Narrative Review
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A Review of the Typical Course of the Musculocutaneous Nerve into the Coracobrachialis Muscle: Its Variability and Possible Clinical Implications

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Abstract

Objective. This literature review highlights the prevalence of the typical course of the musculocutaneous nerve (MCN) through the coracobrachialis muscle (CB), and evaluates the distance from the entrance point of the MCN to the CB, taking the coracoid process (CP) as a landmark. **Methods.** PubMed (MEDLINE), Scopus, and CINAHL online databases were searched in December 2022 for studies reporting the prevalence of the MCN's typical course and the distance between the CP and the MCN entrance point to the CB. **Results.** Twenty-eight studies were included (including 2846 subjects) investigating the MCN's typical course, and eliciting a prevalence of 93.4%. The mean distance of the CP to the entrance point of the MCN's main trunk into the CB was 5.6±2cm (median 6.1cm, in 550 subjects). In 76.12% of cases the MCN's accessory branches entered the CB proximally to the MCN's main trunk. The mean distance from the CP to the entrance point of the MCN's proximal branches to the CB was 3.8±1.2cm (median 3.7cm, in 140 subjects). **Conclusion.** In the vast majority of cases, the MCN had a typical course through the CB. In cases of altered anatomy, the MCN was either absent or passed medially to the CB (without piercing it). The average entrance point of the MCN into the CB from the CP is 5.6 cm. Proximal motor branches of the MCN to the CB are common and usually arise at a mean distance of 3.8cm from the inferior border of the tip of the CP. Surgeons should be aware of both the MCN's typical and its atypical course and these distances to avoid possible complications when operating in the area.

Key Words: Musculocutaneous Nerve ▪ Arm ▪ Coracoid Process ▪ Prevalence ▪ Review Literature.

Introduction

The musculocutaneous nerve (MCN) arises from the brachial plexus (BP) lateral cord and contains fibers from the 5th to 7th cervical spinal nerves (C5-C7). It courses posterior to the pectoralis minor muscle, above the subscapularis muscle tendon, and pierces the coracobrachialis muscle (CB). After exiting the CB, it heads downwards between the biceps brachii and brachialis muscles, and crosses the lateral side of the humerus between the brachioradialis and the lower part of the biceps brachii (BB). During MCN's course, it gives off the motor branches to the CB, BB, and brachialis muscles (1, 2). At the elbow joint, lateral to the BB tendon insertion, the MCN becomes the lateral antebrachial cutaneous nerve, innervating the skin on the lateral side of the forearm (1). Several procedures include the mobilization of muscles inserted into the coracoid process (CP), such as CP transfer and fixation to the anterior part of the glenoid for treating anterior shoulder instability with significant bone loss (3-7) – the Bristow-Latarjet procedure and its modifications - and CB transfer in reconstructive surgery (8, 9). The MCN may also be injured, especially by a medial retractor in the standard anterior deltopectoral approach (10, 11). The MCN, before piercing the CB, may give off motor branches proximal to it. These branches are characterized as accessory innervation. Protection of the MCN is crucial in these operations, and so the distance

of CP-MCN penetration into the CB is frequently recorded as between 5-8 cm (1, 3, 12, 13). In addition, MCNs with higher penetration into the CB have also been reported (14-17). The current study reviews the data literature and estimates the prevalence of the MCN's typical course through the CB.

We refer to the atypical course of the MCN in relation to the CB as either the absence of the MCN or its medial course without piercing the CB. On a secondary basis, the distances between the CP and the entrance point of the MCN into the CB, and between the CP and the point of origin of the proximal branches, as well as the safe zone in order to avoid damaging the MCN intraoperatively, are evaluated.

Methods

A narrative literature review was performed in a systematic manner according to the PRISMA (*Preferred Reporting Items for Systematic Reviews and Meta-Analyses*) guidelines (18).

Search Strategy

The narrative literature review was conducted in PubMed (MEDLINE), Scopus, and CINAHL databases, up to December 19th, 2022, to identify eligible studies, through different combinations of the following search terms: "coracobrachialis", "variation", "main trunk", and "proximal branches" (Supplementary Material 1). The research was conducted independently by two researchers (IP and MP) and in the case of any discrepancies, consultation with a third (AS) was sought. The inclusion criteria were the following: *i. cadaveric or surgical or imaging studies, ii. studies reporting both the MCN absence and CB non-perforation, iii. studies reporting measurements between the CP and the entrance point of the MCN's main trunk or proximal branches to CB, iv. studies providing numerical information on the abovementioned measurements, v. studies published in English, Spanish, or Greek*. Hence, studies that did not meet the criteria (such as those that only investigated the MCN's absence or CB non-perforation by the MCN, but not both) were excluded.

Data Extraction

The following data were extracted from each of the eligible studies: i. First author, ii. Year of publication, iii. Type of study, iv. Study population, v. Mean age with standard deviation (SD) and range, vi. The number of cases of the MCN piercing the CB, vii. The number of cases recording the MCN's absence, viii. The mean distance, SD, and range from the CP to the entrance point of the MCN's main trunk to the CB, iv. The mean distance, SD, and range from the CP to the entrance point of the MCN's proximal branches to the CB, v. The number of cases and proportion of the total population with MCN proximal branches, vi. Point of measurement from the CP.

Risk of Bias Assessment

The Anatomical Quality Assessment (AQUA) Tool (19) was used to assess the included studies' quality, reliability and risk of bias. This tool consists of 25 questions, divided into 5 areas: 1. Objectives and Subject Characteristics, 2. Study Design, 3. Methodology Description, 4. Descriptive Anatomy, and 5. Results Reporting. If all questions had affirmative replies in each domain, the risk of bias was rated as 'low', otherwise as 'high'. A study's overall risk of bias was defined as 'low' if all domains were at low bias risk, 'moderate/ some concerns' if at least three domains were at low bias risk, and otherwise as 'low'.

Results

A total of 126 studies were identified, 28 of which were assessed as full-text articles (Figure 1). Out of these, 23 manuscripts (1, 2, 15, 20-38) were used for estimation of the MCN's typical course, 10 (6, 12, 15, 17, 27, 34, 36, 39-41) for calculation of the distance between the CP and the entrance point of the MCN into the CB, and 7 (2, 6, 12, 15, 17, 36, 40), for computation of the distance between the CP and the point of origin of the proximal branches.

Out of the 28 studies included, four studies were considered of low risk of bias, 23 of moderate risk, and one of high risk. The risk of bias analysis for each domain of all the studies is summarized in Figure 2.

The MCN was found to be piercing the CB in a total of 2,661 subjects, leading to estimation of the unweighted prevalence of the MCN's typical course of 93.4% (Table 1). In cases of atypical

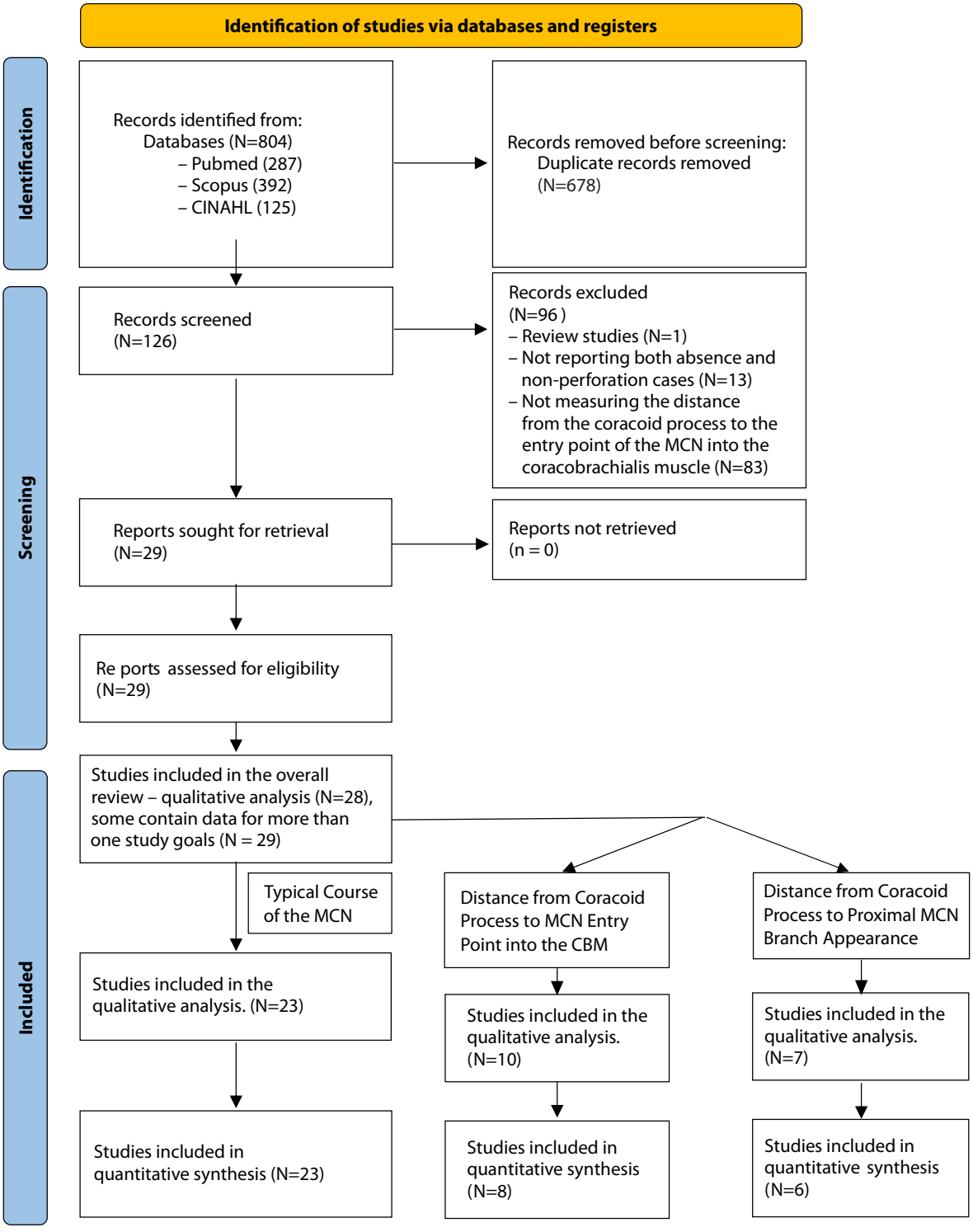

Figure 1. PRISMA 2020 flow diagram for new reviews which included searches of databases and registers only.

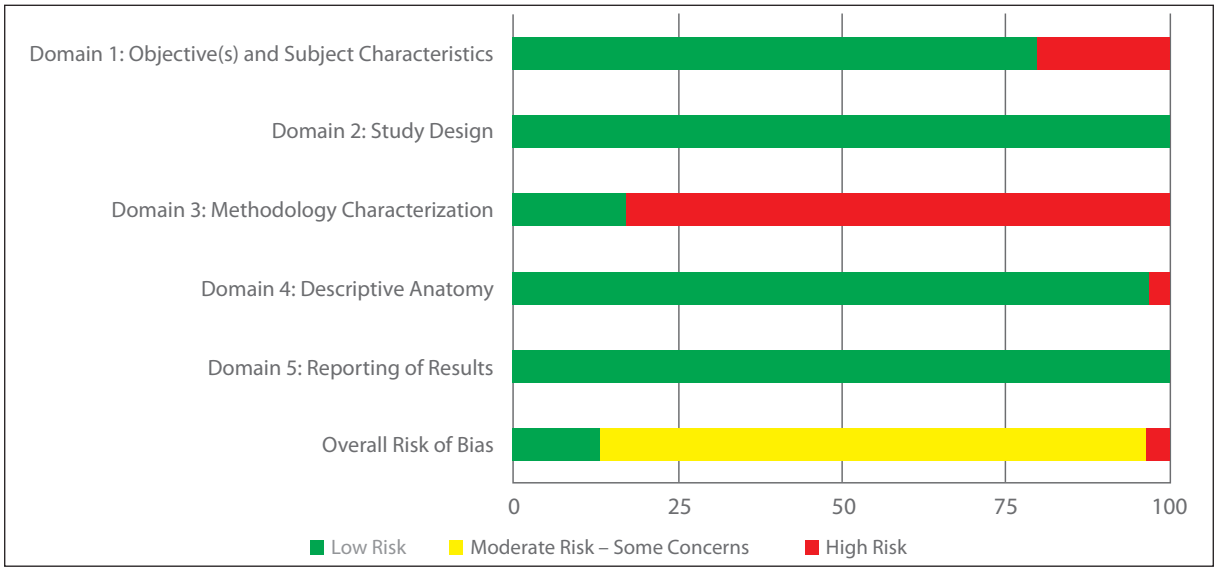

Figure 2. Risk of bias assessment according to the AQUA tool domains.

Table 1. Basic Characteristics of Studies Included (23) in the Review Concerning the Typical Course of the Musculocutaneous Nerve (MCN) in Relation to the coracobrachialis muscle (CB)

Author (s)	Year	Type of Study	Population/ Country	Population (N)	No piercing of CB (N)	MCN absence (N)	MCN typical course (N)	Percentage of typical course
Loukas and Aqueelah (20)	2005	Cadaveric	USA	258	11	1	246	95.3
Maeda et al. (21)	2009	Cadaveric	Japanese	453	10	8	435	96
Patel et al. (22)	2013	Cadaveric	Indian	80	1	2	77	96.3
Venieratos and Anagnostopoulou (23)	1998	Cadaveric	Greek	158	3	-	155	98.1
Ballesteros-Larotta et al. (24)	2018	Cadaveric	Colombian	106	6	4	96	90.6
Claasen et al. (25)	2016	Cadaveric	German	167	3	1	163	97.6
Guerri-Guttenberg and Inglotti (26)	2009	Cadaveric	Argentinian	56	6	2	48	85.7
Ilayperuma et al. (27)	2016	Cadaveric	Sri Lankan	312	52	0	260	83.3
Maiti and Bhattacharya (28)	2018	Cadaveric	India	28	-	-	28	100
Mori (29)	1964	Cadaveric	Japanese	50	3	-	47	94
El-Naggar (30)	2001	Cadaveric	Saudi Arabian	36	3	1	32	88.9
Ozturk et al. (15)	2005	Cadaveric	Turkish	42	0	0	42	100
Padur et al. (31)	2016	Cadaveric	India	82	0	2	80	97.6
Reboucas et al. (2)	2015	Cadaveric	Brazilian	20	0	0	20	100
Uysal et al. (32)	2009	Cadaveric	Turkish	140	4	0	136	97.1
Choi et al. (33)	2002	Cadaveric	British	276	22	0	254	92
Eglseder and Goldman (34)	1997	Cadaveric	USA	54	16	0	38	70.4
Pacha Vicente et al. (35)	2005	Cadaveric	Spanish	46	3	0	43	93.5
Latarjet (1)	1967	Cadaveric	French	106	0	0	106	100
Macchi et al. (36)	2007	In vivo	Ital.ian	69	0	0	69	100
Ferner (37)	1938	Cadaveric	German	167	4	0	163	97.6
Arora et al. (38)	2005	Cadaveric	Indian	100	0	15	85	85
Al-Sobhi et al. (39)	2023	Cadaveric	Saudi Arabian	40	4	1	35	87.5

anatomy, the MCN was either absent or passed medially to the CB without piercing it.

The articles studying the distance from the CP to the entrance point of the MCN's main trunk into the CB included a total of 753 subjects (Table 2). Of those, 550 were included in the analysis and elicited a mean distance of 5.6±2 cm (median 6.1 cm, range 2-11.5 cm). The articles studying the distance of the MCN's proximal branches' origin to the entrance point into the CB included a total of 289 subjects. Of the total population, 76.12% (N=220) had proximal branches of accessory innervation entering the CB. One hundred and forty subjects were eligible for the analysis, eliciting a mean distance of 3.8±1.2 cm (median 3.7 cm, range 1.5-9 cm) (Table 3).

Table 2. Basic Characteristics of the Studies Included (10) Reporting the Distance from the Coracoid Process to the Entrance of the Main Trunk of the Musculocutaneous Nerve (MCN) into the Coracobrachialis Muscle (CB)

Authors	Year	Study type	Population (N)	MCN piercing CB (N)	Length of MCN piercing (cm)			Measurement points of the coracoid process
					Mean	SD	Range	
Clavert et al (6)	2009	Cadaveric	21	21	5.57	1.47	2.20-8.60	The inferior border of the tip
Ilayperuma et al. (27)	2016	Cadaveric	312	260	5.062	2.334	NR	The inferior border of the tip
Ozturk et al. (15)	2005	Cadaveric	42	42	6.20	1.40	3.20-10.4	The inferior border of the tip
Macchi et al. (36)	2007	Cadaveric	12	12	7.70	2.50	3.50-11.5	The inferior border of the tip
Macchi et al (36)	2007	In vivo	69	69	4.60	1.20	2-9	The tip of the CP
Klepps et al. (40)	2001	Cadaveric	20	20	6.10	1.80	3.50-10	The CP
Krassnig et al. (41)	2023	Cadaveric	66	66	7.10	1.80	4-11.10	The inferior border of the tip
Al-Sobhi et al. (39)	2021	Cadaveric	40	36	7.75	1.62	NR	The CP
Singh et al. (17)	2020	Cadaveric	24	24	5.11	1.44	1.67-7.19	The inferior border of the tip
Eglseder and Goldman (34)*	1997	Cadaveric	54	38	4.99	NR	NR	The CP
Flatow et al. (12)*	1989	Cadaveric	93	86	5.60	NR	3.10-8.20	The inferior border of the tip

*Studies not included in the quantitative analysis; N=Value reported in number; SD=Standard Deviation; NR=Not Reported; CP=Coracoid process.

Table 3. Basic Characteristics of the Studies (7) Reporting the Distance from the Coracoid Process (CP) to the Entrance of the Most Proximal Branch of the Musculocutaneous Nerve (MCN) into the Coracobrachialis Muscle (CB)

Authors	Year	Study type	Population (N)	Cases with MCN Proximal Branch (N)	Length of MCN piercing (cm)			Measurement points from the coracoid process exact point
					Mean	SD	Range	
Clavert et al (6)	2009	Cadaveric	21	16	4.06	1.89	1.50-8	The inferior border of the tip
Ozturk et al (15)	2005	Cadaveric	42	42	4.10	1.20	1.70-7.20	The inferior border of the tip
Reboucas et al (2)	2015	Cadaveric	20	20	3.42	0.59	2.38-4.3	The inferior border of the tip
Macchi et al (36)	2007	In vivo	69	29	3.30	0.90	1.50-6.50	The tip of the CP
Klepps et al (40)	2001	Cadaveric	20	16	4.40	1.80	2.10-9.0	The CP
Singh et al (17)	2020	Cadaveric	24	17	3.35	0.81	2.19-4.76	The inferior border of the tip
Flatow et al (12)*	1989	Cadaveric	93	80	3.10	NR	min 1.7	The inferior border of the tip

*Studies not included in the quantitative, N=Value reported in number; SD=Standard Deviation; NR=Not Reported; CP=Coracoid process.

Discussion

The current study provides evidence regarding the MCN's typical anatomy relating to the CB by identifying the prevalence of the MCN piercing the CB, and by calculating the mean distance between the CP and the point where the MCN pierces the CB. Regarding the primary goal of the

current study, in a total of 2,846 shoulders, 93.4% proved to demonstrate the MCN's typical course. In cases of variable anatomy, the MCN was either absent or passed medially to the CB without piercing it.

Developmentally, the MCN derives late during arm development. Disruption in BP differentiation may lead to the MCN's absence (24, 42, 43). In these circumstances, the MCN fibers are fused with the median nerve (MN) in a common trunk, responsible for the anterior arm compartment's motor innervation (21). In embryology "the nerve follows the muscle" and as a result a developmental problem in muscle differentiation also leads to abnormal innervation (24, 42, 43). In the current review, in cases of MCN absence, the CB is usually innervated by the MN's branches, and less frequently by a branch arising directly from the BP's lateral cord.

The CB represents the muscle group of the upper limb adductors. Developmentally, because of human's upright stance, its role became insignificant because gravity contributes to humeral adduction from an abducted position, in conjunction with the latissimus dorsi and the pectoralis major muscles, when active motion is required (30, 44). McMinn and El-Naggar were the first to suggest that the CB is two-headed (30, 44, 45). The superficial (anterior) head originates from the CP, from the medial border of the tendon of the BB's short head, while the deep (posterior) head arises from the lateral border of the BB's short head (CP base) (30). After a short course, the two heads fuse, entrapping the MCN that courses between them. In cases of an MCN that does not pierce the CB, it appears that the CB's deep head is missing. The origin of the CB's two heads from both sides of the short head of the biceps brachii suggests another role for it – that of enhancing the BB, putting the tendon of its short head in the optimal axis for its action (30).

The average distance from the inferior border of the tip of the CP to the entrance point of the MCN's main trunk into the CB is 5.6 cm (median 6.1 cm). The classically described safe zone for the MCN of less than 5 cm from the CP places the MCN in danger. Without considering the MCN's proximal twigs of accessory innervation, three of the studies reported a mean distance of less than 5cm for the MCN's main trunk. MCN injury is one of the classical complications in anterior shoulder instability procedures, that include CP abutment (46-50). Flatow et al (12) reported that in 29% of cases, the MCN entered the CB at a distance less than 5 cm from the CP. This percentage rises to 74.0% in cases of the appearance of proximal branches of the MCN.

Small motor branches to the CB appear in 76.12% of cases, with an average distance of 3.8 cm (median 3.7 cm). Some studies recorded the presence of those accessory branches originating at a high-level position from the MCN's main trunk (12, 17, 36). Although this point needs further investigation, surgeons need to know this correlation when operating in this area, as MCN lesions result in reduced elbow flexion strength and sensory impairment of the forearm's radial aspect.

Limitations of the Study

The main limitation of the current study is the high heterogeneity and the small subject population of some studies. Therefore, combined with the lack of a standard research protocol between the studies, this systematic search of the literature cannot be classified as a systematic review. Moreover, even if it could be statistically plausible to meta-analyze the data to obtain an estimation of the percentage occurrence of the MCN's typical course, these results would not be useful given their poor interpretation ability. Additionally, sensitivity analysis could not explain this heterogeneity and identify possible confounding factors associated with the estimated prevalence – age, type of study, sex, ethnicity, sample size. Another limitation includes the arm position when measuring the distance. Not all studies stated clearly the arm abduction at the point of measurement, which may affect the recorded value, since the MCN is anchored to the CB (8). The proportion of the distance related to the height of the body, or the humeral length can also affect the measurements. Height can affect

interpretation of the measurements, as a measurement of a distance of 5cm from the CP to the piercing point of the CB, with a humeral length of 50 cm, differs from the same measurement with a humeral length of 70 cm. Despite this limitation, because of the large sample in the current review, we believe that the current results can be interpreted as applying to the average human and modified proportionally. Further studies could follow the methodology of Krassnig et al. (41) reporting measurements in numeric values and proportional values according to the humeral length.

Conclusion

The current literature review demonstrated that the unweighted prevalence of the MCN's typical course piercing the CB is 93.4%. The average MCN entrance point into the CB measured from the CP is 5.6cm (median 6.1cm). Small proximal branches of the MCN to the CB are common – in 76.12% of cases - and usually arise at around 3.8cm (median 3.7cm) from the inferior border of the tip of the CP. Surgeons should be aware of the prevalence of the MCN's typical course and these distances to avoid possible complications when operating in the area. Future studies need to be conducted to estimate more precisely the MCN's typical and altered courses, by the inclusion of information such as demographics in the analysis.

What Is Already Known on This Topic:

The musculocutaneous nerve (MCN), on its typical course, arises from the brachial plexus (BP) lateral cord and contains fibers from the 5th to 7th cervical spinal nerves (C5-C7). It courses along the medial aspect of the upper part of the arm, passing above the subscapularis muscle and piercing the coracobrachialis muscle (CB). Variations in this course have been reported, but have not been systematically evaluated. There is lack of current literature systematically reviewing the prevalence of the MCN's typical course into the CB, combining both the MCN's absence and its medial course. Surgeons should be aware of the prevalence of typical and atypical anatomy, to avoid complications.

What This Study Adds:

This narrative literature review summarizes the existing literature, evaluating the variability of the MCN concerning the CB. It demonstrates that the typical course of the MCN exists in 93.4% of the population, which should be taken into consideration in operative procedures around that area. The review also evaluates the average distance from the coracoid process (CP), its tip or its inferior border, to the entrance point of the MCN's main trunk at 5.6cm (median 6.1cm), the presence of small proximal accessory branches from the MCN into the CB in 76.12% and the distance of their appearance from the CP as 3.8cm (median 3.7cm).

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Conflict of Interest: The authors declare that they have no conflict of interest.

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Supplementary Material
Search Terms

Database	Search Term
PubMed	1. ("musculocutaneous"[All Fields] OR "musculocutanous"[All Fields]) AND "coracobrachialis"[All Fields] AND ("distance"[All Fields] OR "distances"[All Fields])
	2. ("musculocutaneous"[All Fields] OR "musculocutanous"[All Fields]) AND "coracobrachialis"[All Fields]
	3. ("musculocutaneous"[All Fields] OR "musculocutanous"[All Fields]) AND (("main"[All Fields] AND ("torso"[MeSH Terms] OR "torso"[All Fields] OR "trunk"[All Fields] OR "trunk s"[All Fields] OR "trunks"[All Fields])) OR (("proximal"[All Fields] OR "proximalization"[All Fields] OR "proximalize"[All Fields] OR "proximalized"[All Fields] OR "proximalizes"[All Fields] OR "proximalizing"[All Fields] OR "proximally"[All Fields] OR "proximals"[All Fields]) AND ("twigs"[All Fields] OR ("branch"[All Fields] OR "branch s"[All Fields] OR "branche"[All Fields] OR "branched"[All Fields] OR "branches"[All Fields] OR "branching"[All Fields] OR "branchings"[All Fields] OR "branchs"[All Fields]))))
Scopus	1. TITLE-ABS-KEY (coracobrachialis AND (variation OR variations)) (ALL (musculocutaneous) AND ALL (coracobrachialis) AND ALL (distance))
	2. (ALL (musculocutaneous) AND ALL (coracobrachialis))
CINAHL	1. TX musculocutaneous AND TX coracobrachialis AND TX distance
	2. TX musculocutaneous AND TX coracobrachialis
	3. TX musculocutaneous AND TX ((main trunk) OR (proximal AND (twigs OR branches)))