Bone loss in anterior instability

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Abstract Bone loss is commonly observed in shoulders with anterior instability. The Latarjet procedure is commonly performed when a glenoid bony defect exists that is greater than 25 % of the glenoid width or when the risk of recurrent instability is higher (i.e., collision-sport athletes). Hill–Sachs lesions need to be assessed as well. For the purpose of assessing the bipolar lesions, the glenoid track concept is useful. A Hill–Sachs lesion that is located more medially than the medial margin of the glenoid track is defined as an engaging Hill–Sachs lesion. A potential treatment for such a condition is remplissage, but this procedure also decreases range of motion. Thus, its application in overhead athletes needs to be carefully considered.

Keywords Shoulder instability · Dislocation · Glenoid · Humeral head · Bony defect · Bony Bankart lesion · Hill–Sachs lesion · Engaging Hill–Sachs lesion · Latarjet procedure · Bristow–Latarjet · Bone graft · Glenoid track · Stabilizer · Stabilization mechanism · Remplissage · End-range stability · Mid-range stability

Introduction

The shoulder joint is the most common site of traumatic dislocation in our body [1]. The essential lesion of an

anterior shoulder dislocation is insufficiency of the inferior glenohumeral ligament (IGHL). The lesion may be on the glenoid side (Bankart lesion), on the humeral side (humeral avulsion of glenohumeral ligament = HAGL lesion), in the midsubstance of the ligament (capsular tear), or a combination of these lesions. Among these lesions, detachment of the IGHL from the glenoid, or a Bankart lesion, is the most common type after initial dislocation [2–4]. When the IGHL detaches from the glenoid rim, it often accompanies a bony fragment of the glenoid, which is called a bony Bankart lesion. In addition, when the humeral head is dislocated anteriorly, a strong compressive force is pushing the anterior rim of the glenoid against the humeral head, which often causes a compression fracture of the humeral head. These bony lesions are very common and need to be properly assessed and treated.

Bone loss of the glenoid

Prevalence

There are two types of glenoid bony defects: (1) fragment type and (2) erosion type. Among the shoulders with recurrent anterior dislocations, 50 % showed the fragment type, and 40 % showed the erosion type [5]. This means that only 10 % of those with a recurrent anterior dislocation have an intact glenoid. Bony lesions of the glenoid and of the humeral head are known to be the risk factors of recurrent instability after surgery [6, 7]. The glenoid defect is related to the number of dislocations and the age of initial dislocation [8].

Biomechanics

It has been said that a glenoid bony defect equal to or greater than one third of the glenoid surface needs to be treated surgically [2, 9, 10]. This one third is a semi-quantitative

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assessment of the defect size and is not applicable to our clinical settings.

Itoi et al [11] first demonstrated the critical size of the glenoid defect biomechanically. They evaluated shoulder stability after the Bankart repair in the presence of a remnant bony defect. They found that a Bankart-repaired shoulder with a bony defect larger than 21 % of the glenoid length (average 6.8 mm) presented with instability and a limited range of motion. They created a bony defect at the antero-inferior portion of the glenoid (4:30 position on the clock face of the right glenoid). By iliac bone grafting, the antero-inferior defect was recreated, and the bony stability assessed by the balance stability angle was completely restored [12]. However, the location of the glenoid defect was later found to be almost anterior, not antero-inferior to the glenoid [13, 14]. More recent studies demonstrated that the bony stability assessed by the stability ratio was significantly decreased after creating a bony defect larger than 26 % of the glenoid width (20 % of the glenoid length) [15]. In addition, shoulder stability after Bankart repair was significantly decreased, with a bony defect larger than 25 % of the glenoid width (19 % of the glenoid length) [16•].

From the clinical view point, Bigliani et al. [17] classified the glenoid rim lesions into three types: type I, avulsion fracture; type II, medially displaced, malunited fracture; and type III, erosion with less than 25 % (IIIA) or greater than 25 % (IIIB) deficiency of the glenoid width. They performed coracoid transfer to a patient with type IIIB with a satisfactory result. Burkhart et al. [6] reported from their clinical experience that an inverted pear glenoid (glenoid with a larger bony defect) was a risk factor of failed Bankart repair. Later, they reported that an inverted pear glenoid had a defect ranging from 25 % to 45 % of the glenoid width [18].

These biomechanical and clinical studies have demonstrated that a defect larger than 25 % of the glenoid width is a critical size, which needs to be treated.

Bone loss of the humeral head

Incidence

Bony defect of the posterolateral humeral head was first described by Malgaigne in 1855 [19]. In 1940, Hill and Sachs [20] wrote a review article that made this lesion well known, which thus carries their names. The incidence of Hill–Sachs lesion increases with an increased number of dislocations: Incidence ranges from 65 % to 67 % after initial dislocation and from 84 % to 93 % after recurrent dislocations [21, 22]. It also depends on imaging modalities. Plain x-rays revealed a Hill–Sachs lesion in 2/27 (7 %) shoulders with initial dislocation, but MRI revealed the lesion in 25/27 (93 %) [23]. Arthroscopic examination

within 72 h of initial anterior dislocation revealed that 15/32 shoulders (47 %) had a Hill–Sachs lesion [24].

Concomitant lesions commonly observed in the presence of a Hill–Sachs lesion are a tear of the subscapularis tendon [25] and an anterior labroligamentous periosteal sleeve avulsion lesion [26].

Biomechanics

Clinically, the critical size of the Hill–Sachs lesion that causes instability is thought to be the medium-sized (4 cm long $\times$ 0.5 cm deep) to large-sized (4 cm long $\times$ 1 cm deep) lesion [2, 27, 28], the lesion greater than 20 % [29] or 25 % [30] of the humeral head surface, the depth greater than 16 % of the humeral head diameter [31], the volume greater than 250 mm³ [32] or 1,000 mm³ [31].

The average size of the Hill–Sachs lesion is 22 mm in width and 5 mm in depth [33]. Using a clock face (12 o'clock = anterior, 3 o'clock = medial, 6 o'clock = posterior, 9 o'clock = lateral) on axial CT images, the lesion is located posterolaterally (average 7:58), with the top of the lesion located more posteriorly (average 6:46) and the bottom of the lesion more laterally (average 8:56) [33]. Cho et al. [34] used 3D-CT and measured the orientation of the Hill–Sachs lesion relative to the long axis of the humerus. The engaging Hill–Sachs lesion was oriented more horizontal, and the nonengaging Hill–Sachs lesion more vertical.

There are some biomechanical studies of the Hill–Sachs lesion. Sekiya et al. [35] created a Hill–Sachs lesion stepwise (12.5 %, 25 %, 37.5 %, and 50 % of the humeral head), performed bone grafting to the lesion, and measured the anterior translation and stability ratio. They found that shoulders with large Hill–Sachs lesions (37.5 % or 50.0 %) may benefit from allograft transplantation to restore shoulder stability. In another series of cadaveric shoulders, they created a 25 % Hill–Sachs lesion and measured anterior translation, in situ capsular force, and bony contact force. A 25 % Hill–Sachs lesion caused only small increases in the anterior translation, capsular force, and bony contact force [36]. Thus, they concluded that a 25 % defect of the humeral head in isolation would not cause recurrent anterior instability. Kaar et al. [37] created a Hill–Sachs lesion stepwise from 1/8 to 7/8 of the radius of the humeral head and measured the humeral head translation until a dislocation occurred. They showed that the end-range stability decreased at a 5/8 radius defect or greater and the mid-range stability decreased at 7/8 radius defect. They suggested that defects of 5/8 of the humeral head radius might require treatment to decrease the failure rate of shoulder instability repair.

From these clinical and biomechanical studies, the surgical indication is still not clear, because the surgical indication cannot be determined by the size of the Hill–Sachs lesion alone. Whether the Hill–Sachs lesion engages with

the glenoid depends not on the size of the Hill–Sachs lesion alone, but on the size and location of the Hill–Sachs lesion relative to the glenoid size. When the shoulder is in abduction and external rotation and moves along the end range of motion, the glenoid shifts along the posterior margin of the humeral head. This contact zone of the glenoid created on the humeral head along the end range of motion is called the *glenoid track* [38]. If the Hill–Sachs lesion is located within the glenoid track, there is no chance that the Hill–Sachs lesion engages with the glenoid (nonengaging Hill–Sachs lesion). If the Hill–Sachs lesion is located more medial than the glenoid track, there is a risk of engagement and dislocation (engaging Hill–Sachs lesion). According to Kurokawa et al. [39], there are two types of engaging Hill–Sachs lesion: the large and wide type and the narrow but medially located type. The medial margin of the glenoid track is located at a distance equivalent to 84 % of the glenoid width in cadaveric shoulders [38] and 85 % in live shoulders [40, 41•].

Evaluation of bone loss

Glenoid defect

It is difficult to depict a glenoid bony defect using plain x-rays, but specific views such as the West-Point view [42] and Bernageau view [43] are useful. CT is more commonly used to assess the location and size of the glenoid defect. The standard axial CT images are inaccurate in estimating the size of the glenoid defect [44]. Recently, although some have reported that there is not much difference in detecting a bony defect of the glenoid between 3D-CT and 2D-CT [45] or between 3D-CT and MRI [46], 3D-CT has become gold standard for precisely assessing glenoid defect size and location [5, 13, 47, 48].

Burkhart et al. [49] reported that during arthroscopy, the bare spot of the glenoid was a consistent reference point that was located almost exactly at the center of the circle defined by the inferior glenoid margin. However, this was later demonstrated not to be exactly at the center of the glenoid circle [50, 51]. Also, this bare spot is less commonly observed in the young [52].

Hill–Sachs lesion

X-ray is not reliable for the assessment of the Hill–Sachs lesion [53]. Sagittal and axial CT images are useful and reproducible in measuring the size of the Hill–Sachs lesion [33, 54]. MRI is useful especially for the assessment of cartilage lesions [55].

Engagement of bipolar lesions

During arthroscopic surgery, the arm is elevated to bring the shoulder in abduction and external rotation. In this position,

if the Hill–Sachs lesion engages with the anterior rim of the glenoid, it is assessed as an engaging Hill–Sachs lesion [6, 34, 56, 57•]. If a Hill–Sachs lesion engages after Bankart repair, that is the true engaging Hill–Sachs lesion. However, dynamic intraoperative assessment is always performed before repairing the Bankart lesion. This may cause an overdiagnosis of the engaging Hill–Sachs lesion. As was previously described, the glenoid track concept makes the definition of the engaging Hill–Sachs lesion very clear [16•]. Kurokawa et al. [39] reported that in their series of 100 shoulders with recurrent anterior dislocation, 94 shoulders had a Hill–Sachs lesion, and 7 of them (7.4 %) were defined as an engaging Hill–Sachs lesion, on the basis of the glenoid track. This incidence of 7.4 % assessed by the glenoid track is far lower than the 45 % assessed during arthroscopy before Bankart repair [56]. Intraoperative dynamic assessment should be carefully interpreted to avoid overdiagnosis.

Treatment

Glenoid defect

Coracoid transfer, such as the Latarjet procedure [58] or the Bristow procedure [59], and bone grafting using an iliac autograft or allograft are commonly performed. Using a standard surgical technique without violating the coracoclavicular ligament, a coracoid graft greater than 25 mm can routinely be harvested for the Latarjet procedure [60]. A biomechanical study showed that a defect as large as 29 % of the glenoid surface area was restored by the coracoid transfer [61]. Another study showed that Latarjet-lateral (conventional Latarjet), in which the coracoid was placed with the lateral surface of the coracoid as the glenoid surface, led to the restoration of glenoid surface from the 30 % defect to a 5 % defect, but Latarjet-inferior (congruent-arc Latarjet), in which the coracoid was placed with the under-surface of the coracoid as the glenoid surface, resulted in complete restoration of the glenoid surface [62, 63]. Latarjet-inferior, however, may be technically demanding. The mechanism of stabilization by the Latarjet procedure is a combination of sling effect, bone block effect, and capsular effect [64, 65]. It enhances shoulder stability a little more than for the normal shoulder [64, 65].

Several surgical techniques of bone grafting have been reported [66–68]. Grafted bone purely fills the glenoid defect, and thus, shoulder stability returns to normal [12]. However, the Latarjet procedure increases the stability more than for the normal shoulder. As was mentioned above, there is surgical indication of the glenoid defect when the defect width is more than 25 % of the glenoid width. Whether you choose the Latarjet procedure (augmenting shoulder stability) or iliac bone grafting (preserving shoulder stability) depends on the

activity level of the patient. An augmentation procedure such as the Latarjet may be indicated for a collision athlete with high risk of recurrence. Neyton et al. [69•] reported that 34 rugby players who underwent the Latarjet procedure had no redislocation after 12 years of follow-up.

The Latarjet procedure has been widely used, and its outcome is very satisfactory [70]. Hovelius et al. [71•] reported a long-term follow-up of more than 10 years after Bristow–Latarjet procedure with 83 % coracoid fusion, 5 % redislocation, and 1 % revision surgery. This procedure is effective in soccer players [72] and rugby players [69•]. The Latarjet procedure can successfully restore shoulder stability in elderly patients [73]. It can also be used in revision surgery [74]. Recently, results after the arthroscopic Latarjet procedure have been reported, with outcomes equivalent to those for the open procedure, although it is clearly more technically demanding [75–77]. Of note, the Latarjet procedure is not recommended for patients with epilepsy. Raiss et al. [78•] reported that redislocation during seizure occurred in 6 out of 14 shoulders (43 %), which is unacceptably high. A systematic review in 2010 concluded that there remains a lack of strong evidence guiding the surgeon in the decision-making process, and thus further research is needed [79].

Hill–Sachs lesion

The concept of treatment is to avoid engagement between the Hill–Sachs lesion and the anterior glenoid rim. This can be achieved by either (1) reducing the range of motion in external rotation or (2) filling the humeral head defect. The former includes anterior soft tissue shortening [80] or rotational osteotomy of the humerus [28]. The latter includes filling the lesion with a bone graft [29, 30] or soft tissue [27, 81] or percutaneous transhumeral head plasty [82, 83]. Connolly [27] described infraspinatus tenodesis into the humeral head defect. Wolf et al. [81] first described the arthroscopic variation of infraspinatus tenodesis, which they termed “remplissage,” which means “to fill” in French, because the humeral head defect was filled with the infraspinatus tendon. The original technique [81, 84] and its modification [85] have been reported. Due to its simplicity, remplissage has become popular and widely used. Open remplissage can also be used in cases with chronic anterior dislocation [86].

Giles et al. [87] compared stability and range of motion of unrepaired 30 % and 45 % Hill–Sachs lesions, repaired by remplissage, humeral head allograft, and partial resurfacing arthroplasty. All 30 % and 45 % Hill–Sachs lesions engaged and dislocated. Remplissage and humeral head allograft effectively prevented engagement in all specimens, but 62 % of partial resurfacing arthroplasty engaged. They concluded that remplissage improved stability but caused reduction in range of motion. Another biomechanical study showed that the 15 % Hill–Sachs lesion caused no dislocation, but remplissage

caused significant reduction in external rotation in adduction (15.1°), but not in abduction (7.7°) [88•]. On the other hand, the 30 % Hill–Sachs lesion caused dislocation, which was prevented by remplissage. The reduction in external rotation was also significant in adduction (14.5°), but not in abduction (6.2°).

Many clinical papers have demonstrated an excellent outcome of remplissage combined with Bankart repair [56, 57•, 81, 84, 89–91]. A comparison between the Bankart repair alone and Bankart repair with remplissage revealed that there were no significant difference in Rowe score or UCLA score, but the recurrent dislocation occurred only in patients in the Bankart repair alone group [91]. Regarding the range of motion, Boileau et al. [57•] reported that the reduction in external rotation after the remplissage was 8° in adduction and 9° in abduction in their series of 42 patients. Return to sports at the preinjury level was 68 %. Considering the restriction of range of motion, usage of remplissage to overhead athletes should be carefully considered.

Conclusion

Bone loss is commonly observed in shoulders with anterior instability. The Latarjet procedure is widely used for a glenoid bony defect greater than 25 % of the glenoid width. Since the procedure increases shoulder stability more than for the normal shoulder, it may be a good indication for collision athletes. The Hill–Sachs lesion needs to be assessed with the glenoid. The glenoid track is a useful tool for assessing the engagement of these bipolar lesions. Assessment of engagement during arthroscopy may lead to overdiagnosis of an engaging Hill–Sachs lesion, because the Bankart lesion has not been repaired. Remplissage is a commonly performed, effective procedure, but it also reduces the range of motion. Thus, its application to overhead athletes needs to be carefully considered.

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