Ulnar Nerve Innervation of the Triceps Muscle: Real or Apparent? An Anatomic Study

Aran Pascual-Font PhD, Teresa Vazquez PhD,
Fernando Marco PhD, Jose R. Sañudo PhD,
Marc Rodriguez-Niedenführ PhD

Received: 6 August 2012 / Accepted: 14 December 2012 / Published online: 3 January 2013
© The Association of Bone and Joint Surgeons® 2012

Abstract

Background Since the 18th century, the existence of ulnar nerve innervation of the medial head of the triceps brachii muscle has been controversial. The evidence for or against such innervation has been based on macroscopic dissection, an unsuitable method for studying intraneural topography or intramuscular branching. The study of smaller specimens (embryos or fetuses) by means of serial histologic sections may resolve the controversy.

Questions/Purposes Using fetal specimens and histology we determined the contributions of the ulnar and radial nerves to innervation of the triceps brachii muscle.

Methods We histologically examined 15 embryonic and fetal arms. Radial nerve branches obtained from six adult arms were analyzed immunohistochemically to determine motor fiber content.

Results The medial head of the triceps brachii muscle was always innervated by the radial nerve (ulnar collateral branch). The branches seeming to leave the ulnar nerve at elbow level were the continuation of the radial nerve that had joined the ulnar nerve sheath via a connection in the axillary region. Immunohistochemistry revealed motor and nonmotor fibers in this radial nerve branch.

Conclusions A connection between the radial and ulnar nerves sometimes may exist, resulting in an apparent ulnar nerve origin of muscular branches to the medial head of the triceps, even though in all our specimens the fibers could be traced back to the radial nerve.

Clinical Relevance Before performing or suggesting new muscle and nerve transpositions using this apparent ulnar innervation, the real origin should be confirmed to avoid failure.

The institution of one or more of the authors (TV, FM, JRS and MRN) has received research funding through postgraduate training courses from the UCM920547 Group.

All ICMJE Conflict of Interest Forms for authors and *Clinical Orthopaedics and Related Research* editors and board members are on file with the publication and can be viewed on request.

Each author certifies that his or her institution approved or waived approval for the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

This work was performed at the Department of Human Anatomy and Embryology I, School of Medicine, Complutense University of Madrid, Madrid, Spain.

A. Pascual-Font, T. Vazquez, J. R. Sañudo,

M. Rodriguez-Niedenführ (✉)

Department of Human Anatomy and Embryology I, School of Medicine, Complutense University of Madrid, Ciudad Universitaria s/n, 28040 Madrid, Spain
e-mail: mrniedenfuhr@pdi.ucm.es

F. Marco

Shoulder and Elbow Unit, Department of Orthopedics, Hospital Clínico San Carlos, Complutense University of Madrid, Madrid, Spain

Introduction

The normal and variant anatomy of nerves and muscle innervation has received much attention since the 18th century, not only for anatomic interest but also for physiologic and clinical importance. Two recent studies [3, 19] described ulnar rather than radial nerve innervation of the medial head of the triceps brachii. An extensive literature review showed that this pattern of innervation has been described by numerous authors since at least the mid-18th century [2, 4–6, 8, 11, 13, 15, 25, 27, 32, 33].

Classic anatomists highlighted the fact that a branch of the radial nerve, leaving it before it entered the spiral

groove, joined the ulnar nerve and innervated the medial head of the triceps brachii muscle [10, 14–17, 24]. Some authors reported this branch ran along the ulnar nerve without actually joining it [7, 16, 24], but in some rare cases it joined the ulnar nerve, putatively forming a real connection although the extent of intermingling of fibers of such a connection has not been confirmed [25, 29, 33]. Even in cases where radial and ulnar nerves were joined, the apparent ulnar nerve fibers that reached the triceps brachii muscle were branches of the radial nerve, and therefore no fibers from the ulnar nerve reached the triceps brachii muscle [7, 17, 24, 28]. These observations contradict a publication [3] wherein ulnar innervation of the triceps brachii muscle was described in 61% of the cases.

There is additional controversy regarding the nature (motor or nonmotor) of the fibers contained in the branches reaching the medial head of the triceps brachii muscle. Although the ulnar collateral branch of the radial nerve enters the medial head of the triceps brachii muscle, it was considered a sensory branch [17] and most of the motor innervation of the medial head of the triceps brachii muscle was considered to be provided by the branch emerging from the radial nerve, close to the spiral groove [17, 20, 21, 23]. An immunohistochemical characterization of fiber-type content of these branches has not been reported so far.

If these nerve supply branches or the medial head of the triceps brachii muscle are intended to be used as a source for reinnervation of denervated muscles, as has been proposed [3], the above indicated controversies need to be addressed. All evidence so far provided to support the existence of ulnar nerve innervation of the medial head of the triceps brachii muscle was based on macroscopic dissection, which may disturb the normal anatomy of small microscopic branches and is inadequate to examine the intraneural morphologic features and intramuscular branching patterns. Appropriately stained serial histologic sections of smaller specimens such as human embryos and fetuses may provide a more relevant technique to address the questions.

In light of these divergent views, we determined (1) whether the medial head of the triceps brachii was innervated only by the radial nerve or contained some ulnar innervation and (2) the motor and nonmotor fiber content of the ulnar collateral branch of the radial nerve.

Materials and Methods

We acquired 15 human embryonic and fetal upper limbs (Table 1). The embryos used were staged according to O’Rahilly and Müller [20], a staging method based on morphologic features rather than only by size. The fetuses were staged according to Patten [22], whose staging

Table 1. Size and age of the embryos and fetuses analyzed

Specimen*	Crown-rump length (mm)	Age of gestation [20, 22]
Embryos		
1 (R and L)	22	52 days
2 (R and L)	23	52 days
3 (R and L)	25	54 days
Fetuses		
4 (L)	32	9 weeks
5 (R and L)	34	9 weeks
6 (R and L)	37	9 weeks
7 (R and L)	44	9 weeks
8 (R and L)	70	11 weeks

* The type of specimen (embryo/fetus) and arms that were analyzed (right and/or left).

method predicts gestation age depending on a range of sizes. The selected embryonic and fetal stages already had acquired adult-like morphologic features; only the size of the structures increased but no additional developmental changes occurred in the upper limb region. The embryos and fetuses were obtained with parental consent according to current law.

The embryonic and fetal specimens were embedded in paraffin to be able to obtain serial sections of 7 to 10 μ m in thickness. The sections were processed without previous dissection, and therefore the anatomic details remained undisturbed. Sections were stained with standard histologic techniques (Bielschowsky, Masson’s trichrome, or Azan). Three of us (APF, TV, MRN) independently examined all sections to track all neural branches; when comparing the individual diagrams drawn by each researcher, no differences could be observed and all branches were identified by all researchers. Initially, we located the sections where the brachial plexus was visible proximal to its terminal branching. From there, consecutive distal sections were serially photographed and examined to identify the radial and ulnar nerves proximally and all their branches distally if any. Tracking of the nerves in a proximal to distal sequence is a reliable method to identify all branches because one can follow the branching and the course as previously reported to track arteries [26]. The thickness of the sections (range, 7–10 μ m) ensures that no branch has been left unidentified as the diameter of any branch is greater than this thickness and even the smallest branches can be observed in several sections. The last section analyzed always corresponded to a level distal to the elbow. The number of sections containing the structures of interest that were analyzed was 120 in the smallest embryo (the number of sections analyzed depended on the size of the embryo or fetus).

The embryos and fetuses used in our study belonged to our collection, and all our attempts to perform immunohistochemical analysis remain unsuccessful, probably owing to the interference in the antibody-epitope recognition by the fixative used to preserve the specimens. Therefore, to assess the content of motor fibers contained in the radial nerve branches, we analyzed neural branches obtained from adult human cadavers. The neural branches were obtained by careful macroscopic dissection exposing all the area extending from the axilla to just distal to the elbow. A surgical microscope was used during the dissection when the neural branches were too small. The radial nerve branch running together with the ulnar nerve known as the ulnar collateral nerve was isolated approximately 1 cm after branching from the radial nerve at the axilla level and before it joined the ulnar nerve, in six upper limbs (from three male and three female cadavers). The nerve branch was embedded in paraffin and 40 to 60 sections of 10- μ m thickness were obtained. Half of the sections were stained following a previously described standard immunohistochemical procedure using a goat anticholine acetyltransferase (ChAT) antibody (AB144P, EMD Millipore Corp, Billerica, MA, USA), which characterizes motor fibers [1]. Control experiments were performed to exclude unspecific immunohistochemical staining. For this purpose, the remaining half of the sections obtained from the same six adult specimens, and corresponding to adjacent sections of those stained with the ChAT antibody, were subjected to the same immunohistochemical procedure but without adding the primary antiChAT antibody. Each stained section was compared with its adjacent nonstained control section.

Results

In all 15 embryonic and fetal upper limbs, branches from the radial nerves (known as the ulnar collateral nerve) emerged at the level of the axillae and ran toward the ulnar nerves (Fig. 1A–C). These branches joined the ulnar nerves' sheaths in the upper third of the arms but without intermingling with the ulnar nerve fibers (Fig. 1D–E). They remained intimately linked to the ulnar nerves until the distal arm regions where they abandoned the ulnar nerves and entered the medial heads of the triceps brachii muscles (Fig. 1F). In one instance owing to the intimate proximity of the ulnar collateral nerve and the ulnar nerve at the level of the axilla, potential intermingling of the fibers could not be excluded; however, no ulnar nerve branches could be observed to the medial head of the triceps in the elbow regions. An additional branch for the medial head of the triceps brachii muscle originated more distally from the radial nerve when this entered the spiral groove (Fig. 1C).

This branch had a larger caliber than the first branch (Fig. 1C). The branches of the radial nerves for the long and lateral heads of the triceps brachii muscles also emerged at axilla levels (Fig. 1A); the lateral heads received additional innervations from the radial nerves in the spiral grooves; these branches were already visible at axilla levels but remained close to the main radial nerve trunks until midarm levels where they entered the muscle bellies to provide their innervations (Fig. 1D). Real ulnar nerve branches to the triceps brachii muscles were not observed in any of the specimens.

In the adult samples, two different anatomic arrangements could be observed. In both cases, the radial nerve branches (ulnar collateral nerve) for the medial heads of the triceps emerged at the level of the axillae and ran toward the ulnar nerves (Fig. 2A). Then the radial nerve branches either joined the ulnar nerves (Fig. 2A) or ran independently along them until reaching the medial heads of the triceps brachii muscles. This ulnar collateral nerve branch, independently of its disposition, is considered a constant branch that was present in all specimens. The immunohistochemical analysis revealed that the ulnar collateral nerves (radial nerve branches) carried ChAT positive and negative fibers, indicating this branch carries some motor innervation but also nonmotor fibers (Fig. 2B–C). The control showed no staining (Fig. 2D–E).

Discussion

The current study was conducted to try to solve the persistent controversy regarding whether the medial head of the triceps brachii muscle receives innervation via the ulnar nerve, and whether the ulnar collateral nerve (branch of the radial nerve) provides motor fibers to the medial head of the triceps brachii muscle or it is just a sensitive branch. These anatomic controversies need to be solved before use of the medial head of the triceps brachii muscle or its nerve supply as a source for reinnervation of denervated muscles [3]. In light of the divergent views, we determined (1) whether the medial head of the triceps brachii was innervated only by the radial nerve or contained some ulnar innervation, and (2) the motor and nonmotor fiber content of the ulnar collateral branch of the radial nerve.

We note limitations to our study. First, the two questions could not be addressed with the same type of material (embryonic and fetal) as all the immunohistochemical procedures were not examined in the embryonic and fetal specimens and we had to rely on samples obtained from adult specimens to assess the fiber-type content of the ulnar collateral nerve. However, taking into consideration that the embryos and fetuses studied already had acquired adult-like morphologic features, it seems unlikely that the

Fig. 1A–F Serial transversal sections (**A** is the most proximal; **F** is the most distal) of a human embryonic upper limb show the innervation of the different triceps brachii heads. (**A**) The white arrow indicates the radial nerve branch to the long head of the triceps brachii (loh), whereas the white arrowhead shows innervation of the lateral head (lah) (Stain, Bielschowsky; original magnification, $\times 4$); scale = 1000 μm . (**B**) This higher magnification view shows the emergence of the ulnar collateral branch of the radial nerve (black arrow) at the axilla level (Stain, Bielschowsky; original magnification, $\times 10$); scale = 100 μm . (**C**) The ulnar collateral branch divides into different branches, one of which (white arrow) is entering the medial head of the triceps brachii (mh) (Stain, Bielschowsky; original magnification, $\times 10$); scale = 100 μm . (**D**) A second branch of the ulnar collateral nerve is entering the medial head of the triceps brachii

muscle (white arrow), whereas the other continues close to the ulnar (u) nerve (black arrow) (Stain, Bielschowsky; original magnification, $\times 10$); scale = 100 μm . (**E**) There is an intimate relation of the ulnar collateral nerve of the radial nerve (black arrow) and ulnar (u) nerve without fusion of the fibers (Stain, Bielschowsky; original magnification, $\times 10$); scale = 100 μm . (**F**) The ulnar collateral nerve (black arrow) enters the medial head of the triceps brachii muscle at the level of the elbow (Stain, Bielschowsky; original magnification, $\times 10$); scale = 100 μm . The axes in the top right corners indicate the anterior (A) and distal (Di) positions; r = radial nerve; m = median nerve; mc = musculocutaneous nerve; ba = brachial artery; bb = biceps brachii muscle; bm = brachialis muscle; h = humerus; ra = radius.

fiber type would change between the prenatal and postnatal adult period, and therefore the results obtained in the adult specimens may be applicable to the embryonic and fetal periods. Therefore the conclusions reached most probably would be the same if the same type of material could have been used to address both questions. Second, the size of the embryonic and fetal sample is not large ($n = 15$) and therefore rare nerve variations may not have been detected. However, the aim of the current study was not to detect rare anatomic variations but to establish whether ulnar nerve innervation occurred in approximately 61% of the

specimens as previously stated [3]. The size of the sample is similar to a previous study in which 18 specimens were used [3], and therefore the conclusions reached in this study may be comparable to those of the study by Bekler et al. Third, owing to the small size of the sample of adult specimens, an exact quantification of the number of fascicles and fiber types in the ulnar collateral nerve was not attempted as it probably would not have provided robust statistical data. However, such quantification was not the aim of our study, which was rather to show whether the nerve had pure or mixed fiber types (either motor or

Fig. 2A–E The adult anatomy and histologic features of the radial and ulnar nerve and the radial and ulnar nerve connection in the axillary and upper arm region are shown. **(A)** This photograph of a right arm shows the apparent connection between the radial (r) and ulnar (u) nerves (black arrows). **(B)** Immunohistochemical staining with antiChAT antibody of the ulnar collateral nerve (shown with a white arrow in Fig. 2A) confirmed its motor nature (arrows) and ChAT negative (nonmotor) fibers in an ulnar collateral nerve fascicle (arrowheads) (Stain, ChAT(+) immunohistochemistry; original magnification, $\times 4$); scale = 500 μm . **(C)** A higher magnification view of

the square in Figure 2B is shown (original magnification, $\times 20$); scale = 100 μm . **(D)** Shown here is an immunohistochemical staining without antiChAT antibody (controlled experiment) of sections corresponding to the same ulnar collateral nerve as in shown in Figures 2B and 2C; there is lack of staining (Stain, ChAT (–) immunohistochemistry; original magnification, $\times 4$); scale = 500 μm . **(E)** A higher magnification view of the square in Figure 2D is shown (original magnification, $\times 20$); scale = 200 μm . m = Median nerve; bb = Biceps brachii muscle; ba = Brachial artery; suct = Superior ulnar collateral artery; v = Vein.

nonmotor), and this aim was achieved with the small sample used. Fourth, interobserver variability is an issue that always may influence the conclusions reached, but in our case the results obtained by three independent researchers were the same. Fifth, the small size of the embryonic and fetal sample did not allow us to analyze the rare cases where the radial nerve is absent [4] as we did not encounter any such case. Taking into consideration that in the previously reported cases, the lack of a radial nerve affected only the sensory branch and this was compensated for by the musculocutaneous nerve [4]; we believe that this does not affect the conclusions reached in the current work in which the main issue is motor innervation of the radial or ulnar nerves.

In all of our embryonic and fetal sections a radial nerve branch originated in the axilla and joined the ulnar nerve along its course to the forearm, as previously described in adults [15]. In some of our adult cases the radial nerve branches seemed to join the ulnar nerves, but our histologic

analysis showed the fascicle remained surrounded by its own perineurium and did not intermingle with proper ulnar nerve fibers; these branches separated from the ulnar nerves in the distal arm to innervate the medial head of the triceps brachii muscles. These observations were in accordance with previous reports [17, 29, 30], but they contradict a recent publication that reported ulnar nerve innervation of the medial head of the triceps brachii muscles in as many as 61% of cases [3]. These differences may be explained because some studies did not follow proximally the apparent ulnar nerve branches to the triceps brachii muscles and therefore these studies probably overlooked the fact that the branches originated from the radial, rather than the ulnar nerve [2, 3, 11, 19]. Those studies that performed a thorough analysis with proximal dissection [7, 15, 24, 28] came to the conclusion that the presence of ulnar nerve branches to the triceps brachii muscle was always associated with a proximal radial and ulnar connection in the axilla. The fact that the ulnar nerve

branches to the triceps brachii muscle could be easily separated from the main ulnar trunk and followed proximally along the radial and ulnar connection to the main radial nerve trunk in the axilla, led to the conclusion that the apparent ulnar nerve branches to the triceps brachii muscle were actually radial nerve branches [7, 15, 24, 28, 29]. All previous studies were based on macroscopic dissection of adult specimens and therefore the ability of the investigators to carefully dissect the specimens may have influenced the conclusions reached. In contrast, our embryonic and fetal analysis did not require dissection and therefore the anatomy was undisturbed. Furthermore, the nature of the material used in the current study allows the study of intraneural morphologic features that is not possible with macroscopic dissection. By using this method, we reached the same conclusion as the classic studies [7, 17, 30, 31]: all the triceps brachii muscle innervations were attributed completely to the radial nerve; furthermore, the intraneural fasciculations observed in our embryonic and fetal specimens mimicked previous observations in adult cadavers [17]. The connection between the radial and ulnar nerves has been noted in a case report [33], but several studies [2, 12, 24] suggest incidences ranging from 0.63% to 3%. These are the cases that could be mistaken with ulnar innervations of the triceps brachii, which has a much lower incidence than recently reported 61% [3]. Furthermore, several studies of the ulnar nerve around the elbow have concluded that proximal to the elbow only capsular branches [9] or muscular branches for the forearm muscles originated from the ulnar nerve [18, 31]. Therefore, only one study has thus far shown a more frequent ulnar than radial innervation of the medial head of the triceps brachii muscle [3]. Finally, one histologic study [3] could not confirm the innervation of the medial head of the triceps brachii muscle was supplied by the ulnar nerve as the images only showed there was muscle and neural tissue; no neuromuscular connection was observed.

The fact that nerve branches enter muscle bellies does not prove they carry motor innervation. The functional importance of the apparent ulnar nerve branches to the medial head of the triceps brachii muscle or the ulnar collateral nerve (radial nerve branch) entering this muscle belly remains controversial. It has been suggested these branches were motor branches and may serve for nerve transposition procedures [3]. However, as reported by Linell [17], one study based on the analysis of nerve injuries showed the motor function of the medial head was not compromised after injury to these branches or the ulnar nerve and therefore these branches were considered mainly sensory. Furthermore, according to some authors [17, 23] most of the innervation of the medial head of the triceps brachii muscle is provided by the branch emerging from the radial nerve close to the spiral groove. Our

immunohistochemical analysis showed that even though ChAT-positive fibers were present in the ulnar collateral nerve (radial nerve branch), a high number of ChAT negative fibers was observed, indicating this radial nerve branch is not exclusively of a motor or sensory nature but rather of a mixed nature containing a variable number of motor and sensory fibers. Future electromyographic studies may determine the exact extent by which each radial nerve branch entering the medial head of the triceps brachii is responsible for its motor innervation.

We found innervation of the medial head of the triceps brachii muscle always was provided by the radial nerve; sometimes a connection between the radial and ulnar nerve existed, resulting in an apparent ulnar nerve origin of the muscular branches to the medial head of the triceps. Our histologic analysis, however, showed the fibers in these ulnar nerve branches to the medial head of the triceps brachii originated from the radial nerve. Therefore, before performing or suggesting new muscle or nerve transposition procedures that use this apparent ulnar innervation, the real origin should be confirmed. Although the controversy of ulnar nerve innervation may continue to exist, we reiterate a statement by Cruveilhier: “The ulnar nerve does not emit any branch in the arm; the mistake of anatomists who claim the contrary comes from the fact that the branch to the medial head of the triceps brachii, that comes from the radial nerve, is intimately linked with the ulnar nerve in most of its course and therefore, in an initial approach it would seem that the branch originates from the ulnar nerve” [7].

Acknowledgments We thank Alicia Cerro and María Dolores Arroyo for excellent technical assistance during the histologic sectioning. The adult cadavers were donated according to the wishes of the individuals when they were alive and the current regulations for body donation.

References

1. Badia J, Pascual-Font A, Vivo M, Udina E, Navarro X. Topographical distribution of motor fascicles in the sciatic-tibial nerve of the rat. *Muscle Nerve*. 2010;42:192–201.
2. Bankart J, Pye-Smith PH, Phillips JJ. Notes of abnormalities observed in the dissecting room during the winter sessions of 1866–7 and 1867–8. *Guy's Hosp Report*. 1869;14:436–455.
3. Bekler H, Wolfe VM, Rosenwasser MP. A cadaveric study of the ulnar nerve innervation of the medial head of triceps brachii. *Clin Orthop Relat Res*. 2009;467:235–238.
4. Bergman RA, Afifi AK, Miyauchi R. *Illustrated Encyclopedia of Human Anatomic Variation*. Available at: <http://www.anatomyatlases.org/AnatomicVariants/AnatomyHP.shtml>. Accessed October 15, 2012.
5. Bergman RA, Thompson SA, Afifi AK, Saadeh FA. *Compendium of Human Anatomic Variation*. Baltimore, MD: Urban & Schwarzenberg; 1988:142–143.
6. Cloquet H. [*Descriptive Anatomy Treatise*. Vol 2] [In French]. 3rd Ed. Paris, France: Crochard; 1824:163–168.

7. Cruveilhier J. [*Descriptive Anatomy*. Vol 4.] [In French]. Paris, France: Bechet Jeune; 1836:809–816.
8. Frohse F, Fraenkel M. [*The muscles of the human arm*]. In: von Bardeleben K, ed. [*Handbook of Human Anatomy*] [In German]. Jena, Germany: Gustav Fischer Verlag; 1908:97–99.
9. Gonzalez MH, Lofti P, Bendre A, Mandelbroyt Y, Lieska N. The ulnar nerve at the elbow and its local branching: an anatomic study. *J Hand Surg Br*. 2001;26:142–144.
10. Gruber W. [The anomalous course of the ulnar nerve in front of the medial epicondyle] [In German]. *Arch Anat Physiol Wissen Med*. 1867;560–564.
11. Haberer H. [A very rare variation of the ulnar nerve] [In German]. *Anat Anz*. 1914;47:596–602.
12. Hirasawa K. [Investigations on the peripheral nervous system. Brachial Plexus and nerves of the upper limb] [In German]. *Arb Anat Inst Kaiserlichen Univ Kyoto*. 1931:95–183.
13. Hovelacque A. [*Anatomy of the Cranial and Spinal Nerves and of the Sympathetic Nervous System*] [In French]. Paris, France: Librairie Octave Doin; 1927:475.
14. Kaplan EB, Spinner M. [*Anatomical variations of the upper limb nerves*]. In: Bonnel F, Mansat M, eds. [*Peripheral Nerves: Surgical Anatomy and Pathology*. Vol 1] [In French]. Paris, France: Masson; 1990:173–178.
15. Krause W. [Contributions to the systematic neurology of the human arm] [In German]. *Arch Anat Physiol Wissen Med*. 1864;349–357.
16. Krause W. [On the ulnar collateral nerve of the radial nerve] [In German]. *Arch Anat Physiol Wissen Med*. 1868;134–136.
17. Linell EA. The distribution of nerves in the upper limb, with reference to variabilities and their clinical significance. *J Anat*. 1921;55:79–112.
18. Marur T, Akkin SM, Alp M, Demirci S, Yalçin L, Oğüt T, Akgün I. The muscular branching patterns of the ulnar nerve to the flexor carpi ulnaris and flexor digitorum profundus muscles. *Surg Radiol Anat*. 2005;27:322–326.
19. Miguel-Pérez MI, Combalia A, Arandes JM. Abnormal innervation of the triceps brachii muscle by the ulnar nerve. *J Hand Surg Eur Vol*. 2010;35:430–431.
20. O'Rahilly R, Müller F. *Developmental Stages in Human Embryos*. Washington, DC: Carnegie Institution of Washington; 1987.
21. Özer H, Açar HI, Cömert A, Tekdemir I, Elhan A, Turanlı S. Course of the innervation supply of medial head of triceps muscle and anconeus muscle at the posterior aspect of humerus (anatomical study). *Arch Orthop Trauma Surg*. 2006;126:549–553.
22. Patten BM. *Human Embryology*. 3rd Ed. New York, NY: McGraw-Hill Book Company; 1968.
23. Piquilloud G, Villani F, Casoli V. The medial head of the triceps brachii: anatomy and blood supply of a new muscular free flap. The medial triceps free flap. *Surg Radiol Anat*. 2011;33:415–420.
24. Ramström M. [Investigations on the innervation of the medial head of the triceps brachii muscle] [In German]. *Anat Anz*. 1918–19;51:420–431.
25. Ranschburg P. [On the anastomosis between the nerves of the human upper limb with special consideration to their neurological and surgical relevance.] [In German]. *Neurol Centralbl*. 1917;36: 521–534.
26. Rodríguez-Niedenführ M, Burton GJ, Deu J, Sañudo JR. Development of the arterial pattern in the upper limb of staged human embryos: normal development and anatomic variations. *J Anat*. 2001;199:407–417.
27. Schaarschmidt A. [*Neurological Tables*] [In German]. Berlin, Germany: Johann Jacob Schüz; 1750: 69–76.
28. Smith GE. A note on the communication between the musculospiral and ulnar nerves. *J Anat*. 1904;38:162–163.
29. Stanescu S, Post J, Ebraheim NA, Bailey AS, Yeasting R. Surgical anatomy of the radial nerve in the arm: practical considerations of the branching patterns to the triceps brachii. *Orthopedics*. 1996;19:311–315.
30. Sunderland S. Metrical and non-metrical features of the muscular branches of the radial nerve. *J Comp Neurol*. 1946;85:93–111.
31. Sunderland S, Hughes ES. Metrical and non-metrical features of the muscular branches of the ulnar nerve. *J Comp Neurol*. 1946;85:113–125.
32. Tissot SA. [*Treatise on nerves and their diseases*.] [In French]. In: [*Works of Mr. Tissot*] [In French]. 9th Ed. Paris, France: Grasset & Comp; 1790:113–114.
33. Villar MF. [Some research on the anastomoses between the nerves of the upper limb: 1. Anastomoses between the musculocutaneous and the median nerves; 2. Anastomosis between the median and ulnar nerves; 3. Anastomoses between the radial and ulnar nerves. On their importance in the functional recovery following nerve sections] [In French]. *Bull et Mem Assoc Anat Paris*. 1888;607–615.