

Positional Anomaly Between the Brachial Plexus and the Scalene Muscles, Concomitant with an Anomalous Path of the Musculocutaneous Nerve. Case Report and Clinical Implication

Anomalía Posicional entre el Plexo Braquial y el Músculo Escaleno Anterior, Concomitante con un Trayecto Anómalo del Nervio Musculocutáneo. Reporte de un Caso e Implicancia Clínica

Emilio Farfán C.; Mark Echeverría M.; Verónica Inostroza R.; Daniela Schneeberger L. & Oscar Inzunza H.

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SUMMARY: Anatomical variations of the scalene muscles are frequent, as are those of the brachial plexus and its terminal nerves. Nonetheless, these variations are reported separately in the literature. The aim of this work is to present a variation of scalene muscles, concomitant with an abnormal path of the musculocutaneous nerve. During a routine dissection of the cervical region, axilla and right anterior brachial region in an adult male cadaver, a supernumerary muscle fascicle was located in the anterior scalene muscle, altering the anatomical relations of C5 and C6 ventral branches of the brachial plexus. This variation was related to an anomalous path of the musculocutaneous nerve that did not cross the coracobrachialis muscle. It passed through the brachial canal along with the median nerve. It then sent off muscular branches to the anterior brachial region and likewise, communicating branches to the median nerve. The concomitant variations of the brachial plexus and scalene muscles they are not described frequently. Knowledge of these variations improves diagnosis, enhancing therapeutic and surgical approaches by reducing the possibility of iatrogenesis during cervical, axillary and brachial region interventions.

KEY WORDS: Anterior scalene muscle; Musculocutaneous nerve; Anatomical variation.

INTRODUCTION

Scalene muscles. The scalene muscles are part of a group of prevertebral muscles of the neck. As a result of their deep position, they are covered by the prevertebral layer of deep cervical fascia (Rouvière & Delmas, 2005). These muscles are inserted superiorly in the transverse processes of the cervical vertebrae and inferiorly in the first two ribs. The anterior scalene muscle extends from the anterior tubercles of the transverse processes from C3 to C6 to the tubercle of the anterior scalene muscle of the first rib; the middle scalene muscle arises from the posterior or anterior tubercles of the transverse processes from C2 to C7, to the first rib behind the subclavian artery groove. The posterior scalene muscle extends from the posterior tubercles of the transverse processes from C4 to C6 to the second rib, posterior to the tuberosity for the anterior serratus muscle. The scalene muscles' main anatomical relation is with the roots that form the brachial plexus roots and the subclavian artery. These structures course between the anterior and middle scalene muscles. Additionally, the suprascapular, transverse neck and ascending cervical arteries

move ventrally to the anterior scalene muscle, the phrenic nerve and the subclavian vein (Strandring, 2016).

Variations of this muscle structure include insertion point changes, the presence of supernumerary fascicles and alteration of anatomical relations. In reference to supernumerary fascicles, scalenus minimus is located between the anterior and middle scalene muscles. It extends from the anterior margin of C6 and C7 transverse processes to the first rib and supra-pleural membrane (Tubbs *et al.*, 2016); this muscle variation is recognized as an official term by the International Anatomical Terminology (Federative International Programme for Anatomical Terminology, 2019).

The "posterior accessory scalene" muscle that extends from the posterior tubercles of the C4 and C6 transverse processes to the first rib. Although located behind the posterior scalene muscle, it is separated by the ventral branches that form the brachial plexus. (Testut, 1884).

Regarding variations within the anatomical relations, Tubbs *et al.*, indicate that the anterior scalene muscle may be found posterior to the subclavian artery, be entirely absent, inserted into the third rib, or be intersected by C4 or C5 nerve roots.

Musculocutaneous nerve. The musculocutaneous nerve is a terminal nerve of the brachial plexus lateral fascicle consisting of nerve fibers of C5 and C6 medullary segments (Rouvière & Delmas). Typically, it originates in the axillary fossa behind the pectoral minor muscle and laterally to the median nerve. Inferiorly and laterally it crosses towards the anterior brachial region, in its path perforates the coracobrachialis muscle; distally and laterally it crosses the arm between the brachial and brachial biceps muscles. Its trajectory finalizes between the supinator muscle and the tendon of the brachial biceps muscle.

During its course it gives off branches to the coracobrachialis muscles, the brachial biceps, brachial, as well as an articular elbow branch. It finalizes its course as the lateral cutaneous nerve of the forearm. It can also give off communicating branches for the median, ulnar, radial and cutaneous brachial medial nerves (Rouvière & Delmas; Standring). The musculocutaneous nerve can vary its course; at times presenting behind the coracobrachialis muscle, may attach to the median nerve, and could also pass behind the biceps brachialis muscle. It has been completely absent (Song *et al.*, 2003), unilaterally or bilaterally; the latter is considered a rare variation (Kaur *et al.*, 2014).

This paper presents a positional anomaly between C5 and C6 ventral branches and anterior scalene muscle, with a variation of the musculocutaneous nerve path. The objective of this work is to describe this finding and discuss possible causes as well as clinical implications.

MATERIAL AND METHOD

A muscular variation found during a routine dissection of the neck and upper right limb is described in a 90-year-old male. The cadaver was fixed in 10 % buffered formaldehyde and placed in cold storage at 4 °C. There was no evidence of previous surgical interventions in the study area, and cause of death was recorded as a myocardial infarction.

The body was that of an individual who expressly stated the will of the donation through a document approved by the CEC MED-UC SCIENTIFIC ETHICAL COMMITTEE (project 190115002 approved favorably on 03/07/2019).

Dissection of the right cervical region was performed by initially removing the skin, platysma and cervical fasciae. During dissection of the root of the neck, the presence of a supernumerary muscular fascicle was detected between the anterior and middle scalene muscles. This modified the situation and typical anatomical relation of the brachial plexus, altering the organization of its trunks.

In order to identify variations in the distribution of the brachial plexus, the axillary dissection was performed by removing the major and minor pectoral muscles. This was carried out in the same manner in the right anterior brachial region. Initially the skin was lifted through an extended incision between the base of the axilla and the upper third of the forearm; cutaneous tissue was then removed laterally, leaving the deep fascia intact. During dissection of the brachial plexus fascicles, an abnormal situation was found with respect to origin and path of the musculocutaneous nerve. On further investigation a proximal to distal nerve was monitored, which originated in the brachial plexus and extended to the elbow fossa.

It was therefore possible to identify the insertion points of the supernumerary muscular fascicle, relating to the above, the alterations generated by this fascicle, as well as the variation of the musculocutaneous nerve path and its branching pattern.

RESULTS

Positional anomaly between C5-C6 ventral branches and anterior scalene muscle. In the right cervical region, a supernumerary muscular fascicle with an oblique arrangement was located between the anterior and middle scalene muscles. The upper tendon inserted in the anterior tubercle of the transverse C4 process, in front of the middle scalene muscle. Its lower extreme inserted in the first rib, forming a common tendon with the anterior scalene muscle. Supernumerary muscular fascicle diameters were as follows: Longitudinal diameter 82 mm, transverse diameter 4 mm, and anteroposterior 3 mm.

From upper to lower supernumerary muscle fascicle the following anatomical relations were observed: The anatomical structures located anterior were the ascending cervical artery, C5 and C6 ventral branches, and anterior scalene muscle. Structures found posteriorly along with the middle scalene muscle, the C7, C8 and T1 ventral branches; the suprascapular artery (which crossed the muscular belly of the middle scalene) and the subclavian artery. On the lateral side with the transverse artery of the neck; it was in

close contact medially with the vein and vertebral artery. From its deep surface, this muscle belly received a nerve from C7 ventral branch and vascular branches of the transverse cervical and ascending cervical vessels, from the superficial surface (Fig. 1).

The anterior scalene muscle had cranial insertion in the anterior tubercles of C5 and C6 transverse processes. Its longitudinal diameter was 72 mm, the transverse 11 mm and the anteroposterior 5 mm (Fig. 1).

Anomalous path of the musculocutaneous nerve. In the right axillary fossa the anomalous path of the musculocutaneous nerve was noted. It did not cross the coracobrachialis muscle, and did not entry in the anterior arm region. Variations in its anatomical relations and in muscle innervation of the anterior brachial region were observed.

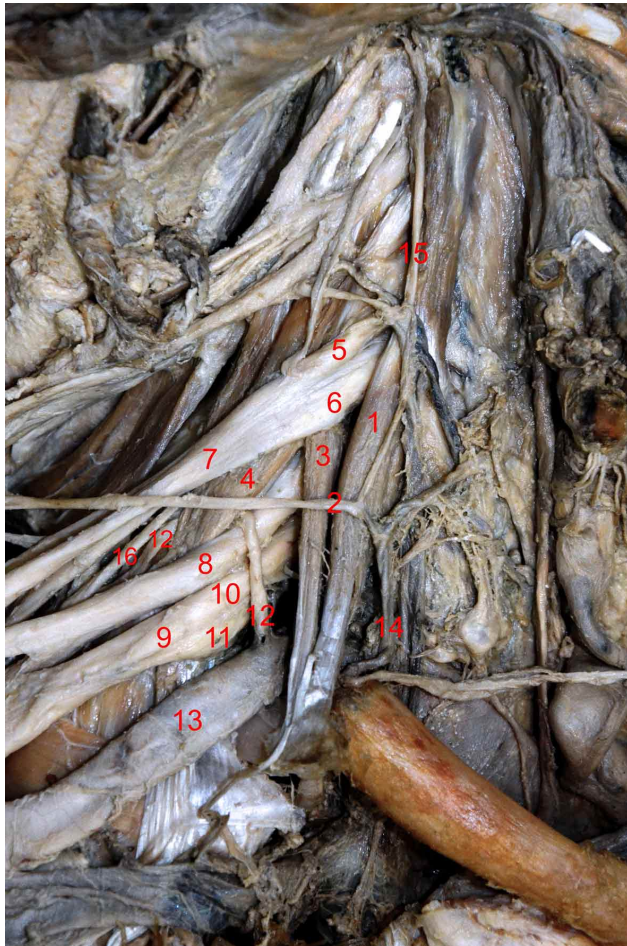


Fig. 1. Dissection of the right cervical region. 1. M. Anterior scalene; 2. A. Transverse of the neck; 3. Supernumerary muscle fascicle; 4. M. Middle scalene; 5. Ventral branch C5; 6. Ventral branch C6; 7. Upper trunk; 8. Middle trunk; 9. Lower trunk; 10. Ventral branch C8; 11. Ventral branch T1; 12. A. Suprascapular; 13. A. Subclavia; 14. Thyrocervical trunk; 15. A. Ascending Cervical; 16. N. Suprascapular.

Union of the anterior divisions of upper and middle trunks conformed the lateral fascicle of the brachial plexus. Following measurement, longitudinal diameter of 4 mm and a transverse diameter of 8 mm were found. This fascicle ended at the level of the second segment of the axillary artery by dividing into the musculocutaneous nerve and lateral root of the median nerve. The latter measured showed a longitudinal diameter of 51 mm and a transverse diameter of 0.5 mm.

The musculocutaneous nerve continued the path of the lateral fascicle. It followed the second segment of the axillary artery laterally, giving origin at this point, to a branch for the coracobrachialis muscle. Upon reaching the upper third of the arm, it crossed before the brachial vein, entered in the braquial duct, lateral to the median nerve and anterior to the brachial artery (Fig. 2). In the brachial duct, musculocutaneous and median nerves were joined by a dense fascia, giving the impression of forming a single nerve, which when removed allowed confirmation that these were independent nerves. During its brachial path, the musculocutaneous nerve gave origin to muscular nerves for the anterior region of the arm and communicating branches for the median nerve, a total of 6 nerves are described below, from proximal to distal (Fig. 3).

1. Branch for the coracobrachialis muscle: Originated inside the axilla, at the level of the second part of the axillary artery, from the lateral aspect of the musculocutaneous nerve 11 mm from the origin of said nerve. It entered the coracobrachialis muscle through the medial aspect of the muscular abdomen, its longitudinal diameter was 56 mm and its transverse diameter was 1 mm.
2. Upper communicating branch for the median nerve: Originated from the medial aspect of the musculocutaneous nerve, within the brachial duct in the upper third of the arm, 84 mm from the origin of the musculocutaneous nerve. It was attached to the median nerve, anterior to the brachial vessels, its longitudinal diameter was 57 mm and its transverse diameter was 1 mm. This branch received a communicating branch from the median nerve.
3. Branch for the biceps brachial muscle: Originated from the lateral aspect of the musculocutaneous nerve in the upper third of the arm, 118 mm from the origin of the musculocutaneous nerve. It presented anterior to the brachial artery and entered the anterior brachial region between the brachial and biceps brachial muscles, along with muscular branches of the brachial vessels.

Interiorly, the branch for the biceps brachial divided

into two branches for this muscle. One lateral for the long head and another medial for the short head, which pierced their respective muscle bellies by their deep facet; longitudinal diameter of this nerve was 62 mm and its transverse diameter 2 mm.

4. Branch for the brachial muscle: Originated in the middle third of the arm, from the lateral aspect of the musculocutaneous nerve 134 mm from its origin. It entered the brachial region through the lower third of the arm between the brachial and brachial biceps muscles,

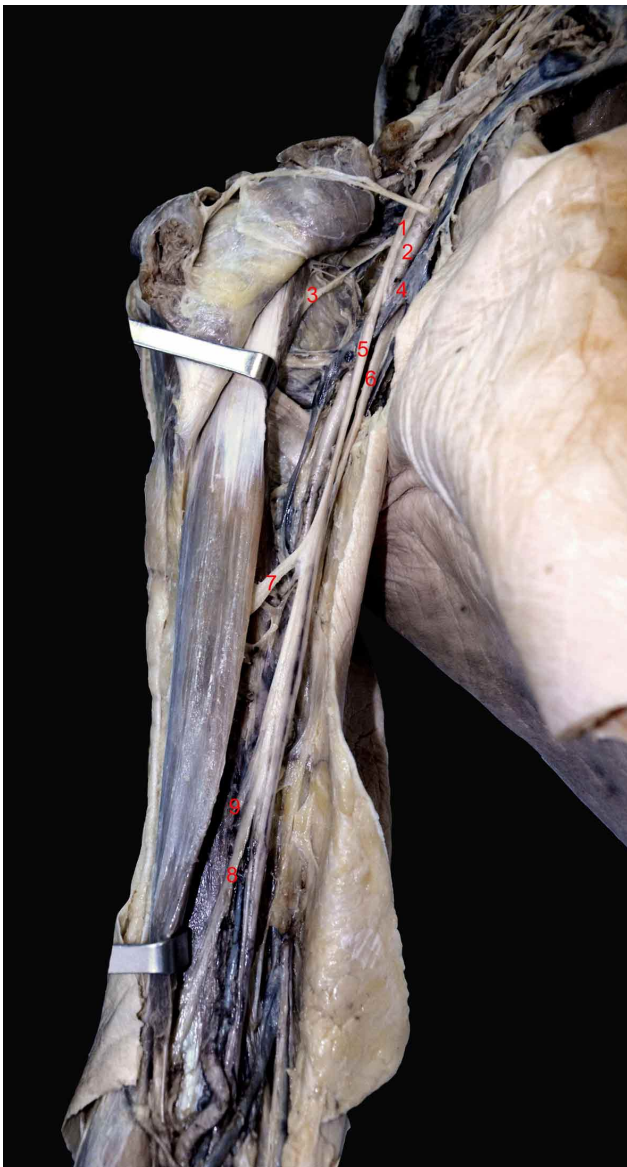


Fig. 2. Axilla and right anterior brachial region dissection 1. Lateral fascicle; 2. A. Axillary; 3. Branch for the coracobrachial muscle; 4. V. Axillary; 5. Musculocutaneous nerve; 6. Median nerve; 7. Branch for the biceps brachial muscle; 8. Lateral antebrachial cutaneous nerve; 9. Branch for the brachial muscle.

bifurcating into two branches prior to accessing this compartment. One superior and one inferior branch penetrated the superficial facet of the muscular abdomen along with muscular branches of the brachial arteries. Its longitudinal diameter measure from the bifurcation origin, was 62 mm and its transverse diameter 2 mm. The upper branch measured a longitudinal diameter of 1 mm from bifurcation; lower branch measured 55 mm longitudinal diameter and 1mm transverse diameter.

5. Lower communicating branch for the median nerve: Originated in the middle third of the arm, from the medial aspect of the musculocutaneous nerve, 167 mm from its

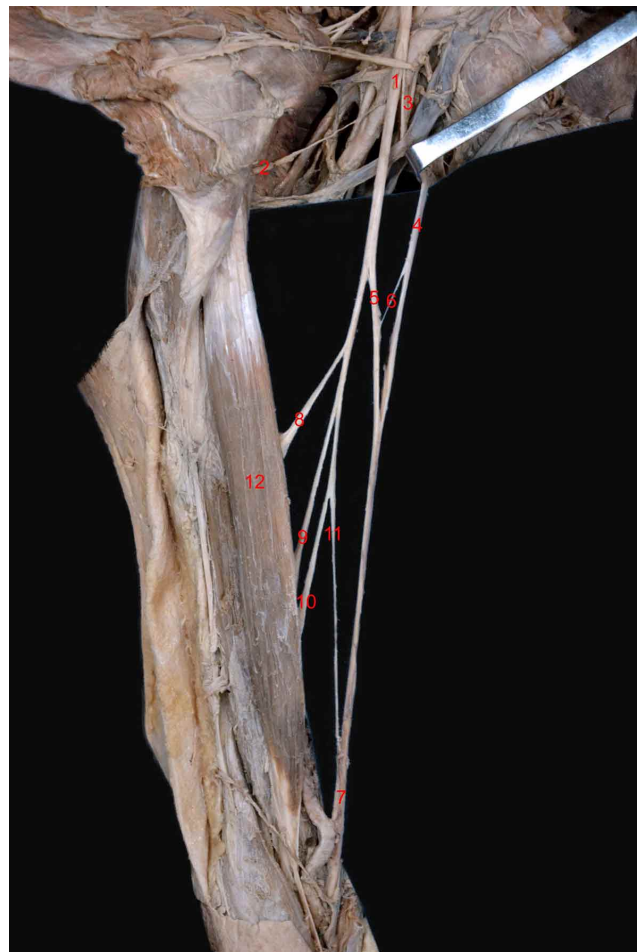


Fig. 3. Dissection of the right anterior brachial region. 1. Musculocutaneous nerve; 2. Branch for the coracobrachialis muscle; 3. Union of the two roots of the median nerve; 4. Median nerve previous to communicating branches; 5. Upper communicating branch for the median nerve; 6. Communicating branch from the median nerve to the superior communicating branch for the median nerve; 7. Median nerve post communicating branches; 8. Branch for the biceps brachial muscle; 9. Branch for the brachial muscle; 10. Lateral antebrachial cutaneous nerve; 11. Lower communicating branch for the median nerve.

origin. It is directed inferiorly and medially towards the median nerve to join it, prior to entering the elbow fossa, its longitudinal diameter was 96 mm and its transverse diameter 0.5 mm.

6. Lateral antebrachial cutaneous nerve: Corresponds to the continuation of the musculocutaneous nerve after giving rise to the inferior communicating branch for the median nerve. It crossed the lower third of the previous brachial region between the biceps brachial and brachial muscles, emerging in the cubital fossa through the lateral bicipital groove, crossed the deep fascia and was located quite deep, in relation to the cephalic vein. Subcutaneous path continued through the forearm, with 142mm longitudinal diameter and 1mm transverse diameter measured from its origin.

DISCUSSION

The anatomical variations between the scalene muscles and the brachial plexus' origin is the interaction of these structures during embryonic development.

The unique blastema from which the scalene muscles derive is crossed by the developing vessels and nerves intended for the upper limb. These neck structures have correlation in the thorax, the anterior scalene is comparable to the external intercostal muscle, the middle and posterior scalenes to the internal and intimate intercostals respectively. The subclavian vessels and nerves of the brachial plexus on the other hand, correspond to the intercostal vessels and nerves that cross the lateral wall of the thorax (Orts Llorca, 1970).

The upper limb develops from mesenchymal tissue during the fourth week of fetal development (Radunovic *et al.*, 2019). Brachial plexus begins its formation on day 33 of development (Moore *et al.*, 2016), and muscle mass of the scalenes approximately on day 50 (Som & Laitman, 2017). This muscle mass is initially unique and subsequently traversed by the brachial plexus and subclavian artery (Milliez & Sakka, 1993). The interaction of this muscle mass with the nervous primordium (Radunovic *et al.*, 2013) and blood vessels is decisive in establishing their anatomical relations and generating anatomical variations in the neck and upper limb.

Anterior scalene muscle division. In reference to the different variations described in the scalene muscles, the minimum scalene muscle is unilaterally more frequent, 32 %, Harry *et al.* (1997) and 19.2 % Sakamoto (2012). Nevertheless, we did not consider that the supernumerary fascicle found in the present work corresponded to a

minimum scalene muscle; this muscle has an upper insertion, typically in anterior tubercles of C6 and C7 transverse processes, and inferiorly in the first rib's inner margin. It extends to the cervical pleura (Testut; Standring; Tubbs *et al.*), which has no relation to the insertions of the supernumerary fascicle found.

Sakamoto described a variant of the middle scalene muscle, in which the muscle separates into two muscular bellies, one dorsal and another ventral. They are separated by a common root of the dorsal nerve of the scapula and long thoracic nerve. However in that analysis the ventral branches of the brachial plexus maintained their usual interscalene position.

Regarding the anterior scalene muscle, its absence is rare. However it can be found double or with independent origins (Tubbs *et al.*). Muscular fascicles that form the above are basically different, and as many as 2, 3 or 4 fascicles may be found in this muscle (Testut), which can directly alter their anatomical relations.

The anterior scalene muscle of this dissection maintained its upper insertions in the anterior tubercles of C5 and C6 transverse processes; no insertion was noted in C3 and C4 according to previous descriptions (Testut; Rouvière & Delmas; Standring). Nonetheless, supernumerary fascicle inserted superiorly in the anterior tubercle of C4 transverse process and adjacent to the anterior scalene shared a lower tendon that was inserted into the tubercle for the anterior scalene muscle of the first rib. Additionally, supernumerary fascicle transverse diameter, was equivalent to one third of the anterior scalene muscle, and was separated by C5 and C6 ventral branches.

Uemura *et al.* (2007) reported one case where bilaterally the subclavian artery was located anteriorly with respect to the anterior scalene muscle, and as in our case, these muscles presented inserts in C5 and C6 transverse processes but not in C3 and C4. On the other hand Leonhard *et al.* (2016) described that in a sample of 65 bodies 47.7 % presented variations with respect to the normal pattern of the interscalenic situation of the brachial plexus. These were classified into 4 categories:

1. Single perforation, when the upper trunk of the brachial plexus passes through the anterior scalene muscle (38.5 %).
2. Multiple perforations, when the perforation of this muscle is done by the upper and middle trunks (3.1 %).
3. Perforation of C5, when the ventral branch of C5 crosses the anterior scalene muscle (3.1 %).
4. Anterior variant, when the upper trunk (C5 and C6) transits the anterior surface of the anterior scalene muscle (3.1 %).

According to observations during this study, the anomaly found corresponds to a variation of the upper muscular fascicles of the anterior scalene, which in addition to presenting a one less fascicle (corresponding to the one inserted in C3) showed repositioning with respect to the C5 and C6 ventral branches, interposing between the upper trunk and the middle and lower trunks of the brachial plexus. According to the classification of Leonhard *et al.* the variation described in this work would be equivalent to a “single perforation”. However in our case there was a division of the muscular belly of the anterior scalene, instead of perforation, caused by the course of C5 and C6 ventral branches, during embryonic development (Fig. 1).

Anomalous path of the musculocutaneous nerve. The musculocutaneous nerve shares a common embryological origin with the median nerve. Both arise from the anterior divisions of the developing brachial plexus as it enters the upper limb, as noted in the diverse variations described in the literature. During the 5th week of development the outline of the upper limb is placed in front of spinal segments C5 to T1. Specifically, nerves are formed and attach on days 32 and 33, thereby constituting the brachial plexus (Radunovic *et al.*, 2019). Axons are introduced into the general outlines of the upper limb, and develop into dorsal and ventral muscle masses, fusing with a specific pattern, where sensitive axons use motor axon guidance. Following array of the axons in the brachial plexus, they continue their journey through the upper limb to the destination region final site of innervation. Presumably, from signals produced by the muscle to be innervated (Moore *et al.*).

Regarding variations of the musculocutaneous nerve, Radunovic *et al.* (2013) indicate that these reach an average of 20 % among the different studies of this nerve. Complementing the above, Sirico *et al.* (2019) mention that when variations in the supraclavicular portion of the brachial plexus are observed, it is more likely to find a mixed variation that involves other variations along the same brachial plexus.

Anatomical variations of the musculocutaneous nerve most frequently reported in the literature, correspond to the absence of this nerve, its duplicity, the presence of branches communicating with the median nerve, or the existence of a musculocutaneous nerve that does not penetrate the coracobrachial muscle and instead, joins the median nerve on its way through the brachial duct. The latter according to Tubbs *et al.* it is one of the most common variations and its incidence has been reported by Choi *et al.* (2002) in 7.4 % of cases, by Chitra (2007) in 6 % and by Kervancioglu *et al.* (2011) between 10-22 %.

Communicating branches originating from the musculocutaneous nerve toward the median nerve vary in number, and their volume is inversely proportional to the volume of median nerve lateral root. Therefore, these communicating branches correspond to axons destined for the median nerve, which accompany the musculocutaneous nerve beyond the origin of the lateral root, to distally join the median nerve (Rouvière & Delmas; Strandring).

Different frequencies of these communications have been reported in the literature, for example Choi *et al.*, found communicating branches in 21 % of cases, and Guerri-Guttenberg & Ingolotti (2009) in 43 %. Locating more than one communicating branch is less frequent, with reports of 2 % of the cases according to Choi *et al.* and 7.7 % according to Guerri-Guttenberg & Ingolotti; these may be located at proximal and/or distal levels. The findings presented in this paper correspond to a triple communication, since two branches extended from the median musculocutaneous nerve, and one extended from the median to the superior communicating branch of the musculocutaneous nerve were found (Fig. 3). This is similar to type 4 of the Le Minor classification (Le Minor, 1990), in which the musculocutaneous fibers join the lateral root of the median nerve and, after a certain distance, the musculocutaneous nerve arises from the median nerve. In our case, the first impression was that due to the fascial tissue that united both nerves (Fig. 2), however when removing the tissue, it was confirmed that both nerves were independent and the case corresponded to a path of the musculocutaneous nerve through the brachial duct.

According to Guerri-Guttenberg & Ingolotti classification, our case can be described as musculocutaneous nerve originating from the lateral fascicle of the brachial plexus. The musculocutaneous nerve does not perforate the coracobrachial muscle and presents two or more communications, both at the proximal and distal level with the median nerve.

Clinical implications. According to the literature, variations of the scalene muscles may include accessory fascicles, modification of muscle insertions and alteration of anatomical relations.

Accessory fascicles between the anterior and middle scalene muscles are significant in light of their relation with the brachial plexus, the subclavian artery and eventual neurovascular compression on these structures (Harry *et al.*; Jones *et al.*, 2019). Compression of these structures may occur at the cervical level and cause neurological and/or vascular symptoms toward the upper limb (Jones *et al.*). This condition affects between 0.3 and 8 % of the North American

population (Molina & D'Cuhna, 2008). 90 % of cases are due to neurovascular causes and the onset of symptoms usually occurs between 20 and 50 years of age; prevalence is higher in women (Jones *et al.*).

In our opinion, absence of the musculocutaneous nerve is critical and as relevant as path variations. In each case the dissector will come across such atypical situations and will have to carefully scrutinize between tissues, to locate the origin and innervation pattern of the anterior brachial region, thus avoiding unintended iatrogenesis and lacerations during dissection.

Regarding the nerve distribution. Considering the various types of anomalies, medical procedures may not always provide the desired results. Thus, thorough knowledge of the number of nerves in a muscular belly and their point of entry, may very well improve the administration of therapies. For instance, in cases of trigger point dry needling, or during electric muscle stimulation, may achieve better response in muscle fiber contraction.

Finally, we believe it is important to highlight the findings of this study. Given that we did not find previous reports in the literature, the discovery of these two variations simultaneously, is noteworthy. Particularly relevant and which Sirico *et al.*, pointed out, when there are variations in the supraclavicular portion of the brachial plexus, it is more likely to find a mixed variation involving other variations along the same plexus. The aforementioned may determine the appearance of atypical signs and symptoms, and also influence therapeutic practices.

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FARFÁN, C. E.; ECHEVERRÍA, M. M.; INOSTROZA, R. V.; SCHNEEBERGER, L. D. & INZUNZA, H. O. Anomalía posicional entre el plexo braquial y el músculo escaleno anterior, concomitante con un trayecto anómalo del nervio musculocutáneo. Reporte de un caso e implicancia clínica. *Int. J. Morphol.*, 38(4):845-852, 2020.

RESUMEN: Las variaciones anatómicas de los músculos escalenos son frecuentes, así como también las del plexo braquial

y sus nervios terminales. Sin embargo la literatura científica las presenta por separado. El propósito de este trabajo es presentar una variación de los músculos escalenos concomitante con un trayecto anómalo del nervio musculocutáneo. Disección de rutina de región cervical, axila y región braquial anterior derechas realizada en un cadáver adulto de sexo masculino. Se encontró un fascículo muscular supernumerario para el músculo escaleno anterior que alteraba las relaciones anatómicas de los ramos ventrales C5 y C6 del plexo braquial. Esta variación estaba acompañada por un trayecto anómalo del nervio musculocutáneo, el cual no atravesaba al músculo coracobraquial y transitaba por el conducto braquial acompañando al nervio mediano. Desde allí enviaba a la región braquial anterior ramos musculares y al nervio mediano ramos comunicantes. Las variaciones conjuntas del plexo braquial y los músculos escalenos no se presentan con frecuencia. Conocerlas enriquece la capacidad diagnóstica, terapéutica y quirúrgica. Reduciendo la posibilidad de iatrogenia al intervenir en las regiones cervical, axilar y braquial.

PALABRAS CLAVE: Músculo escaleno anterior; Nervio musculocutáneo; Variación anatómica.

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Corresponding author:

Emilio Farfán Cabello M.Sc. Kigo.

Profesor Asistente

Departamento de Anatomía, Facultad de Medicina
Pontificia Universidad Católica de Chile.

Av. Libertador Bernardo O'higgins 340

Edificio Pregrado de Medicina 8° Piso

Santiago

CHILE

Email: efarfanc@uc.cl

ORCID: 0000-0002-8819-2945

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