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SHOULDER

Effect of scapular external rotation on the axillary nerve during the arthroscopic Latarjet procedure: an anatomical investigation

Felipe Reinares[1] · Jean-David Werthel[1] · Constantina Moraiti[1] · Philippe Valenti[1]

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Abstract
Purpose The first purpose of this study is to measure the distance between the axillary nerve and the exit point of K-wires placed retrograde through the glenoid in the setting of an arthroscopic Latarjet procedure. The second objective is to evaluate whether manual external rotation of the scapula alters that distance.
Methods In seven fresh–frozen specimens, two 2.0-mm K-wires were drilled through the glenoid using an arthroscopic Latarjet retrograde glenoid guide. These were drilled into the glenoid at the 7- and 8-o'clock positions (right shoulders) and at the 4- and 5-o'clock positions (left). K-wires were oriented parallel to the glenoid articular surface and perpendicular to the long superoinferior axis of the glenoid, 7 mm medial to the joint surface. Two independent evaluators measured the distances between the axillary nerve and the exit point of the K-wires in the horizontal plane (AKHS for the superior K-wire and AKHI for the inferior K-wire) and in the vertical plane (AKV). Measurements were taken with the scapula left free and were repeated with the scapula placed at 15° and 30° of external rotation.
Results With the scapula left free, scapular external rotation was 34° ± 2.3°. In this position, the AKHS was 2.5 ± 1.6, 6.3 ± 1.2 mm at 15° of external rotation (ER) and 11.4 ± 1.4 mm at 30° ER. The AKHI distance was 0.37 ± 1.6, 3.4 ± 1.4 and 10.6 ± 2.1 mm, respectively, for the scapula left free, at 15° ER and 30° of ER. The AKV distances were, respectively, 0.12 ± 0.2, 4.9 ± 1.6 and 9.9 ± 1.7 mm. The increase in all distances was statistically significant ($p < 0.001$).
Conclusion Increasing scapular external rotation significantly increases the distance between the axillary nerve and the exit point of the K-wires, increasing the margin of safety during this procedure. Therefore, increased external rotation of the scapula could be an effective tool to decrease the risk of iatrogenic axillary nerve injury.
Level of evidence Cadaveric study, Level V.

Keywords Shoulder arthroscopy · Arthroscopic Latarjet procedure · Axillary nerve · Nerve injury · Shoulder instability

Investigation performed at Ecole de Chirurgie du Fer à Moulin, Paris, France.

✉ Jean-David Werthel
jdwerthel@gmail.com

Felipe Reinares
freinares@gmail.com

Constantina Moraiti
tina.o.moraiti@gmail.com

Philippe Valenti
philippe.valenti@wanadoo.fr

[1] Department of Shoulder Surgery, Institut de la Main, Clinique Jouvenet, 6 Square Jouvenet, 75016 Paris, France

Introduction

The functional results after Latarjet procedure are well documented with a low rate of failure, and complications have been reported in biomechanical studies and clinical series with long-term follow-up [1, 4, 6, 15, 18, 20, 21, 23].

Recently, some authors have described an arthroscopic technique to perform this procedure with encouraging initial results [5, 17]. In these techniques, the bone graft is either fixed with screws or endobuttons. The holes for these are drilled through a retrograde guide in one technique [5] and

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through an anterograde in the other [17]. Drilling through a retrograde guide can represent a risk as the K-wires can exit close to the brachial plexus and to the axillary nerve [5, 16]. In a recent systematic review of 45 studies, Griesser et al. [13] showed that neurovascular complications were identified in 1.2 % of 1721 open and 177 arthroscopic Latarjet procedures. Temporary and permanent axillary nerve injuries represented one-third of these lesions.

It has been hypothesized that modifying the scapula's orientation while drilling through a retrograde guide could prevent the axillary nerve from being at risk by placing it further from the exit point of the K-wires.

The primary purpose of this study is to measure the distance between the axillary nerve and K-wire exit point on the glenoid using a retrograde guide in the setting of an arthroscopic Latarjet procedure. The secondary objective is to evaluate whether manual external rotation of the scapula can modify that distance and decrease the risk of iatrogenic axillary nerve injury.

Materials and methods

Preparation of cadaveric models

Seven fresh–frozen shoulder specimens were obtained from our institutional anatomy laboratory (Ecole de Chirurgie du Fer à Moulin, Paris). Shoulders were included if they had a scar-free shoulder with no medical history of shoulder pathology. Specimen was kept at room temperature for 2 h prior to the procedure and installed in the "beach chair" position, with the upper limb hanging freely in order to allow its mobilization.

The dissection was performed through an extended deltopectoral approach. All skin and subcutaneous tissues were resected in order to expose the anatomical structures. The pectoralis major was retracted medially, and a tenotomy of pectoralis minor was performed in order to expose the brachial plexus and the subscapularis muscle. The axillary nerve was then identified during its oblique course in front of the subscapularis muscle and its horizontal course on the inferior border of the subscapularis muscle.

Surgical procedure

All specimens were instrumented using a novel arthroscopic Latarjet glenoid guide (*Biomet*, *Warsaw*, *IN*). It is a retrograde guide which requires a posterior portal approach (2 cm) through which two, 2.0-mm K-wires are drilled in the glenoid. The portal approach was located 2 cm inferior and 2 cm medial to the posterosuperior angle of the acromion. Through this approach, the posterior fibres of the deltoid were retracted superiorly and the fibres of the

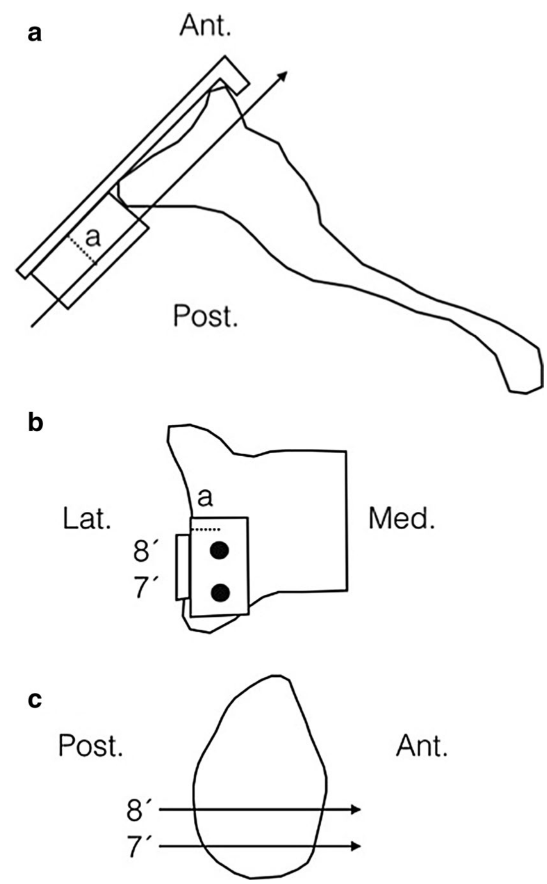

Fig. 1 Position of the K-wire in the glenoid. **a** Superior view of the glenoid guide (distance a: 7 mm. **b** Posterior view of glenoid guide. **c** Lateral view to the glenoid)

infraspinatus muscle were split horizontally in order to perform a small vertical posterior arthrotomy to access the glenohumeral joint. The glenoid drill guide was introduced in the joint through the posterior approach. The two K-wires were drilled into the glenoid at the 7- and 8-o'clock positions in right shoulders and at the 4- and 5-o'clock positions in left shoulders, parallel to the glenoid articular surface and perpendicular to the long superoinferior axis of the glenoid. The guide allows the introduction of the K-wires 7 mm medial to the joint space to fix the coracoid bone graft flush to the anterior margin of the glenoid (Fig. 1).

Measurements

Two measurements (Fig. 2) were taken using a digital caliper (DigiMax, Wiha, Bruges, France) separately by two different blinded observers. First, the distance in the horizontal plane between the tip of the K-wire (anterior to the subscapularis) and the axillary nerve (AKH) was measured. This distance was measured for both the superior (AKHS) and inferior (AKHI) K-wires. The second distance in the

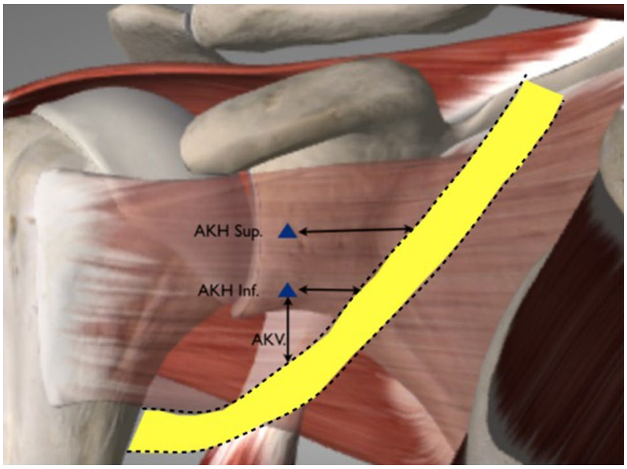

Fig. 2 Schematic drawing of the measurements: the distance in the *horizontal plane* between the tip of the K-wire (anterior to the subscapularis) and the axillary nerve (AKH). This distance was measured for both the superior (AKHS) and inferior (AKHI) K-wires and the distance in the *vertical plane* between the tip of the inferior K-wire and the axillary nerve (AKV)

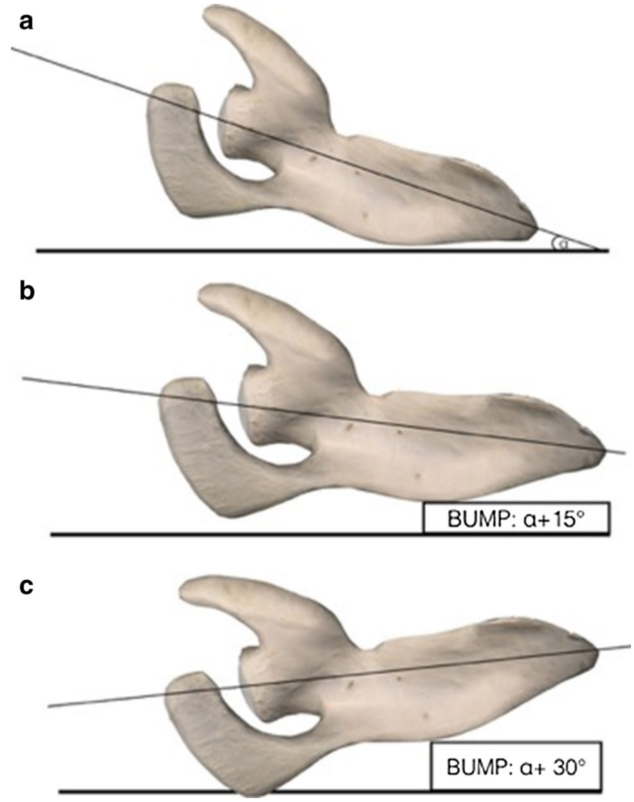

Fig. 3 Measurement of scapular external rotation. **a** Scapula *left* free. **b** Scapula placed at 15° of external rotation. **c** Scapula placed at 30° of external rotation

vertical plane between the tip of the inferior K-wire and the axillary nerve (AKV) was also measured.

The horizontal plane was defined as the plane parallel to the fibres of the middle subscapularis. The AKH distance was positive when the axillary nerve was medial to the K-wire and negative when it was lateral. The vertical plane was defined as the plane between the two K-wires; the AKV distance was positive when the axillary nerve was below the K-wire and negative when it was above.

These measurements were taken with the shoulder in neutral rotation with the scapula left free. Once the measurements had been taken, the K-wires were removed and the scapula was placed at 15° of external rotation using a bump. In this position, the guide was positioned again and the two K-wires were placed as described above. Measurements were taken, and the whole operation was repeated after having placed the scapula at 30° of external rotation. External rotation of the scapula was determined by measuring the angle between the K-wire and the perpendicular to the posterior rigid support of the operating table in the coronal plane of the chest (Fig. 3). In order to validate our method and the accuracy of our measurements in the cadaveric model, all these were performed by two blinded evaluators and interobserver variability was measured.

Statistical analysis

A power analysis was conducted based on a prior estimate of the effect sizes for the outcome variables using a previous feasibility study and the results of a previous study published by Yoo et al. [27]. Assuming a difference in the position of the axillary nerve of at least 10 mm between the different degrees of scapular external rotation, seven specimens provide an 98 % power to detect a significant difference in the position of the axillary nerve at an a-level of 0.05 (Stata 11® for Mac, StataCorp, Texas, USA).

All measurements were taken in millimetres and were presented in measures of position and of dispersion (mean and standard deviation).

The results were compared by subgroups (scapular external rotation) using Student's t tests and multivariate analysis (ANOVA). The Pearson correlation test was used to assess interobserver correlation.

All statistical analysis was performed using Stata 11® (StataCorp, Texas, USA). This was a cadaveric study and all procedures performed in our study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Results

In the "beach chair" position, with the scapula left free and the arm placed in neutral rotation, mean scapular external rotation was 34° ± 2.3°. In this position, the mean distance between the superior K-wire and the axillary nerve in the horizontal plane (AKHS) was 2.5 ± 1.6 mm. In one case (14 %), the K-wire was drilled through the axillary nerve.

The AKHS distance increased as the scapula was placed in external rotation: 6.3 ± 1.2 mm at 15° and 11.4 ± 1.4 mm at 30° of external rotation. No contact between the superior K-wire and the nerves was observed when the scapula was placed at 15° and 30° of external rotation (Figs. 4, 5).

When the scapula was left free, the mean distance between the inferior K-wire and the axillary nerve in the horizontal plane (AKHI) was −0.37 ± 1.6 mm. The inferior K-wire was drilled through the axillary nerve in four cases (57 %) and was found to be 4 mm medial to the nerve in one case (14 %). This distance also was found to increase as the

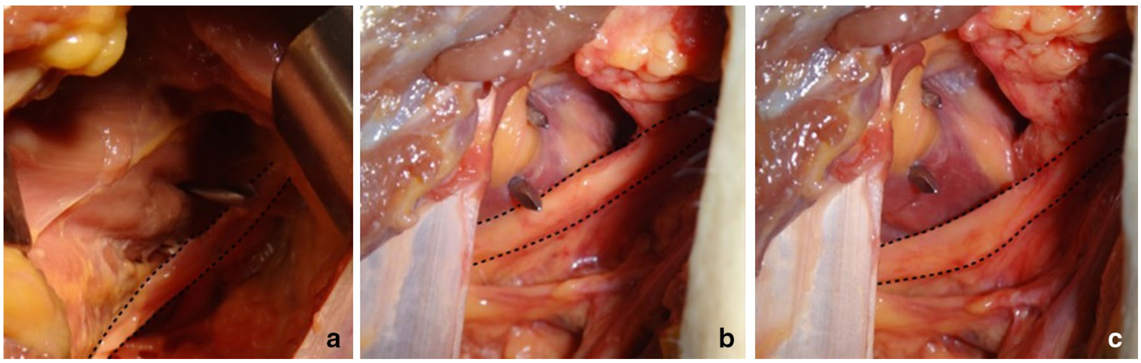

Fig. 4 Cadaveric case N°4. **a** Scapula *left* free. The inferior K-wire is in contact with the axillary nerve. **b** Scapula placed at 15° of external rotation. Significant increase in the distance between the inferior K-wire and the axillary nerve. **c** Scapula placed at 30° of external rotation. Significant increase in the distance between the inferior K-wire and the axillary nerve. The axillary nerve is *highlighted* with a *dashed line*

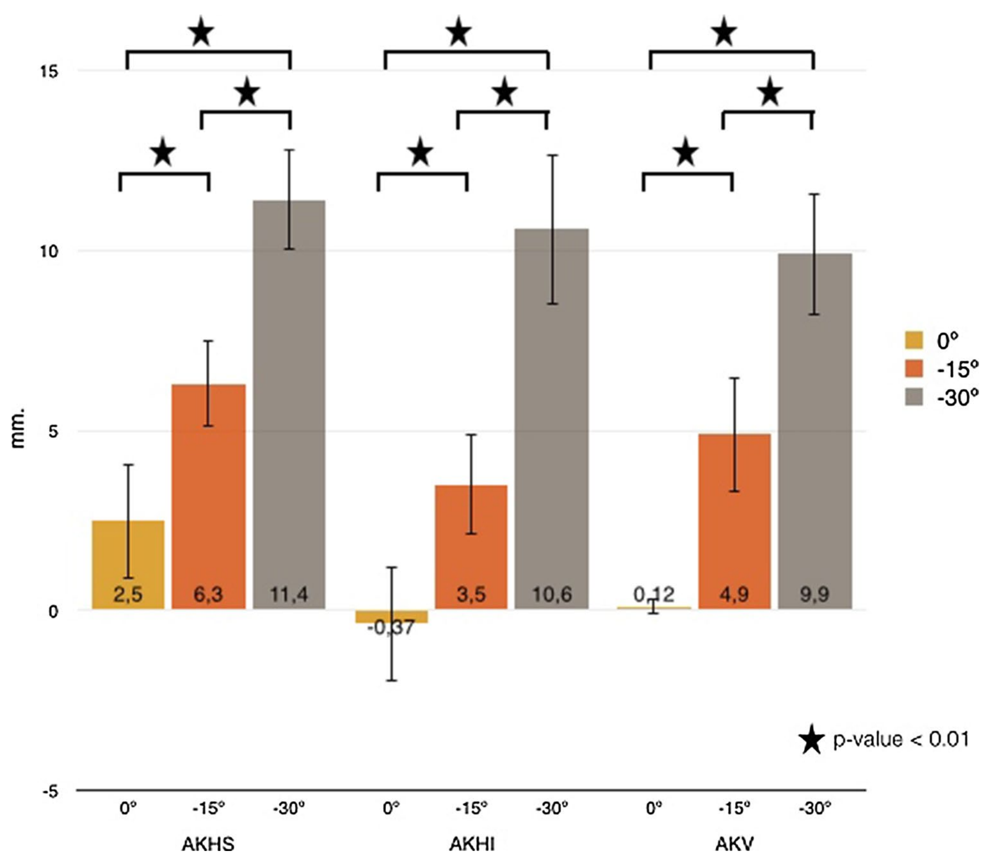

Fig. 5 Different measurements by group (scapular external rotation). Statistically significant increase in the distance in all measurements when the scapula was placed at 15° or 30° of external rotation

scapula was placed in external rotation: 3.4 ± 1.4 mm at 15° and 10.6 ± 2.1 mm at 30°. No contact between the inferior K-wire and the nerve was observed when the scapula was placed at 15° and 30° of external rotation ($p = 0.009$).

When the scapula was left free, the mean distance between the inferior K-wire and the axillary nerve in the vertical plane (AKHV) was 0.12 ± 0.2 mm. Again, placing the scapula at 15° and 30° of external rotation increased this distance to 4.9 ± 1.6 and 9.9 ± 1.7 mm, respectively ($p = 0.002$).

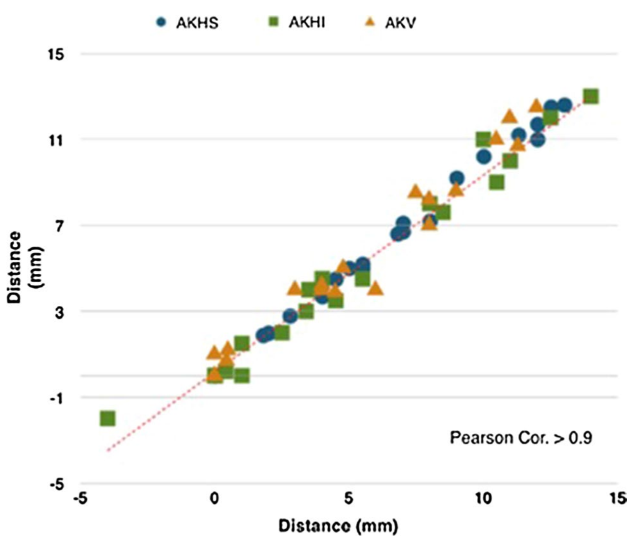

Fig. 6 Interobserver correlation for the different measurements. The Pearson coefficient was >0.9

Interobserver variability was low as the correlation between the measurements of all variables performed by the two observers was very high ($r > 0.9$). The curve obtained is shown in Fig. 6.

The values measured by the two independent observers are listed in Table 1. The mean and standard deviation for each measurement are summarized in Fig. 5, and an example is presented in Fig. 4.

Discussion

The most important finding of this study is that the distance between the axillary nerve and the K-wires varies significantly in both the horizontal and vertical planes when the scapula is externally rotated. This manoeuvre significantly increased the margin of safety when drilling the glenoid tunnels and the securing the coracoid graft.

In a high rate of cases (57 %), the inferior K-wire was directly found to be drilled through the axillary nerve when measurements were taken with the scapula left free. When the scapula was placed at 15° or 30° of external rotation,

Table 1 Distance between the axillary nerve and the K-wires depending on the position of the scapula

	Normal scapular version	AKHS			AKHI			AKV		
		0°	−15°	−30°	0°	−15°	−30°	0°	−15°	−30°
Observer no. 1										
Case										
1	38°	1.8	6.8	11.3	0	3.4	8	0	4	8
2	32°	5	8	12	0.4	5.5	8.5	0.45	6	7.5
3	35°	2	5.5	10	0	4	10	0	8	12
4	34°	2	4.5	12	0	2.5	10.5	0	4	9
5	31°	0	5.5	13	−4	1	11	0	4.5	10.5
6	35°	4	7	9	0	4.5	14	0	3	11
7	33°	2.8	7	12.5	1	3.5	12.5	0.5	4.8	11.3
Observer no. 2										
Case										
1	38°	1.9	6.6	11.2	0	3	8	0	4.2	8.2
2	32°	5	7.2	11	0.2	4.5	7.6	0.7	4	8.5
3	35°	2	5.2	10.2	0	4.5	11	0	7	12.5
4	34°	2	4.5	11.7	0	2	9	0	4	8.6
5	31°	0	5	12.6	−2	0	10	0	3.9	11
6	35°	3.7	7.1	9.2	0	3.5	13	1	4	12
7	33°	2.8	6.7	12.5	1.5	4	12	1.2	5	10.7

AKHS, distance between superior K-wire and axillary nerve in horizontal plane; AKHI, distance between inferior K-wire and axillary nerve in horizontal plane; AKV, distance between inferior K-wire and axillary nerve in vertical plane no contact between the K-wire and the axillary nerve was observed.

Several cadaveric studies described the risk of axillary nerve injury in different shoulder surgical approaches; however, most of them focus on the relationship between the anterior branch of the axillary nerve and the deltoid muscle and the acromion [3, 7, 10, 24, 25]. The axillary nerve has been shown to be situated approximately 1 cm below the inferior rim of the glenoid by Apaydin et al. [2]. Yoo et al. [27] described the relationship between the axillary nerve and the glenoid rim during arthroscopy. They determined that the closest points from the glenoid were between the 5:30- and 6:00-o'clock position in right shoulders or 6:00- and 6:30-o'clock position in left shoulders with a distance ranging between 10 and 25 mm. The position of the arm affected the distance between the glenoid and the nerve [26], and the greatest distance was found when the arm was placed in abduction and neutral rotation. Nourissat et al. [22] published the only study which evaluated the position of the axillary nerve in the mini-open arthroscopically assisted Latarjet procedure. They measured the distance between the axillary nerve and an anterior arthroscopic portal made at the same level as the glenoid surface at the theoretical level of the graft with an inside-out technique. The axillary nerve was found to be 27 mm (range 20–30 mm) medial to the portal on average.

The Latarjet procedure and more recently the arthroscopic Latarjet are increasingly performed in the treatment of anterior shoulder instability [6, 14, 18]. Severe nerve injury has been reported after this procedure because of the close relationship between the brachial plexus and the subscapularis muscle [8, 9]. These relationships have been found to be modified after Latarjet procedure, and this could increase the risk of nerve injury in revision cases [12].

It has been shown that positioning the humerus in external rotation when placing the screws during a Latarjet procedure would minimize the risk of lesion of the suprascapular nerve [19], but the effect of patient positioning in the operating room on the position of the scapula is not clearly known. However, it seems that this position changes whether the patient is placed in the beach chair position or in dorsal decubitus. Most surgeons perform the open Latarjet procedure in dorsal decubitus with a bump under the medial part of the scapula. This places the scapula in external rotation and is probably the reason why the axillary nerve is rarely seen during open Latarjet. This study shows that placing the scapula in external rotation is crucial to prevent severe axillary nerve injuries. During arthroscopic Latarjet, the patient is placed in the beach chair position. In this position, it is also essential to place a bump behind the medial part of the scapula to increase its external rotation in order for the K-wires to exit further from the axillary nerve anteriorly.

The course of the axillary nerve from its origin to the inferior border of the subscapularis is located in a triangle bordered superiorly by the inferior border of the pectoralis minor, laterally by the conjoint tendon and medially by the axillary artery [11]. In this segment, the axillary nerve gives motor branches to the subscapularis. Therefore, it appears essential to remain lateral from the conjoint tendon during the dissection to prevent from any risk of injury of the axillary nerve or its branches. For this reason, we propose to cut the coracoid process only after having performed the split of the subscapularis to preserve the conjoint tendon as a landmark during this surgical step.

This study has several limitations. First, it was performed in a cadaveric model in which the periarticular muscle tone does not exist although this can be obtained intraoperatively by cauterization? of the patient. Secondly, this study did not consider other peripheral nerves that may be affected by this type of procedure such as the musculocutaneous or the suprascapular nerve which have both been described in the literature as a source of potential complications. However, the suprascapular nerve is not at risk in this technique as the K-wires are drilled from posterior to anterior nor is the musculocutaneous nerve as the K-wires exit laterally to the conjoint tendon. Thirdly, cadaveric subjects were not differentiated in genders.

The strength of this study is based on a strict methodology; an analysis of the exact sample size with a power analysis greater than 95 %; the use of interobserver validation of the measures, with rates of correlation greater than 0.9; our intervention (external rotation of the scapula) representing not only a statistical benefit, but also one clear theoretical clinical benefit.

Conclusion

External rotation of the scapula significantly can increase the distance between the position of the coracoid graft and the axillary nerve. Therefore, increased external rotation of the scapula using a bump could be an effective tool to decrease the risk of iatrogenic axillary nerve injury during arthroscopic Latarjet procedure.

Compliance with ethical standards

Disclosures Philippe Valenti receives royalties for shoulder prosthesis design from FH Orthopedics. The other authors, their immediate families and any research foundations with which they are affiliated did not receive any financial payments or other benefits from any commercial entity related to the subject of this article.

Ethical standard Each author certifies that his or her institution approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

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