Optimization of bone-block positioning in the Bristow-Latarjet procedure: A biomechanical study

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\section*{A R T I C L E   I N F O}
Article history:
Accepted 27 March 2014

Keywords:
Bristow-Latarjet
Coracoid graft
Conjoint tendon
Biomechanical test
Shoulder instability

\section*{A B S T R A C T}
\textbf{Background:} In the Bristow-Latarjet procedure, optimal positioning of the coracoid bone-block on the anterior aspect of the glenoid (standing or lying on the glenoid rim) remains debated. A biomechanical study assessed the effect of the position of the bone-block with its attached conjoint tendon on anterior and inferior stabilization of the humeral head.

\textbf{Materials and methods:} The Bristow-Latarjet procedure was performed on 8 fresh cadaveric shoulders. The bone-block size was systematically at 2.5 × 1 × 1 cm. Anterior translation of the humeral head was stress induced under 30-N traction, in maximum external rotation at 0° and at 90° abduction: respectively, adduction and external rotation (ADER), and abduction and external rotation (ABER). Under radiological control, displacement of the center of the humeral head was compared with the glenoid surface at the 3, 4 and 5 o’clock (medial, antero-inferior and inferior) positions for the 2 bone-block positionings.

\textbf{Results:} The lying position at 4 o’clock substantially decreased anterior and inferior displacement of the humeral head respectively in ADER and ABER; and in ABER it also tended to decrease anterior translation, but not significantly. The standing bone-block position did not affect translation.

\textbf{Conclusions:} Positioning the bone-block so that it lies on the anterior aspect of the glenoid in the middle of the antero-inferior quarter of the rim at 4 o’clock can decrease anterior displacement of the humeral head and inferior glenohumeral translation, especially in ADER for anterior displacement and in ABER for inferior displacement.

\textbf{Study design:} Laboratory study.

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1. Introduction

Bristow-Latarjet surgery involves altering the coracoid process and the coraco-biceps tendon to stabilize the shoulder. The procedure is recommended when shoulder dislocation is associated with a bony defect of the anterior glenoid rim but can be performed as a first procedure for selected patients [1]. This procedure aims to stabilize the shoulder by the bony effect of the coracoid process graft increasing the size of the glenoid and the conjoint tendon sling pushing back the humeral head to produce a new strong inferior glenohumeral ligament [2]. The block must be in the antero-inferior quarter of the glenoid rim, but the exact position remains unclear.

During the procedure, the bone-block can be placed lying down or standing up. Arthroscopic Bristow-Latarjet surgery can involve both positions, but clinical experience has not shown the best position. The current biomechanical study aimed to evaluate the effect of positioning of the coracoid process, lying down or standing up on the antero-inferior aspect of the glenoid, on shoulder stability with the surgery.

2. Material and methods

The current study was performed after approval of the local ethics committee. We used 8 fresh cadaveric shoulders.

2.1. Technical procedure

Shoulders and arms were removed from bodies, and the entire cuff was retained. The deltoid and pectoralis muscles and clavicle...
were removed. The arm was retained with the shoulder intact, and the scapula was screwed to a radiolucent support. The humeral bone was retained up to the elbow, which was dislocated, and the forearm was removed. The Bristow-Latarjet procedure was performed as reported by Young [3] but without use of the coraco-acromial ligament, to evaluate the effect of the bone with the conjoint tendon.

With the arm in abduction and external rotation (ABER), the coraco-acromial ligament was incised at the coracoid attachment. With the arm in abduction and internal rotation (ADIR) the medial side of the coracoid was exposed. The pectoralis minor was released directly from the coracoid. The “knee” of the coracoid was cut with an oscillating saw, perpendicular to the coracoid process. Soft tissue was removed from the inferior surface of the coracoid.

To compare results between each shoulder, the coracoid was cut into a 2.5-cm graft. Two 3.2-mm holes were created in the center of the coracoid bone-block, one in the axis of the graft and one perpendicular to it (Fig. 1).

With the arm in external rotation (adduction and external rotation [ADER]), the subscapular muscle was opened horizontally at two-thirds and one-third height of the tendon and muscle. The tendon was not closed at the end of the procedure [3]. The capsule and anterior labrum were removed. The anterior rim was identified and divided into superior and anterior parts. A superior point was located at 3 o’clock, corresponding to the equator of the glenoid surface, and an inferior point was located at 6 o’clock. Three holes were drilled at 3, 4, and 5 o’clock in the anterior part of the glenoid. With use of a specific device [4,5], 3 glenoid anchor screws were placed in each location, perpendicular to the glenoid rim. With use of a special compression screw, the bone graft was fixed lying or standing on the glenoid rim for radiography and measurements. We tested 6 positions of the bone-block: 3 lying down (3L, 4L, 5L) and 3 standing up (3S, 4S, 5S) (Fig. 1). A steel wire identified superior and inferior limits of the conjoint tendon (Fig. 2).

2.2. Biomechanical testing

ADER and ABER were defined and obtained by putting the arm in external rotation. This external rotation was assessed when obtaining a bicondylar line of the elbow perpendicular to the radiolucent plate use to fix the scapula. In such condition, each shoulder was tested with the same external rotation position.

With the arm in ADER, we located and placed an anchor at the center of the humeral head for creating anterior traction by pulling on the sutures by use of an electronic dynamometer. With the arm in ABER, we used the same procedure with the 2 other anchors for traction anterior (in the center of the humeral head) and inferior (at the calcar level) to the humeral head (Fig. 2). With the arm in ADER, 30-N anterior-axial traction systematically induced anterior dislocation.

For each position (ADER and ABER), we obtained 3 AP and profile radiographs with and without 30-N axial traction. X-rays were performed systematically parallel to the plate of fixation of the scapula for AP views to assess inferior translation. The surgical C-arm X-ray system rotated of 90° to obtain profile to assess anterior translation. The center of the humeral head was defined on X-rays as the center of the smallest circle including the humeral head (point d in the white circle, Fig. 2A). A glenoid axis (a line 2A) was designed, passing at each extremity of the glenoid surface seen on X-rays.

Anterior displacement was assessed in ADER and ABER by comparing 3 radiographs for each graft position, with and without 30-N axial traction, by the mean differential displacement of line, perpendicular to the glenoid surface axis, passing through the center of the humeral head, from 0 to 30-N axial traction.

Inferior displacement was assessed in ABER by comparing 3 radiographs for each graft position, with and without 30-N axial inferior traction, by the mean differential displacement over the glenoid axis (a) and the center of the humeral head (d) (Fig. 2C).

In order to obtain a reproducible axis of traction for each humeral head and for all humeral head, pulling on was performed parallel or perpendicular to the plate of fixation of the scapula, depending of the tested condition.

3. Data collection

3.1. Conjoint tendon projection

To assess the “slinging” effect of the conjoint tendon body behind the humeral head, we evaluated the coverage of the head in each position by AP radiographs of shoulders with the superior and inferior border of the conjoint tendon identified by steel wires. The projection of the area of the tendon behind the humeral head was measured for each condition by use of Surface Evolver®. This surface was evaluated only in ABER.

3.2. Radiological measurement

From AP and lateral radiographs obtained 3 times for each position with and without 30-N traction, differential displacement was measured between the center of the glenoid surface and center of the humeral head. Mean displacement was calculated for each position of the bone-block in each position test. Displacement was measured for each case in value of millimetre but also as a ratio of the glenoid axis surface (Fig. 2A) in mm/translation value in mm (x, Fig. 2C). The glenoid axis surface was the length of the axis of the glenoid, between each extremity of the glenoid surface.

3.3. Statistical analysis

Statistical analysis involved use of R 2.13.2 software (http://www.R-project.org), the R Foundation for Statistical
Fig. 2. A. Lateral radiograph showing: d point: the center of the humeral head identified as the center of the smallest circle involving ll the humeral head; a: glenoid axis, passing by the 2 extremites of the projection of the glenoid. F segment: surface of the glenoid axis, corresponding to the size (in mm) of the segment between the 2 extremities of the glenoid projection. Horizontal dash line: projection of the center of the humeral head, perpendicular (90°) to the glenoid axis ans glenoid axis surface. B. Profile radiograph showing the inferior displacement on the humeral head in abduction and external rotation (ABER). The inferior displacement is measured between the axis of the glenoid rim as a reference, with subtraction of the distance of the line passing through the center of the head at 0 and 30 N. Sutures were passed through the anchor located at the calcar and fixed at the other end to the electronic dynamometer to induce 30-N traction. x: value of the translation comparing the perpendicular projection [b and c] of the center of the humeral head at O (d) and at 30 N (e) axial traction, to the axis of the glenoid surface (a). C: covered head; CTP: conjoint tendon projection; y and values collected to calculate the percentage of projection of the conjoint tendon behind the head coverage = Y/Y*. C. AP radiograph showing the projection of the conjoint tendon (identified by inferior and superior steel wires) behind the head in ABER. The percentage of covered head and remaining conjoint tendon under the head is measured for each coracoid graft position (here: 3 o’clock standing [SIS] (CA: covered head; CTP: conjoint tendon projection; y and z values collected to calculate the percentage of projection of the conjoint tendon behind the head coverage = Y/Y*). [x: value of the translation comparing the perpendicular projection [b and c] of the center of the humeral head at O (d) and at 30 N (e) axial traction, to the axis of the glenoid surface (a)].

Computing, Vienna, Austria). Data were compared by Anova, and differences were statistically significant at P<0.05.

4. Results

4.1. Anterior displacement

No dislocation occurred with 30-N axial displacement in ABER and ADER for each graft position. For profile radiographs, anterior differential displacement was assessed for 30-N traction. In ADER, mean displacement was 8.51, 10.58, and 8.59 mm for 4, 3, and 5 L, respectively, and 16.42, 13.7 and 10.16 mm for 4, 3, and 5 S, respectively (Fig. 3A and B). In ABER, mean displacement was 5.81, 6.28 and 8.09 mm for 4, 3, and 5 L, respectively, and 7.03, 8.62 and 10.27 mm for 4, 3 and 5 S, respectively. In ADER, the lying-down position of the bone-block produced a statistically significant difference, with better limitation of the displacement, at 5 L (P=0.0044) and 3 L (P=0.034). Displacement was significantly lower at 4 L than 3L or 5 L (P=0.03) in ABER but was not significant in ABER.

4.2. Inferior displacement

In ABER, inferior displacement was lower for 4 L than 3 or 5 L (P=0.032) and for all 5 positions (P=0.032). Translation value was 3.03, 3.87, 6.29 mm for 4, 3 and 5 L position and 4.88, 4.88, 5.03 mm for 4, 3 and 5 S position (Fig. 4).

4.3. The conjoint tendon projection

In ABER, the projection of the conjoint tendon was the same, for the same location of the graft. At 3 o’clock (S or L) 100% of the projection of the conjoint tendon covered the humeral head. At 4 S, 68% of the conjoint tendon covered the head, but 32% was under the head, whereas at 4 L, 74% of the conjoint tendon covered the head, but 26% was under the head. At 5 S, 66% of the conjoint tendon...
covered the head, but 34% was under the head, and at 5 L, 69% of the conjoint tendon covered the head, but 31% was under the head. On profile radiographs, in ABER, for each corresponding position (i.e., 3 L vs. 3 S; 4 L vs. 4 S; 5 L vs. 5 S), the projection of the conjoint tendon systematically increased from 0.4 to 1.2 cm behind the humeral head (Fig. 4).

5. Discussion

Since its first description, in 1954 [6] and 1958 [5], coracoid bone-block transfer has been greatly modified a lot. According to the early promoters, the coracoid graft was placed in the middle of the anterior aspect of the glenoid. This position is obvious in the papers of Latarjet [5] and Bristow [7]. The paper of May [8] is more confusing. The coracoid graft seems to be in the inferior glenoid in the radiograph in the paper, but in the text, the author states that the graft is placed in the middle of the anterior aspect of the glenoid. Patte [9] was the first author to insist on the importance of placing the coracoid graft at the inferior part of the glenoid rim, where the glenoid margin was smoothed or worn by the humeral head dislocation.

Under the influence of this author, the subscapularis muscle is no longer totally transected and the sling effect is emphasized [9]. Currently, most authors fix the bone-block through the subscapular muscle, at two-thirds superior and one-third inferior, as initially described by Latarjet and Bristow, respecting the tendon and thus limiting the risk of fatty infiltration of the muscle [10–13]. Because of this low-aggression approach, the glenoid cannot be seen exactly and thus the exact positioning of the coracoid process cannot be seen. Many authors report the importance of good positioning of the bone block behind the antero-inferior quarter of the glenoid, emphasizing the risks of failure or complications with bad positioning. Bad positioning of a graft is frequent. Allain [14] reported 58%, Hovelius [15] 36%, Cassagnaud [16] 10% and Huguet [17] 45% bad positioning. All authors agree on the importance of perfect positioning of the bone-block: if it is too lateralized, it can induce osteoarthritis and limit the internal rotation with conflict between the graft and the humeral head. If it is too medialized, it induces recurrent dislocation or subluxations. The exact eight of the positioning is unclear in the antero-inferior quarter of the glenoid. Some authors point to the risk of recurrence with positioning of the bone-block over the equator (3 o’clock position), whereas Young and Walch [18] recommend placing it at a higher level on the glenoid in patients with hyperlaxity, to increase the sling effect of the coraco-biceps tendon on the subscapular muscle.

Two positions can be used to fix the coracoid process to the glenoid: standing up, as reported by Doursoumain [4] and Boileau [19] or lying down like Hovelius [20] or Walch and Lafosse [21]. Most authors used the lying-down position for the coracoid graft, which differs only by the number of screws used to secure the graft. Doursoumain is the only author to clearly demonstrate the standing-up position of the coracoid graft. However, he used a specific instrumentation and a specific screw to secure the graft against the glenoid.

Clinical studies report the same clinical outcomes with standing-up and lying-down positions. The increasing interest in arthroscopic shoulder surgery has led to the development of the arthroscopic Bristow-Latarjet procedure [19,21,22]. The procedure is more than a choice motivated by the technical difficulties and limitation of arthroscopy. Informations brought by biomechanical tests should help in decision-making.

Many elements must be considered in choosing the position of the coracoid process. The size of the glenoid defect can be an element. For a larger defect, a larger graft must be used and a lying-down graft is recommended [2]. In the current study, we did not

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Fig. 3. A. Anterior displacement of the humeral head in adduction and external rotation (ADER) position. S, standing position; L, lying-down position. Data are mean SD. ** P<0.001; *** P<0.0001 compared with (B) anterior displacement of the humeral head in abduction and external rotation (ABER), no difference among values.

Fig. 4. A. Inferior displacement of the humeral head in ABER. Data are mean percentages. B. Projection of the conjoint tendon over and under the humeral head in ABER. Data are mean percentages.
create a defect of the glenoid because the Bristow-Latarjet procedure is largely performed in France in patients without any glenoid bone defect because of risk of recurrence for very young patients [1].

In describing the technical procedure, Walsh [3] focused on the importance of using the coraco-acromial ligament to reinforce the stabilization of the shoulder. Wellmann [23] demonstrated its importance in a biomechanical study. To explore the effect of only graft position, we did not use the coraco-acromial ligament or suture it to the capsule. Furthermore, using the coraco-acromial ligament is not possible with the standing-up graft, because the insertion of the ligament is thus horizontal, and the shoulder capsule insertion is vertical.

We used the same length of graft for the lying-down or standing-up position. A shorter graft, in a standing position, might prevent the inferior anterior displacement because of an earlier effect of the conjoint tendon or subscapular “hammock” rule. This method will decrease the size of the bone-block and should have limited effect on bony reconstruction of the glenoid. Those data should be considered when choosing a position.

The 30-N axial traction was based on Wellmann [23], who emphasize the importance of the subscapularis muscle in the Bristow-Latarjet procedure.

Our biomechanical study demonstrated in an anatomic model achieving good anterior and inferior stabilization with a bone-block fixed lying down rather than standing up on the glenoid rim. For a lying-down graft, the shoulder displacement was significantly lower at 4 than 3 or 5 o’clock. Using a standing-up graft displaced the action of the conjoint tendon forward, thus decreasing the anterior stabilization. This finding can be explained by 2 theories. First, in ABER, the conjoint tendons act too late because they are too far from the humeral head. Second, the sling effect, created by the crossing of the subscapular muscle is not present, because the conjoint tendon is too anterior to the subscapular muscle, thus preventing the hammock effect described by Patte. In this position, the conjoint tendon covers the two-thirds inferior part of the humeral head in ABER, thus participating in the stabilization [2].

One important limitation of the current biomechanical study is the active contraction of muscles (subscapularis and biceps) that would play a crucial role in anterior shoulder stabilisation.

The size of the graft necessary to treat the glenoid defect has to be considered by the surgeon before surgery. These biomechanical findings suggest that, if the defect is large and a large graft is needed, a lying-down graft is recommended. With not-large defects, a standing-up position can be used, but the graft mustn’t be too long to prevent a too-late effect of the conjoint tendon crossing the subscapular muscle. In our biomechanical study, the best anterior and inferior stabilization was obtained with a lying-down graft at 4 o’clock.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References


