of median nerve being formed all three roots [12]. Another study found the median nerve to be formed on the left side of a cadaver by the lateral root only [13].

According to an earlier report, although the brachial plexus was formed from C5, C6, C7, C8 and T1 roots, the upper trunk was formed by C5 and C6 but before joining the C6, the C5 gave a direct branch to the subclavius muscle and the dorsal scapular nerve. The same study showed C6 to give rise to two small direct branches to the pectoralis minor and a large branch to the latissimus dorsi muscle [14] There was a communication observed between the musculocutaneous and median nerves in the same report. The authors described the variation as a type III where the communication between median and musculocutaneous nerves were present distal to the entry of musculocutaenous nerve into the coracobrchialis muscles [14]. The authors also described the medial pectoral nerve to arise from C6 root. It also gave branches to the pectoralis minor according to the same report.

There are reports of MN having additional contribution from the lateral cord which was detected in a 55-year-old male cadaver of Indian origin [15]. Interestingly, in the same study it was observed that the median nerve was located medially to the axillary artery on the right upper limb, instead of being positioned anterolaterally [15]. Another study observed the fibres of the lateral root running along with the medial cord of the brachial plexus to wind around the axillary artery from the posterolateral to the anteromedial direction [16]. Interestingly, majority of the brachial plexus anomalies were reported on the right side while few have been reported on the left side [17]. Another research study observed the MN to have an additional contribution from the lateral cord [18]. A Japanese study observed entire anterior division of the middle trunk of the brachial plexus to cross the axillary artery and join the medial root of the median nerve which was the continuation of the medial cord after the cord branched off the ulnar nerve [5]. The same study found that there was no MCN which pierced the coracobrachialis muscle.

Usually, the median nerve does not innervate the coracobrachialis which is otherwise innervated by the musculocutaneous nerve. Research studies also reported the median nerve innervating muscles of the anterior compartment of arm in the absence of musculocutaneous nerve in 11.2% superior extremities Budhiraja *et al.* [19]. In such cases, involvement of median nerve may result in total loss of actions of the muscles of both arm and forearm.

Communication between the median nerve and the musculocutaneous nerves are also commonly seen. A previous study observed a communication between the median nerve and the musculocutaneous nerve close the origin of the medial artery [20]. An earlier research observed the complete absence of the lateral root [21].

Radial Nerve: The radial nerve originates from the posterior cord (C5, 6, 7, 8, T1). It is the largest branch of the brachial plexus which descends posterior to the third part of the axillary artery. It passes through the radial or spiral groove of the humerus. Fractures involving the middle third of shaft involves injury to the radial nerve. It pierces the intermuscular septum to enter the anterior compartment and then anterior to the lateral epicondyle, it gives off superficial and deep branches [9]. The branches of radial nerve innervate extensor compartment of the arm and the forearm.

Anomalies Related to the Radial Nerve: In one of the research studies, the radial nerve was formed from the anterior and posterior divisions of the posterior cord [22]. This study was contrary to an earlier study which showed the posterior cord to divide into two to enclose the suprascapular artery [23].

Axillary Nerve: It originates from the posterior cord with the fibres derived from C5,6 roots ventral rami. In its course, it is first lateral to the radial nerve and posterior to the axillary artery and then traverses the quadrangular space. It gives off anterior and posterior branches. The axillary nerve innervates the deltoid, teres minor and triceps muscles. The axillary nerve has its anterior branch winding round the surgical head of the humerus and all fractures at this part involves the axillary nerve damage. The axillary nerve is also injured in faulty injections to the deltoid muscle.

Anomalies Related to the Axillary Nerve: The isolated anomalies related to axillary nerve are rare. However, a past study reported a bilateral anomaly of the axillary nerve branching into terminal branches before entering the quadrangular space of arm and the nerve did not traverse the quadrangular space [24].

Musculocutaneous Nerve: The musculocutaneous nerve originates from the lateral cord of the brachial plexus. It innervates the BBC muscles *i.e*. biceps, brachialis and the coracobrachialis muscles. In case of injury to the musculocutaneous nerve, the flexion of the arm produced by the BBC muscles are affected.

Anomalies Related to the Musculocutaneous Nerve: An earlier study reported the musculocutaneous nerve nerve to be absent on the right upper limb of a 54-year-old male cadaver [25]. In the same study, it was observed that after the origin of the lateral pectoral nerve, the lateral cord continued as lateral root of median nerve with another branch joining the ulnar and median root of the median nerve [25]. In the absence of the MCN, the arm muscles were supplied by the median nerve.

There are other studies on the absence of the musculocutaneous nerve on the right side of a 65-year-old male cadaver of Indian origin [26]. Interestingly, the same study reported a direct branch from the lateral cord supplying the coracobrachialis in the absence of musculocutaneous nerve [26]. The variations were associated with higher bifurcation of the brachial artery [26]. In another study, the absence of musculocutaneous nerve was associated with a medial cutaneous nerve of arm and medial cutaneous nerve of forearm arising as a common trunk but were separated in the middle of the arm [27]. Another study reported the absence of musculocutaneous nerve [28]. The same study reported the median nerve to be formed in the upper part of the arm, anterior to the brachial artery and innervating the biceps, coracobrachialis and brachialis muscles. Another Thai study observed small branches from the first and second intercostobrachial nerves to be present under the cover of anomalous duplicated axillary arch muscles [29]. Thus, it is not uncommon to find nerve anomalies with other associated variations.

An Indian study reported the bilateral absence of musculocutaneous nerve on both sides of a 43-year-old female cadaver [30]. The authors also found similar findings with respect to a direct branch from the lateral cord which innervated the coracobrachialis in the absence of musculocutaneous nerve [30]. According to earlier research studies, in case the musculocutaneous nerve is absent, the muscles of the arm are innervated by the median nerve [31]. Usually, the musculocutaneous nerve pierces the coracobrachialis mucle but a Korean study found that musculocutaneous nerve did not pierce the coracobrachialis muscle [32]. The same study observed that the musculocutaneous nerve was rudimentary in the right arm and all branches originated from the median nerve separately [32].

Japanese anatomists also reported in their study, the musculocutaneous nerve not to pierce the coracobrachialis rather the musculocutaneous , the lateral cord of the brachial plexus and the median nerve were contained in a common sheath of connective tissue [33].

Embryological Explanation for Nerve Anomalies Related to Brachial Plexus: The development of forelimb muscles in the human limb may be explained by the regional expression of five *Hox* D genes [34]. It is presumed that the development of the brachial plexus involves a single radicular cone of axons of spinal nerves and these nerves organize themselves to form dorsal and ventral divisions [35]. The nerve fibres of C5, 6 may take an abnormal pathway [36] Neurobiotaxis has been attributed to this abnormal pathway [11, 36]. It has been thought absence of MCN may be the remnant of the primitive nerve supply of the arm [37].

It was reported that the growth cones of the motor axons move to the base of the limb bud and mix in a specific pattern to form the brachial plexus and continue in the upper limb [38]. Many tropic substances such as brain-derived neurotropic growth factor, c-kit ligand, neutrin-1, neutrin-2, etc. attract appropriate growth cones or support the viability of the growth cones that seem to take the right course [39]. Altered signalling between the mesenchymal cells and the neuronal growth cones or circulatory factors at the time of fission of brachial plexus cords has been reported to be main cause for any variation in the nerve pattern [40]. Few researchers have thought that the absence of the MCN is based on the recapitulation theory which states that ontogeny repeats phylogeny [28].

Researchers have also opined that the presence of anomalies may be due to random factors influencing the mechanism of formation of the limb muscles and the peripheral nerves which occurs embryonic life [41].

Clinical Implications of Nerve Anomalies Related to Brachial Plexus: In the absence of symptoms, any nerve anomaly may not be detected clinically. Anomalies may be incidental findings during routine cadaveric dissections and autopsies. Often nerve compression if present in any living individual, may lead to pain.

Proper anatomical knowledge of the normal and abnormal presence of nerves of the brachial plexus is important for better understanding and correct interpretation of clinical neurophysiology [11]. Abnormal position of any nerve may result in inadvertent injury during any surgical procedure. There are reports of entrapment neuropathies due to anomalous nerves [42]

Knowledge of anomalous presence of branches from brachial plexus may also be important for surgical procedures of the axilla and the upper arm, such as nerve block, cannulation of the axillary vessels during cardiopulmonary bypass, axillary artery perfusion, while transposing and anastomosing the cephalic vein with axillary vein to treat cephalic arch stenosis internal fixation of humeral fracture, surgical resection of axillary tumors [43, 44].

CONCLUSION

We as anatomists feel that normal and abnormal brachial plexus anatomy may be important for surgeons in day-to-day clinical practice. Further research information may need to be disseminated supplementing the information conveyed in standard anatomy textbooks. The present review is a humble attempt to highlight the brachial plexus anomaly with regard to the Asian scenario.

REFERENCES

1. Moore, K.L., A.F. Dalley and A.M.R. Agur, 2010. Clinical Oriented Anatomy. Wolters Kluwer and Lippincott Williams and Wilkins, pp: 721-726.
2. Shetty, S.D., B. Satheesha Nayak, V. Madahv, C.S. Braganza and S.N. Somayaji, 2011. A Study on the Variations in the Formation of the Trunks of Brachial Plexus. Internatioanl Journal of Morphology, 29: 555-8.
3. Prakash, L.V. Prabhu, J. Kumar and G. Singh, 2006. Brachial plexus with two trunks and double axillary veins: Applied importance and clinical implications. Firat Tip Dergisi Turkey,11: 210-2.
4. Aggarwal, A., D. Sahni, H. Kaur, Y.K Batra and R.V. Sondekoppam, 2012. A rare anatomical variation of the brachial plexus: single cord anomaly. Anesth Analg, 114: 466-70.
5. Toshio, N., Shigenori, Tanaka and M. Shigeki, 1998. Two rare anomalies of the brachial plexus. J Anat., 1998 February, 192: 303-304.
6. Kerr, A, 1918. The brachial plexus of nerves in man the variations its formation and branches. American Journal of Anatomy., 23: 285-395.
7. Obara, M., 1958. On the brachila plexus of the Japanese fetus. Nippon Ikadaigaku Zasshi., 25: 94-123.
8. Song, W.C., H.S. Jung, H.J. Kim, C. Shin, B.Y. Lee and K.S. Koh, 2003. A variation of the musculocutaneous nerve absent. Yonsei Medical Journal, 44: 1110-3.
9. Williams, P.L., 1995. Gray's Anatomy, Elsevier Churchill Livingstone, pp: 1271.
10. Bhanu, P.S. and K.D. Sankar, 2012, Bilateral absence of musculocutaneous nerve with unusual branching pattern of lateral cord and median nerve of brachial plexus. Anat Cell Biol,45: 207-10.
11. Saeed, M. and A.A. Rufai, 2003. Median and musculocutaneous nerves: variant formation and distribution. Clin Anat, 16: 453-7.
12. Goyal, N., Harjeet and M. Gupta, 2005. Bilateral variant contributions in the formation of median nerve. Surg Radiol Anat., 27: 562-5.
13. Patil, S.T., M.M. Meshram, A.P. Kasote and N.Y. Kamdi, 2012. Formation of median nerve from single root on left side and communicating branch from median nerve to musculocutaneous nerve on right side. Morphologie, 96: 51-4.
14. Singhal, S., V.V. Rao and R. Ravindranath, 2007. Variations in brachial plexus and the relationship of median nerve with the axillary artery: a case report. J. Brachial Plex Peripher Nerve Inj., 3: 2-21.

15. Srijit, D. and S. Paul, 2005. Anomalous branching pattern of lateral cord of brachial plexus. International Journal of Morphology.,23:289-292.
16. Kumar, M.R.B., G. Siddaraju and K.P. Bhagath, 2009. Nerve loop around the axillary vessels by the roots of the median nerve a rare variation in a south Indian male cadaver: a case report. Cases Journal, 2: 179.
17. Matejcik, V., 2005. Variations of nerve roots of the brachial plexus. Bratisl Lek Listy, 106: 34-6.
18. Rao, B.S. and V. Leela, 2013. Variant Formation Of Median Nerve- a Review Of Literature. Int J Pharm Bio Sci., 4: 669 672.
19. Budhiraja, V., R. Rastogi, A.K. Asthana, P. Sinha, A. Krishna and V. Trivedi , 2001. Concurrent variations of median and musculocutaneous nerves and their clinical correlation--a cadaveric study. Italian Journal of Anatomy and Embryology., 116: 67-72.
20. Agarwal, S., A. Tuli and S. Raheja, 2011. Communication between median and musculocutaneous nerves in the forearm hooking around the origin of the median artery: a rare variation. Anat Sci Int., 86: 175-7.
21. Datta, I., A.K. Ghoshal and A. Ray, 2011. Complete absence of lateral root of median nerve and communication of musculocutaneous nerve with median nerve--a case report. JIMA., 109: 341-2.
22. Jamuna, M., 2010. A rare variation in the mode of termination of posterior cord of brachial plexus. IJAV., 3: 95-96.
23. Bhat, K.M.R. and V. Grijavallabhan, 2008. Variation in the branching pattern of posterior cord of brachial plexus. Neuroanatomy,7: 10-11.
24. Gupta, M., N. Goyal and Harjeet, 2004. Bilaterally anomalous formation and distribution of posterior cord of brachial plexus. Nepal Med Coll J., 6: 133-5.
25. Arvind, K.P., C.S. Ramesh Babu, R. Archana, R. Anita, C. Jyoti, K.V. Rakesh, K. Navneetand A.K. Srivastava, 2012. Absence of musculocutaneous nerve: embryological basis. Asian Journal of Medical Sciences, 3: 21-4.
26. Tomar, V. and S. Wadhwa, 2012. Asymmetric bilateral variations in the musculocutaneous and median nerves with high branching of brachial artery. Acta Medica ((Hradec Kralove) 55: 189-92.
27. Banu, S., K. Devishankar and P.J. Susan, 2010. Formation of median nerve without the medial root of medial cord and associated variations of the brachial plexus. IJAV., 3: 27-9.
28. Parchand, M.P. and S.T. Patil, 2013. Absence of musculocutaneous nerve with variations in course and distribution of the median nerve. Anat Sci Int, 88: 58-60.
29. Lamsaard, S., N. Uabundit, K. Khamanarong, K. Sripanidkulchai, K. Chaiciwamongkol, M. Namking, S. Ratanasuwan, P. Boonruangsri and W. Hipkaeo, 2012. Anat Cell Biol, 45: 288-90.
30. Bhanu, P.S. and K.D. Sankar, 2012. Bilateral absence of musculocutaneous nerve with unusual branching pattern of lateral cord and median nerve of brachial plexus. Anat Cell Biol., 45: 207-10.
31. Le Minor, J.M., 1990. A rare variation of the median and musculocutaneous nerves in man. Arch Anat Histol Embryol., 73: 33-42.
32. Jeon, C.H.,K.H. Kee, J.Y. Kim and SP. Yoon, 2013. Bilateral variations of musculocutaneous nerves with rare pattern in a Korean female cadaver. Anat Sci Int., 88: 167-70.
33. Nakatani, T., S. Mizukami and S. Tanaka, 1997. Three cases of the musculocutaneous nerve not perforating the coracobrachialis muscle. Kaibogaku Zasshi., 72: 191-4.
34. Sadler, T.W., 2012. Medical Embryology. 12th edn, Wolters Kluwer/ Lippincott Williams and Wilkins: pp: 155.
35. Iwata, H., 1960. Studies on the development of the brachial plexus in Japanese embryo. Rep Dept Anat Mie Prefect Univ Sch Med.,13: 129-144.
36. Prasada Rao, P.V. and S.C Chaudhary, 2000. Communication of the musculocutaneous nerve with the median nerve. East Afr Med J.,77:498-503.
37. Guerri-Guttenberg, R.A.andM. Ingolotti, 2009. Classifying musculocutaneous nerve variations. Clin Anat., 22: 671-83.
38. Gary, C., S.B. Schoenwolf, P.R. Bleyl, Brauer and H. Philippa, 2014. Francis-West, Larsen's Embryology 4th edition, Elsevier Publications, Accessed from website: https://www.inkling.com/read/larsens-human-embryology-schoenwolf-bleyl-brauer-francis-west-4th/chapter-18/innervation-of-developing-limb on 23.2.
39. Larson, W.J, 2001. Development of peripheral nervous system.3rd ed. Pennsylvania: Churchill Livingstone, pp: 115-156.
40. Streeter, G.L, 1912. From The development of nervous system: III. Peripheral nervous system. In *Handbook of human embryology Volume 2*. Edited by: Keibel F, Mall FP. Philadelphia: JB Lippincott Co; pp: 1-156.

41. Roberts, W.H., 1992. Anomalous course of the median nerve medial to the trochlea and anterior to the medial epicondyle of the humerus. Ann Anat., 174: 309-11.
42. Retzl, G., S. Kapral, M. Greher and W. Mauritz, 2001. Ultrasonographic findingsof the axillary part of the brachial plexus. Anesth Analg., 92: 1271-5.
43. Zattera, G., P. Totaro, A.M. D'Armini and M. Vigano, 2009. Deltoido-pectoralis approach to axillary vessels for full-flow cardiopulmonary bypass. Eur J. Cardiothorac Surg, 35: 913-4.
44. Kian, K., S.W. Unger, R. Mishler, D. Schon, O. Lenz and A. Asif, 2008. Role of surgical intervention for cephalic arch stenosis in the "fistula first" era. Semin Dial., 21: 93-6.