VIA MEDICA

ORIGINAL ARTICLE

Folia Morphol.
Vol. 64, No. 2, pp. 101–108

ISSN 0015–5659
www.fm.viamedica.pl

Musculocutaneous and median nerve connections within, proximal and distal to the coracobrachialis muscle

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[Received 6 April 2004; Revised 21 February 2005; Accepted 22 February 2005]

During dissection of the brachial plexus variations have frequently been observed in the formation and further ramification of the cords to form the musculocutaneous and median nerves (MCN and MN). The present study was undertaken to localise the connections (the communication pattern) of the MN and the MCN with respect to the point of entrance of the MCN to the coracobrachialis muscle.
A total of 129 formalin-fixed cadavers were dissected for this purpose. For simplicity we classified the communication patterns as Types I, II, III and IV. In 82 (63.5%) of 129 cadavers 119 communications were found to be present. We were able to identify 4 different patterns of communication. Type I (54 communications, 45%): the communications were proximal to the point of entry of the MCN into the coracobrachialis, Type II (42 communications, 35%): the communications were distal to the point of entry of the MCN into the coracobrachialis, Type III (11 communications, 9%): the MCN did not pierce the coracobrachialis and Type IV (9 communications, 8%): the communications were proximal to the point of entry of the MCN into the coracobrachialis and additional communication took place distally.
Precise knowledge of variations in MCN and MN communications may prove valuable in traumatology of the shoulder joint, as well as in plastic and reconstructive repair operations.

Key words: musculocutaneous nerve, median nerve, coracobrachialis muscle, communications, connections, brachial plexus

INTRODUCTION

The musculocutaneous nerve (MCN) and median nerve (MN), are two of the 4 terminal nerves of the brachial plexus. Typically, the MCN extends from the lateral cord opposite the lower border of the *pectoralis minor*, pierces the coracobrachialis and descends laterally between the biceps and brachialis to the lateral side of the arm. It innervates the coracobrachialis, both the heads of the biceps brachii and the brachialis. The branch to the coracobrachialis leaves the MCN before it enters the muscle; its fibres are from C7 and may branch directly from the lateral cord. After the MCN pierces the coracobrachialis it will descend further, branching off to supply the biceps and brachialis muscles [13].

The typical course of the MN is also of importance to this study. Initially, the MN enters the arm lateral to the brachial artery. Near the insertion of the coracobrachialis it crosses in front of the artery

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and descends medially to the cubital fossa. At this point it lies posterior to the bicipital aponeurosis and anterior to the brachialis [3].

Various authors describe variations of the course, distribution and branching pattern of MCN. However, the connecting patterns with MN at the coracobrachialis levels are unknown.

In "Gray's anatomy" [13] the MCN is described as having frequent variations. Possible variations include the MCN running behind the coracobrachialis, or adhering to the MN for some distance and passing behind the biceps brachii muscle. Communications between the MCN and MN have been observed as fibres of the MN actually running in the MCN and less frequently in the opposite direction [3]. Our study focuses on the frequency and classification of these types of connection (or communication) in the region of the brachial plexus and proximal to the piercing of the coracobrachialis by the MCN.

It is clinically important to classify brachial plexus communications for surgeons executing plexus repair. In Osborne's paper of MCN repair surgical procedures, the goal was to repair injuries to the MCN and restore proper skeletal muscle function [8]. This requires an awareness of the branching and course of the MCN from the brachial plexus. Also critical for such repair operations is recognition of the possibility that communications with the MCN and the MN itself may also require reconstruction, since fibres from the MCN have a tendency to run with the MN [4]. For this reason we examined a series of cadavers and analysed the connection patterns between the MCN and MNs within, proximal and distal to the coracobrachialis.

MATERIAL AND METHODS

Our study is based on anatomical dissections of 129 cadavers, which provided 258 arms and brachial plexuses. The specimens were of both sexes, 100 male and 29 female and ranged in age from 48 to 78 years old with a mean age of 69 years. 100 cadavers were examined during the "Human Body" course at Harvard Medical School, throughout the academic semesters of 2001, 2002 and 2003. The final 29 cadavers were examined during the anatomy course at the American University of the Caribbean School of Medicine during the winter and summer semesters of 2003. All the cadavers were fixed in 4% formalin, phenol and alcohol solution and routinely dissected by first-year medical students.

In order to obtain a clear field for visualisation of the brachial plexus and particularly the MCN, MN and coracobrachialis muscle, the following structures were removed: *pectoralis major* was dissected proximal to its insertion and reflected medially, *pectoralis minor* was removed at its origin along the ribs and reflected superiorly and the axillary vein was identified at the axilla and reflected medially.

The dissected specimens were analysed with the aid of digital image analysis as previously described by the authors [14]. For the analysis all the dissected specimens were recorded with a Sony digital camera (model: Sony Cyber-Shot DSC-f717) and studied using a computer-assisted image analysis system (all measurements were carried out with the Lucia program (1998 edition for Windows), made by Nikon (Laboratory Imaging Ltd., Precoptic Co., Medical and Optical Instruments, Poland). The purpose of the software was to allow easy and accurate translation of pixel differences into metric measurements.

Where possible, we measured the distance from the origin of the connection of the MCN with the MN to their termination. The origin of each MCN connection was also measured in relation to the coracobrachialis muscle. All measurements were carried out with the Lucia program. Our results were analysed with Student's t-test (Table 1) using Statistica for Windows v. 6.2 and considered statistically significant when values were $p < 0.05$.

RESULTS

We were able to dissect bilaterally the brachial plexuses of 129 cadavers, providing a total of 258 specimens. In all, 82 cadavers contained variations, with bilateral communications in 37 cadavers (45.1%, 74 communications) and unilateral communications in 45 cadavers (54.9%, 45 communications).

To facilitate comparisons between specimens and to analyse various communication patterns between the MCN and MN, the communications were divided into 4 groups (Table 1, Fig. 1). The 119 variations found made up 46% of the 258 specimens. Analyti-

Table 1. Ranges and mean distances seen in each communication pattern (Types I, II, III, IV)

	Range [cm]	Mean distance [cm]	$p < 0.05$
Type I	2.8–6.4	4.6	$p < 0.76$
Type II	2.6–6	4.5	$p < 0.88$
Type III	2.5–5.1	4.3	$p < 0.95$
Type IV	5.2–7.8	6.1	$p < 0.046$

NS — not statistically significant difference

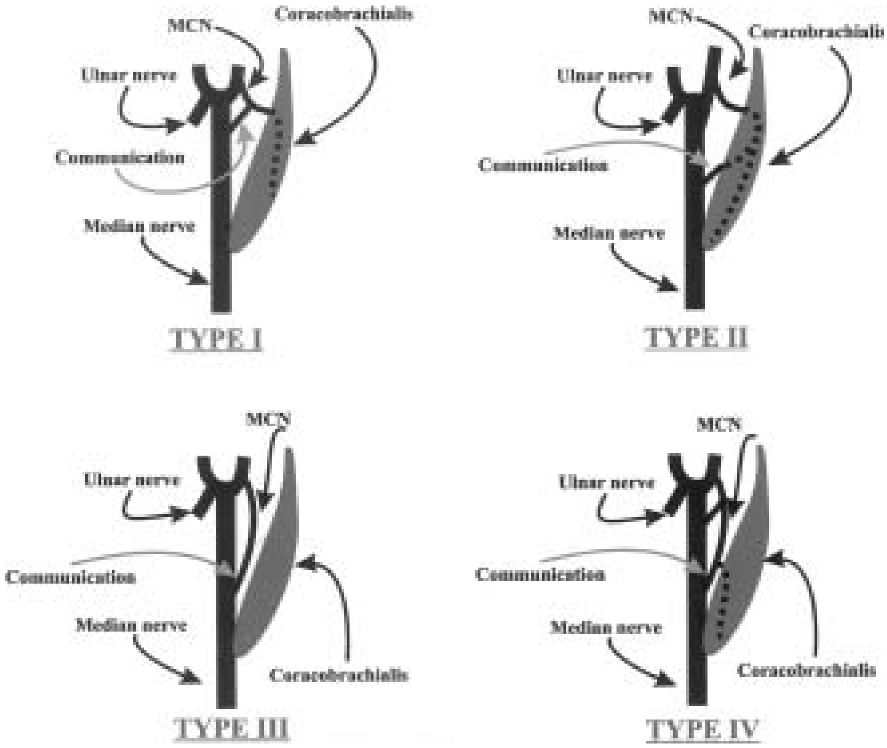

Figure 1. A graphic representation of the 4 main types in the classification of the MCN-median communication.

cally the most frequently observed communication was that of Type I (54/119, 45%). Communications of Type I are defined as being proximal to the point of entry of the MCN into the coracobrachialis (Fig. 2). Before the nerve entered the coracobrachialis a branch to the MN was given off.

In Type II (42/119, 35%) the communications were distal to the point of entry of the MCN into the coracobrachialis (Fig. 3). After the typical course of the MCN through the coracobrachialis, a branch from the MCN was seen leaving from within the coracobrachialis and joining the MN. In Type III (11/119, 9%) the MCN did not pierce the coracobrachialis (Fig. 4). In this instance the MCN gave off branches to the coracobrachialis without piercing the muscle.

Finally, a variation in which both Type I and II coexisted was noted in Type IV (9/119, 8%) (Fig. 5). In this variation the communications were proximal to the point of entry of the MCN into the coracobrachialis and additional communication took place distally. Additionally, variations were found that included combinations of types. Both Type II and III were found in 2 specimens (2/119, 1.7%) and a combination of Type II and IV were found in 1 specimen (1/119, 0.8%) (Fig. 6). The remaining 139 specimens showed no additional communications (Fig. 7).

The distance from the origin of the connection of the MCN with the MN to its termination ranged from 2.5 cm to 7.8 cm with a mean of 4.6 cm. In Table 1 the ranges and the mean distances are seen in each communication pattern (Types I, II, III, IV) and a statistical analysis is given. As can be noted from Table 1, the mean distances of the communicating branches between the different types are very similar, with the exception only of Type IV, in which there is a clear statistical difference with the other types in this distance.

DISCUSSION

To the best of our knowledge Gegenbaur was the first author to investigate variations of communication patterns between MN and MCN [5]. In his study of 28 cases, he classified the communications according to our Type I (20/28, 71.4%) and Type IV (5/28, 17.8%). As our study indicates, he found Type I to be the most prevalent and Type IV the least prevalent but did not observe Types II or III. This same prevalence of Type I, lack of Types II and III and paucity of Type IV is evident in the 6 studies that followed Gegenbaur's work: Testut [9], Villar [12], Vallois [10], Hirasawa [6], Buch-Hansen [1], and Kosugi et al. [7]. All the aforementioned au-

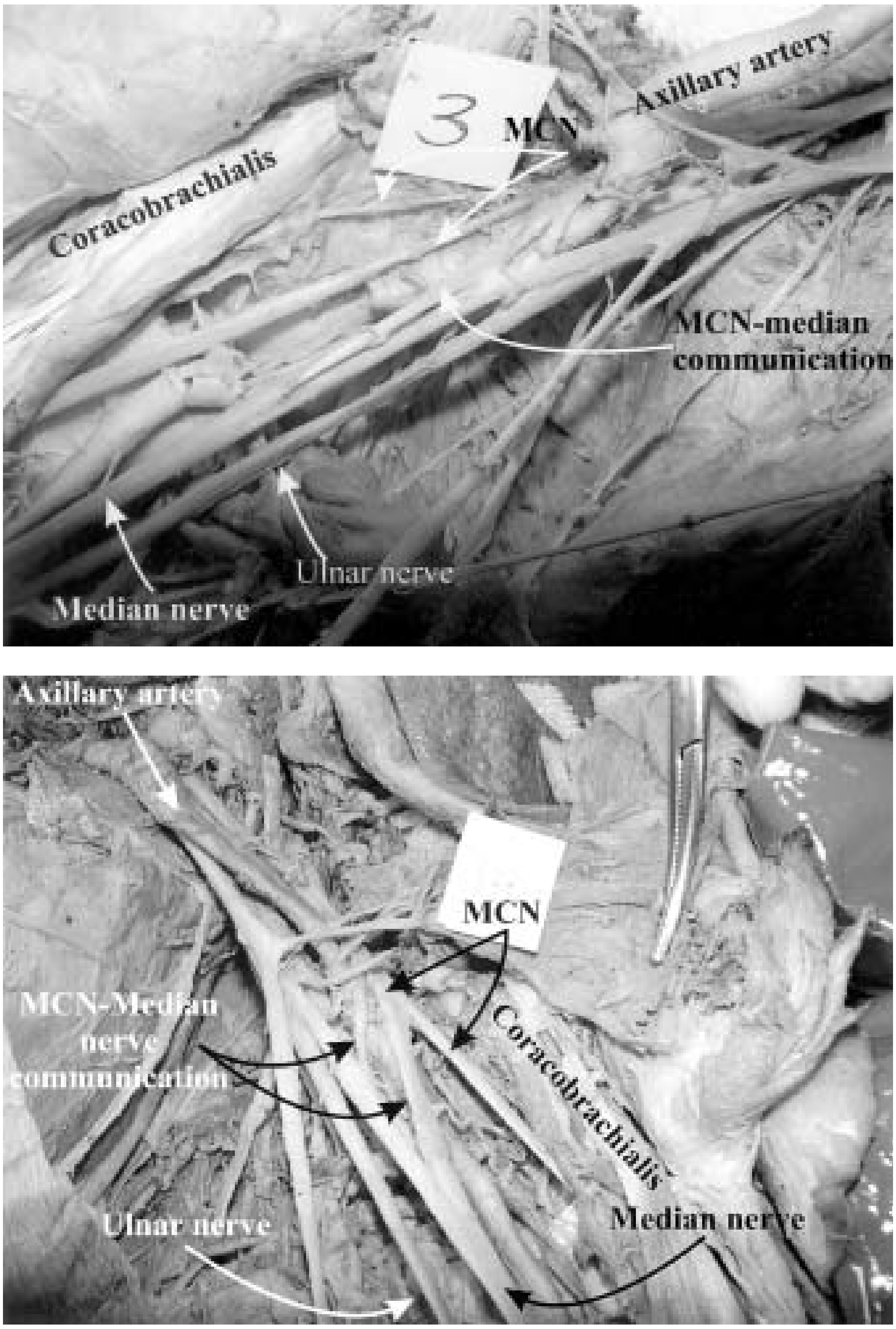

Figure 2. Note the Type I communication between the MCN and MN, which is proximal to the point of entry of the MCN into the coracobrachialis.

thors found in their studies that the majority of the communications were of Type I, few were of Type IV and that there was an absence of Types II or III. The only study to lack Type IV was that of Buch--Hansen [1] in 1955. The precedent set by Gegenbaur alone was followed for classification and not broadened in the description of the MCN and median communications until the study of Venieratos and Anagnostopoulou [11].

The work of Venieratos and Anagnostopoulou [11] was the first study in over 100 years to apply new classifications to the variety of communications seen in MCN and MN communication, as well as reaffirming the prevalence of Type I. Additionally, their study was the only one to find Type II as the most common communication between the MCN and MN. Furthermore, Types I, II and III were observed but they did not find a Type IV, a mixture of types or fusion of the

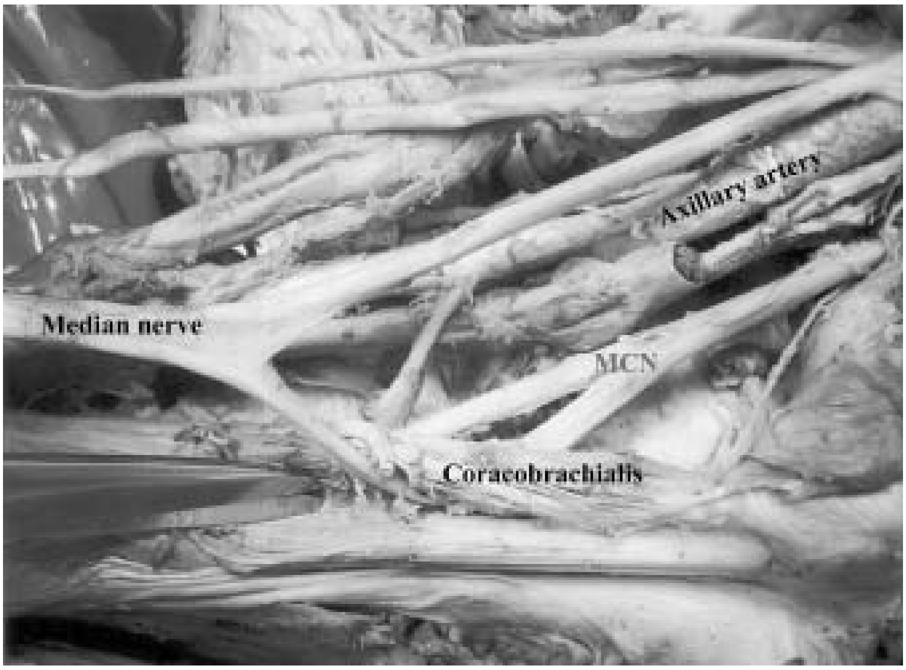

Figure 3. Note that the MCN-MN communications are distal to the point of entry of the MCN into the coracobrachialis.

Figure 4. In Type III the MCN did not pierce the coracobrachialis. In this instance the MCN is giving off branches to the coracobrachialis without piercing the muscle.

MCN and MN. This same study when undertaken by Choi et al. [2] included 73 specimens that were additionally classified by the number of communications between the MCN and MN but lacked Types II and III. Table 2 is a revised version of the data set forth by Choi, which includes our findings in relation to those of past studies of MCN and MN communications, and organised according to our classification.

As seen in the table, it can be concluded that Type I (communications were proximal to the point of entry of the MCN into the coracobrachialis) is continually the most common variation among MCN and

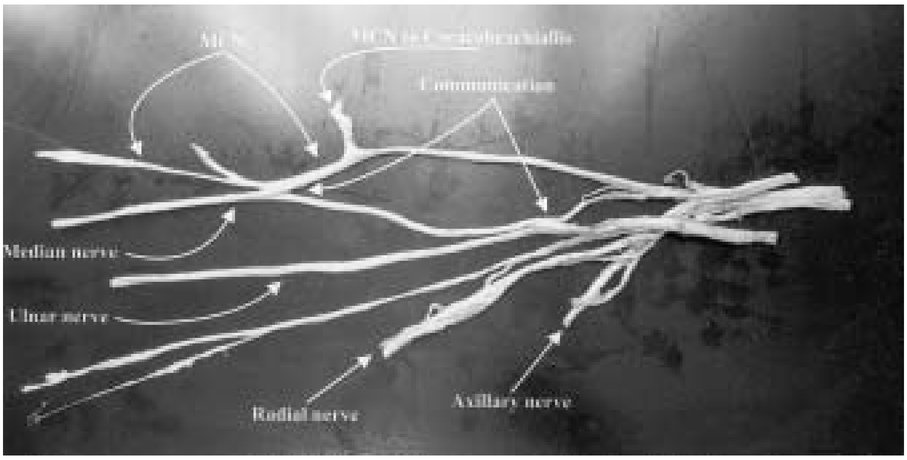

Figure 5. Note that the communications are proximal to the point of entry of the MCN into the coracobrachialis and that additional communications are taking place distally.

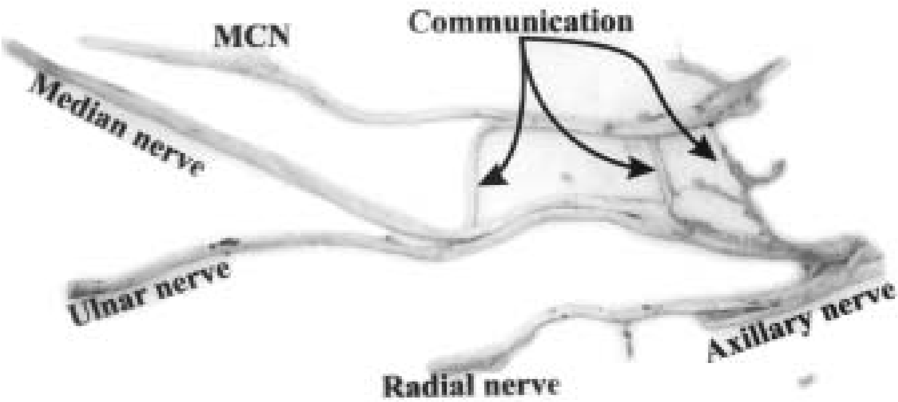

Figure 6. In this case the communications were multiple (3) and we describe it as a combination of Types II and IV.

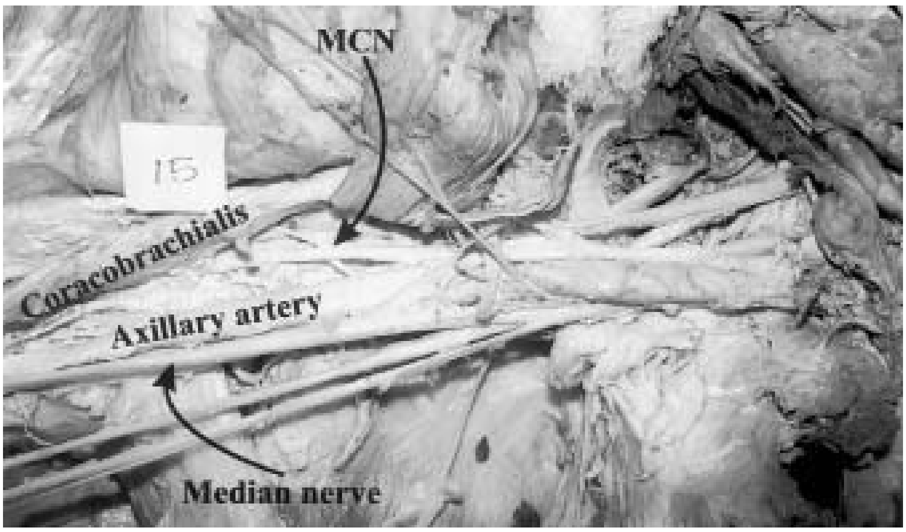

Figure 7. No communication between MCN and MN was identified.

Table 2. Patterns of MCN-MN communication described by previous authors and classified according to our data

	Sample	Cases	Fused	Type I	Type II	Type III	Type IV	Plexus
Gegenbaur [5]	41	28	3	20 (71.4%)	–	–	5 (17.8%)	–
Testut [9]	105	38	6	29 (76.3%)	–	–	1 (2.6%)	2
Villar [12]	37	17	7	9 (24.3%)	–	–	1 (2.7%)	–
Vallois [10]	200	90	11	66 (33%)	–	–	5 (2.5%)	8
Hirasawa [6]	106,123	2,46	2	37 (77.1%)	–	–	9 (18.7%)	–
Buch-Hansen [1]	75	8	2	5 (62.5%)	–	–	–	1
Kosugi et al. [7]	75	43	3	35 (81.4%)	–	–	5 (11.6%)	–
Venieratos and Anagnostopoulou [11]	158	22	0	9 (41%)	10 (45%)	3 (14%)	–	–
Choi et al. [2]	276	73	14	53 (72.6%)	–	–	5 (1.8%)	–
Present study	**258**	**119**	**1 (0.8%)**	**54 (45%)**	**42 (35%)**	**11 (9%)**	**9 (8%)**	**–**
Total	1454	486	49	317	52	14	40	11

Fused — a joining of the MCN and MN; distally they separate; Plexus — refers to the plexiform pattern seen in many connecting branches

MN communications. Our study has taken on the broadest classification of the variable communications made between the MCN and MN. We ourselves have observed all 4 types of communication, further distinguishing the intricacies and complexities of the variations that exist.

The anastomosis between the MCN and MN is by far the most frequent of all the variations that may be observed in the formation and course of the nerves of the brachial plexus [11]. A plausible explanation of this fact is that this frequent anastomosis is equivalent to the presence of a double lateral root of the MN.

Embryologically, the presence of anastomosis may be attributed to random factors influencing the mechanism of formation of the limb muscles and the peripheral nerves. The limb muscles develop from the mesenchyme of seemingly local origin, while the axons of the spinal nerves grow distally to reach the muscles and/or skin. Thus, a lack of coordination between these two processes may lead to the development of multiple variations [11].

Recognition and understanding of these communications is critical in surgical repair to the plexus and shoulder. In a number of cases of MCN reconstruction the nerve has been found divided as a result of operations to stabilise the glenohumeral joint [8]. There is a possibility that communications within the MN itself may also require reconstruction, since fibres from the MCN have a tendency to run with the MN. This may anatomically complicate repair and post-operative retention of brachial function. Relevant to this same region is the necessity to identify and protect the musculocutaneous nerve and its communications in coracoid mobilisation procedures.

Our study has reaffirmed that communication(s) between the MCN and MN are common and their presence must be determined during clinical assessment and repair of the upper limb and brachial plexus. For the particular variation in a given patient to be deciphered, the broadest and most accurate information regarding possible communications must be made available to clinicians.

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