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Research Article - Human Anatomy Case Report

Unilateral absence of Casserio's nerve and a communicating branch to the median nerve. An additional variant of brachial flexors motor innervation

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Abstract

Anomalies of the brachial plexus including the distribution of the nerves as well as its terminal branches in the upper limb have been largely described in the literature. In this case report we describe a further variant of brachial plexus formation identified during routine anatomical dissection of the right upper limb of a 62-year-old Caucasian female cadaver. On the right side no musculocutaneous nerve was identified, the median nerve was formed as expected but a short extra branch communicating between the lateral cord and the medial head of the median nerve appeared. Coracobrachialis muscle was innervated by a direct branch from the lateral cord, while biceps brachialis and brachialis muscles were reached by collaterals of the median nerve. Moreover, in the distal half of the upper limb, the median nerve contributed to the innervation of the lateral aspect of the forearm skin via the lateral cutaneous nerve of the forearm. In order to analyze this specific variant relevance we compared it with all the similar previous reported cases, trying to explain the embryological bases of the variant. The knowledge of anatomical variations of peripheral nerves is pivotal not only for surgeons, radiologists and anesthesiologists that may operate on the axilla, but also for every medical doctor to understand inexplicable clinical signs.

Key words

Median nerve, musculocutaneous nerve, brachial plexus, anatomical variation, lateral cord.

Introduction

During the third week of gestation the peripheral nervous system begins to develop. The upper limb buds are visible by days 26-27. The brachial plexus appears as a single radicular cone in the upper limb of embryos 34-35 days old. The main branches grow distally and divide into dorsal and ventral primary rami. Dorsal primary rami innervate dorsal axial musculature, vertebral joints and the skin of the back. Ventral primary rami innervate ventral body wall and the limbs forming the major nerve plexuses (Moore et al., 2015). The brachial plexus is formed by the anastomoses between the ventral rami of the spinal nerves from C5 to T1 with a variable contribution from C4 and T2. It supplies the innervation for thorax and shoulder girdle muscles, articulations and skin of the upper limb. The brachial plexus is the most variable part of the peripheral nervous system, prevalence of variations is reported

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between 12.8% and 53% (Pandey et al., 2007; Johnson et al., 2010; Pacholczak et al., 2011). The musculocutaneous nerve has frequent variations and they were discussed extensively even in very early articles (Kerr, 1918; Hovelaque, 1927; Ferner, 1938). Its variants are present in 6.25% of the cases; among them its absence seems to be rare, ranging in human subjects from 1.4% to 11.2% as reported in some studies (Choi et al., 2002; Beheiry, 2004; Chitra, 2007; Guerri-Guttenberg and Ingolotti, 2009; Budhiraja et al., 2011). In this case report, we focus on both musculocutaneous and median nerves anatomy in order to characterize an additional anatomical variation we found during cadaveric dissection.

Materials and methods

A cadaver of an adult Caucasian female was properly embalmed following the routine procedure of our anatomical dissecting laboratory. The axilla and the arm regions of right upper limb were meticulously dissected: namely, a skin incision along the line between the jugular notch and xiphisternal joint was made and then it was continued following the inferior border of the mammary gland until the median axillary line. After the reflection of skin and subcutaneous tissue the pectoralis major and minor were overturned to access the axilla, where the brachial plexus and the axillary artery were surrounded by the axillary sheath and fat. To improve the dissection of the arteries and nerves, the axillary vein was removed. Unusual communication and distribution of median nerve and musculocutaneous nerve were identified. The same anatomic preparation was subsequently performed on the left upper limb to study and compare the brachial plexus anatomy.

All the figures were digital, realized using Adobe Photoshop cs5 and Adobe Illustrator cs6.

Results

During a gross anatomy course for undergraduate medical students we observed a particular disposition of the nerves fibers that supply the flexor of the arm on the right upper limb of a 62-year-old Caucasian female cadaver. The musculocutaneous nerve, as reported in literature, should arise solely from the lateral cord. On the right side, it was absent. All the flexor muscles of the arm were supplied by branches from the median nerve except the coracobrachialis muscle that was innervated by a direct branch from the lateral cord (Fig. 1). Using the coracoid process as a reference point, we measured brachial flexor branches position: the nerve to the coracobrachialis muscle arose 5.6 cm distal to the coracoid process, the origin of the fibers to biceps brachii muscle was at 13.6 cm and the branch to the brachialis muscle at 17.2 cm. Below the last branch to brachialis, the median nerve gave off the lateral cutaneous nerve of the forearm that passed beneath the biceps brachialis muscle and went to the anterior aspect of the forearm (Fig. 1). Comparing arm flexor size among the two sides we did not encounter any variation in number of heads, length or mass volume. The trunks of the plexus were normal on both sides of the body, while on the right side we observed another variant at the origin of the median nerve, namely an extra con-

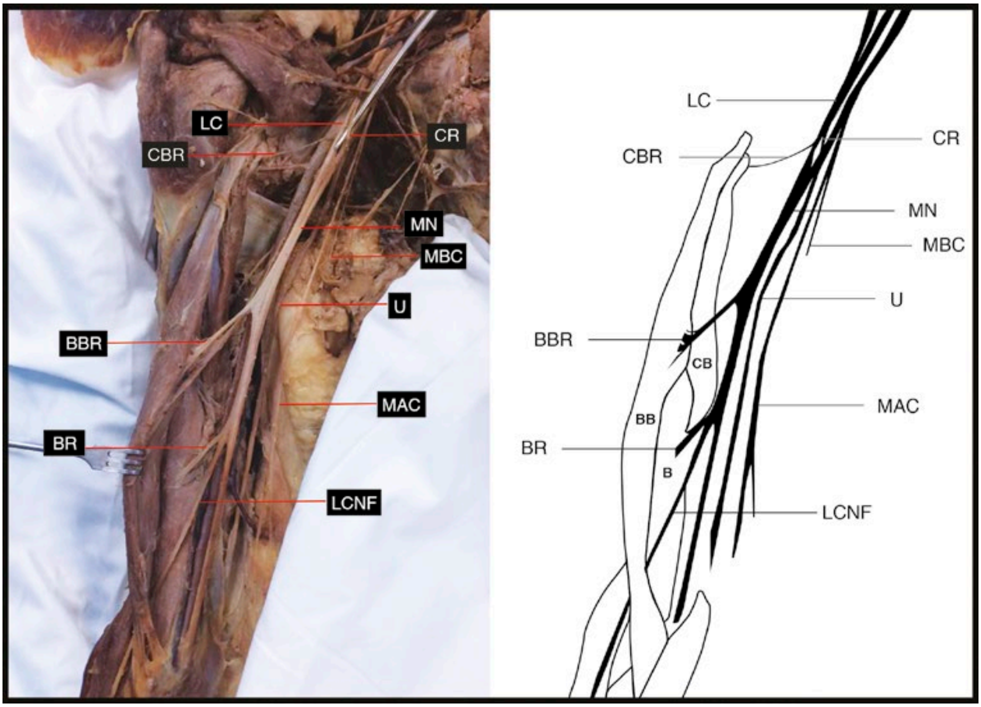

Figure 1. Absence of musculocutaneous nerve and innervation of the flexor muscles, except coracobrachialis, by branches of the median nerve. CB: coracobrachialis muscle; BB: biceps brachialis muscle; B: brachialis muscle; LC: lateral cord; MN: median nerve; CR: communicating branch; CBR: coracobrachialis ramus (nerve arising directly from the lateral cord); BBR: biceps brachii ramus (nerve); BR: brachialis ramus (nerve); MBC: medial brachial cutaneous nerve; MAC: medial antebrachial cutaneous nerve; U: ulnar nerve; LCNF: lateral cutaneous nerve of the forearm.

nection between the lateral cord and the median head of the medial nerve (Figs. 1, 2). We did not encounter any vascular abnormality in this case. We performed the same dissection on the left upper limb to study if the same variation was present. On dissecting the left axilla no anatomical variants were noted.

Discussion

Musculocutaneous anatomical variations

The course of the musculocutaneous nerve and its relationship with the coracobrachialis muscle was first observed by the Italian anatomist Giulio Cesare Casserio (1561-1616), student of the anatomist Girolamo Fabrici d'Acquapendente from Padua. It is one of the two terminal branches of the lateral cord, the other one is the lateral root of the median nerve. Musculocutaneous nerve primarily hosts fibers from the fifth and sixth cervical nerves (Standring, 2015), in 50% - 80% of individuals the

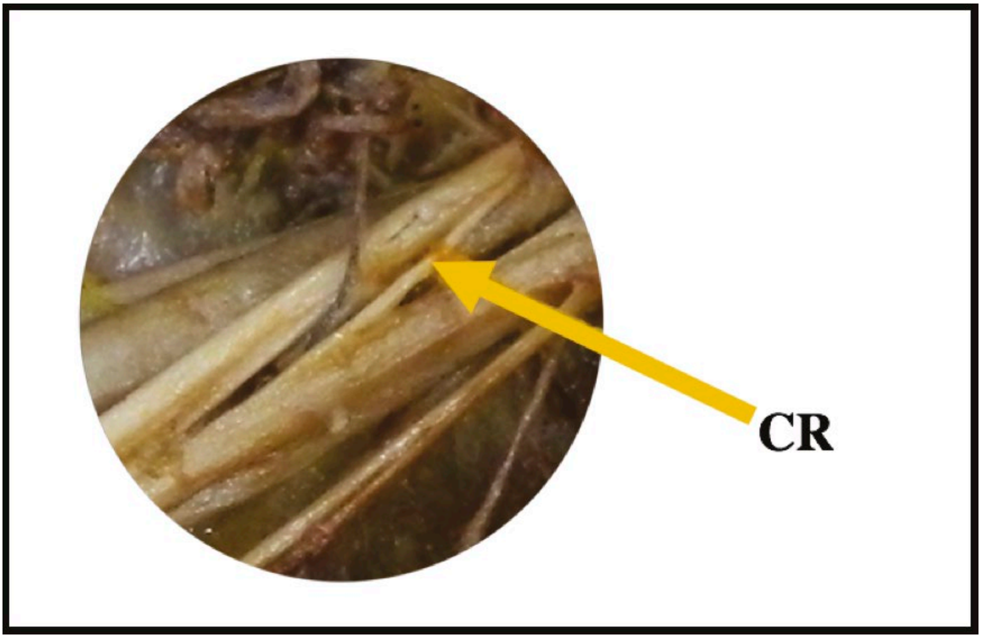

Figure 2. CR: communicating branch between the lateral cord and the medial root of the median nerve.

fourth and seventh cervical nerves may also contribute (Kerr, 1918). Its origin usually occurs at the level of the third part of axillary artery, where the lateral cord is lateral to the vessel (Standring, 2015); it arises solely from the lateral cord in 88.75% cases but it may also receive a contribution from the medial and the posterior cords (Kerr, 1918). Musculocutaneous nerve descends lying on the subscapularis muscle and subsequently passes through coracobrachialis muscle, which it innervates. Then it gives branches to biceps brachii and brachialis muscles and terminates as the lateral cutaneous nerve of forearm, deep to the biceps brachii, before emerging lateral to it and running down the lateral aspect of the forearm (Standring, 2015).

Failure of nerve fibers to divide into the common anatomic form often leads to abnormal branch patterns. Several kinds of variations of the musculocutaneous nerve have been reported, among them: musculocutaneous and median nerve sharing a communicating branch, muscular branches to brachial flexors transposed to median nerve and the absence of the musculocutaneous nerve (Le Minor, 1990; Venieratos and Anagnostopoulou, 1998; Adiguzel, 2000; Prasada Rao and Chaudhary, 2001; Choi et al., 2002; Song et al., 2003; Budhiraja et al., 2011; Pacholczak et al., 2011; Jeon et al., 2013; Parchand and Patil 2013; Sarkar and Saha, 2014; Gümüsburun and Hayashi et al., 2017).

The specific pattern we found is not belonging to any type described in the current literature.

Le Minor (1990) classified musculocutaneous and median nerve variations into five types based on the positional relationship between musculocutaneous nerve and coracobrachialis muscle (Fig. 3a). Type I (normal): there are no communicating

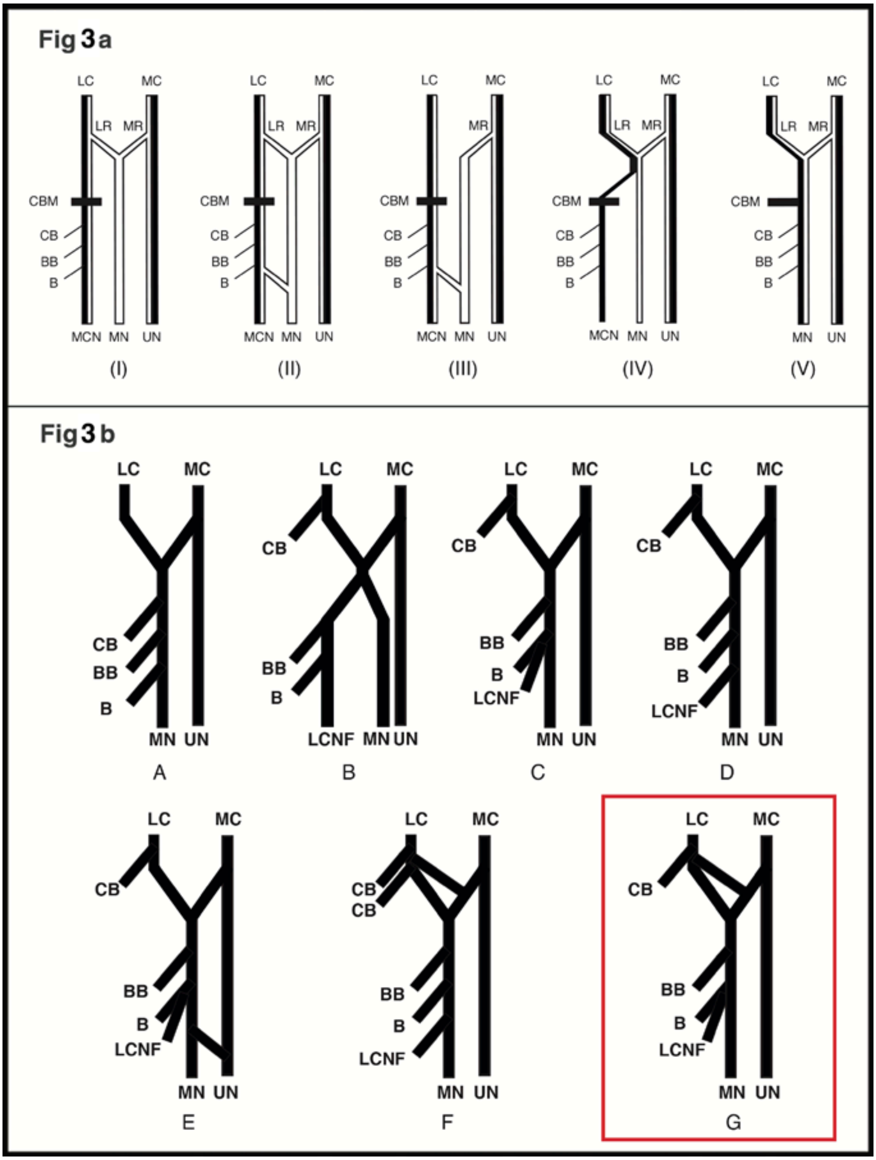

Figure 3. a) Classification of variations of the median nerve and the musculocutaneous nerve according to Le Minor (1990). CBM: position of the coracobrachialis muscle; CB: coracobrachialis ramus (nerve); BB: biceps brachii ramus (nerve); B: brachialis ramus (nerve); LR: lateral root forming the median nerve; MR: medial root of the median nerve; LC: lateral cord; MC: medial cord; MCN: musculocutaneous nerve; MN: median nerve; UN: ulnar nerve. b) Musculocutaneous nerve absence: cases where the transposition of the arm flexors innervation was similar to our case. A: Type V of Le Minor classification (1990); B: Prasada Rao and Chaudhary (2001); C: Budhiraja et al., (2011); D: Sarkar and Saha (2014); E: Gumusburun and Adiguzel (2000); F: Song et al., (2003); G: present case. LC: lateral cord; MC: medial cord; CB: coracobrachialis ramus (nerve); BB: biceps brachii ramus (nerve); B: brachialis ramus (nerve); MN: median nerve; UN: ulnar nerve; LCNF: lateral cutaneous nerve of the forearm.

rami between musculocutaneous nerve and median nerve, as described in classic textbooks. Type II: this pattern is similar to the normal but an extra ramus connects the musculocutaneous nerve and the median nerve while it gives the branch for the brachialis muscle. Type III: fibers from the lateral root follow the musculocutaneous nerve distally and leave it to unite with the medial head of the median nerve only after the musculocutaneous nerve originates rami to coracobrachialis, biceps brachii and brachialis muscles. Type IV: the musculocutaneous nerve arises from the median nerve as a proper and independent nerve after the origin of the median nerve. Type V: the musculocutaneous nerve is absent. Its fibers run into the median nerve along its course. All the brachial flexors are innervated by median nerve rami. Our finding is not corresponding to any of the Le Minor (1990) types described, however the type that is more similar to our case is type V (Fig. 3a).

Several authors found variants with absence of musculocutaneous nerve that do not have the same morphology as Type V of Le Minor classification (Budhiraja et al., 2011; Sarkar and Saha, 2014). In their cases all the arm flexors where innervated by rami originating from the median nerve and the coracobrachialis ramus arose from the lateral cord of the brachial plexus (Fig. 3b). Gümüsburun and Adiguzel (2000) described a similar pattern but there was also an extra anastomosis between the ulnar nerve and the median nerve (Fig. 2b). Prasada Rao and Chaudhary (2001) reported a case where musculocutaneous nerve was absent and arm flexors were innervated by two main branches: the coracobrachialis ramus arising from the lateral cord, and a ramus innervating the other arm flexors arising after the fusion of the medial and the lateral roots of the median nerve (Fig. 3b). Another description in the current literature shows an appearance similar to our variant but still different: two branches were identified inserting into the coracobrachialis muscle instead of just one (Song et al., 2003).

Recently, Hayashi et al. (2017) proposed a novel classification of muscolocutaneous nerve variations, nevertheless it does not include our specific pattern morphology.

Allocating musculocutaneous nerve variations into the already described classifications may be challenging. Lack of a clear and complete definition in current classifications leads to problems such as having three nomenclatures for the same anatomical variation (Guerri-Guttemberg and Ingolotti, 2009). Choi et al. (2002) refer as musculocutaneous nerve fused with the median nerve the condition that other author name musculocutaneous nerve absence (Nakatani et al., 1997; Gümüsburun and Adigüzel, 2000; Prasada Rao and Chaudhary 2001). Choi et al. (2002) and Buch-Hansen (1955) describe as musculocutaneous nerve absence a variation that occurs only when all the branches arising from the median nerve into the arm are sensitive rami. Hence, difference between musculocutaneous nerve absence and fusion needs to be clarified. Furthermore a complete musculocutaneous nerve classification including all the already published anatomic variants needs to be structured. Considering all these classification and nomenclature issues it is hard to quantify the real prevalence of musculocutaneous nerve absence. However, it is clear that musculocutaneous nerve absence belong to the most rare variations among brachial plexus variability (Guerri-Guttemberg and Ingolotti, 2009).

Thereafter, as nerves are called with their specific name due to their course of innervation and not from their origin (Song et al., 2003), it is reasonable to consider that in the present case report the median nerve was a combined nerve and the musculocutaneous nerve was absent on the right upper limb.

Embryological bases

Anatomical variations of the brachial plexus can be a consequence of aberrant development of the trunks, divisions and cords. An explanation of the different morphology may be achieved by understanding normal embryological development. Brachial plexus growth begins at the 34th to 35th day of intrauterine life when regional expression of Hox D genes leads to the development of forelimb muscle from the mesenchyme of paraxial mesoderm. Here, paraxial mesoderm differentiates into dermatomes, sclerotomes and myotomes. The last ones enlarge rapidly both dorsally and ventrally and divide into a dorsal epaxial portion and ventrolateral hypaxial portion. At this time, neural crest cells growing out of the neural tube make contact with the cells of the corresponding myotome, as the developing nerves begin to split into a dorsal primary ramus and a ventral primary ramus connected to corresponding portions of the myotome (Morgan and Tabin, 1994; Moore et al., 2015; Sadler, 2015). During further development, the nerve grows inside the muscle and follows it during any successive migration. This connection once established will be maintained during further development. The distribution area of developing axons is regulated by several factors: the signaling between the neuronal growth cones and the mesenchymal cells, the expression of specific chemoattractants and chemorepulsants (brain derived neurotrophic factor, C-kit ligand, netrin-1, netrin-2 etc) and specific circulatory factors overproduced at the brachial plexus's time of fission (Larsen, 2001; Catala and Kubis, 2013). The constituents of the extracellular matrix play a crucial role in the control of neural crest cell migration, in particular fibronectin, laminin, and tenascin. These molecules are recognized by integrins which are surface receptors expressed by neural crest cells (Catala and Kubis, 2013). After careful investigation of the complex developmental process driving the formation of brachial plexus, it is not surprising that anatomical variations of the brachial plexus are common. Alterations in these process lead to anomalies in the nerve supply to muscles (Prasada Rao and Chaudhary, 2001).

Clinical correlations

In the present case musculocutaneous nerve fibers ran into the median nerve and the musculocutaneous nerve was absent. Absence of the musculocutaneous nerve indicates that most of the nerve fibers of C5 and C6 passed via the lateral root to the median nerve and then distributed to muscles of the anterior compartment of the upper arm as well as anterolateral cutaneous area of the forearm through the branches of the median nerve (Moore et al. 2015). This variation does not lead to paralysis of the arm flexors neither to hypoesthesia of the lateral surface of forearm, since motor and sensory fibers can arise from other nerves (Budhiraja et al., 2011).

Lesions of the median nerve in cases where the musculocutaneous nerve is absent and its fibers are transposed to the median nerve would lead to unexpected clinical signs. In addition to the normal median nerve palsy related symptomatology, it will result in the paralysis of the brachialis, coracobrachialis and biceps brachii muscles. It would also produce a weak flexion at the elbow and a weak supination when the elbow is flexed. Loss of sensation or burning dysesthesia of the lateral aspect of the forearm could also follow (Gillingham and Mack 1996).

Being aware of musculocutaneous nerve absence is clinically relevant for surgeons, orthopedists and anesthetists performing treatment on the upper limb (Prasada Rao and Chaudhary, 2001; Budhiraja et al., 2011). During flap dissection, shoulder reconstruction, axillary lymph node dissection and surgical procedures around the shoulder/axillary area accidental nerve damages may happen, especially if the surgeon is familiar with the normal anatomic course of the nerve and its regional relationship, but not aware of all the possible variants that may be present (Flatow et al., 1989; Budhiraja et al., 2011; Hayashi et al., 2017). Information about the course and the topography of the musculocutaneous nerve is important also for anesthetic axillary plexus block, where a selective block of the musculocutaneous nerve is necessary to achieve a successful anesthetic axillary plexus block. It could not be achieved in case of unknown musculocutaneous nerve absence (Kjelstrup et al., 2017).

Compliance with ethical standards

Informed consent was obtained from all individuals who had a right to express it according to Italian law.

Conflict of interest

The Authors declare no conflict of interest. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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