DOI: 10.7860/JCDR/2019/39912.12533

Original Article

Anatomy Section

Variations in the Branching Pattern of the Radial Nerve Branches to Triceps Brachii Muscle

MYTHRAEYEE PRASAD[1], BINA ISAAC[2]

ABSTRACT

Introduction: The axillary nerve arises from the posterior cord of the brachial plexus and supplies the deltoid and teres minor muscles. Axillary nerve injuries lead to abduction and external rotation weakness. In such cases, branches to the heads of triceps brachii muscle have been transferred to the axillary nerve to establish reinnervation of the deltoid muscle. In addition, the triceps nerve branches can be nerve recipients to reinstitute elbow extension.

Aim: To study the different branching patterns of the radial nerve branches to triceps brachii muscle.

Materials and Methods: Twenty eight upper limbs from adult cadavers were dissected to record variations in the branching pattern of the radial nerve branches to triceps brachii.

Results: The branching patterns seen were types A 1 (3.6%), B1 (1st pattern) 1 (3.6%), B2 (2nd pattern) 1 (3.6%), and C3 22 (78.6%). Two new patterns observed were: type B2 (6th pattern) 1 (3.6%) and type D (2nd pattern) 2 (7.1%). The long head had single innervation in 89.3% cases and the lateral and medial heads had dual innervation in 10.7% and 7.1% cases respectively.

Conclusion: The knowledge of the different branching patterns that are present will help surgeons to identify the most suitable radial nerve branch to triceps brachii that can be used for nerve transfer to restore the motor function of the deltoid muscle or to reanimate the triceps brachii muscle.

Keywords: Axillary nerve, Nerve transfer, Pattern of branching

INTRODUCTION

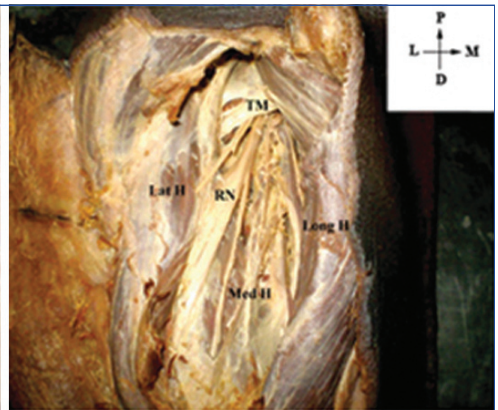
The axillary nerve or brachial plexus can sustain injuries from trauma, traction injuries, shoulder dislocation or due to complications that occur during shoulder surgery [1]. The deficits that result are predominantly elbow flexion, shoulder abduction, and external rotation. Inability to abduct the shoulder can be especially very debilitating for the patient [2-4]. Sometimes, there is more than one branch of the radial nerve that supplies one of the heads of the triceps brachii, and hence these branches can be transferred to the injured axillary nerve [5].

There have been studies that have shown that transfer of the nerve to the long head of the triceps to the axillary nerve have helped to restore the function of the deltoid muscle [6-10]. Other studies where the nerve to the lateral head of triceps [11-13] and the nerve to medial head [14] have been transferred to the axillary nerve to restore shoulder function have been reported.

The branching pattern of the radial nerve to triceps brachii muscle is complex. Uerpairojkit C et al., have described four patterns of branching, based on the number of branches given off from the radial nerve to the triceps brachii [15]. The present study was conducted to determine whether there are any variations in the branching pattern of the radial nerve branches to triceps brachii muscle, that have not previously been reported in the literature. Knowledge of the variations in the branching patterns will help to identify the branch most suitable for reinnervation of the deltoid muscle.

MATERIALS AND METHODS

The present observational study was conducted for the duration of one year, i.e., March 2015-Feb 2016. Twenty eight upper extremities belonging to 14 cadavers (10 males and 4 females) used for student dissection were subjected to this study. The number of female cadavers used was less, as there were only few female cadavers available at the time of the study. The mean age of the cadavers was 73±17 years (range: 44-90 years). The study was undertaken after obtaining the approval of the Institutional Review Board. The arms used showed no evidence of any gross malformation or deformity. With cadavers in the prone position, a vertical incision was made from the tip of the acromion process to the olecranon process. The three heads of the triceps brachii muscle were exposed and separated (Long H-Long Head; LatH-Lateral Head; Med H-Medial Head; TM-Teres Major). The Radial Nerve (RN) was carefully dissected and the branching pattern of the nerve branches to each head was observed [Table/Fig-1,2].

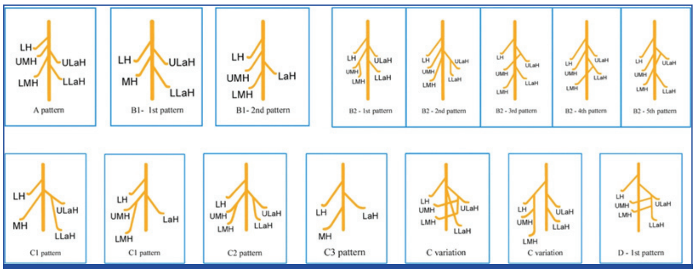


[Table/Fig-1]: The long and lateral heads of triceps brachii exposed.
[Table/Fig-2]: Dissection showing the radial nerve branches to the three heads.
(Images from left to right)

The patterns of branching of radial nerve branches to the triceps brachii seen in the present study were classified according to the study done by Uerpairojkit C et al., [Table/Fig-3] [15].

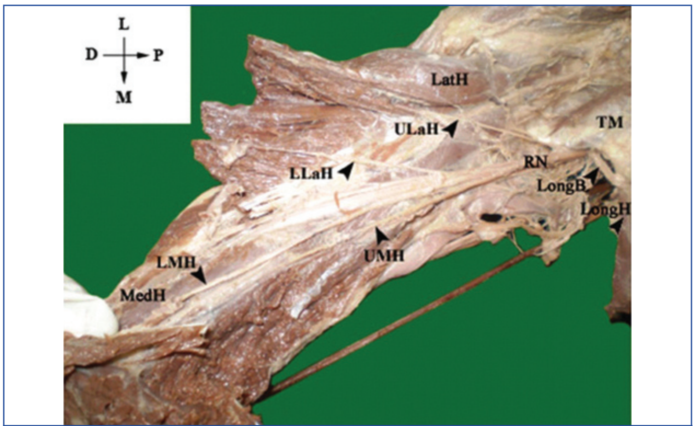
RESULTS

Types A, B1 (1st pattern), B2 (2nd pattern), and C3 patterns were seen. Two new patterns observed were type B2 (6th pattern) and type D (2nd pattern).



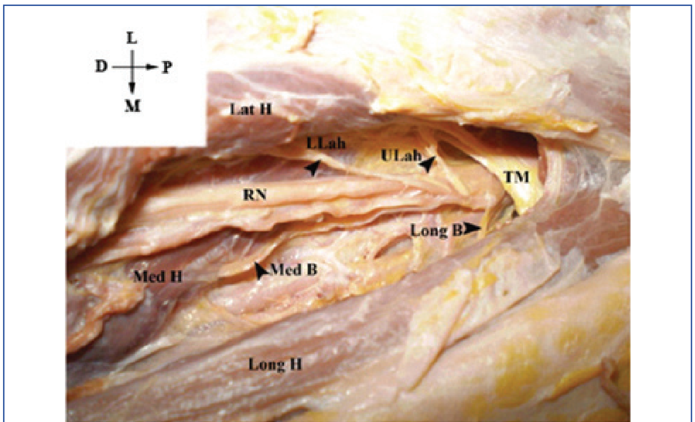
[Table/Fig-3]: Schematic diagram showing the different branching patterns.

Type A pattern: There were five branches. They were the branch to the long head (Long B), the upper branch of the lateral head (ULaH), the lower branch of the lateral head (LLaH) the upper branch of the medial head (UMH), and the lower branch of the medial head (LMH). This type was seen in one case (3.6%) [Table/Fig-4].



[Table/Fig-4]: Type A pattern.

Type B1 (1st pattern): There were four branches and they were the branch to the long head (Long B), the upper branch of the lateral head (ULaH), the lower branch of the lateral head (LLaH) and the branch to the medial head (Med B). This type was seen in one case (3.6%) [Table/Fig-5].

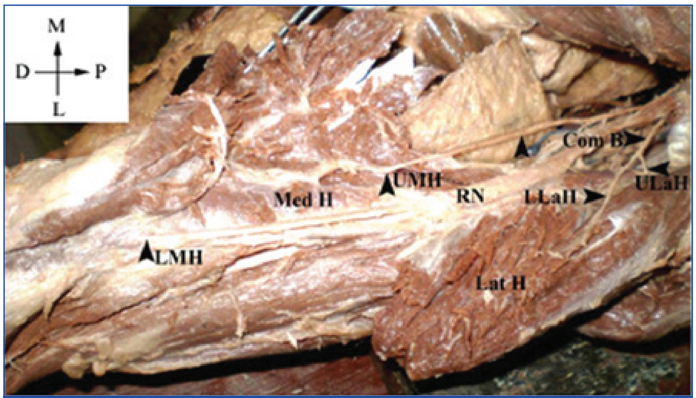


[Table/Fig-5]: Type B1 (1st pattern).

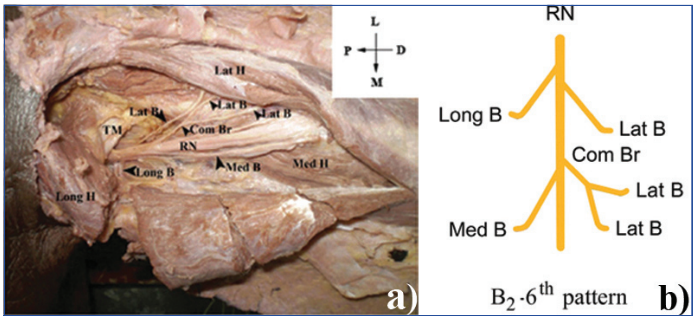
Type B2 (2nd pattern): There were four branches and they were a branch to long head (Long B), a common branch to the lateral head which further divided into two (ULaH and LLaH), a branch to upper part of medial head (UMH) and a branch to lower part of medial head (LMH). This type was seen in one case (3.6%) [Table/Fig-6].

Type B2 (6th pattern): There were four branches and they were a branch to long head (Long B), a branch to lateral head (Lat B), a common branch to the lateral head (Com Br) which further divided into two, and a branch to medial head (Med B). This type was seen in one case (3.6%) [Table/Fig-7a,b]. This branching pattern has not been reported earlier.

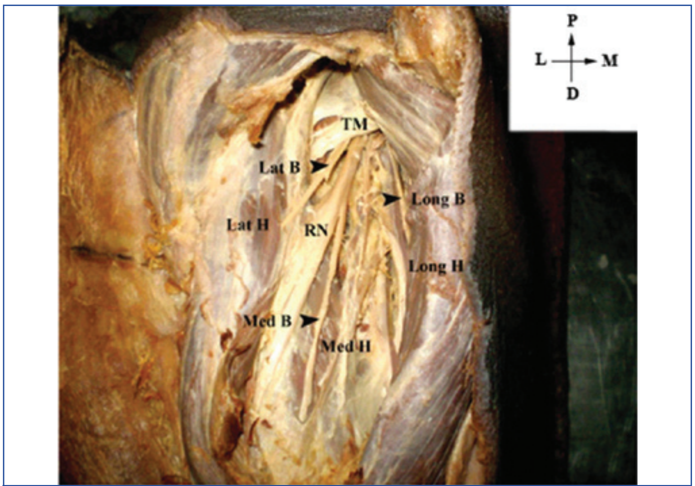
Type C3 pattern: There were three branches; one to each head with no common branch. This type was seen in 22 cases (78.6%) [Table/Fig-8].



[Table/Fig-6]: Type B2 (2nd pattern).
The long head of triceps had one branch which is not seen in this view of the picture.

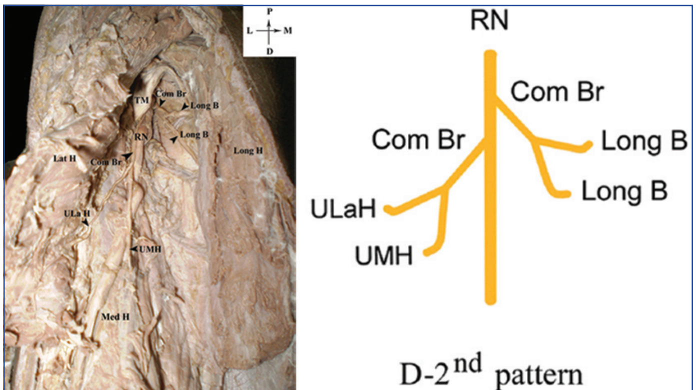


[Table/Fig-7a]: Type B2 (6th pattern).
[Table/Fig-7b]: Schematic diagram showing Type B2 (6th pattern).



[Table/Fig-8]: Type C3 pattern.

Type D (2nd pattern): There were two common branches; one common branch (Com Br) dividing into two to supply the long head (Long B) and another common branch dividing into two to supply the Upper Part of Lateral Head (ULaH) and Upper Part of Medial Head (UMH). This type was seen in two cases (7.1%) [Table/Fig-9a,b]. This branching pattern has not been reported earlier. The results are summarised in [Table/Fig-10].



[Table/Fig-9a]: Type D (2nd pattern).
[Table/Fig-9b]: Schematic diagram showing Type D (2nd pattern).

Types	No. of branches	Variation
A	5	Branch to the long head (Long B) Upper branch of the lateral head (ULaH) Lower branch of the lateral head (LLaH) Upper branch of the medial head (UMH) Lower branch of the medial head (LMH)
B1 (Ist pattern)	4	Branch to the long head (Long B) Upper branch of the lateral head (ULaH) Lower branch of the lateral head (LLaH) Branch to the medial head (Med B).
B2 (2nd pattern)	4	Branch to long head (Long B) Common branch to the lateral head which further divided into two (ULaH and LLaH) Branch to upper part of medial head (UMH) Branch to lower part of medial head (LMH)
B2 (6th pattern)	4	Branch to long head (Long B) Branch to lateral head (Lat B) Common branch to the lateral head (Com Br) which further divided into two Branch to medial head (Med B)
C3 pattern	3	One branch to each head
D (2nd pattern)	2	One common branch (Com Br) dividing into two to supply the long head (Long B) One common branch dividing into two to supply the upper part of lateral head (ULaH) and upper part of medial head (UMH)

[Table/Fig-10]: The different branching types.

Types B1 (2nd pattern), B2 (1st, 3rd, 4th and 5th patterns), C1, C2, C variations and D (1st pattern) were not observed in the present study.

DISCUSSION

Shoulder stabilisation and reconstruction of abduction-external rotation are very important in patients with brachial plexus injuries, as the more distal functions will be affected by the condition of the shoulder [16,17]. It is important for the patient to achieve elbow extension in order to stabilise the elbow without using the opposite hand and is imperative for overhead activities and to achieve a more useful grasp [18].

Nerve transfer procedures have gained importance in the treatment of brachial plexus and axillary nerve injuries where, a nerve branch from a muscle that has more than one branch innervating it is taken and connected to an injured nerve that supplies a muscle whose function has been jeopardised as a result of the injury. The remaining innervated muscles should compensate the function of the sacrificed nerve [19].

There are not many studies available describing in detail the pattern of innervation of the triceps heads and the number of branches for each head which are suitable for nerve transfer. Theoretically, each of the triceps branches can be used for transfer, however, it remains controversial which of the branches should be used. The comparison between the study by Al-Meshal O et al., [5] and the present study showing the variations in the number of branches to each head of triceps brachii is shown in [Table/Fig-11].

		Al-Meshal O et al., [5] (n=25)	Present study (n=28)
	No. of branches	No. of specimens	No. of specimens
Long head	1	23 (92%)	25 (89.3%)
	2	2 (8%)	3 (10.7%)
Lateral head	1	-	25 (89.3%)
	2	11 (44%)	3 (10.7%)
	3	7 (28%)	-
	4	5 (20%)	-
	5	2 (8%)	-
Medial head	1	22 (88%)	26 (92.9%)
	2	3 (12%)	2 (7.1%)

[Table/Fig-11]: Variations in the number of branches of radial nerve to each head of triceps brachii.

In axillary nerve injury, the branch to the long head of triceps brachii has been used to surgically reconstruct the axillary nerve [12,13,20-24]. The branch to the long head of triceps muscle has the largest diameter and highest number of axons when compared with the other branches and hence, it can be used to reinnervate the anterior axillary nerve branch, as well as the branch to the teres minor muscle simultaneously [8,12]. Since, teres minor muscle is essential for external rotation, it is important to include this muscle in the treatment of reconstruction [25]. Moreover, Witoonchart K et al., found that the nerve to long head was close to the anterior branch of axillary nerve and hence, it became an appropriate donor to the axillary nerve without using a nerve graft [8]. A posterior approach was recommended for this transfer as both the donor and recipient nerves were visualised well using this approach [6]. It has been shown that among the three heads of triceps, the long head played the least important role whereas the medial and the lateral heads showed a considerable amount of activity during elbow extension. When the nerve to the long head of the triceps had been transferred to the axillary nerve, 45.5% of the original motor neuron pool could be reinnervated [8].

The branch to the medial head of triceps muscle can be considered as a suitable donor nerve, because there are two or three branches to the medial head, one proximal and two other branches more distal with enough length for transfer and end to-end coaptation without tension [12-14]. In high brachial plexus injuries, where the deltoid is paralysed but the axillary nerve is anatomically preserved, it is better to perform reinnervation using the triceps long and/or the upper medial head motor branch dissected via the axilla [26]. However, in isolated axillary nerve lesions, the axillary nerve may be damaged as far distally as its entrance into the deltoid. The branch to the medial head and anconeus is a long one and can be used for lesions of the terminal divisions of the axillary nerve [13].

Bertelli JA et al., in their study found the upper branch to the lateral head arose from the radial nerve, whereas the lower branch to the lateral head was a branch of the lower medial head motor branch [13]. The branch to the upper part of the lateral head was used to reconstruct the axillary nerve through a posterior approach. The function of the lateral head was not compromised as it had a dual innervation. While considering the branch to the lateral head as a possible donor, Witoonchart K et al., found it had a similar diameter to the long head motor branch [8]. In another study, by Bertelli JA et al., patients with axillary nerve injuries who underwent surgical repair using a motor branch of the triceps brachii, had complete abduction of the shoulder restored [12]. In 10 patients with avulsion injuries of the brachial plexus, among the multiple nerve transfers performed on them was the transfer of the branch to the lateral head of triceps to the axillary nerve [11].

Although, textbooks of Anatomy state that the triceps brachii muscle is supplied by the radial nerve, there are studies that show that the long head of triceps does have an additional supply from the axillary nerve [27-29]. In an individual with dual innervation, the axillary branch to the triceps could be rerouted to the deltoid while the radial nerve branch to the triceps could be left intact to maintain triceps function.

Uerpairojkit C et al., did a detailed study on the branching patterns of the radial nerve branches to the heads of triceps brachii muscle. They described four patterns of branching namely A, B, C and D in 79 cadaveric arms belonging to the Thai population. The distribution of the patterns in their study were-Type A in 21 arms, type B1 (1st pattern)-7 arms, type

B1 (2nd pattern)-10 arms, type B2 (B2-1st pattern in 9 arms, B2-2nd pattern in 2 arms, B2-3rd pattern in 3 arms, B2-4th pattern in 5 arms and B2-5th pattern in 2 arms), type C1-7 arms, type C2-5 arms, type C3-2 arms, type C variations-3 arms and type D (1st pattern)-3 arms [Table/Fig-12] [15].

Types of patterns	Uerpairojkit C et al., [15]	Present study
Population	Thai (n=79)	Indian (n=28)
Type A	21 (26.5%)	1 (3.5%)
Type B1 (1st pattern)	7 (8.8%)	1 (3.5%)
Type B1 (2nd pattern)	10 (12.6%)	-
Type B2 (1st pattern)	9 (11.3%)	-
Type B2 (2nd pattern)	2 (2.5%)	1 (3.5%)
Type B2 (3rd pattern)	3 (3.7%)	-
Type B2 (4th pattern)	5 (6.3%)	-
Type B2 (5th pattern)	2 (2.5%)	-
Type B2 (6th Pattern)	-	1 (3.5%)
Type C1	7 (8.8%)	-
Type C2	5 (6.3%)	-
Type C3	2 (2.5%)	22 (78.5%)
Type C variations	3 (3.7%)	-
Type D (1st pattern)	3 (3.7%)	-
Type D (2nd Pattern)	-	2 (7.1%)

[Table/Fig-12]: Patterns of radial nerve branching to triceps brachii seen in different studies.

In the present study of 28 arms belonging to the Indian population, the patterns seen were type A in 1 arm, type B1 (1st pattern)-1, type B2 (2nd pattern)-1, and type C3 in 22 arms. Two new patterns observed were type B2 (6th pattern) in 1 arm and type D (2nd pattern) in 2 arms. The finding of two new patterns suggests that the branching of the radial nerve branches to the triceps brachii is highly variable [Table/Fig-12].

The most common pattern found in the study by Uerpairojkit C et al., were types A (26.5%) and B2 (26.5%), whereas it was type C (78.5%) in the present study. Hence it is important to know the prevalent pattern in a particular population while undertaking neurotisation procedures and reconstructive surgeries [15].

In the present study, the long head is supplied by a single branch from the radial nerve in 89.3% of cases. This is in accordance with the findings of Al-Meshal O et al., who in their study of 25 cadaveric arms found the long head had a single branch innervating it in 92% cases [5]. It has been known that the long head plays a minimal role in elbow extension. The lateral head had radial nerve branches supplying its upper and lower parts in 10.7% of cases in the present study. In a similar study by Al-Meshal O et al., there was more than one branch supplying the lateral head in all the specimens. In 44% of specimens, there were two branches and the proximal branch to the lateral head was the ideal one. This was because the most proximal branch arose from the radial nerve about 4 cm from the humeral head, and hence could easily reach the anterior branch of the axillary nerve [5]. The medial head had branches supplying its upper and lower parts in 7.1% of cases in the present study, which is in accordance with the findings of Al-Meshal O et al., where there were two branches supplying the medial head in 12% cases [5]. The advantages of using the nerve to the medial head is that it is easy to dissect the nerve in the intermuscular interval between the long and lateral heads of the triceps and its harvest does not require intramuscular dissection [5].

LIMITATION

The limitation of the present study was the small sample size.

CONCLUSION

This study provides information that is beneficial when nerve transfer procedures are undertaken. The radial nerve branches to triceps brachii can be used either as nerve donors to the axillary nerve to reinnervate shoulder abduction or as nerve recipients to reinstitute elbow extension. The study shows that variations in the branching pattern of the radial nerve branches to triceps brachii exist and an understanding of the variations that can occur is extremely useful for the surgeons as the variant will make them more careful in dealing with nerve transfer procedures, reconstructive surgery, nerve entrapment surgery, compressive neuropathies and in pain management therapy.

ACKNOWLEDGEMENTS

The authors thank the fluid research committee, Christian Medical College, for funding this project.

REFERENCES

[1] Lee SK, Wolfe SW. Nerve transfers for the upper extremity: New horizons in nerve reconstruction. J Am Acad Orthop Surg. 2012;20(8):506-17.
[2] Kotwal PP, Mittal R, Malhorta R. Trapezius transfer for deltoid paralysis. J Bone Joint Surg Br. 1998;80(1):114-16.
[3] Ruhmann O, Gosse F, Wirth CJ, Schmolke S. Reconstructive operations for the paralyzed shoulder in brachial plexus palsy: Concept of treatment. Injury. 1999;30(9):609-18.
[4] Ruhmann O, Schmolke S, Bohnsack M, Carls J, Wirth CJ. Trapezius transfer in brachial plexus palsy: Correlation of the outcome with muscle power and operative technique. J Bone Joint Surg Br. 2005;87(2):184-90.
[5] Al-Meshal O, Gilbert A. Triceps innervation pattern: Implications for triceps nerve to deltoid nerve transfer. Bio Med Research International. 2013;2013:132954.
[6] Leechavengvongs S, Witoonchart K, Uerpairojkit C, Thuvasethakul P. Nerve transfer to deltoid muscle using the nerve to the long head of the triceps, II: A report of 7 cases. J Hand Surg Am. 2003;28:633-38.
[7] Leechavengvongs S, Witoonchart K, Uerpairojkit C, Thuvasethakul P, Malungpaishrope K. Combined nerve transfers for C5 and C6 brachial plexus avulsion injury. J Hand Surg Am. 2006;31:183-89.
[8] Witoonchart K, Leechavengvongs S, Uerpairojkit C, Thuvasethakul P, Wongnopsuwan V. Nerve transfer to deltoid muscle using the nerve to the long head of the triceps, part I: An anatomic feasibility study. J Hand Surg Am. 2003;28:628-32.
[9] Flores LP. Brachial plexus surgery: The role of the surgical technique for improvement of the functional outcome. Arq Neuropsiquiatr. 2011;69:660-65.
[10] Lu J, Xu J, Xu W, Xu L, Fang Y, Chen L, et al. Combined nerve transfers for repair of the upper brachial plexus injuries through a posterior approach. Microsurgery. 2012;32:111-17.
[11] Bertelli JA, Ghizoni MF. Reconstruction of C5 and C6 brachial plexus avulsion injury by multiple nerve transfers: Spinal accessory to suprascapular, ulnar fascicles to biceps branch, and triceps long or lateral head branch to the axillary nerve. J Hand Surg Am. 2004;29:131-39.
[12] Bertelli JA, Kechele PR, Santos MA, Duarte H, Ghizoni MF. Axillary nerve repair by triceps motor branch transfer through an axillary access: Anatomical basis and clinical results. J Neurosurg. 2007;107:370-77.
[13] Bertelli JA, Santos MA, Kechele PR, Ghizoni MF, Duarte H. Triceps motor nerve branches as a donor or receiver in nerve transfers. Neurosurgery. 2007;61:333-39.
[14] Colbert SH, Mackinnon S. Posterior approach for double nerve transfer for restoration of shoulder function in upper brachial plexus palsy. Hand (New York). 2006;1:71-77.
[15] Uerpairojkit C, Ketwongwiriya S, Leechavengvongs S, Malungpaishrope K, Witoonchart K, Mekrungcharas N, et al. Surgical anatomy of the radial nerve branches to triceps muscle. Clin Anat. 2013;26(3):386-91.
[16] Terzis JK, Barmpitsioti A. Secondary shoulder reconstruction in patients with brachial plexus injuries. J Plast Reconstr Aesthet Surg. 2011;64(7):843-53.
[17] Kostas-Agnantis I, Korompilias A, Vekris M, Lykissas M, Gkiatas I, Mitsionis G, et al. Shoulder abduction and external rotation restoration with nerve transfer. Injury. 2013;44:299-304.
[18] Madsen M, Marx RG, Millett PJ, Rodeo SA, Sperling JW, Warren RF. Surgical anatomy of the triceps brachii tendon. Am J Sports Med. 2006;34:1839-43.
[19] Bertelli JA, Taleb M, Mira JC, Ghizoni MF. Functional recovery improvement is related to aberrant reinnervation trimming: A comparative study using fresh or predegenerated nerve grafts. Acta Neuropathol (Berl). 2006;111:601-09.
[20] Chuang DC-C. Nerve transfers in adult brachial plexus injuries: My methods. Hand Clinics. 2005;21(1):71-82.
[21] Colbert SH, Mackinnon SE. Nerve transfers for brachial plexus reconstruction. Hand Clinics. 2008;24(4):341-61.
[22] Tung TH, Mackinnon SE. Nerve transfers: Indications, techniques, and outcomes. Journal of Hand Surgery. 2010;35(2):332-41.
[23] Teissier P, Lazerges C, Marès O, Bosch C, Chammas M. Nerve transfer in isolated deltoid palsy: Branch of the long head of the triceps to the axillary nerve. Chir Main. 2012;31(5):239-43.

[24] Lee JY, Kircher MF, Spinner RJ, Bishop AT, Shin AY. Factors affecting outcome of triceps motor branch transfer for isolated axillary nerve injury. J Hand Surg Am. 2012;37(11):2350-56.
[25] Jácome DA, Uchôa de Alencar FH, Vieira de Lemos MV, Kobig RN, Rocha JFR. Axillary nerve neurotization by a triceps motor branch: comparison between axillary and posterior arm approaches. Rev Bras Ortop. 2018;53(1):15-21.
[26] Bertelli JA, Ghizoni MF. Nerve transfer from triceps medial head and anconeus to deltoid for axillary nerve palsy. J Hand Surg Am. 2014;39(5):940-947.
[27] DeSèze MP, Rezzouk J, de Sèze M, Uzel M, Lavignolle B, Midy D, et al. Does the motor branch of the long head of the triceps brachii arise from the radial nerve? An anatomic and electromyographic study. Surg Radiol Anat. 2004;26:459-61.
[28] Erhardt AJ, Futterman B. Variations in the innervation of the long head of the triceps brachii: A Cadaveric Investigation. Clin Orthop Relat Res. 2017;475:247-50.
[29] Nanjundaiah K, Jayadevaiah SM, Chowdapurkar S. Long head of triceps supplied by axillary nerve. Int J Anat Var. 2012;5:35-37.

PARTICULARS OF CONTRIBUTORS:
1. Assistant Professor, Department of Anatomy, Christian Medical College, Vellore, Tamil Nadu, India.
2. Professor, Department of Anatomy, Christian Medical College, Vellore, Tamil Nadu, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Bina Isaac,
Professor, Department of Anatomy, Christian Medical College, Bagayam, Vellore-632002, Tamil Nadu, India.
E-mail: isaac@cmcvellore.ac.in

FINANCIAL OR OTHER COMPETING INTERESTS: As declared above.

Date of Submission: Oct 11, 2018
Date of Peer Review: Oct 29, 2018
Date of Acceptance: Nov 26, 2018
Date of Publishing: Feb 01, 2019