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Management of Complex Anterior Shoulder Instability: a Case-Based Approach

Nathan Olszewski[1] · **Michael Gustin**[1] · **Emily J. Curry**[1] · **Xinning Li**[1]

Abstract
Purpose of the Review The goal of this review is to provide a guide on surgical decision-making options for complex anterior shoulder instability using a case-based approach.
Recent Findings Arthroscopic Bankart repair is well documented for having successful outcomes in patients with isolated labral tear involvement with minimal bone loss. Latarjet is a generally accepted procedure in patients with 20–30% glenoid bone loss. When bone loss exceeds that which cannot be managed through Latarjet, a range of options exist and are highly dependent upon the extent of osseous deficiency on both the glenoid and humeral sides, surgeon experience, and patient-specific factors. The use of reverse total shoulder arthroplasty for the management of chronic locked shoulder dislocations has been described as a successful management option.
Summary Treatment options for complex anterior shoulder instability range widely based on patients' presenting exam, surgical history, amount of glenoid bone loss, size of Hill-Sachs lesion, and surgeon preference. When selecting the appropriate surgical intervention, the treating surgeon must consider the patient history, physical exam, and preoperative imaging along with patient expectations.

Keywords Anterior shoulder instability · Latarjet procedure · Eden-Hybinette procedure · Bankart repair · Remplissage · Pectoralis major transfer · Reverse total shoulder arthroplasty · Critical Glenoid Bone Loss

This article is part of the Topical Collection on *Management of Anterior Shoulder Instability*

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Introduction

Shoulder instability is defined as a loss of ability for the soft tissue and bony structures to provide adequate restraints to keep the humeral head centered about the glenoid [1–3]. Anterior shoulder instability is a common problem, with an overall incidence rate of 23.9/100,000 person-years for 2002 through 2006, with the most common cause of anterior instability being traumatic anterior shoulder dislocations [4•, 5•, 6, 7]. In general, half of the patients aged from 30 to 40 years who experience a primary anterior dislocation will not continue to experience instability or subluxation symptoms with long-term follow-up [8•]; however, those younger than 30 years of age, involved in high demand athletic activity, male sex, and those who sustained a bony injury to the glenoid or humerus are at a greater risk for recurrent instability including subluxations and dislocations [9•, 10, 11]. Patients with recurrent anterior shoulder instability will typically present with a greater degree of damage to the bony and soft tissue structures [12, 13].

Arthroscopic Bankart repair has been well documented for having successful outcomes for patients with isolated anterior inferior labral tear involvement and minimal bone loss [14•, 15•]. Both arthroscopic and open Bankart repairs are most successful in patients with primarily labral damage in the presence of minimal glenoid bone loss [14•, 15•]; however, higher failure rates are reported in patients with significant glenoid or humeral head bone loss [16•, 17, 18, 19•]. For patients with glenoid bone defects between 20 and 30%, the Latarjet procedure has been shown to be an effective management strategy [20•, 21•, 22]. However, the success of the Latarjet is highly dependent upon surgical technique, surgeon's own

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technical skills, and ensuring adequate coracoid fixation and screw positioning.

Bone grafting (iliac crest) with an Eden-Hybinette procedure provides the best outcomes in instances where the glenoid deficiency exceeds that which can be corrected with a Latarjet procedure or in cases of a failed Latarjet procedure [23]. An engaging or "off track" Hill-Sachs lesion that persists after addressing the glenoid can be managed through bone grafting of the humeral head and/or remplissage procedures [24]. Remplissage procedures have worse outcomes with a large defect on the humeral head [14•, 25]. Muscle and tendon transfer in the setting of anterior shoulder instability with chronic subscapularis ruptures, such as the pectoralis major tendon transfer, can also be used in conjunction with an above bony procedure to help stabilize the humerus [16•, 17, 26]. Finally, reverse total shoulder indications have expanded tremendously and are now used in the setting of chronic locked anterior shoulder dislocations [25, 26]. Reverse shoulder arthroplasty risk factors for failure are related to glenoid bone quality, weight, male sex, and proximal humerus fractures [26, 27]. Given the numerous management options and the complex interaction between the glenoid, humeral head, and soft tissue lesions, the surgeon must have a keen understanding of the osseous and soft tissue anatomy to restore stability to the shoulder joint.

Many factors must be considered when selecting the appropriate surgical intervention for complex anterior shoulder instability, and these include the evaluation of glenoid and humeral bone defects, the extent of osseous deficiency, the surgeon's personal experience with specific reconstructive techniques, and patient-specific factors. Given the lack of literature to direct surgical management in these cases of complex anterior shoulder instability, we strive to provide a guide on decision-making options for surgical intervention. The goal of this review is to provide a guide on surgical decision-making options for complex anterior shoulder instability using a case-based approached and the best available evidence in the literature to direct management. We strive to provide examples of options for surgical management in these complex cases with the decision-making steps and surgical techniques used for each case-based management. Furthermore, please see the proposed senior author's (XL) management algorithm for failed arthroscopic or open Bankart repair (Fig. 1).

Case 1: Recurrent Instability Following Arthroscopic Bankart Repair

History/Exam/Imaging

MM is a 19-year-old, right hand dominant male with recurrent anterior instability of the right shoulder following an arthroscopic Bankart repair 2–1/2 years prior. Following his initial repair, he had successfully returned to playing hockey and full sporting activities but was reinjured with re-dislocation of his right shoulder after a fall while playing lacrosse. He continued to experience shoulder instability in the 3 months following the incident after a trial of physical therapy.

His exam was positive for apprehension and a positive relocation sign. The posterior load jerk test did not cause pain, and there was no pain with O'Brien's sign. Range of motion was normal, with 5/5 rotator cuff strength in all planes of motion. CT scan and MR arthrogram were obtained, showing a Bankart lesion with around 10% glenoid bone loss. Exam under anesthesia demonstrated full passive range of motion and 3+ anterior load and shift and 1+ inferior and posterior load and shift.

Surgical Procedure

The patient was brought to the operating room and placed under general anesthesia in the beach chair position. The posterior portal was established with a 30° arthroscope, and the superolateral and anterior 5 o'clock position portals were also established. Arthroscopic findings demonstrated a re-tear of the labral repair in the anteroinferior labrum; however, the capsulolabral tissue was of good quality (Fig. 2a). The previous anchors and loose sutures were removed using arthroscopic biters, and the capsulolabral complex was mobilized off the anteroinferior glenoid rim using the arthroscopic CoVator 20 degree wand (ArthroCare, Austin TX), allowing for visualization of the subscapularis muscle belly (Fig. 2b). There was 10% glenoid bone loss present (preoperative CT measurement), with good quality of the anterior capsule labral tissue. Thus, the decision was made intraoperatively to perform a revision arthroscopic Bankart repair.

Following mobilization of the capsulolabral complex, an Iconix 2.3-mm anchor was placed with a 25° curved guide at the 5:30 position of the glenoid rim. The curved guide along with the all-suture anchors allowed the senior surgeon to place the anchors low on the glenoid. Two sutures were shuttled across the anteroinferior capsule and labral rim, and the capsulolabral complex was shifted. Subsequently, the capsulabral complex was further shifted with four 2.9-mm pushlock anchors and labral tape using a knotless fixation technique (Fig. 2c). The final repair construct was stable, and the humeral head was well centered. Our patient is now 6 months from the revision arthroscopic Bankart repair and is doing well without any evidence of recurrent subluxation or dislocation events. He has returned to his preinjury sporting activities with full range of motion, strength, and negative apprehension sign.

Case Discussion

In patients with failed arthroscopic Bankart repair and minimal glenoid bone loss (< 13.5%), revision arthroscopic Bankart repair is an option if the remaining anterior capsulolabral complex is of good quality that allows for mobilization and repair. The quality of this tissue can be evaluated with a

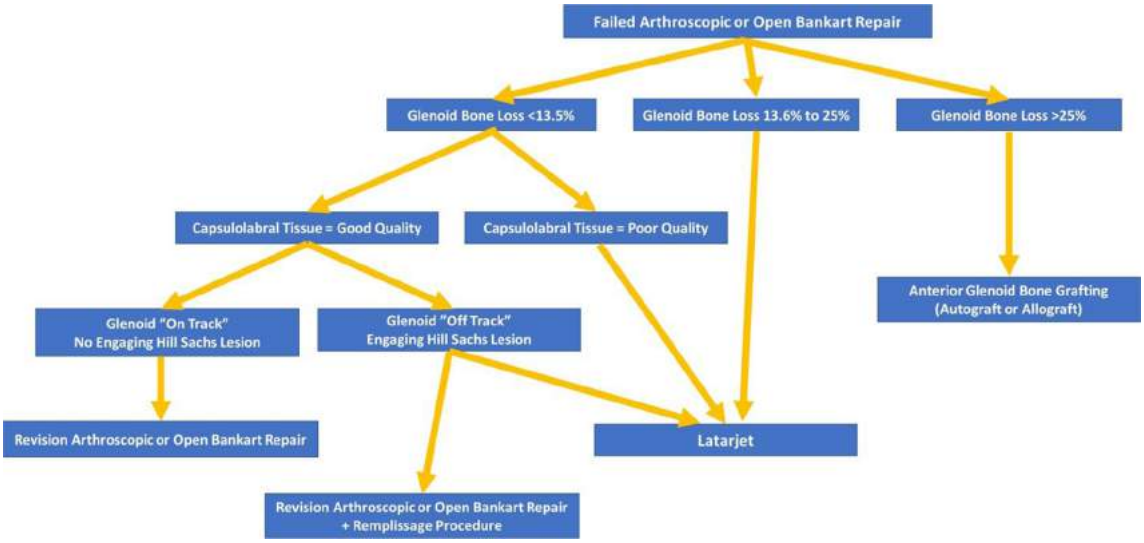

Fig. 1 Senior author (XL) proposed management algorithm for failed arthroscopic or open Bankart repair based on the amount of glenoid bone loss and whether the Hill-Sachs lesion will engage or not engage

preoperative MRI and also during the diagnostic arthroscopy. It is essential in these complex revision cases that the patient is consented for both arthroscopic revision Bankart repair and also for possible Latarjet or other anterior bone grafting methods. The surgeon must be prepared to convert the arthroscopic approach into open glenoid bone grafting or Latarjet if the quality of the tissue anteriorly is poor and does not allow for arthroscopic revision fixation. This patient possessed a number of risk factors for recurrent shoulder instability following the original Bankart repair, which included male sex, young age, and high-demand athletic activity or contact sports [9•, 11]. The senior author approached this case with a revision arthroscopic Bankart repair given the minimal glenoid bone involvement (~ 10%) and the good quality of the remaining capsulolabral complex that allowed for a stable repair as determined at the time of diagnostic arthroscopy.

In patients with minimal glenoid bone loss, arthroscopic Bankart repair has been shown to achieve stability in up to 96% of patients and 93.5% of contact athletes at 27 months of follow-up [14•], with similar outcomes in first-time dislocators as compared to those with recurrent instability [28]. Furthermore, using a matched cohort, Blonna et al. [29•] recently found that arthroscopic Bankart repair produced superior results compared to Latarjet in terms of return to sport rates, range of motion, and subjective perception of the shoulder in patients with recurrent shoulder instability in the absence of significant bone loss. Kim et al. [30] evaluated 23 patients with failed Bankart repair that were treated with revision arthroscopic surgery and reported 18/23 patients or 78% returned to pre-injury activity levels. In the five patients that failed arthroscopic revision Bankart surgery, engagement in contact sports was correlated with failure. Arthroscopic revision Bankart surgery did not result in significant loss of external rotation compared to the contralateral side, and interestingly, preoperative external rotation was the most predictive factor for functional return after surgery [30].

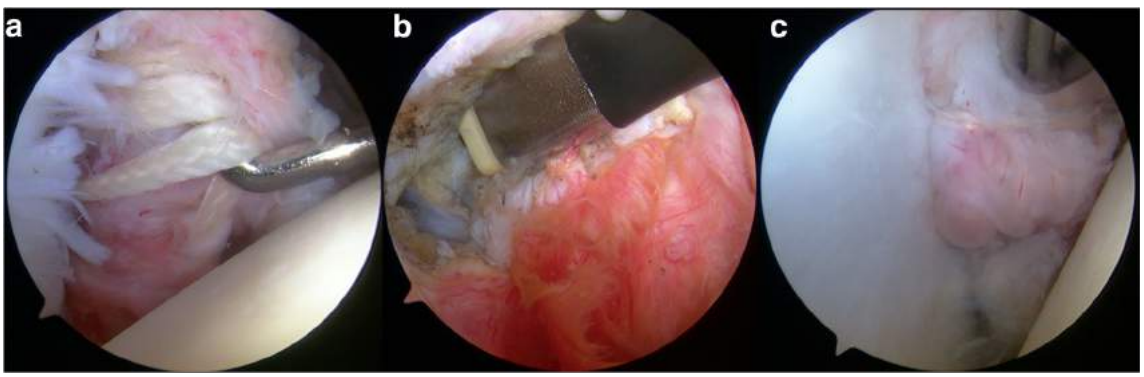

Fig. 2 **a** Arthroscopic evaluation demonstrates retear of the original Bankart repair following a traumatic instability event. The anterior capsulolabral tissue is in good quality with the loose labral tape. **b** Arthroscopic CoVator 20 degree wand (ArthroCare, Austin TX) is used to elevate the capsulolabral tissue off the glenoid rim. The subscapularis muscle is visualized after the mobilization. **c** Final arthroscopic picture of the revision Bankart repair with labral tape and knotless fixation

Neri et al. also reported good to excellent outcomes after arthroscopic revision Bankart repair with 8/12 patients or 73% returning to previous activity levels [31].

In patients who experience significant bony defects, defined as an engaging Hill-Sachs lesion or glenoid bone loss > 20%, high rates of persistent instability following Bankart repair have been reported in the literature [14•] as compared to Latarjet [20•, 21•, 32]. Shaha et al. [33•] reported the sub-critical bone loss as 13.5% and found that patients that are above this amount of bone loss had significant higher rates of recurrent instability and also poorer functional outcome compared to the subset of patients with < 13.5% bone loss. Thus, in patients with significant glenoid bone loss (> 13.5%), revision arthroscopic Bankart repair would result in unacceptable recurrence risk and functional outcome. The senior author would recommend Laterjat or anterior glenoid bone grafting with either allograft or autograft as the treatment of choice. Furthermore, in patients that have failed one arthroscopic revision surgery, the outcomes of repeated arthroscopic revision Bankart surgery is poor. Marquardt et al. [34] reported that after the first revision Bankart surgery, more than half of the patients experience recurrent instability and only 23% (seven patients) achieved good to excellent outcomes after the second revision Bankart repair.

Case 2: Bony Bankart with Hill-Sachs Lesion and Major Glenoid Bone Loss

History/Exam/Imaging

MS is a 25-year-old male with multiple recurrent anterior shoulder dislocations following a right arthroscopic Bankart repair performed at an outside institution. Upon presentation, he reported multiple episodes of locked anterior shoulder dislocations after surgery. He is currently over 1 year from his original surgery.

On exam, he demonstrated severe functional deficits and apprehension with the affected shoulder. Range of motion was full compared to contralateral side. He had positive apprehension and positive relocation sign. A CT scan was obtained, which revealed greater than 20% anterior inferior glenoid bone loss, a bony Bankart lesion medialized on the glenoid (Fig. 3a), and a Hill-Sachs lesion (Fig. 3b).

Procedure

The patient was brought to the operating room and placed under general anesthesia in the beach chair position. Exam under anesthesia demonstrated 3+ anterior load and shift with engagement of the Hill-Sachs lesion on the anterior glenoid with the arm in abduction and external rotation. The posterior portal was established for diagnostic arthroscopy, and a 30° arthroscope was inserted. Findings confirmed 20% bone loss at the anteroinferior glenoid rim with a large Hill-Sachs lesion on the posterior humeral head. At this time, open Latarjet was determined as the appropriate course of management due to the amount of glenoid bone loss.

Soft tissue was dissected down to the deltopectoral interval, and the cephalic vein was retracted laterally. The coracoid process was identified, and the conjoint tendon was split following further dissection and retraction of the pectoralis and deltoid. The pectoralis minor was released, and the undersurface of the coracoid was dissected out. The coracoid was then cut approximately 1–1/2 cm from its tip, and the coracoacromial ligament was released at the acromion. The subscapularis muscle was split in its middle aspect, and the conjoint tendon was further dissected freely.

A capsulotomy was performed, and the joint space was exposed. The anteroinferior region was dissected out, revealing a bony Bankart lesion. The region was debrided to a smooth surface. Two evenly spaced screw holes were drilled in the coracoid. The anterior and inferior glenoid was then drilled using the same-sized drill bit. The coracoid was secured to the anteroinferior rim with two screws (Fig. 4a, b). The capsulotomy was closed utilizing the released coracoacromial ligament.

Our patient is now 1 year from surgery and is doing very well. His forward flexion is 0–180°, abduction is 0–100°, and external rotation is 0–70°. He is without apprehension and relocation signs and has 5/5 rotator cuff strength. He has returned to full activity.

Discussion

This case represents the importance of recognizing and evaluating for the amount of glenoid bone loss and the appropriate selection of arthroscopic fixation versus addressing the bone loss anteriorly with either Laterjat or bone grafting to minimize recurrence and failure [8•, 14•, 35•]. The presence of significant bony lesions has been shown to dramatically increase the recurrence rate of shoulder instability following arthroscopic Bankart repair alone [9•, 11, 14•, 16•, 29•]. The surgeon faces the challenge of identifying and determining the severity of bony defects in order to select the appropriate course of management for these patients presenting with chronic shoulder dislocations and glenoid bone loss.

This patient presented to the senior author's clinic following a failed arthroscopic Bankart repair, with an engaging Hill-Sachs lesion and around 20% glenoid bone loss. The extent of his glenoid osseous lesion and engaging Hill-Sachs lesion precluded an arthroscopic revision surgery. Burkhart et al. reported 67% failure rate in patients after arthroscopic Bankart repair in patients that present with an inverted-pear glenoid that represented > 25% glenoid bone loss. In their follow-up study of 102 patients that underwent an open

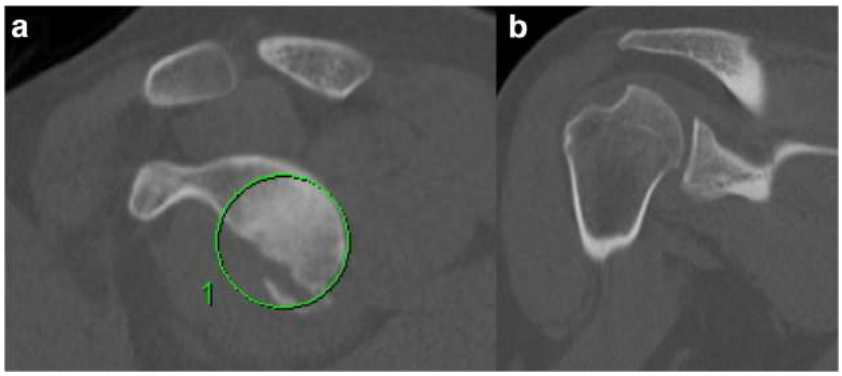

Fig. 3 **a** Sagittal CT imaging demonstrates significant anterior glenoid bone loss (> 20%) and bony Bankart lesion after failure of the original repair. **b** Coronal CT imaging shows a large Hill-Sachs lesion on the humeral head

Latarjet procedure for shoulder instability with > 25% bone loss, 95% success rate was reported with only four patients reporting persistent recurrent shoulder instability [36]. Furthermore, in cases with bipolar bone defects, the senior author recommends treating the engaging Hill-Sachs lesion by increasing the glenoid track anteriorly with either Latarjet or bone grafting only, so that the defect can no longer engage the glenoid rim [37]. Latarjet procedures enlarge the glenoid platform, while also stabilizing the shoulder with the conjoint tendon, subscapularis muscle, and remnant of the coracoacromial (CA) ligament. This method has been shown to be effective in restoring shoulder stability and functional capacity in patients with bipolar bone defects and with significant glenoid bone loss, even in populations with greater than normal overhead activity and upper extremity stress [9•, 20•, 21•, 22, 32]. Long-term follow-up in 319 shoulders after the Bristow-Latarjet procedure also showed excellent clinical outcomes with 5% having recurrent dislocations and only 1% or three shoulders requiring revision surgery. Bony fusion of the coracoid to the glenoid was observed in 83% of the cases in this series [38•].

Case 3: Failed Latarjet and Chronic Subscapularis Rupture

History/Exam/Imaging

BK is a 41-year-old male with a complex history of left shoulder instability. He had undergone multiple shoulder operations with the most recent of which was a failed Latarjet done 2 years ago. At presentation, he reported multiple subsequent dislocations. On physical exam, the patient demonstrated 30° of active forward flexion, 80° of passive flexion, and 60° of abduction limited by pain, and apprehension with external rotation. Dynamic anterior superior escape of the humeral head was noted when the patient was trying to raise his arm. There was no evidence of subscapularis function with belly press and bear hug weakness. CT scan and MRI were obtained, both of which demonstrated approximately 10% bone loss at the anterior glenoid as well as grade 4 Goutallier fatty changes in the subscapularis muscle (Fig. 5a) with a chronic midsubstance tear (Fig. 5b).

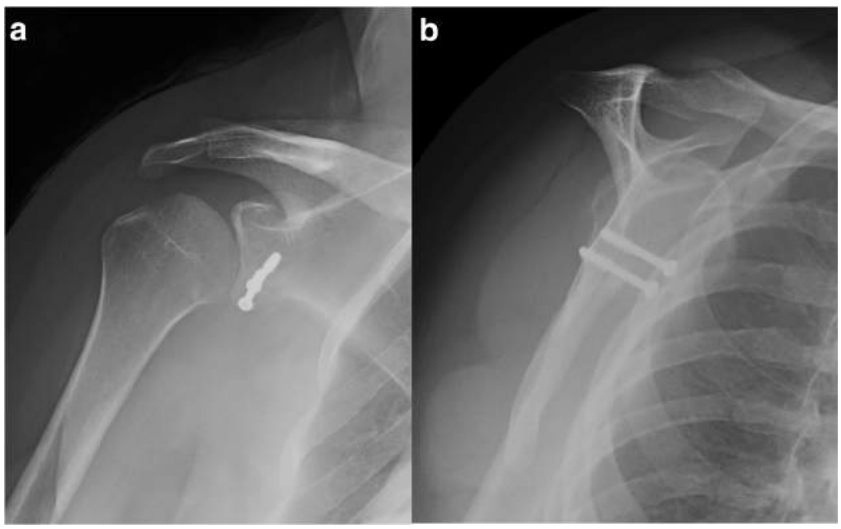

Fig. 4 **a** Grashey radiograph shows two partially threaded screws fixing the coracoid transfer. **b** The Y view shows the coracoid fixation with the two partially threaded screws

Procedure

The patient was brought to the operating room and placed under general anesthesia in the beach chair position. The posterior portal was established, and a diagnostic arthroscopy was performed using a 30° arthroscope. Arthroscopy confirmed around 10% bone loss at the anteroinferior glenoid and midsubstance full-thickness subscapularis tear. The decision was made to perform an Eden-Hybinette (iliac crest bone grafting) procedure with pectoralis major transfer through an open deltopectoral approach. The clavicular and sternal head of the pectoralis were identified, and the insertion was taken down. A flat bone bed was created in the anteroinferior glenoid region using a burr, to which an iliac crest autograft was affixed using two 5.0 osteopenia partially threaded screws (Smith and Nephew, Memphis, TN). The graft was stable and flush with the glenoid surface (Fig. 6a). The anterior capsule was further repaired to the iliac crest bone graft using the freed capsule and the scar tissue anteriorly. Two additional anchors were placed in the humeral head and neck junction to complete the anterior capsule repair. The entire pectoralis major was transferred to the lesser tuberosity using a double-row technique with suture anchors (Fig. 6b). The biceps tendon was then tenodesed into the bicipital groove. Postoperative radiographs demonstrate the humeral head is well centered on the glenoid (Fig. 6c).

Discussion

Patients with failed Latarjet and chronic subscapularis rupture with grade 4 Goutallier fatty changes present a complex and challenging case for the surgeon. The failure of the Latarjet in this particular case was likely due to the malpositioning of the bone graft medially onto the glenoid neck and also due to subscapularis insufficiency. The fatty infiltration of the subscapularis muscle belly demonstrates the chronicity of the tear. The absence of the subscapularis muscle with the failed Latarjet resulted in the patient presenting with dynamic anterosuperior escape of the shoulder, which points to the limited capacity of the anterior cuff to stabilize the joint in the absence of the intact subscapularis. Addressing both the chronic subscapularis deficit and failed anterior glenoid Latarjet is essential to the success of this revision surgery.

While there has been some variability in reporting on the effectiveness of pectoralis major transfers in addressing anterior shoulder instability, multiple recent reports find significant short-term and long-term improvements in stability following the procedure, especially in cases of isolated subscapularis insufficiency [39–41]. Substituting the subscapularis with the pectoralis major as a rotator cuff muscle changes the vector forces experienced by the joint and tends to result in anterior translation of the humeral head if done in isolation. Thus, performing an isolated pectoralis major transfer in patients with anterosuperior escape will result in unpredictable outcomes and increased failure rates. The Eden-Hybinette graft, much like a Latarjet, increases the anterior dimension of the glenoid, compensating for the more anteriorly translated center of rotation for the humeral head caused by this vector change. Eden-Hybinette procedures have previously proven successful in patients who have failed a Latarjet procedure [23]. Lunn et al. [23] reported good to excellent outcomes in 34 patients that had the Eden-Hybinette procedure for failed Latarjet. They found that revision with the Eden-Hybinette successfully prevented recurrence in up to 68% of patients in their series.

Two years postoperatively, our patient was doing very well functionally. Physical exam was completely normal, with full range of motion, 5/5 strength of abduction, bear hug, and belly press, without apprehension. He has since been able to return to work without limitations. The key to the successful outcome for this patient was performing the combined anterior iliac crest bone grafting to increase the glenoid excursion in addition to the pectoralis major transfer to compensate for the anterior translation of the center of rotation after the muscle transfer. The biomechanical rationale is well described in the case report published by Li et al. in Orthopedics [42•].

Case 4: Chronic Locked Anterior Glenohumeral Dislocation and Arthritis

History/Exam/Imaging

JS is a 49-year-old male with a history of severe left shoulder instability with more than 40 dislocations over a 20-year period and presented to the clinic with a locked anterior glenohumeral dislocation that occurred over 1 year prior. He was seen at an outside hospital where the dislocation was found to be irreducible and was scheduled for surgery; however, due to insurance problems, the surgery was cancelled. He had chronic pain and limitations in his range of motion. On physical exam, the patient demonstrated forward flexion of 50°, abduction 35°, external rotation to neutral, and internal rotation limited to just his side only. A CT and MRI of the shoulder were obtained, revealing a locked anterior dislocation, with a large Hill-Sachs lesion and a bony Bankart (Fig. 7a, b). Additionally, the patient had rotator cuff tears visualized on the MRI.

Procedure

The patient was brought to the operating room and placed under general anesthesia in the beach chair position. A deltopectoral approach was taken, and the soft tissue was dissected down to the cephalic vein, which was retracted laterally with the deltoid. The conjoint tendon was then

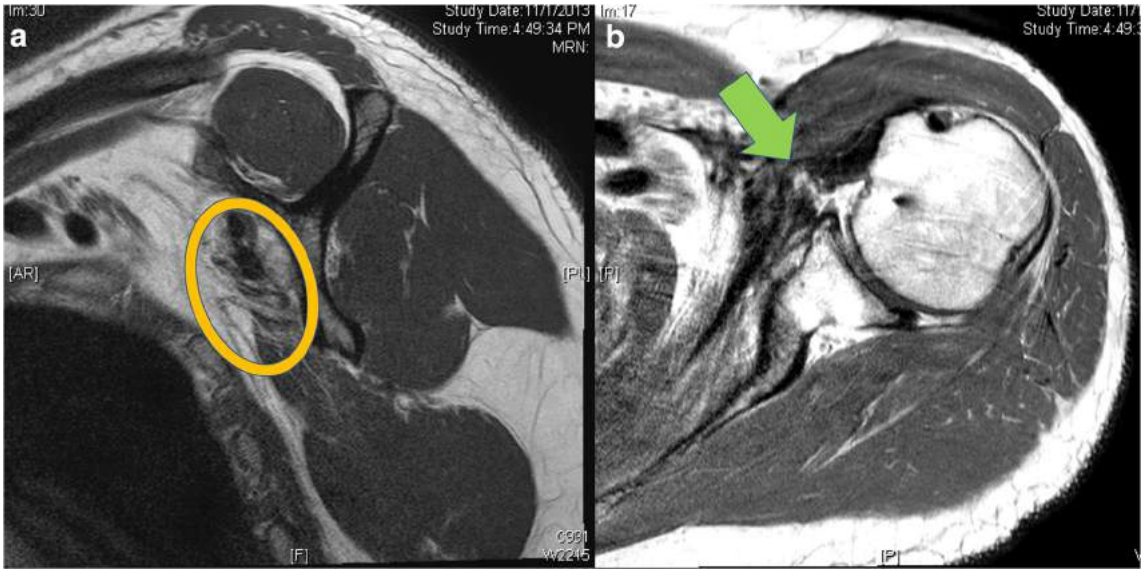

Fig. 5 **a** T1 sagittal images show grade 4 fatty infiltration (circle) of the subscapularis muscle belly. **b** Axial T1 MRI images show a full thickness tear (arrow) of the subscapularis tendon

separated from the adhesions over the subscapularis, and the subscapularis was released. The humeral head was locked out anteriorly. The biceps tendon was identified and tagged. Subsequently, the subscapularis was peeled and released which made dislocating the shoulder possible with external rotation. The engaged humeral head was visualized with approximately 30% of bone loss posteriorly. Diffuse cartilage loss was observed on both the glenoid side and the humeral head. Decision was made to perform a reverse shoulder arthroplasty. A 36-mm glenosphere with 4 mm of lateralization was placed in 10° of inferior tilt. The humerus was cut in 20° of retroversion, and the regular stem was press-fitted into the humeral canal. A constrained liner was used for the final reduction and implantation (Fig. 8a). The patient is now 2 years out from surgery and is pain-free. He has gained most of his function back with subjective shoulder value to be 90%. He has a forward flexion of 0–160°, abduction of 0–90°, and external rotation of 0–30° (Fig. 8b).

Discussion

Surgical options are limited in patients that present with chronic locked anterior shoulder instability. In the senior author's experience, when the shoulder is dislocated and locked out for more than 1 month, it is extremely difficult to achieve a closed reduction. These cases must be addressed surgically with open reduction and then address the glenoid bone loss and/or humeral head bone loss. In the subset of patients with arthritis or cartilage changes who are older and lower demand, reverse shoulder arthroplasty will predictably restore stability and improve the functional outcome after surgery. In this particular case, due to the advanced nature and chronicity of the injury, and cartilage loss with rotator cuff tear, few surgical interventions remained that would provide good functional capacity for this patient. It was decided with the patient to pursue reverse total shoulder arthroplasty (RTSA) due to its ability to predictably provide the best functional outcome.

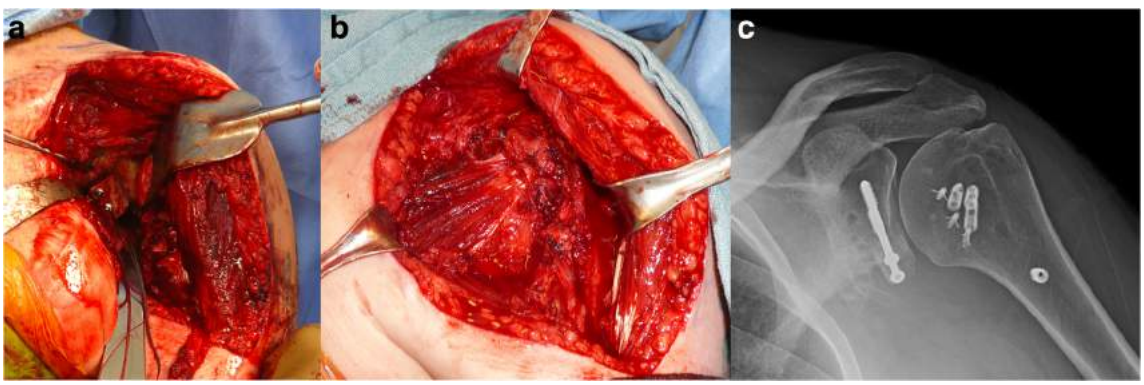

Fig. 6 **a** Iliac crest bone grafting to the anterior glenoid. **b** Pectoralis major transfer for chronic subscapularis rupture. **c** Postoperative radiograph at 1 year after surgery

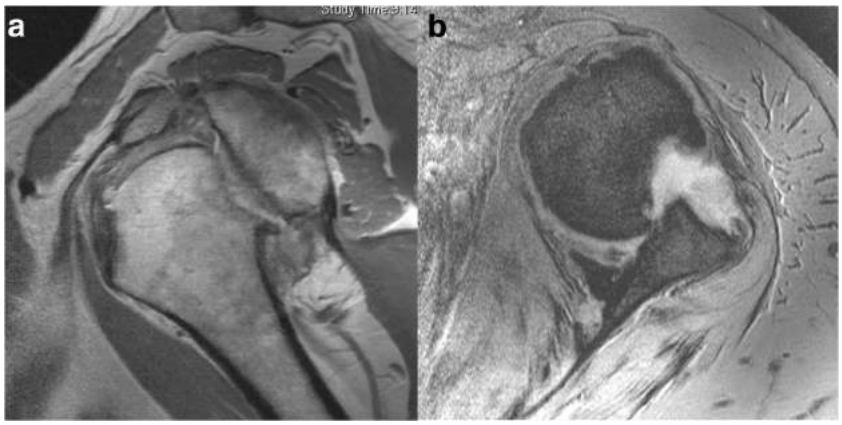

Fig. 7 **a** T1 sagittal MRI images show anterior locked humeral head dislocation. **b** T2 axial image demonstrated the locked out humeral head dislocation with a large Hill-Sachs lesion

Although young for a RTSA and despite the relatively high risk for complications including glenoid failure, dislocation, or revision surgeries, recent studies show that RTSA produces improved pain control, range of motion, and patient satisfaction in patients with locked anterior shoulder dislocation [25, 43, 44•]. Raiss et al. [45] reported the outcome of 22 patients with locked chronically dislocated shoulders treated with the reverse shoulder arthroplasty. They found good to excellent outcomes in 18/22 or 81% of patients with a mean shoulder flexion of 103° and external rotation of 15°. However, there were seven complications (32% complication rate) leading to revision surgery in six cases. The authors concluded that the reverse shoulder is a viable treatment option for these complex patients; however, the overall functional improvement is only fair to good with a higher complication rate. As these injuries are rare and reported samples remain small, further investigation into these challenging cases is certainly merited, especially with regard to long-term outcome and stability after the reverse shoulder arthroplasty.

Other Surgical Options for Complex Anterior Shoulder Instability: Remplissage

The special challenge of maintaining the stability of the shoulder using only the Bankart repair in the presence of large or engaging Hill-Sachs lesions is born out in the literature [14•, 46]. When untreated, Hill-Sachs lesions tend to engage the glenoid rim, destabilizing the glenohumeral joint which may lead to recurrent instability. The principles of "remplissage," or "filling" of humeral head bone defects with the posterior capsule and infraspinatus tendon to treat large, engaging Hill-Sachs lesions were described by Wolf and Pollack [47]. These procedures can be performed through an open approach, as originally described by Connolly [48], or via arthroscopy as described more recently in literature [47]. The mechanism of the procedure is to convert an intra-articular defect to an extra-articular one by means of anchoring it to the posterior cuff and consequently preventing engagement of the glenoid rim. As a result, in patients with greater than 20–25% humeral head bone

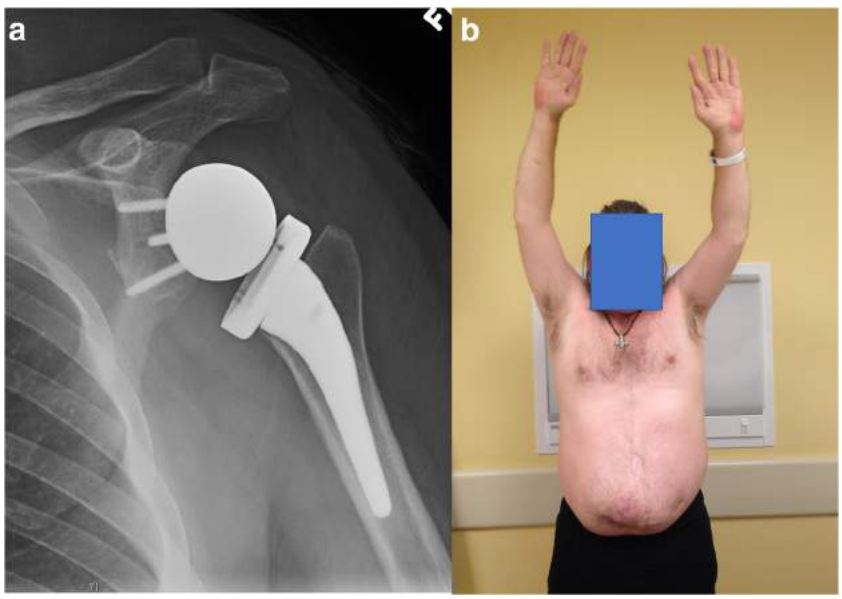

Fig. 8 **a** Postoperative radiology of the reverse shoulder arthroplasty. **b** One year after surgery, the patient regained most of his left shoulder function back with excellent range of motion

loss, remplissage is contraindicated, as there will be insufficient articular surface to generate stability.

The anatomy resultant from remplissage is understandably concerning for anterior tightness, and limited external rotation and abduction, and these concerns have been corroborated in some studies [49]. Recent reports, however, demonstrate excellent range of motion, return to sport in as many as 95% of patients, and improved subjective perception of the shoulder even in the presence of decreased range of motion [46, 47, 49–51]. Ko et al. [46] found that patients undergoing combined remplissage plus Bankart repair in fact experienced less loss of external rotation as compared to those undergoing Bankart only, likely due to the increased capsular plication required to ensure stability in the Bankart only group [46]. While failure rates have been reported as high as 14.7% [51], recurrence is usually seen in below 10% of patients, with some long-term studies reporting rates as low as 0–5% [46, 52]. Addition of the remplissage procedure to the Bankart repair is an option to decrease recurrence rate in patients with engaging Hill-Sachs lesions and anterior glenoid bone loss between 13.5 and 25%. Please see Fig. 1.

Humeral Head Bone Grafts

In patients with engaging or "off-track" Hill-Sachs lesions affecting greater than 25% of the humeral head, stabilization at the joint is often challenging. In these patients, the orientation of the Hill-Sachs lesion is such that, during functional motion, the defect engages the glenoid rim and is said to be "off-track," while those that are oriented obliquely to the rim do not engage during functional movements and are said to be "on-track" [24]. Without concomitant glenoid bone loss, bone grafting can be used in order to best preserve the native anatomy at the joint. Using bone plug autografts or fresh/frozen allografts, the surgeon fills the defect and restores the articulating surface of the humeral head to prevent future engagement with the glenoid rim. Similarly, in patients with Hill-Sachs lesions whose depth is 25% or greater than the diameter of the humeral head, the prognostic value of remplissage is poor and bone grafting is preferable [51].

Because such severe lesions are rare in the absence of glenoid insufficiency, reports on the effectiveness of these procedures continue to be scarce. In one of the larger studies of 18 patients receiving humeral head allografts, Miniaci and Gish [53] found 16 had returned to work at 50 months of follow-up, though complications such as partial graft collapse, early radiographic evidence of osteoarthritis, mild subluxation, and hardware complications were common [53]. A recent meta-analysis performed by Saltzman et al. [54] revealed similar results across eight case reports and four case series and also suggested that fresh allografts may decrease the rate of graft failure.

Conclusion

As is illustrated by each of these cases, treatment options for complex anterior shoulder instability widely range based on the patients presenting exam, surgical history, amount of glenoid bone loss, and size of Hill-Sachs lesion (engaging vs. not engaging). The treating surgeon must combine the patient history, physical exam, and preoperative imaging findings along with patient expectations and pre-injury activity levels to determine which procedure will give the patient the best functional outcome with decreased failure risk. Scrutiny must be placed on the extent of soft tissue damage and the amount of glenoid and humeral head bony deficiency to address stability without sacrificing mobility. Arthroscopic revision Bankart repair has a role in cases of recurrent instability after primary repair where there is both good soft tissue (capsulolabral complex) remaining and minimal bony damage (glenoid bone loss < 13.5%) [14•, 29•, 55]. In cases of larger bony involvement about the glenoid (> 13.5%), the Latarjet procedure has been shown to have good outcomes for patients [9•, 20•, 21•, 22, 35•]. In the subset of patients presenting with > 25% glenoid bone loss and large Hill-Sachs lesion, anterior bone grafting must be considered using either iliac crest of allograft. Muscle transfers along with remplissage and humeral head bone grafting are other alternative options that are available to the surgeon based on individual cases. It is imperative that the surgeon be technically sound and make the right decision regarding the surgical management to avoid the risk of failure necessitating further revision surgery, which have higher rates of complications and worse outcomes [14•, 23].

Compliance with Ethical Standards

Conflict of Interest Nathan Olszewski, Michael Gustin, and Emily J. Curry declare that they have no conflict of interest.

Xinning Li reports equity in, and is an editorial board member of, Journal of Medical Insight.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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