S ORIGINAL ARTICLE

Shoulder structure and function following the modified Latarjet procedure: a clinical and radiological review

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The authors declare no conflict of interests

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ABSTRACT

Background To evaluate the clinical and radiological outcomes of the modified Latarjet procedure for traumatic, antero-inferior glenohumeral joint instability.

Methods Case series were used with a mean follow-up of 21.3 months for clinical and radiological review and 47.2 months for recurrent instability. Shoulder function was evaluated by clinical examination and validated shoulder scales: Western Ontario Shoulder Stability Index (WOSI), Melbourne Instability Shoulder Score (MISS) and the Insalata Shoulder Questionnaire. Shoulder structure was evaluated by computed tomography.

Results Thirty-two cases were enrolled (mean age 27.0 years). One patient reported a redislocation during the follow-up period. Clinical examination revealed that the median external rotation (at 0° and 90° abduction) was reduced on the operative side by 7.5° ($p < 0.01$) and 10° ($p < 0.001$), respectively. Subjective shoulder function was good. Mean (SD) scores on the WOSI, MISS and the Insalata scales were 78.0 (19.7), 75.8 (11.5) and 89.3 (9.9), respectively. No loss of subscapularis strength was identified ($p > 0.05$). Radiological evaluation revealed a mean (SD) pre-operative glenoid surface area loss of 169.5 (48.5) mm² reconstituted surgically by a bone block of 225.4 (73.8) mm². Subscapularis muscle bulk was reduced on the operative side, above the level of the muscle split ($p < 0.05$).

Conclusions The Latarjet procedure reliably restores lost glenoid surface area, shoulder stability, strength and function. A small loss of external rotation is expected and related to altered subscapularis anatomy.

INTRODUCTION

Traumatic, antero-inferior shoulder dislocation is common in young, active people [1–3]. Structural damage to the glenohumeral joint invariably ensues, and surgical treatments aim to restore anatomy and stability [4]. Depending on the extent of soft tissue and bone damage, surgery to restore anatomy may necessitate bone reconstitution. Several procedures have been described to restore glenoid bone loss [5]. The Latarjet procedure currently enjoys popularity as a result of its combination of bone (coracoid process transfer) and soft tissue restoration (coraco-acromial ligament), as well as its dynamic stabilizing effect (conjoined tendon, subscapularis) [6].

The size and contour of the coracoid process is consistent, relative to the glenoid [7]. This makes it an ideal graft to reconstitute the fractured or eroded antero-inferior glenoid. Positioning of the bone graft relative to the glenoid, in all planes, is important to ensure stability of the glenohumeral joint and to minimize the risk of iatrogenic arthrosis [8]. Achievement of bony union should ensure long-term stability of the reconstructed glenoid. Although it has been widely reported that significant bone loss from the antero-inferior glenoid necessitates bony reconstitution [9], postoperative computed tomography (CT) quantification of bone loss and reconstitution has not been previously reported.

The subscapularis muscle is an important anterior stabilizer of the glenohumeral joint [10]. Although the original Latarjet

technique described complete detachment and subsequent repair of the subscapularis [11], modifications to this have included an L-shaped detachment of the upper half, or a horizontal split of the subscapularis in the line of its fibres. These modifications have been shown to better preserve subscapularis strength and function [12]. The effect of passage of the conjoined tendon through the mid-substance of the subscapularis muscle is to inferiorize the inferior portion. This is purported to have a positive effect on stability but a potentially negative effect on range of external rotation, particularly in abduction.

The present study aimed to assess both the clinical and radiological outcomes of the modified Latarjet procedure, undertaken through a subscapularis splitting approach. Clinical evaluation incorporating validated shoulder scores, range of motion and strength testing will indicate shoulder function. Utilizing spiral CT, we aimed to assess changes to shoulder structure, both bony and soft tissue, and to correlate these with clinical outcomes. Overall rates of redislocation are also reported.

MATERIALS AND METHODS

The present study comprised a case series of 32 patients with a minimum of 6-months follow-up post Latarjet procedure. It was conducted at two private institutions in Melbourne, Victoria, Australia (The Avenue and Glenferrie Private Hospitals). Initial

clinical and radiological data collection took place during the period of January 2010 to June 2011. Additional data collection to evaluate overall rates of redislocation took place in May 2013. A total of 27 of the initial 32 patients participated in this second phase of data collection. Ethics approval was obtained from The Avenue Hospital Human Research Ethics Committee and all participants provided their informed consent.

Participants were identified from clinical databases and were recruited via a telephone call and a follow-up letter of invitation to participate. All procedures were performed by either ME, GH or SB between January 2006 and August 2010 (Table 1). Patients with less than 6 months of follow-up were excluded from the study.

Each participant completed three validated shoulder instability questionnaires to assess subjective shoulder function: the L'Insalata shoulder questionnaire [13], Western Ontario Shoulder Instability Index (WOSI) [14] and Melbourne Instability Shoulder Score (MISS) [15]. Scores close to 100 indicate excellent shoulder function.

The principal investigator examined all participants in an outpatient clinic setting to assess the active range of movement of both shoulders. Elevation (in the plane of the scapula), internal rotation and external rotation (both at 0° of abduction and at 90° of abduction) were measured using a Protek goniometer (Protek, Bern, Switzerland; accurate to 1°). Clinical evaluation of subscapularis strength was performed using the belly press

test with a Mecmesin dynamometer (Mecmesin, Slinfold, UK; accurate to 0.1°N). Although the absolute accuracy of these instruments has not been independently verified, identical technique was utilised for all examinations, to ensure relative accuracy of measurements. Each subject maintained maximal isometric contraction for 5 seconds with the maximal torque strength measured in newtonmeters. This test was repeated after a 5-minute interval. The unaffected contralateral upper limb was also measured and utilized as the comparator.

The second phase of data collection was a follow-up telephone call to enquire about any dislocation episodes since the initial phase of data collection. Five patients were unable to be contacted (one deceased, four lost to follow-up).

Participants subsequently underwent fine slice spiral CT scan of both shoulders using a Philips Brilliance 64 CT scanner (Philips, Guildford, UK). The tube parameters were 140 kV and between 150 mAs and 230 mAs depending on patient size. A slice thickness of 1 mm and increments of 0.5 mm were used. The measurements were obtained on the Extended Brilliance TM Workspace Workstation, version 2.6.1 (Philips). Assessment of union and position of the transferred coracoid bone block was made. The position was assessed in two planes: (i) mediolateral position in relation to the articular surface on axial images and (ii) 'clock face' position on the reconstructed 'en face' sagittal oblique view of the glenoid.

Assessment of glenoid bone was performed using reconstructed 'en face' glenoid views with digital subtraction of the humeral head. Both linear and cross-sectional measurements of antero-inferior bone loss were quantified. Linear measurement of pre-operative glenoid bone loss and its subsequent restitution was calculated according to the formula described by Burkhart et al. [16]. Glenoid surface area measurements were taken according to the method of Sugaya et al. [17] to quantify both pre-operative bone loss from the antero-inferior glenoid, and postoperative bone restitution (Fig. 1).

Our CT evaluation borrows from a similar technique of CT analysis described by Hantes et al. [18]. In their cadaver study, Hantes et al. recreated an 'en face' glenoid view from three-dimensional (3D) CT with digital humeral head subtraction. Our technique recreates the same glenoid surface view by reconstructing two-dimensional (2D) spiral images in the plane of the glenoid. As well as being able to assess surface area of the native glenoid and the reconstituted glenoid using the slice at the level of the articulation (Fig. 1), evaluation of slices medial and lateral to the plane of the glenoid can then be used to determine bone block position and union. Radiological evaluation of subscapularis muscle was performed on axial CT by lineal measurement of muscle belly bulk, both above and below the operative split, based on the technique described by Maynou et al. [12]. Comparative measurements were taken at standardized levels from the contralateral, unaffected shoulder (Fig. 2)

The primary study outcome was subjective shoulder function. Secondary clinical outcomes were glenohumeral stability, range of motion and subscapularis muscle strength. These functional outcomes were then correlated to radiological measures

Table 1 Latarjet operative technique.

The procedure was performed using a standardized technique in all cases. All patients were placed in the semi-supine position, with the operative limb draped free. A deltopectoral approach was utilized and the coracoid process exposed. The interval between the conjoint tendon and pectoralis minor was delineated and the coracoacromial ligament was detached from the undersurface of the acromion. Coracoid osteotomy was then performed, aiming for a minimum graft length of 20 mm. The bone graft was then mobilized with the conjoint tendon, taking care to preserve the musculocutaneous nerve. The deep surface of the graft was decorticated and two drill holes passed through the graft

The subscapularis tendon was delineated, and a horizontal split performed one third to one half of the way from the superior border of the tendon, commencing at the musculotendinous junction to facilitate a clear plane between muscle and capsule. Once exposed, the capsule was split horizontally, and reflected off the anterior glenoid neck

The shoulder joint was then inspected, and the anterior glenoid rim and glenoid neck decorticated to accept the coracoid bone graft. The graft was fixed adjacent to the glenoid in the anterior-inferior quadrant, aiming to achieve a congruent extension (or reconstitution) of the glenoid articular surface. Following fixation of the coracoid graft, the capsulo-labral complex was then repaired to the rim of the native glenoid, leaving the coracoid graft in an extra-articular position. Suture anchors were utilized for this repair, and a capsular plication was incorporated into the repair, along with the transferred coraco-acromial ligament. The capsular sutures were tightened with the arm in neutral rotation and 20° abduction. The subscapularis split was then closed in its tendinous portion, following which routine wound closure was performed

Post-operative care consisted of 4 weeks in a sling, performing passive range of motion exercises, limiting external rotation to neutral and forward flexion to 90°. After 4 weeks, active and assisted range of motion was commenced, and resistance exercises at 8 weeks post-operation

Fig. 1 Computed tomographic assessment of glenoid bone. Individual images from top left across to top right, then second row:

- (1) Surface area measurement of circular lower two-third glenoid.
- (2) Surface area measurement of pre-operative glenoid bone loss.
- (3) Linear measurement of the glenoid diameter.
- (4) Linear measurement of the transferred bone block.
- (5) Surface area measurement of the transferred bone block.

Fig. 2 Computed tomographic assessment of subscapularis muscle bulk. Linear measurement of subscapularis muscle bulk on sagittal images both above and below the operative split.

assessing glenoid bone structure and subscapularis muscle structure.

The sample size was based on the primary outcome. The non-operative shoulder was used as a control and assumed to have a functional score of 100. We determined that a functional score of less than 80 for the operative shoulder would represent a clinically significant residual loss of function. Hence, with subjective shoulder functions for the non-operative and operative shoulders of 100 and 80 (SD 20), respectively, at least 26 participants were required (two-sided, power 0.95, $p < 0.05$).

Most data are reported descriptively using mean (SD), median (interquartile range) or as percentages. An independent samples Student's t -test and the Mann–Whitney U -test were used to compare parametric and nonparametric continuous data, respectively. SPSS, version 19.0 (IBM Corp., Armonk, NY, USA) was employed for all analyses. $p < 0.05$ was considered statistically significant.

RESULTS

Thirty-two participants were enrolled. They comprised 31 (96.9%) males and the mean (SD) age was 27 (5) years. The mean (SD) follow-up period for evaluation of recurrent instability was 47.2 (19.7) months, with follow-up clinical assessments undertaken at a mean of 21.3 (12.4) months following surgery. Eighteen (56.2%) participants had surgery performed on their nondominant upper limb. Twenty-six (81.2%) participants had undergone previous shoulder surgery with a mean number of previous surgeries of 1.15 (range 0 to 4). One episode of re-dislocation was reported after a mean follow-up of 47.2 months in 28 patients. The dislocation was sustained after a diabetic related seizure. This occurred 1 month after the patient had participated in the clinical and radiological review and 9 months after their Latarjet procedure. This patient later died from a condition unrelated to their shoulder instability. This represents an overall rate of redislocation of 1:28 (3.5%) at almost 4 years, excluding the four patients who were lost to follow-up after the clinical and radiological evaluation.

Overall subjective shoulder function was good (Fig. 3). The mean (SD) MISS score was 75.7 (11.5). The mean (SD) WOSI score was 78.0 (19.7) (Table 2). The mean (SD) L'Insalata score was 89.2 (9.9) (Table 3). However, all scores were significantly less ($p < 0.01$) than the expected score for a normal shoulder [100 (SD) 20].

Comparison of the operative and non-operative sides revealed no significant differences in forward flexion, internal rotation or strength of subscapularis ($p > 0.05$) (Tables 4 and 5). However, median external rotation, at 0° and 90° abduction, was reduced

Fig. 3 Individual patient questionnaire scores. MISS, Melbourne Instability Shoulder Score; WOSI, Western Ontario Shoulder Stability Index.

Table 2 Western Ontario shoulder instability index

Scale domain	Mean	(SD)
Physical (1000)	216.1	(192.2)
Sports/recreation/work (400)	85.7	(83.3)
Lifestyle (400)	68.6	(77.8)
Emotions (300)	92.0	(91.1)
Total score (2100)*	462.8	(414.0)
Percentage normal	78.0	(19.7)

*Maximum score possible; lower total scores indicate better shoulder function.

Table 3 L'Insalata shoulder score

Scale domain	Mean	(SD)
Global (15)	12.6	(2.1)
Pain (40)	36.8	(5.5)
Activities (20)	19.1	(1.2)
Recreation (15)	11.2	(3.3)
Work (10)	9.8	(0.7)
Total (100)*	89.2	(9.9)

*Maximum score possible.

Table 4 Range of motion examination findings

	Operative side		Non-operative side		<i>p</i>
	Median	(IQR)	Median	(IQR)	
Elevation	180°	8°	180°	0°	0.35
Internal rotation level*	T5	3	T5	2	0.08
External rotation at 0° abduction	65°	25°	72.5°	19°	<0.01
External rotation at 90° abduction	80°	19°	90°	10°	<0.001

*Vertebral level achieved with the thumb of the hand by maximum internal rotation of the shoulder. IQR, interquartile range.

on the operative side by 7.5° (65° versus 72.5°; $p < 0.01$) and 10° (80° versus 90°; $p < 0.001$), respectively (Table 4).

CT examinations were undertaken for 27 participants and revealed bony union in 26. There was one case of fibrous union. All bone blocks were positioned between 3 o'clock and 6 o'clock (antero-inferior quadrant) on the 'en face' view of the glenoid. The majority (62.9%) of bone blocks were congruent with the articular surface on axial CT images. In two (7.4%) cases, the lateral edge of the coracoid was positioned lateral to the glenoid surface by 2 mm. In eight (29.6%) cases, the lateral edge of the coracoid bone block was positioned medial to the glenoid surface by a mean (SD) distance of 3 (0.1) mm.

On anteroposterior linear measurements, the mean (SD) glenoid bone loss was 7.9 (0.3) mm. This represented a mean (SD) percentage bone loss of 26.6% (0.9%). The mean (SD) width of the transferred bone block was 7.8 (0.3) mm.

Table 5 Subscapularis strength using a dynamometer (Nm²)

	Operative	(SD)	Non-operative	(SD)	<i>p</i>
Subscapularis strength (Time 1)	96.9	(29.9)	100.7	(28.9)	0.60
Subscapularis strength (Time 2)*	100.1	(29)	102.9	(27.5)	0.69

*Time 2: strength test 5 minutes after the initial test.

The mean (SD) glenoid surface area loss was 169.5 (45.8) mm². This represented a mean (SD) percentage glenoid surface area loss of 23% (5%). The surface area of the coracoid bone graft reconstituted a mean (SD) glenoid surface area of 225.4 (73.8) mm².

Mean (SD) subscapularis muscle bulk was relatively reduced above the level of the muscle split on the operative side [30.3 (5.2) mm] compared to the non-operative side [33.2 (4.8) mm]. This was statistically significant ($p < 0.05$). The muscle bulk below the operative split did not differ [20.2 (5.9) mm versus 21.5 (5.2) mm, respectively].

DISCUSSION

Latarjet described his technique for open stabilization of the shoulder in 1954 [11]. The combined benefits of transferring bone, tendon and ligament have been well described [19,20]. Although the surgical technique has been significantly modified in subsequent descriptions, the principles of this 'triple effect' have been maintained. These modifications have been developed to improve outcomes related to bone union [21], subscapularis strength [12] and joint congruity [22]. Some controversy exists in the literature as to what is the predominant stabilizing effect of this procedure [23,24].

Clinical outcomes reported in the literature for the Latarjet procedure are difficult to interpret. Success related to stability is clearly demonstrable [8], although whether the procedure carries a significant incidence of degenerative arthritis in the longer term is not clear. Loss of range of motion and loss of subscapularis strength are also areas of ongoing discussion in the literature [25,26]. The present study demonstrates reliable success with only one incidence of redislocation, and consistently high clinical outcome scores. Good correlation between the outcome measures has also been demonstrated. The follow-up period for this patient cohort is short, and a longer-term follow-up is required to confirm our good early results.

The potential loss of subscapularis strength following the Latarjet procedure has been well documented. Conversely, the inferior displacement of the inferior portion of subscapularis has been identified as important in the stabilizing effect of the procedure [27]. Maynou et al. have described the utilization of CT to assess the bulk of subscapularis muscle following the Latarjet procedure [12]. Interestingly, CT appearances of the subscapularis muscle showed a diminution in muscle width above the horizontal split, although not below. It is our opinion that this represents a uniform loss of subscapularis muscle bulk postoperatively, although the

loss is masked by the fact that the inferior portion of the muscle is displaced and therefore the relative loss of height is compensated by a relative increase in width. Subscapularis strength was not significantly diminished, and this correlates with other studies utilizing the horizontal splitting technique [28]. With regard to the assessment of subscapularis muscle, our CT measurement was of subscapularis width rather than cross-sectional area or volumetric rendering. This was a result of the limited field of the CT scans performed. Further work using 3D volume rendering of subscapularis would help to confirm our postulates with respect to overall volume loss, offset by inferior displacement.

The finding of a statistically significant loss of external rotation both with the arm by the side and at 90° of abduction is consistent with the tethering of the inferior portion of subscapularis, as well as the capsular plication performed as part of the procedure. Our raw data set did not demonstrate any improvement in either external rotation range, clinical scores or subscapularis strength beyond 6 months to 12 months of follow-up; however, patient numbers preclude us from demonstrating this statistically.

By adapting the CT analysis technique described by Hantes et al. [18], we have been able to accurately quantify both pre-operative bone loss and postoperative bone restitution in our patient cohort. This has not previously been reported in a patient series. All but one patient demonstrated pre-operative glenoid bone loss of greater than 20% by linear [16] or cross-sectional area [18] measurements. These findings represent the most commonly recognized and accepted indications for a bone block type procedure [5]. Our CT analysis confirmed reproducible graft position, both with regard to mediolateral congruity, and with regard to placement in the antero-inferior quadrant. CT demonstrated not only that glenoid bone loss could be accurately measured, but also that coracoid bone transfer reconstituted the surface area of bone lost in all cases. The present study demonstrates a high rate of bony union but no dramatic osteolysis, which has been reported as high as 59% [27]. In our one case of fibrous non-union, follow-up clinical scores were high, and the patient reported no subjective instability at follow-up. However, subsequent to our clinical follow-up, this patient sustained a diabetic seizure and redislocated his shoulder. This resulted in dislodgement of the bone graft with bending of the screws, and the creation of a large (> 30%) Hill–Sachs defect on the humeral head. Revision stabilization surgery consisted of replacement of the coracoid bone graft with iliac crest graft, and restitution of the humeral head bone loss using a metallic segmental resurfacing (hemicap) prosthesis. This was the only case of recurrent instability and the reasons for this may have related to both non-union of the coracoid graft, as well as a new and significant traumatic episode. This patient represented the only incidence of recurrent dislocation in our cohort, with mean follow-up of almost 4 years for this outcome parameter.

Although the mean function scores were generally good, they were significantly less than what would be expected for a normal shoulder joint. Regardless of the function score, the primary objective of the Latarjet procedure is to prevent the recurrence of shoulder dislocation. This outcome measure will be best assessed longitudinally, and the relatively short-term clinical follow-up of this case series is the main limitation of the present study. It is

our opinion, however, that the radiological and objective clinical findings reported in the present study add further knowledge regarding expected outcomes following the Latarjet procedure. We have demonstrated that important parameters to measure recovery from the surgery stabilize within 6 months to 12 months of surgery. These include restoration of subscapularis strength, range of motion, and bony union. Through secondary patient contact, we have identified only one episode of recurrent dislocation with mean follow-up of almost 4 years (47.2 months). Longer-term clinical outcomes for this cohort of patients will be pursued in the future.

Further limitations of the present study relate to measurements attained on postoperative CT scanning. Hantes et al. has described a 3D CT technique of measuring native glenoid surface area and coracoid bone block surface area following bone grafting in cadavers [18]. To our knowledge, this technique has not been reported in a clinical setting. This technique has been adapted for use with reconstructed 2D spiral CT in the present study. Because pre-operative CT scans were not available for most cases, we performed a post-hoc evaluation of the glenoid to differentiate native from reconstituted bone. This technique may have limitations with the maturation of bone grafting over time as the demarcation between native glenoid and coracoid graft becomes less obvious. However, in our case series, the intersection between the native bone and graft was clearly identifiable in all cases (Fig. 1).

Pre-operative shoulder function scores were not collected for the present study. Although it would have been of some interest to statistically compare the differences between pre- and postoperative scores, it is evident from the long-term follow-up data that almost all patients had stable postoperative joints. We consider that the most clinically relevant comparison was how close to fully functional joints the postoperative shoulders actually were. This is reflected in our sample size calculation.

Conclusions

We conclude that the modified Latarjet procedure provides a reliable stabilization procedure for antero-inferior glenohumeral instability with glenoid bone loss of more than 20%. There is complete reconstitution of glenoid bone surface area, with high rates of bony union. Subscapularis splitting avoids weakness but contributes to loss of external rotation both by the side and in abduction. Range of motion, strength and clinical function appear stable by 6 months to 12 months after surgery, with no statistically significant change in outcome parameters beyond this period. Failure of bone union may predispose to further instability, and we recommend radiological confirmation of union before return to at risk activities.

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