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Changes in the Neurovascular Anatomy of the Shoulder After an Open Latarjet Procedure

Defining a Surgical Safe Zone

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Background: Although previous literature has described the relevant anatomy for an open anterior Bankart approach of the shoulder, there is little known regarding the anatomic relationship changes in the neurovascular structures after an open Latarjet procedure.

Purpose: To define the neurovascular anatomy of the native shoulder in relation to the coracoid and to define the anatomy after the Latarjet procedure in relation to the glenoid to determine distances to these neurovascular structures with and without neurolysis of the musculocutaneous nerve (MCN) from the conjoint tendon.

Study Design: Descriptive laboratory study.

Methods: Fourteen fresh-frozen male cadaveric shoulders (7 matched pairs) were utilized. The distances of 7 neurovascular structures (the main trunk of the MCN at its insertion into the conjoint tendon, the MCN at its closest location to the coracoid process, the lateral cord of the plexus, the split of the lateral cord and MCN, the posterior cord of the plexus, the axillary nerve, and the axillary artery) to pertinent landmarks were first measured in the native state in relation to the coracoid. After the Latarjet procedure, these landmarks were measured in relation to the glenoid. In addition, measurements of the MCN distances were performed both with and without neurolysis of the MCN from the conjoint tendon. All measurements were performed using digital calipers and reported as medians with ranges.

Results: The median MCN entry into the conjoint tendon was 56.5 mm (range, 43.0-82.2 mm) and 57.1 mm (range, 23.5-92.9 mm) from the tip of the coracoid in the neurolysis group and nonneurolysis group, respectively (P = .32). After the Latarjet procedure, the median MCN entry into the conjoint tendon was 43.8 mm (range, 20.2-58.3 mm) and 35.6 mm (range, 27.3-84.5 mm) from the 3-o'clock position of the glenoid in the neurolysis and nonneurolysis groups, respectively (P = .83). The median MCN entry into the conjoint tendon was 35.6 mm (range, 25.1-58.0 mm) and 36.3 mm (range, 24.4-77.9 mm) from the 6-o'clock position in the neurolysis group and nonneurolysis group, respectively (P = .99). After the Latarjet procedure, the closest neurovascular structures in relation to both the 3-o'clock and 6-o'clock positions to the coracoid were the axillary nerve at a median 27.4 mm (range, 19.8-40.0 mm) and 27.7 mm (range, 23.2-36.1 mm), respectively.

Conclusion: This study identified a minimum distance medial to the glenoid after the Latarjet procedure to be approximately 19.8 mm for the axillary nerve, 23.6 mm for the posterior cord, and 24.4 mm and 20.2 mm for the MCN without and with neurolysis, respectively. Neurolysis of the MCN did not significantly change the distance of the nerve from pertinent landmarks compared with no neurolysis, and routine neurolysis may not be indicated. However, the authors still advise that there may be clinical benefit to performing neurolysis during surgery, especially given that the short length of the MCN puts it at risk for traction injuries during the Latarjet procedure.

Clinical Relevance: The findings of this study provide an improved understanding of the position of the neurovascular structures after the Latarjet procedure. Knowledge of these minimum distances will help avoid iatrogenic damage of the neurovascular structures when performing procedures involving transfer of the coracoid process.

Keywords: shoulder; anterior instability; bone loss; Latarjet procedure; coracoid transfer

The Latarjet procedure, which was first described in 1954,[18] has emerged as a common surgical option for recurrent anterior shoulder instability with positive clinical outcomes.[2,15,21,30] Typically, the Latarjet procedure is

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indicated when anterior glenoid bone loss reaches 20% to 25% because this has been reported to be the critical amount of bone loss for which isolated Bankart repair would not suffice to restore anterior shoulder stability in biomechanical studies.[28,29] However, the rates of complications after open coracoid transfer procedures range from 15% to 30%,[4,13,20] with reported neurovascular injuries in 1.8% of cases. Of these, the musculocutaneous nerve (MCN), axillary nerve, and axillary artery are most commonly injured (0.6%, 0.3%, and 0.3%, respectively).[4,13] In a series of 34 patients, Delaney et al[7] also reported that 20% had a transient clinically detectable nerve deficit (all axillary nerve) after the Latarjet procedure, while 77% of patients had a nerve alert while using neuromonitoring intraoperatively.

The relevant anatomic landmarks for the Latarjet procedure or other anterior approaches to the shoulder joint have been described,[1,6,10,14,17,19] with the majority focusing on the anatomy of the MCN before surgical intervention.[1,10,17] In addition, to the best of the authors' knowledge, one study measured the preoperative and postoperative relationship of the MCN to the coracoid process after the Latarjet procedure,[6] while another measured the axillary nerve, axillary artery, and MCN after the Latarjet procedure in relation to the glenoid.[10] Thus, there is a paucity of quantitative descriptions of the distances of relevant neurovascular structures to pertinent landmarks in the native state and how these distances change in relation to the coracoid and glenoid after an open Latarjet procedure. Quantification of the distances of these structures to the coracoid and glenoid may help to decrease complications during primary or revision Latarjet procedures by providing a minimum safe distance for surgical dissection.

Many surgeons advocate performing neurolysis of the MCN to allow for further mobilization of the nerve and thereby diminish the neurovascular risks when performing a coracoid transfer procedure. Therefore, the purpose of this study was to define the neurovascular anatomy of the shoulder in the native state and after the Latarjet procedure with and without neurolysis of the MCN. Our first hypothesis was that there would be consistent and reproducible distances to identify the important neurovascular structures for the native and postoperative shoulders. In addition, we hypothesized that there would be no difference in the position of the MCN with and without neurolysis.

METHODS

Study Design

Seven matched pairs (n = 14) of fresh-frozen male cadaveric shoulders with a mean age of 53 years (range, 35-68 years) were used in this study. Two additional cadaveric shoulders were used for pilot testing to identify landmarks and to define and standardize the testing protocol. The cadaveric specimens utilized in this study were donated to a tissue bank for the purpose of medical research and then purchased by our institution.

All shoulders were analyzed in both the native state and after the Latarjet procedure. In addition, 2 groups—(1) neurolysis of the MCN from the posterior aspect of the conjoint tendon and (2) the MCN left in situ without neurolysis—were analyzed for differences in the location of the neurovascular structures. The matched shoulders were randomly assigned to each group.

Specimen Preparation

The overlying skin and subcutaneous tissue of the shoulders were removed to facilitate exposure. To best approximate the physiological tension of the neurovascular structures and to maintain the normal position and anatomy of the shoulder, a pin was drilled through the clavicle to the scapula to rigidly secure the clavicle in an anatomic position, and sutures were used to secure the neurovascular structures proximomedially. A deltopectoral approach was then performed to identify the coracoid process and conjoint tendon (short head of the biceps brachii and coracobrachialis) at its origin to the tip of the coracoid process. The pectoralis minor was sharply dissected off the coracoid process medially with a No. 15 blade and reflected to expose the underlying neurovascular structures. Proceeding with fine dissection utilizing tenotomy scissors, we identified the following neurovascular structures with the goal of minimizing any displacement during dissection: the main trunk of the MCN where it penetrates the coracobrachialis muscle, the MCN at its closest location to the coracoid process, the lateral cord of the plexus, the split of the lateral cord and MCN, the posterior cord of the plexus, the axillary nerve, and the axillary artery (Figures 1 and 2). All structures were measured in the inferomedial direction with the shoulder in neutral position and the humerus fixed at the side as well as measured at the shortest distance in reference to the relevant bony surgical landmarks.

For the 2 groups, the neurolysis group involved standard neurolysis of the MCN performed during the Latarjet procedure in which the nerve was meticulously released from all fascial attachments on the posterior aspect of the conjoint tendon down to its insertion into the conjoint tendon.[22] In the nonneurolysis group, the MCN was left in situ without neurolysis. The conjoint tendon was released from fascial attachments to the capsule to mobilize the

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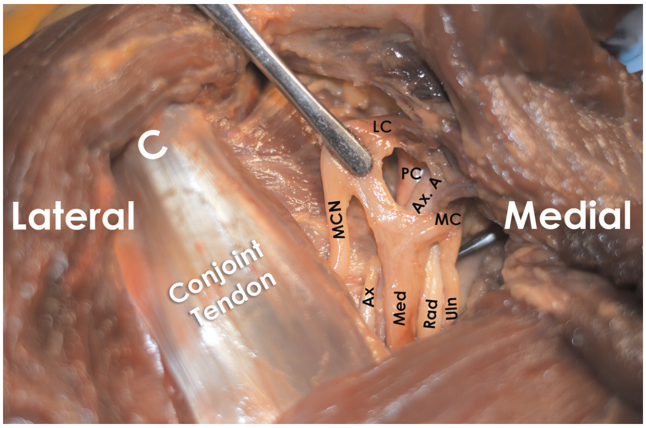

Figure 1. Cadaveric dissection of a right shoulder demonstrating the anatomic relationship between neurovascular structures and the coracoid process: the main cords of the brachial plexus (medial [MC], lateral [LC], and posterior [PC]) along with the trunk of the musculocutaneous nerve (MCN) and its insertion into the conjoint tendon. Additionally, the axillary nerve (Ax) and axillary artery (Ax. A) and median (Med), radial (Rad), and ulnar (Uln) nerves are shown.

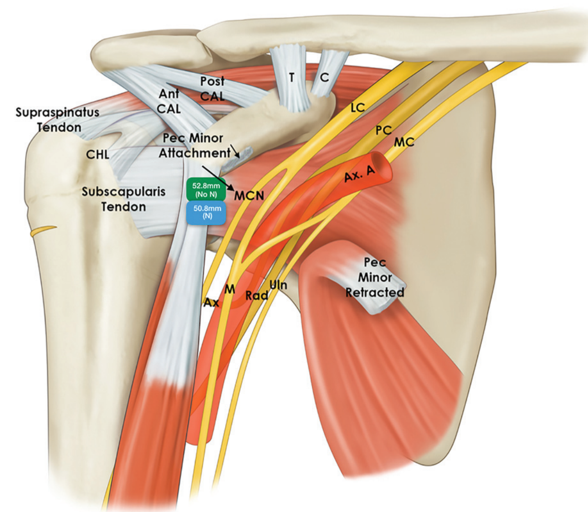

Figure 2. Illustration of the relevant measured neurovascular structures in the native anterior right shoulder. The medial (MC), lateral (LC), and posterior (PC) cords along with the musculocutaneous nerve (MCN) and its trajectory into the conjoint tendon. Additionally, the axillary nerve (Ax) and axillary artery (Ax. A) and median (Med), radial (Rad), and ulnar (Uln) nerves are shown. Ant CAL, anterior band of the coracoacromial ligament; C, conoid ligament; CHL, coracohumeral ligament; post CAL, posterior band of the coracoacromial ligament; T, trapezoid ligament.

tendon and the coracoid bone block for the Latarjet procedure, and this was performed in a similar fashion in both the neurolysis group and nonneurolysis group.

Measurements were first performed in the native state, after pectoralis minor release, using digital calipers as previously reported in the literature, with the scapula rigidly fixed in a custom-made clamp and the arm on the side and the shoulder in neutral rotation.[1,6,14] These digital calipers have a manufacturer-reported accuracy of 0.025 mm (Swiss Precision Instruments). Two authors (C.M.L. and A.S.B) performed the measurements twice, and interobserver reliability was calculated from the mean of these 4 measurements. All measurements of the neurovascular structures (Table 1) were made in reference to 2 landmarks of the coracoid process: the tip at the most anterior point of the coracoid, and a point 23 mm proximal to the edge at the location of the osteotomy site for the coracoid cut. This 23-mm distance was based off of the senior author's (R.F.L.) clinical practice for performing the Latarjet procedure and is also consistent with previous studies that performed osteotomy between 20 and 25 mm from the tip of the coracoid.[5,26-28] Measurements to the glenoid were not able to be performed at this point because it would have disrupted the approach for the Latarjet procedure.

Next, the Latarjet procedure was performed using the classic technique through a subscapularis split and with the inferior aspect of the coracoid placed flush with the face of the glenoid.[9,12,23] The coracoacromial ligament was cut sharply with a No. 15 blade, 1 cm lateral to its insertion on the coracoid, so that a sleeve of the coracoacromial ligament would be available for repair as described in the classic technique.[22] A 90° oscillating saw was used to perform osteotomy 23 mm proximal to the anterior tip of the coracoid process. The conjoint tendon was left attached to the coracoid process. The inferior surface of the coracoid was decorticated with a 10-mm fine sagittal saw in a standard fashion before fixation. A subscapularis split was created sharply in the midpoint of the subscapularis tendon and continued through the anterior joint capsule to facilitate exposure of the anterior glenoid defect.[22] To simulate a clinically relevant defect that remains unstable after Bankart repair,[28,29] a 6-mm bony glenoid defect was created starting between the 3-o'clock and 5-o'clock positions of the glenoid, and the cut was made parallel to the long axis of the glenoid with an oscillating saw. Digital paper templates using a true-circle technique[16] were utilized to ensure that the same-sized osteotomy site was made for each specimen.[8,24] With use of a clamp, the coracoid was drilled in a lag fashion, and an offset guide was utilized to ensure that the bone block was flush with the glenoid face before fixation. The coracoid bone block was then fixed into place using two 3.75-mm cannulated fully threaded metal screws and suture washers (Glenoid Bone Loss Set; Arthrex) (Figure 3).

After the Latarjet procedure, measurements were performed to the neurovascular structures using the same protocol as with the native state, with the scapula rigidly fixed in a custom-made clamp and the arm on the side and the shoulder in neutral rotation. For the Latarjet procedure state, the 3-o'clock and 6-o'clock positions of the newly reconstituted glenoid were utilized as the relative bony landmarks. These positions reflected the location of structures of interest after coracoid bone transfer and fixation (Figure 4). To determine the 3-o'clock and 6-o'clock

TABLE 1
Preoperative and Postoperative Measurements of the Neurolysis and Nonneurolysis Groups[a]

	Preoperative, mm				Postoperative, mm			
	Nonneurolysis: Coracoid		Nonneurolysis: Osteotomy Site		Nonneurolysis: 3 o'clock		Nonneurolysis: 6 o'clock	
	Median (Range)	Mean ± SD	Median (Range)	Mean ± SD	Median (Range)	Mean ± SD	Median (Range)	Mean ± SD
Entry of MCN	57.1 (23.5-92.9)	54.6 ± 22.4	64.0 (39.9-102.5)	65.4 ± 21.2	35.6 (27.3-84.5)	43.9 ± 20.5	36.3 (24.4-77.9)	39.2 ± 18.0
Closest MCN	52.8 (26.4-66.6)	49.9 ± 15.1	60.7 (42.0-71.5)	57.1 ± 12.2	32.1 (29.3-44.9)	34.4 ± 5.9	31.2 (24.5-41.0)	32.7 ± 5.9
LC	65.3 (39.1-74.0)	60.7 ± 12.1	63.0 (48.4-75.0)	62.7 ± 10.4	38.9 (30.9-54.2)	42.4 ± 9.1	41.6 (35.3-66.2)	44.4 ± 11.0
Split (MCN/LC)	64.5 (44.3-77.9)	60.9 ± 12.5	65.5 (53.6-78.0)	65.6 ± 9.6	40.5 (34.9-52.5)	43.1 ± 6.9	42.9 (36.9-63.0)	44.8 ± 9.3
Posterior cord	53.4 (35.9-73.5)	53.3 ± 14.1	58.9 (41.0-75.7)	55.8 ± 13.4	30.7 (23.6-49.3)	34.0 ± 9.1	35.4 (27.5-51.6)	39.3 ± 9.6
Axillary nerve	50.7 (37.8-64.2)	50.6 ± 8.8	58.7 (47.2-66.3)	57.3 ± 7.3	27.4 (19.8-40.0)	28.3 ± 7.5	27.7 (23.2-36.1)	29.0 ± 4.7
Axillary artery	52.3 (40.9-58.6)	51.1 ± 7.0	57.0 (49.5-65.9)	57.3 ± 6.4	31.1 (25.5-43.9)	32.4 ± 6.2	32.4 (27.9-36.7)	32.2 ± 3.4
	Neurolysis: Coracoid		Neurolysis: Osteotomy Site		Neurolysis: 3 o'clock		Neurolysis: 6 o'clock	
	Median (Range)	Mean ± SD	Median (Range)	Mean ± SD	Median (Range)	Mean ± SD	Median (Range)	Mean ± SD
Entry of MCN	56.5 (43.0-82.2)	59.3 ± 13.8	68.4 (34.5-91.3)	65.7 ± 19.3	43.8 (20.2-58.3)	42.5 ± 14.0	35.6 (25.1-58.0)	39.2 ± 13.1
Closest MCN	50.8 (41.0-75.2)	52.1 ± 10.9	56.8 (48.0-79.2)	58.9 ± 11.1	33.9 (16.9-55.3)	33.1 ± 13.1	33.1 (20.7-53.3)	33.0 ± 10.6

[a]Preoperative measurements of the neurolysis and nonneurolysis groups at the 2 bony surgical landmarks: anterior tip of the coracoid process and osteotomy site 23 mm proximal to the tip. Postoperative measurements of the neurolysis and nonneurolysis groups at the 3-o'clock and 6-o'clock positions on the glenoid. Entry of MCN indicates entry of the MCN into the conjoint tendon, and closest MCN indicates the closest position of the MCN to the structure. LC, lateral cord; MCN, musculocutaneous nerve.

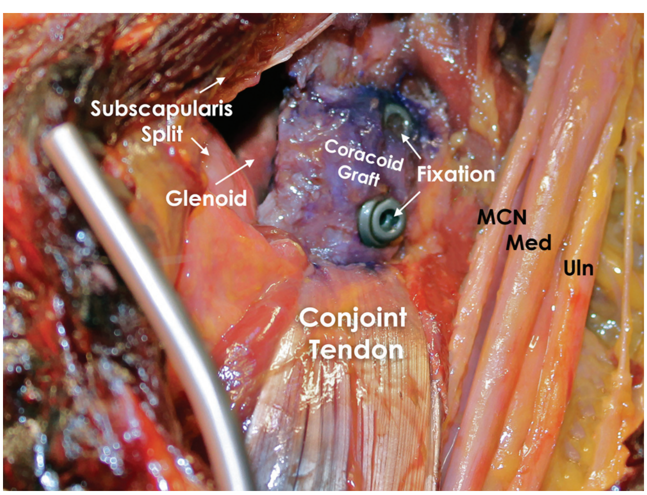

Figure 3. Photograph demonstrating fixation of the coracoid graft in a right shoulder with 2 metal screws in relation to the brachial plexus and other relevant structures (nonneurolysis group). Musculocutaneous nerve (MCN), median nerve (Med), and ulnar nerve (Uln).

positions by 2 perpendicular lines on the major axis of the transverse and longitudinal axes (with a central intersection), the 3-o'clock and 6-o'clock points were marked with a surgical marker to maintain consistency throughout testing.

Statistical Analysis

Anatomic measurements were summarized with medians and ranges. Comparisons between the neurolysis and

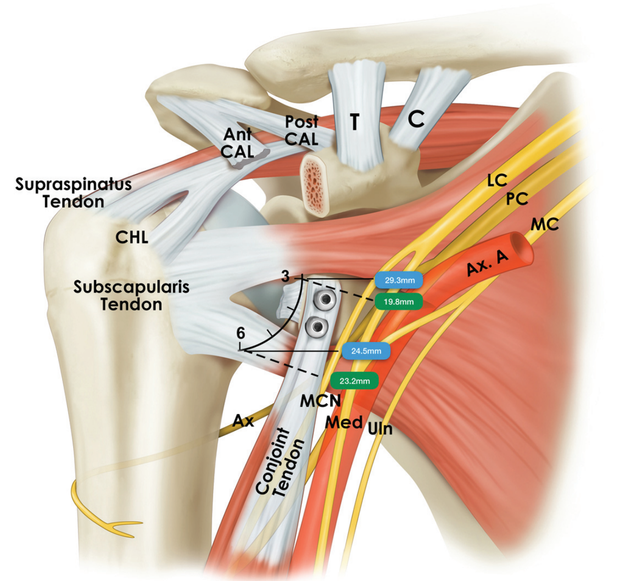

Figure 4. Illustration of the relevant measured neurovascular structures after the Latarjet procedure on a right shoulder. Distances to the musculocutaneous nerve (MCN) (solid lines, light blue) and to the axillary nerve (Ax) (dashed lines, green) are demonstrated. The lateral (LC) and posterior (PC) cords along with the MCN (MC) and its modified trajectory after the Latarjet procedure are demonstrated. Additionally, the Ax and axillary artery (Ax. A) and median (Med) and ulnar (Uln) nerves are also shown. Ant CAL, anterior band of the coracoacromial ligament; C, conoid ligament; CHL, coracohumeral ligament; post CAL, posterior band of the coracoacromial ligament; T, trapezoid ligament.

nonneurolysis groups were made using paired *t* tests. Measurement reliability was assessed with the intraclass correlation coefficient (ICC). The 2-way random-effects, single-measure absolute agreement definition of the ICC was used, and 95% bootstrap CIs were presented. *P* values <.05 were deemed statistically significant. The statistical software R (R Foundation for Statistical Computing) was used for all analyses.[25] For the MCN neurolysis to nonneurolysis comparison, assuming a 2-tailed, parametric, matched-pair comparison of means and an alpha of .05, 7 specimens was sufficient to detect an effect size of 1.3 (Cohen *d*) with 80% statistical power.

RESULTS

All measurements are reported as medians with ranges. For preoperative measurements, intrarater (ICC > 0.96 [95% CI, 0.95-0.98]) and interrater (ICC > 0.88 [95% CI, 0.84-0.92]) reliability were excellent. Also, for postoperative measurements, intrarater (ICC > 0.98 [95% CI, 0.96-0.98]) and interrater (ICC > 0.89 [95% CI, 0.85-0.92]) reliability were excellent.

Preoperative Measurements of Neurovascular Structures to the Coracoid

The MCN was the closest neurovascular structure to the tip of the coracoid in all shoulders. The median closest position of the MCN was 50.8 mm (range, 41.0-75.2 mm) from the tip of the coracoid in the neurolysis group and 52.8 mm (range, 26.4-66.6 mm) from the tip of the coracoid in the nonneurolysis group (*P* = .62) (Table 1). The median MCN entry into the conjoint tendon was 56.5 mm (range, 43.0-82.2 mm) inferior to the tip of the coracoid in the neurolysis group and 57.1 mm (range, 23.5-92.9 mm) from the tip of the coracoid in the nonneurolysis group (*P* = .32).

The closest neurovascular position of the MCN to the osteotomy site of the coracoid in the neurolysis group was 56.8 mm (range, 48.0-79.2 mm) and 60.7 mm (range, 42.0-71.5 mm) in the nonneurolysis group (*P* = .64). The closest neurovascular structures in relation to the osteotomy site were the axillary nerve at 58.7 mm (range, 47.2-66.3 mm), the axillary artery at 57.0 mm (range, 49.5-65.9 mm), and the posterior cord at 58.9 mm (range, 41.0-75.7 mm), respectively.

Postoperative Measurements of Neurovascular Structures to the Glenoid

After the Latarjet procedure, all chosen neurovascular structures were identified and measured inferomedially to the 3-o'clock and 6-o'clock glenoid positions. The closest neurovascular structure in relation to both the 3-o'clock and 6-o'clock positions to the coracoid was the axillary nerve at 27.4 mm (range, 19.8-40.0 mm) and 27.7 mm (range, 23.2-36.1 mm), respectively (Table 1). The posterior cord was also located at 30.7 mm (range, 23.6-49.3 mm) from the 3-o'clock position and 35.4 mm (range, 27.5-51.6 mm) from the 6-o'clock position of the base of the coracoid.

The MCN was the most superficial structure in all shoulders. The closest position of the MCN was 33.9 mm (range, 16.9-55.3 mm) from the 3-o'clock position in the neurolysis group and 32.1 mm (range, 29.3-44.9 mm) in the nonneurolysis group (*P* = .83). From the 6-o'clock position, the closest position of the MCN was 33.1 mm (range, 20.7-53.3 mm) in the neurolysis group and 31.2 mm (range, 24.5-41.0 mm) in the nonneurolysis group (*P* = .93).

The MCN entry into the conjoint tendon was 43.8 mm (range, 20.2-58.3 mm) from the 3-o'clock position of the glenoid in the neurolysis group and 35.6 mm (range, 27.3-84.5 mm) in the nonneurolysis group (*P* = .83). The MCN entry into the conjoint tendon was 35.6 mm (range, 25.1-58.0 mm) from the 6-o'clock position in the neurolysis group and 36.3 mm (range, 24.4-77.9 mm) from the 6-o'clock position in the nonneurolysis group (*P* = .99) (Table 1).

DISCUSSION

The most important finding of this study was the identification of minimum distances from relevant anatomic landmarks both before and after Latarjet coracoid transfer for key neurovascular structures. Neurolysis of the MCN did not significantly change the position of the nerve after the Latarjet procedure, which refuted that portion of our hypothesis. Based on these findings, routine neurolysis of the MCN during the Latarjet procedure may not be indicated. After the Latarjet procedure, the axillary nerve was the closest neurovascular structure to the 3-o'clock and 6-o'clock glenoid positions. This is important for both primary graft fixation and in the event of the need for revision surgery to understand the proximity of the axillary nerve and other neurovascular structures to avoid iatrogenic injuries to these structures. It should be noted that these neurovascular structures may even be closer to the transplanted coracoid after complications following primary Latarjet procedures, particularly after coracoid nonunion or malunion.

The reported rate of neurovascular injuries may be increased with revisions or reoperations, given that all of the 7 neurovascular landmarks measured in this study were close to the surgical bony landmarks of the reconstituted anterior glenoid at 3 o'clock and 6 o'clock. Therefore, the authors believe that the quantitative anatomic relationships from this study will be most valuable for Latarjet procedure revisions or reoperations.

To the best of the authors' knowledge, only 2 previous studies have evaluated the anatomy of neurovascular structures after the Latarjet procedure.[6,11] Clavert et al[6] reported that the average distance from the inferior tip of the coracoid to where the MCN entered the conjoint tendon was 55.7 mm before and 48.6 mm after the Latarjet procedure. Of note, potential differences between Clavert et al[6] and the current study were that Clavert et al[6] used embalmed specimens, and the exact location that they measured on the coracoid after the Latarjet procedure was not explicitly reported. Freehill et al[11] also measured the distance of the axillary nerve, axillary artery, and MCN from the 3-o'clock position of the glenoid after the Latarjet procedure, but they measured in the lateral/medial and superior/inferior directions and did not measure in relation to the closest aspect of the neurovascular structures, which the present authors believe is the most clinically relevant position. It should also be noted that in this current study, the posterior cord and the axillary nerve and artery were all closer in proximity than the MCN without neurolysis for minimum distances to the 3-o'clock glenoid position, demonstrating that these structures may even be at a higher risk for injuries than the MCN after the Latarjet procedure.

The MCN has been reported to be the most commonly injured nerve during open coracoid transfer surgery[13] and the most superficial neurovascular structure of the brachial plexus. In addition, studies have hypothesized that the short relative length of the MCN puts it at risk for traction injuries during exposure of the Latarjet procedure or with the use of retractors.[3,14] As a result, multiple studies have investigated the anatomy of the MCN.[1,6,10,14,17,19] In this current study, the MCN penetrated the coracobrachialis muscle at a median of 56.5 mm and 57.1 mm from the inferior tip of the coracoid for the neurolysis and nonneurolysis groups, respectively. This was consistent with previous reports that have ranged from 48 mm to 61 mm.[1,6,10,14,17] Therefore, the authors agree with previous studies that, given this study's results and previous studies demonstrating the variability of the MCN, the commonly cited "safe zone" of 5 cm from the coracoid tip to the MCN insertion into the conjoint tendon is likely not applicable to all shoulders.[6,10,14] Furthermore, the median closest aspect of the MCN was 50.8 mm and 52.8 mm from the tip of the coracoid for the neurolysis and nonneurolysis groups, respectively, in the current study. In addition, the minimum closest distance of the MCN to the tip of the coracoid was 41.0 mm and 26.4 mm for the neurolysis and nonneurolysis groups, respectively. Apaydin et al[1] and Lo et al[19] also investigated the distance to the closest aspect of the MCN to the anteromedial portion of the coracoid tip, and they reported that the MCN was a mean of 29 mm and 33 mm, respectively. These are less than in the current study and may be related to differences in cadaveric specimen preparation and study population as described below. Apaydin et al[1] used embalmed specimens and had 40% female specimens, while Lo et al[19] used 5 specimens with 60% being female. This current study used all male specimens to diminish the number of variables in the study, and we theorized that the median distances in an all-male study population may be slightly larger than the distances represented by the female population.

In this current study, we also measured the native distances of other relevant neurovascular structures in addition to the MCN. Two previous studies have also measured the preoperative anatomy of the Latarjet procedure. Hawi et al[14] looked at the relevant arthroscopic anatomy for the Latarjet procedure and reported that the lateral cord, split of the MCN and lateral cord, and posterior cord were 40 mm, 37 mm, and 40 mm, respectively, from the tip of the coracoid before the Latarjet procedure. Lo et al[19] measured the lateral cord, axillary nerve, and axillary artery at 28.5 mm, 30.3 mm, and 36.8 mm, respectively, from the tip of the coracoid in a study of 5 cadaveric specimens. As with the measurements for the MCN, the median distances in this current study were slightly larger and may be related to the all-male population that was used because both previous studies used 60% or more female cadaveric specimens.

The neurolysis and nonneurolysis groups were chosen for this current study given that neurolysis of the MCN is commonly performed during the Latarjet procedure. Neurolysis is commonly performed to decrease tension on the nerve, identify the nerve intraoperatively to decrease iatrogenic injuries, and theoretically position the nerve further away from the coracoid process.[22] In contrast to our hypothesis, performing neurolysis did not significantly increase the distance of the MCN to the coracoid before or after the Latarjet procedure was performed. However, the authors still advise that there may be clinical benefit to performing neurolysis during surgery, especially given that the short length of the MCN puts it at risk for traction injuries during the Latarjet procedure.[3,14]

Limitations in the present study include those that are inherent to a cadaveric study design. This includes the variability of the anatomy of the brachial plexus, which was accounted for in the study design with matched-pair specimens. However, the authors recognize that there may also be some variability between these matched pairs. Also, even though the plexus was sutured proximally to maintain proper tension, the tension may not have been physiological and may have caused changes in the distances measured. Because of the cadaveric model, we are unable to simulate postoperative scarring in the case of a revision procedure. Caliper measurements provided 2-dimensional distance between structures, which may have resulted in an underestimation or overestimation of the true 3-dimensional distance. Because these shoulders had no previous injury, measurements could differ from the real clinical scenario. Additionally, a fixed position of the humerus during quantitative data collection limited the utilization of data at other flexion, rotation, and abduction positions because of the possible distortion of the anatomic relationships. These measurements may be slightly changed with shoulder rotation, and we recommend further studies to evaluate the changes in anatomy at different shoulder rotation angles. Finally, all the analyzed specimens were male to diminish the number of variables in the study. Thus, the measurements might not be representative of the female population.

CONCLUSION

This study identified a minimum surgical safe zone medial to the glenoid after the Latarjet procedure to be approximately 19.8 mm for the axillary nerve, 23.6 mm for the posterior cord, and 24.4 mm and 20.2 mm for the MCN without and with neurolysis, respectively. Knowledge of these minimum safe zone distances will help avoid iatrogenic damage of the neurovascular structures during or after the Latarjet procedure when revision surgery is indicated.

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