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REVIEW

Current concepts in the management of recurrent anterior gleno-humeral joint instability with bone loss

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Abstract

The management of recurrent anterior gleno-humeral joint instability is challenging in the presence of bone loss. It is often seen in young athletic patients and dislocations related to epileptic seizures and may involve glenoid bone deficiency, humeral bone deficiency or combined bipolar lesions. It is critical to accurately identify and assess the amount and position of bone loss in order to select the most appropriate treatment and reduce the risk of recurrent instability after surgery. The current literature suggests that coracoid and iliac crest bone block transfers are reliable for treating glenoid defects. The treatment of humeral defects is more controversial, however, although good early results have been reported after arthroscopic Remplissage for small defects. Larger humeral defects may require complex reconstruction or partial resurfacing. There is currently very limited evidence to support treatment strategies when dealing with bipolar lesions. The aim of this review is to summarise the current evidence regarding the best imaging modalities and treatment strategies in managing this complex problem relating particularly to contact athletes and dislocations related to epileptic seizures.

Key words: Shoulder dislocation; Bone loss; Latarjet; Hill-Sachs lesion; Remplissage

Core tip: Managing recurrent anterior gleno-humeral instability with bone loss is challenging. Each case needs to be assessed on its own merits with consideration of both glenoid and humeral bone defects and their relative position to each other. Latarjet and iliac crest graft transfers are reliable for treating glenoid lesions. The treatment of humeral defects is controversial - the early results of Remplissage for small defects are promising; large defects may require bony reconstructions or partial resurfacing. The evidence remains limited when addressing bipolar lesions.

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INTRODUCTION

Shoulder instability can be defined as a symptomatic abnormal motion of the humeral head relative to the glenoid during active shoulder motion[1,2]. Traumatic anterior glenohumeral dislocations or subluxations can lead to recurrent instability, especially in young contact athletes and epileptic patients with humeral and/or glenoid bone loss[3]. Failure to identify and address the bone loss when planning treatment can result in unsuccessful soft tissue stabilization procedures being performed with recurrent dislocations[2,4]. This has been previously demonstrated by Burkhart and De Beer[2] where 89% of contact athletes who failed soft tissue stabilization procedures were found to have significant bone loss.

Bone loss in the context of glenohumeral instability includes glenoid, humeral or combined defects. Glenoid defects are mainly located in the antero-inferior glenoid between the 2 and 6 o'clock positions[5].

Humeral osseous defects in the context of anterior glenohumeral instability, referred to as Hill-Sachs lesions, occur where the posterolateral aspect of humeral head abuts against the anterior glenoid[6]. Posterior dislocations are associated with reverse Hill-Sachs lesions with an impaction fracture over the anteromedial aspect of the humeral head[3]. Co-existing osseous defects of the humerus and glenoid are termed bipolar lesions. Bipolar lesions can be defined as "on-track" or "off track", which describes the degree to which the humeral Hill-Sachs defect engages the glenoid defect in a position of 90 degrees of abduction and external rotation of the shoulder[7].

Epidemiology

A recent population-based study by Leroux *et al*[8] reported a 20% incidence of recurrent instability following a first time anterior shoulder dislocation in all adult patients. The highest risk group was young (< 20 years), male patients with an incidence density ratio of 98 per 100000 person-years. Other studies have also shown that young athletes and those that participate in high-energy contact sports are most likely to develop glenohumeral instability following an initial traumatic dislocation[9,10].

Epileptic patients present as a challenging subgroup due to a tendency to develop large bipolar lesions, especially if their condition is poorly controlled[11,12]. Bone loss in epileptic patients is also caused by underlying metabolic bone disorders with a reduced bone density seen in 20%-70% of patients taking antiepileptic medication[13].

Several studies have analysed the incidence of bone loss in shoulder instability. Edwards *et al*[14] reviewed plain films of chronic anterior shoulder instability and found an osseous lesion of glenoid in 78% and humeral impaction fracture in 73%. A series of two-dimensional (2D) computed tomography (CT) scans has shown glenoid bone loss in 86% of patients with glenohumeral instability[15]. Sugaya *et al*[16] found a glenoid osseous defect in 50% of patients with recurrent shoulder instability. The presence of a Hill-Sachs lesion consistent with humeral bone loss in recurrent shoulder instability is estimated to be between 38% and 88%[17,18].

There are few studies focusing on the incidence of bipolar bone loss in shoulder instability. However it should be noted that radiological studies have shown that the presence of an isolated glenoid or humeral defect increases the chances of an associated bipolar defect by a factor of 2.5 to 11[19,20].

CLINICAL PRESENTATION AND EXAMINATION

It is important to elicit a comprehensive history when assessing patients with recurrent glenohumeral instability. One must identify the age at which the instability began and the mechanism of injury, especially of the very first dislocation. Most commonly, patients identify a traumatic injury at young age but it is important to elicit whether there has been repeated injury or trauma, particularly in athletes or epileptic patients. The direction of initial dislocation and instability must be noted as well as the position of the arm at the time of injury. In cases of recurrent instability it is the key to document the level of force required to dislocate. Indeed, patients who dislocate during low energy activity such as turning in bed, reaching out for objects, putting a coat or seatbelt on, or whilst sleeping are likely to have a greater degree of concomitant bone loss and instability. The patient may describe mechanical symptoms such as locking whilst moving their shoulder suggesting an engaging bony defect on the humeral head or glenoid. The number of instability episodes per year should be noted and whether any dislocations or subluxations needed reducing in the Emergency Department or in the operating room. It is also important to record the patient's level of function and specific tasks performed causing apprehension. Enquiring about any underlying medical conditions such as epilepsy or collagen disorders is also vital information to obtain.

Key aspects of the examination include establishing intact cuff and neurological function and any associated stiffness that may be present in chronic conditions where degenerative joint changes may already have occurred. There are a number of special tests which can be performed to assess the degree of glenohumeral instability. The load and shift helps assesses the integrity of the glenoid. The humeral head is compressed into the glenoid fossa while an anterior and posterior translation force is applied. Following bone loss the resistance to this force is lost and it is possible to dislocate or subluxate the humeral head[21]. The apprehension test assesses whether the patient experiences the sensation of instability when the shoulder is in the position of 90 degrees of abduction and varying degrees of external rotation. Patients with significant bone loss typically experience apprehension at lower degrees of abduction[22]. A reducing relocation force can then be applied to see if this reduces the pain. It is also important to assess for signs of laxity: One can examine for a sulcus sign, which suggests inferior shoulder laxity. This is achieved with traction of the humerus and measuring the gap between the lateral acromion and the humeral head and comparing with the unaffected side[23]. The Gagey hyper-abduction test looks for laxity in the inferior glenohumeral ligament and is useful to look for baseline laxity in the other/normal shoulder[24].

INVESTIGATION AND IMAGING

Plain radiographs

Initial investigations commence with plain radiographs of the shoulder. These include a true ("turned") antero-posterior (AP), axillary and scapula Y view. Other special plain films described include the West Point View, which can demonstrate a glenoid rim fracture. The presence of a Hill-Sachs lesion can be identified with the aid of the Stryker Notch view[22]. The Bernageau radiographic view has been described in order to calculate the degree of glenoid bone loss in glenohumeral instability[25]. It involves taking an X-ray with the shoulder in abduction and directing the beam at 20 degrees to the horizontal, so that the antero-superior border of the glenoid is in line with the anterior line of the scapula on the image. The diameter of the glenoid is measured and compared with the healthy side to estimate bone loss. A study by Pansard *et al*[26] however showed poor correlation with arthroscopic findings in affected individuals in a small retrospective cohort of patients with glenoid bone loss.

CT

Glenoid bone loss: Most imaging studies have focused on the evaluation of glenoid bone loss in shoulder instability. Current evidence suggests that 3D-CT is the gold standard imaging technique available to provide an accurate measure of the degree of bone loss. Chuang *et al*[27] showed good correlation between degree of bone loss using 3D-CT with arthroscopic assessment in 188 patients.

Bishop *et al*[28] performed a cadaveric study comparing the modalities of 2D-CT, 3D-CT and MRI to quantify bone loss and concluded that 3D-CT was the best modality to evaluate glenoid bone loss. 2D-CT relies upon orientating the beam directly perpendicular to the glenoid otherwise bone loss can be underestimated or overestimated.

There are also various different measurement techniques performed using 3D-CT to accurately quantify the glenoid defect. Several authors have concluded that the PICO measurement technique reliably produces an accurate and reliable measure of glenoid bone loss in shoulder instability[29-31]. The PICO method involves obtaining en-face 3D views of both the affected and normal glenoid. The healthy shoulder image is superimposed onto the affected side and the defect resembles the area of bone loss between the two. Bois concluded that 3D-CT was superior to 2D-CT and analysed three different 3D techniques to accurately quantify bone loss. The PICO method was found to be the most reliable measure of bone loss in 3D-CT[32,33]. However, the PICO technique has a number of drawbacks including the need to scan both shoulders increasing the radiation dose. Furthermore it is unsuitable for bilateral cases as relies on the presence of a "normal" shoulder.

Sugaya *et al*[16] reported good results in 100 patients using the "best fit circle principle". This assumes that inferior 2/3 of the glenoid resembles a "perfect circle", which has been supported by cadaveric studies[34]. The degree of bone loss can be calculated by finding the amount of surface area missing on the affected shoulder scan[17]. This method relies on scanning the affected shoulder alone and is currently the most widely used method.

Humeral bone loss: Studies evaluating imaging in humeral bone loss are limited. In a study of 104 patients 3D-CT was used to evaluate the parameters of the humeral Hill-Sachs defect. The use of CT with 3D reconstructions was able to accurately ascertain the size, shape and location of the defect and thereby can be predictive of humeral Hill-Sachs engagement[35]. Chen *et al*[36] reported that the degree of humeral bone loss can be reliably calculated by dividing the area of impaction by the total arc of the articular surface.

Ultrasonography and humeral bone loss

Ultrasound scanning has been shown to be able to detect the presence of humeral Hill-Sachs lesions[37]. It's advantageous as it is readily available, avoids radiation, and allows one to obtain dynamic multi-planar images[38]. Ultrasound scanning has also been shown to have a sensitivity and specificity comparable with CT arthrograms in identifying Hill-Sachs lesions[39]. However, its limitations include operator dependence and it cannot be used to quantify the size of the humeral head defect, and thus has a limited role in pre-operative planning.

Magnetic resonance imaging

Glenoid bone loss: Magnetic resonance imaging (MRI) scanning is advantageous to CT as it allows a detailed evaluation of the soft tissues around the shoulder as well as imaging the bone. Furthermore, it avoids the risks of radiation exposure. A study of 18 cadavers revealed that the accuracy of MRI in measuring glenoid defects was comparable to CT. They used the "best circle" method previously described and applied the technique to MR[40]. Moroder *et al*[41] however compared

CT with MRI in 83 patients in the pre-operative planning stage to evaluate bone defects in shoulder instability and reported that CT was found to be superior in their study.

Hijusmans' cadaveric study showed good accuracy of MR arthrograms when assessing glenoid bone loss[42]. This finding was supported in another study of 35 patients with glenoid bone loss where MR arthrograms were found to have good intra- and inter-observer reliability[43]. Both studies showed that MR arthrograms were comparable to 3D-CT. A study by Modi *et al*[44] with 103 patients reported that the sensitivity/specificity of MRA for glenoid bone loss was 0.58/1.00 and this increased to 0.75/1.00 when performing abduction external rotation views in addition to standard views.

Evidence to support the use of MRI is still limited and larger more significantly powered studies are required prior to it being considered equivocal to the current gold standard 3D-CT modality when trying to assess bone loss.

Humeral bone loss: Studies have reported on the ability of MRI to detect the presence of humeral Hill-Sachs lesions[45,46]. One study considered whether MRI could accurately predict the presence of a Hill-Sachs lesion diagnosed arthroscopically: In 83 patients, 90.6% specificity and 96.3% sensitivity were reported[46]. Evidence is limited on the ability of MRI to accurately quantify the degree of humeral bone loss. Further trials are required to evaluate this further.

MANAGEMENT

The management of bone loss in shoulder instability starts by understanding the role of patient demographics and functional demand. Failure of conservative management in glenohumeral instability has been found to be considerably higher in younger patients, especially athletes with high functional demand. A prospective study reported up to 90% recurrence rate in young athletes under 24-year-old following a first time shoulder dislocation[47]. Specifically, participation in contact sports was a significant patient factor in developing recurrent instability[48,49]. It is important to identify the chronicity of the shoulder problem, the functional restriction and quantification of the glenoid and humeral bone loss prior to treatment. Non-operative management in the context of bone loss in shoulder instability is reserved for high-risk surgical candidates, patients with low functional demands and those with poor compliance to rehabilitation protocols. In the specific case of patients with epilepsy, it is vital to achieve good seizure control prior to considering surgical intervention due to the high risk of surgical failure in this complex group of patients, especially as they often present with severe bipolar bone loss. We have attempted to present an algorithm, based upon the amount of glenoid and humeral bone loss, to guide management after considering the evidence currently available in the literature (Figure 1).

Glenoid bone loss

0%-25% bone loss: The literature suggests that patients with glenohumeral instability with up to 15% isolated glenoid bone loss can be treated with an arthroscopic soft tissue Bankart repair alone[50]. Initial trials favoured open stabilization over arthroscopic Bankart repair[51,52]. A systematic review by Brophy *et al*[53] reported instability following arthroscopic and open Bankart repairs to be comparable. However, a study by Rhee *et al*[54] reported a higher risk of failure with arthroscopic repair over open surgery in contact athletes although this was level 4 evidence.

In patients with 15%-25% bone loss, management is dependent on the level of functional demand of the patient. Balg *et al*[55] devised the instability severity index score, which identified six risk factors that may predict failure of an arthroscopic soft tissue Bankart repair. These included age < 20 years, participation in contact sports, competitive level, shoulder hyperlaxity, a Hill-Sachs lesion and a loss of contour of the glenoid rim. Scoring > 6/10 on this scale predicted a 70% failure of Bankart repair in such patients.

Thus in high demand patients or those with a significantly high instability index score, effort must be made to address the bony lesion. In the acute setting, where the glenoid bony fragment can be identified, early open reduction and internal fixation of the fragment is advised. Studies have shown that open reduction and fixation of a glenoid rim fracture with screws shows good outcomes at 1 year and a high rate of union[56,57]. Comminution and the inability to fix the fragment, necessitates a bony reconstruction procedure such as a Latarjet procedure[21]. In contrast, lower demand patients may be successfully managed with a soft tissue Bankart procedure alone.

> 25% bone loss: Significant bone loss has been described where the glenoid takes the appearance of an "inverted pear" shape. This corresponds to at least 25% bone loss. Burkhart *et al*[2] identified a 67% recurrent instability rate in such patients undergoing a soft tissue Bankart repair in contrast to 4% in those without bony deficiency.

In an acute setting, anatomical reduction may be achieved using open or arthroscopic reduction and internal fixation of the rim fragment. In cases where this is not possible reconstruction of the osseous defect is required. There are several ways this can be achieved including coracoid transfer procedures and the use of autografts or allografts to restore the bony anatomy of the glenoid.

Coracoid transfer procedures include the Bristow and Latarjet techniques. The Bristow procedure transfers the tip of the coracoid with its attached conjoined tendon to the anterior glenoid[58]. The Latarjet procedure involves transfer of approximately 3 cm of the coracoid in addition to the conjoined tendon hence provides a greater bony augment and allows fixation with two screws rather than one, as with the Bristow, increasing the stability and chance of successful union[59]. It also extends the

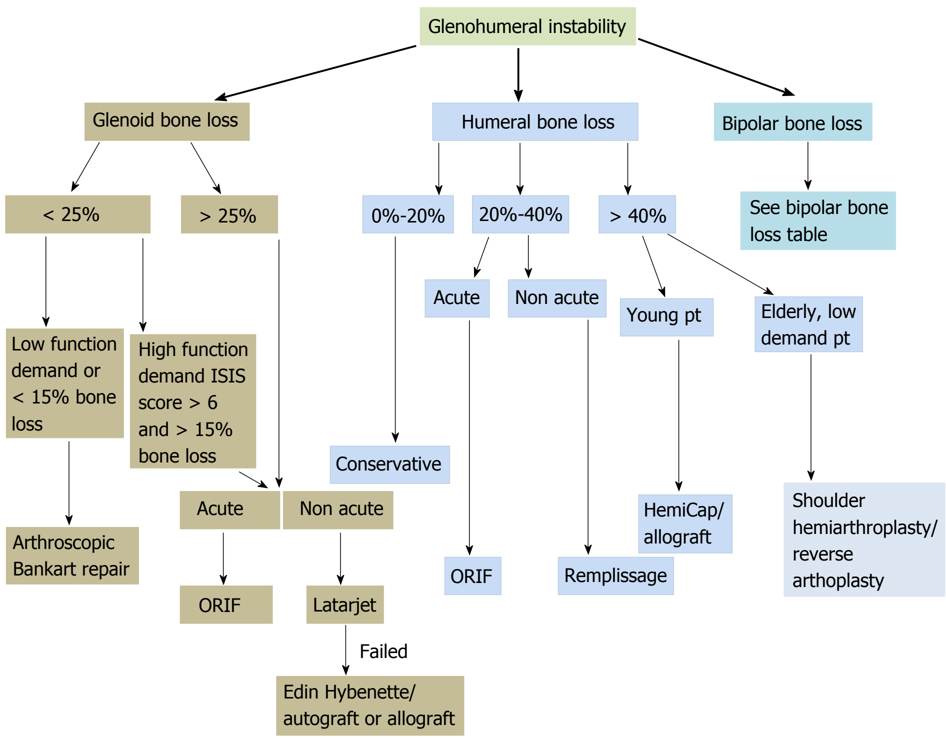

Figure 1 Management of glenoid and humeral bone loss in shoulder instability. ISIS: Instability severity index score; ORIF: Open reduction and internal fixation; pt: Patient.

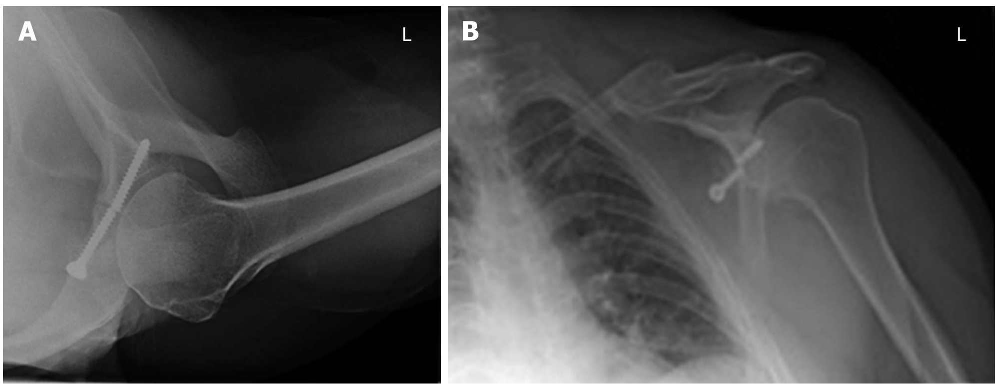

Figure 2 45-year-old gentleman with previous open latarjet procedure for left shoulder instability. Subsequent non-union of graft and failure of metalwork is seen on the axillary (A) and antero-posterior (B) radiographs.

concavity of the glenoid articular arc increasing the ability to resist off axis loads that allow the shoulder to subluxate or dislocate[60]. The transfer of the conjoined tendon with the graft also contributes to increased stability as it acts as a sling across the antero-inferior capsule when the shoulder is in abduction and external rotation. The original Latarjet procedure has been modified to preserve the inferior subscapularis muscle contributing to soft tissue stability. Furthermore the graft may be kept extra-articular by repair of the capsule to the native glenoid, which helps to stop the graft abrading the humeral surface[61].

Several studies have reported good outcomes with the Latarjet procedure, with low rates of recurrent instability, high patient satisfaction and return to sports[60,62]. Critics of the open Latarjet have focused on the loss of external rotation post procedure, which could have an adverse impact on overhead throwing athletes, and the development of osteoarthritis[63]. Other complications include infection, neurological injuries, non-union of the Latarjet graft and failure of metalwork (Figure 2).

A developing concept is an arthroscopic Latarjet procedure, which is a technically demanding procedure and should only be undertaken by the expert arthroscopist. Lafosse *et al*[64] reported no recurrence in 96 patients treated with an arthroscopic Latarjet with 91% of patients reporting an excellent subjective outcome on Disabilities of Arm, Shoulder and Hand score. Boileau *et al*[65] have advanced the technique by combining arthroscopic Latarjet with a Bankart repair (2B3 procedure). It is thought that repairing the residual capsular labrum contributes to shoulder stability and helps maintain proprioceptive fibres

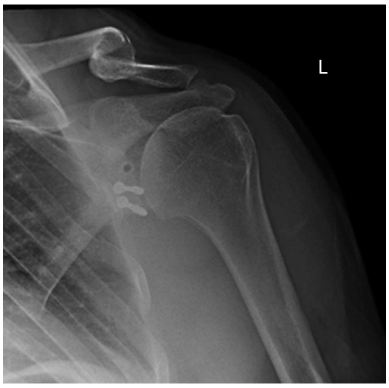

Figure 3 Failed latarjet procedure in Figure 1 treated with an Eden Hybinette procedure using an autologous iliac crest bone graft. The graft position and fixation with 2 screws is shown on the antero-posterior radiograph.

needed in athletes. Ninety-one percent of patients had no evidence of osteoarthritis with this technique, with all throwing athletes returning to sports, and only a mean 9 degree loss of external rotation on the operated side.

Glenoid reconstruction with autograft or allograft is another technique aimed at anatomically reconstructing the osseous defect. It addresses the bone defect but does not address the loss of stability caused by the laxity of the inferior glenohumeral ligament[66]. Griffin *et al*[3] has suggested that an autograft or allograft may be a used in cases of a failed Latarjet or in cases of concurrent coracoid fracture. It may also be of use in massive glenoid bone loss where the coracoid transfer is not enough bone stock to augment the defect.

The most commonly described autograft has been the Eden-Hybinette procedure. This involves using the inner table of the iliac crest as an autologous graft to augment the glenoid defect (Figure 3). Both intra and extra-articular grafts have been described. Studies have reported good outcomes in the use of iliac crest bone autograft in patients. However these studies are limited by small population groups and limited follow-up period[67-69]. The use of a distal clavicle arthroscopic autograft has also been reported[70].

Several studies have commented on the use of allografts for glenoid reconstructions. These include distal tibia[71] and femoral head allografts[72]. It has been proposed that the use of allografts may have several advantages over autografts including a more accurate restoration of the anatomical contour of the glenoid as well as the addition of a cartilaginous interface for articulation with the humeral head. Sayegh *et al*[73] conducted a systematic review into the use of allografts in addressing glenoid bone loss. This study concluded a recurrence rate of instability of 7.1% following allograft procedure with excellent subjective clinical outcome. The review included a collection of small population studies hence the effectiveness and limitations of this treatment are yet to be fully understood.

It has been proposed that low demand patients may still be managed successfully with arthroscopic Bankart stabilization. Kim *et al*[74] showed that in a study of 36 non-athletic individuals with low functional demand, arthroscopic stabilization produced a satisfactory outcome in patients with glenoid bone loss of 20%-30%. However in patients with excessive joint laxity, arthroscopic stabilization is unreliable with a recurrent instability rate of 23%. These findings are also supported by a study of 21 patients with 20%-30% bone loss by Mologne *et al*[75]. One must be cautious with these findings, however, as both studies are poorly powered statistically with limited follow-up duration.

Humeral bone loss

0%-20% bone loss: Current concepts suggest that a humeral bone defect of 0%-20% can be managed conservatively. A trial of immobilization followed by physiotherapy focusing on dynamic shoulder stabilizers is warranted. In most individuals this will be a suitable management strategy, especially in the elderly and low demand patients[76] (Figure 1).

It is important to understand however high demand athletes, such as baseball players, who require stability throughout extremes of motion may require surgery at a lower threshold of bone loss.

20%-40% bone loss: Various different surgical strategies have been described for managing humeral bone loss > 20%. In cases where a humeral defect has been detected within 3-4 wk of injury, anatomical fixation of the defect has been described. This involves disimpaction of the humeral defect by elevating it with a bone tap until anatomy of the head is restored. The defect can then be held with cortical screws and defect be filled with cancellous bone graft. Unfortunately there is noticeable lack of evidence in the literature focusing on this technique's outcome and indication[77,78].

The Remplissage technique has recently become more popular for the treatment of engaging Hill-Sachs lesions. This involves a tenodesis of the infraspinatus tendon and posterior capsule into the humeral head defect rendering the defect extra-articular and thus preventing engagement with the glenoid rim[79]. It is now usually performed arthroscopically and can be combined with a Bankart repair to address combined humeral and glenoid defects where glenoid bone loss is < 25%. Open techniques involve mobilizing the tendon free from its attachment on the greater tuberosity and suturing it into the defect over the lateral humeral cortex. In larger defects up to 40% it is advisable to osteotomise the greater tuberosity with the infraspinatus tendon and to fix the bone and tendon transfer into the defect with fully threaded cancellous screws[80].

The reported outcomes of arthroscopic remplissage are promising. Purchase, Sahajpal *et al*[80] reported a recurrent instability rate of 7% at 2 years post surgery with no significant loss in range of motion. Other studies report a loss of external rotation between 1.9 to 8 degrees[81,82]. A 90% return to sport has been reported following the procedure. A systematic review comparing remplissage, weber osteotomy and allograft procedures

Table 1 Management of bipolar bone loss in shoulder instability

	Bipolar bone loss			
	Non engaging humeral Hill-Sachs "on-track"	Engaging humeral Hill-Sach "off-track" < 40% loss	Engaging humeral Hill-Sachs "off track" large defect > 40% loss. Young pt	Engaging humeral Hill-Sachs "off track" large defect > 40% Elderly pt
Glenoid bone loss < 25%	Arthoscopic Bankart repair	Remplissage ± Bankart	HemiCap ± Bankart	Shoulder hemiarthroplasty
Glenoid bone loss > 25%	Latarjet procedure	Latarjet + remplissage	Latarjet + HemiCap	Reverse shoulder replacement

pt: Patient.

for humeral bone loss found that remplissage had the better outcome scores and fewer complications[83].

Historically proximal rotational humeral osteotomy, described by Weber *et al*[84] in 1969, was used to treat young adults with moderate to severe Hill-Sachs lesions with aim of restoring stability. This involved a subcapital humeral osteotomy with medial rotation of humeral head by 25 degrees and imbrication of subscapularis tendon and anterior capsule. As a result the humeral defect could not engage the glenoid through the arc of motion. However the procedure is associated with high complication rates and has fallen out of favour[85,86].

> 40% bone loss: In young patients with large humeral defects (> 40% bone loss), osseous allograft reconstruction has been described as a useful strategy to avoid the need for prosthetic replacement. The data in the literature on this technique is very limited and further work is needed to evaluate the efficacy and limitations of technique. Miniaci *et al*[85,86] used fresh frozen cryopreserved humeral head allografts in 18 patients. The graft is size and side matched to reconstruct the humeral head following chevron osteotomy of the Hill-Sachs defect. At 50 mo there were no episodes of instability and an 89% return to work. Two patients had partial graft failure and three showed early evidence of osteoarthritis. Another strategy has been the use of femoral head allografts. In a study of 13 patients there was a high Constant score 86.8 at 54 mo with one case of osteonecrosis noted[87].

An emerging technique in the treatment of young patients with bone loss > 40% has been the use of a partial resurfacing prosthesis such as the HemiCAP® (Arthrosurface, Franklin, MA, United States). This uses a spherical cobalt chrome component to fill the Hill-Sachs defect and restore joint congruity. The technique requires patients to have at least 60% normal bone stock, hence is contraindicated in those with osteoporotic bone[88]. The largest case series performed by Raiss *et al*[89] only involved 10 patients. They performed uncemented partial resurfacing in locked anterior dislocation patients with significant humeral bone loss and found an increase Constant score of 41 points post operatively with two re-operations for dislocation and glenoid erosion. Other case reports have been discussed in the context of bipolar bone loss where the engaging humeral defect was treated with this technique[90,91].

The lack of significant evidence in the literature suggests that there is no consensus strategy as to how to treat young patients with large degrees of humeral bone loss. Shoulder hemiarthroplasty is advocated in low demand or elderly patients with osteopenic bone and young adults in whom the strategies discussed above are not appropriate. Indeed in those patients with concomitant glenoid wear it may be sensible to consider a total shoulder replacement[92].

Bipolar humeral and glenoid bone loss

The management of bipolar or combined humeral and glenoid bone loss in the context of shoulder instability is an evolving concept. This degree of bone loss is usually seen after multiple traumatic dislocations and epileptic seizures. The key factors are the degree of bone loss involved but also whether the humeral Hill-Sachs lesion engages or not. The significance of the interaction between the humeral and glenoid defect can best be understood using the glenoid track principle. Yamamoto *et al*[93] described the glenoid track as the zone of contact between the humeral head and the glenoid at 90 degrees of shoulder abduction relative to the trunk. The region corresponds to 83% of diameter of the glenoid and represents a distance from the medial point of the contact area to the medial margin of the rotator cuff insertion on the humerus[94]. Thus glenoid bone loss decreases the size of the glenoid track (Table 1).

If the humeral Hill-Sachs bone lesion lies within the diameter of the glenoid track, there is bone support adjacent to this and the lesion is described as being "on-track". If the defect lies outside this region, there is no adjacent bone support and the lesion is "off track". If the Hill-Sachs lesion is "off-track" it gives rise to a more unstable shoulder in the context of bipolar bone loss. An updated definition of an engaging humeral bone lesion can be defined as one that lies outside of the glenoid track[50].

The concepts described can help determine the management of bipolar bone loss in shoulder instability. We have previously discussed the treatment of both glenoid and humeral bone loss individually. Di Giacomo *et al*[7] has proposed an algorithm for combined bone loss. Fundamental to this is whether the humeral bone lesion is "on track" or not. Bipolar defects with an "on-track" humeral defect may be treated by addressing the glenoid defect alone. Hence < 25% glenoid bone loss can be managed with arthroscopic Bankart repair and > 25% bone loss with a Latarjet procedure.

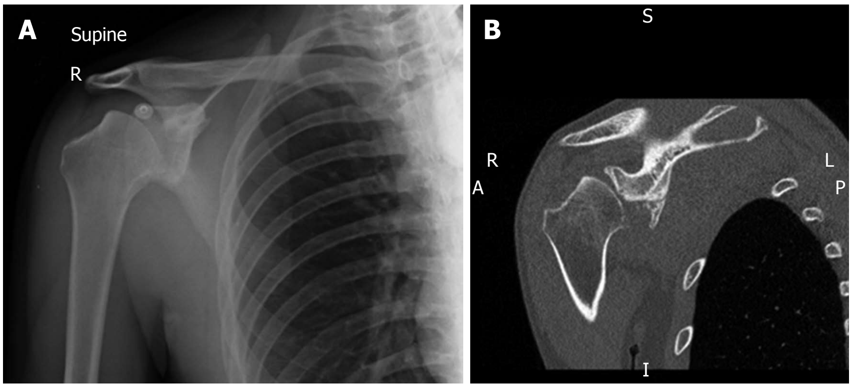

Figure 4 Antero-posterior radiograph (A) and computed tomography scan (B) of a 25-year-old epileptic with massive bipolar bone loss. He was found to have > 25% glenoid bone loss and > 40% humeral bone loss pre-operatively.

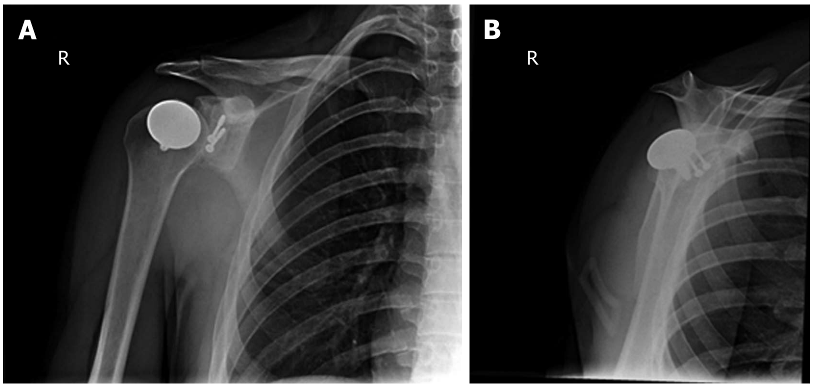

Figure 5 Antero-posterior (A) and scapular Y (B) views of an epileptic patient with massive bipolar bone loss treated with a humeral HemiCap and Latarjet procedure.

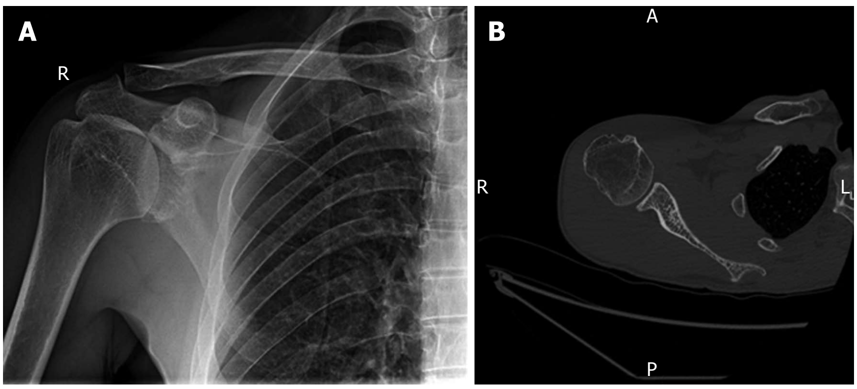

Figure 6 42-year-old manual worker with anterior shoulder instability with < 25% glenoid bone loss and an engaging Hill-Sachs lesion. He was managed successfully with an arthroscopic Remplissage and Bankart repair. Pre-operative antero-posterior radiographs (A) and computed tomography (B) images are demonstrated.

Patients with an "off-track" humeral bone defect require both the glenoid and the humeral defect to be addressed. Ranne *et al*[25] described successfully combining an open Latarjet and Remplissage in a patient with severe bipolar bone loss. This may be a reasonable option in those with > 25% glenoid bone loss with engaging humeral defects. In cases with significant > 40% humeral bone loss and > 25% glenoid loss, treatment with a combination of an open Latarjet with a partial resurfacing/replacement or allograft reconstruction procedure would address both the glenoid and humeral bone loss respectively (Figures 4 and 5). Those, however, with a lesser degree of glenoid bone loss < 25% with an "off-track" humeral Hill-Sachs may be successfully treated with a combined arthroscopic Bankart and Remplissage procedure (Figure 6).

In the case of failure of such procedures, the only available options for salvage surgery may be to consider shoulder fusion in younger patients (Figure 7), and reverse shoulder arthroplasty is older, lower demand

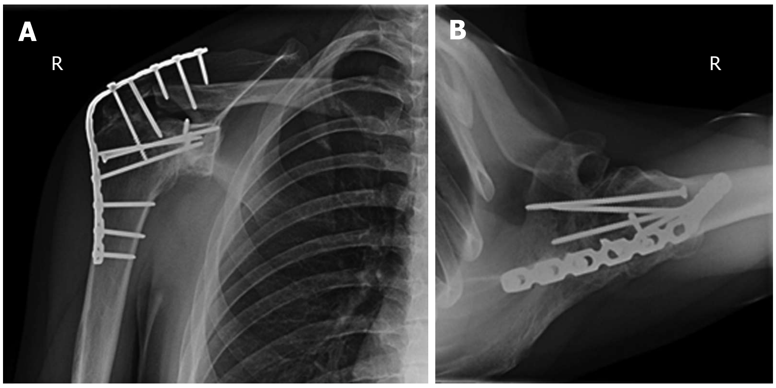

Figure 7 Antero-posterior (A) and axillary view (B) radiographs six months following shoulder fusion after failure of a combined HemiCap and Latarjet procedure in an epileptic patient with massive bipolar bone loss.

patients to restore stability and maintain some function.

CONCLUSION

Bone loss in shoulder instability is a challenging problem to orthopaedic clinicians. In this review we have addressed the current concepts in identifying and treating such patients using best current evidence available. Currently the literature is limited and further high level evidence studies are needed to further investigate the benefit of different surgical strategies, particularly in the area of combined humeral and glenoid bone loss.

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