State of the Art Review

Controversies in surgical management of anterior shoulder instability. State of the Art

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ABSTRACT

Arthroscopic Bankart repair (ABR) has been accepted as a standard procedure for anterior shoulder instability with a minimum or no glenoid bone loss and an on-track Hill-Sachs lesion if present. However, several controversies exist in the surgical treatment of anterior shoulder instability. This article will discuss some of these controversies in “simple,” dislocations (without bone loss) as well as, “complex,” (with critical bone loss). Determining which patients will benefit from an arthroscopic procedure depends on multiple factors including age, activity level, adequate determination of bone loss, performed with feasible and reliable imaging techniques. In the absence of concomitant significant bony and soft tissue pathology, ABR alone can provide satisfactory clinical results on a long-term basis. Controversies, including whether to remove cartilage from the edge of the glenoid, knotted versus knotless anchors, and routine rotator interval closure, still exist. In cases with significant bone loss, several bone restoring procedures have been described, such as, the Latarjet procedure, iliac crest bone graft, arthroscopic anatomic glenoid reconstruction with a frozen distal tibial allograft, and fresh distal tibial allograft reconstruction. This article will address these controversies and provide guidance based on available published data.

Introduction

Arthroscopic Bankart repair (ABR) has been accepted as a standard procedure for anterior shoulder instability with a minimum or no glenoid bone loss and an on-track Hill-Sachs lesion. However, several controversies exist in the treatment of anterior shoulder instability. Removal of cartilage from the anterior edge of the glenoid has been described to enhance and enlarge the bony bed and optimize labral tissue healing. However, this practice remains controversial, as cartilage removal has been shown to lower load on the anteroinferior rim of the glenoid leading to stress shielding which may be related to bone resorption after ABR. Knotless anchors for ABR have gained popularity for numerous reasons including ease of use, tensionability and reduced time in the operating room. Basic science and clinical studies have shown knotless anchors to perform equally to knotted anchors. However, some surgeons remain steadfast in using knotted anchors. A rotator interval closure has been described in addition to ABR, but there is little clinical evidence to support this in patients without ligamentous laxity and in patients who do not have a persistent sulcus sign with shoulder externally rotated.

Several options are available in cases of complex instability with critical bone loss, including iliac crest bone graft (ICBG), Latarjet, arthroscopic frozen, extra-articular distal tibia allograft (DTA), and fresh osteochondral DTA placed intra-articularly. Each of these techniques has advantages and disadvantages, all of which will be explored in this article.

Complete assessment of the patient and bone loss is a must!

Anterior glenohumeral dislocation is known to cause a certain amount of disruption of normal anatomy which is mainly dependent upon the nature of the instability (either recurrent or primary) and...
patient age (the younger the patient the more prone he/she is to recurrent dislocation) [1,2]. In case of primary instability, bony lesions which are known to contribute to re-dislocation (i.e., engaging Hill-Sachs lesions and/or anteroinferior glenoid bone loss) are found more frequently than in recurrent instability [3,4]. Conversely, a high prevalence of anterior labral lesions in first-time dislocators is observed [5-9]. One of the key factors in dictating adequate treatment is the presence or absence of bone loss both on the glenoid and the humeral head. In fact, the presence of bipolar bone defect increases with age at dislocation and of the key factors in dictating adequate treatment is the presence or absence of bone loss both on the glenoid and the humeral head. In fact, the presence of bipolar bone defect increases with age at dislocation and negatively impacts postoperative recurrence rates after simple ABR [10-12]. Also, chronic dislocators are more likely to present with “off-track” lesions due to cumulative damage to the anteroinferior glenoid margin, coupled with the primary presence of a Hill-Sachs defect [13]; these factors are known to increase the likelihood of failure of ABR. It has then become a familiar dilemma for the surgeon to be faced with the choice of which surgical procedure best suits the patient, as several factors besides bone and soft-tissue pathology come into play, namely age at dislocation, number of dislocations, time since first dislocation, contact/collision athlete.

To provide a certain amount of guidance in the treatment algorithm of shoulder dislocation, several “screening” tools are available. The Instability Severity Index Score (ISIS) and its subsequent adaptations [14,15] (Fig. 1) take into consideration radiographic and non-radiographic factors: in a patient with no radiographic changes, clinical factors (i.e., age ≤ 20, overhead/contact sport at a competitive level, presence of hyperlaxity) can still warrant more than an isolated labral repair (i.e., remplissage or coracoid transfer- Latarjet). The Glenoid Track Instability Management Score (GTIMS) [16] further developed the ISIS by incorporating the “glenoid track concept” into the algorithm [17]. A recent meta-analysis was carried out for both ISIS >3 and ISIS >6 to assess its reliability in predicting failure after ABR: seven studies (1380 shoulders) demonstrated a higher recurrence risk in patients with an ISIS >3 compared to patients with an ISIS ≤3 (RR = 3.28; P = 0.0007); four studies (1,136 shoulders) demonstrated a higher recurrence risk in patients with an ISIS >6 compared to patients with an ISIS ≤6 (RR = 4.88; P < 0.00001). Also, 13 studies (2,113 shoulders) demonstrated a higher recurrence risk in patients with a glenoid bone loss compared to patients without bone loss (RR = 2.22; P = 0.0001), three studies (667 shoulders) demonstrated a higher recurrence risk in patients with an off-track Hill-Sachs lesion compared to patients with an on-track lesion (RR = 3.24; P = 0.002) and finally, four studies (473 shoulders) demonstrated a higher recurrence risk in patients with at least two dislocations lesion compared to patients with one dislocation (RR = 1.74; P = 0.03) [18]. Therefore, after a single episode of shoulder dislocation, no or minimal anteroinferior glenoid bone loss (and consequently minimal chances of an “off-track” lesion) can be reasonably expected. It must be kept in mind that for adequate quantification of glenoid bone loss, two and three-dimensional computed tomography (CT) is the preferred method due to its higher sensitivity when compared to standard radiographs [19-21]. The use of magnetic resonance imaging (MRI) is emerging due to its supposed comparable reliability when compared to CT, although results are still somewhat mixed [22-26].

The determination of what constitutes a “critical” bone loss has been debated in the recent literature. The amount that was deemed unacceptable for simple labral repair has progressively decreased from 25% to 15% [11]. Also, the recent addition of “subcritical” bone loss by Shaha et al. [27] refined the treatment algorithm in high-demand patients: a glenoid bone loss greater than 13.5% resulted in unacceptable low functional scores in this patient population when treated with ABR alone, despite the absence of frank episodes of postoperative recurrence. Despite the absence of glenoid bone loss (or even its presence but with minimal size), the morphological features the Hill-Sachs lesion can contribute to suboptimal postoperative outcomes. Yamamoto et al. [28] considered that even in patients with an on-track lesion, a Hill-Sachs occupancy greater than 75% of the glenoid track (defined as “peripheral-track lesion”) lead to significant worse outcome scores when compared to patients with the Hill-Sacks occupancy lower than 75% (defined as “central-track lesion”) (Fig. 2). Arciero et al. [29] found that as little as 2-mm glenoid defect, combined with a medium-sized Hill-Sachs lesion, could compromise ABR: approximately 8% bone loss would be sufficient to warrant additional/different procedure in addition to labral repair.

![ISIS scoring system and algorithm (Boileau et al. JBJS Am. 2012). With the Glenoid Track Instability Management Score (GTIMS), there is no recommendation of humeral head defect size or glenoid bone loss. If smaller, this would not trigger to add remplissage or perform a Latarjet procedure.]
In patients with small glenoid bone loss with a medium-sized Hill-Sachs lesion, the choice of technique is either between ABR ± Remplissage or Latarjet procedure. Recent meta-analyses found that these two procedures are overall roughly equivalent in terms of postoperative reduction of recurrence and clinical results; yet, bone block procedures such as Latarjet carry a higher risk for complications [29–31]. ABR + remplissage has also been proven superior to ABR alone in case of subcritical bone loss and a Hill-Sachs lesion [32]. In case no tangible bone loss is present on either side, isolated ABR can provide excellent results [33]. They concluded that below subcritical bone loss and a Hill-Sachs lesion [32]. In case no tangible bone loss is present on either side, isolated ABR can provide excellent results even in the high-demand patient. Dickson et al. [33] evaluated outcomes of ABR in intercollegiate football athletes with on-track lesions (i.e., non-engaging Hill-Sachs): at more than 3 years postoperatively, only patients with glenoid bone loss greater than 13.5% displayed significant recurrence rates. They concluded that below subcritical glenoid bone loss values, ABR alone was sufficient to provide reliable outcomes and low recurrence rates. More recently, Di Giacomo et al. [34] proposed an algorithm in order to treat patients considering the amount of glenoid bone loss: in patients with minimal bone loss (0%–15%), soft tissue repair alone may be sufficient. Yet, in what the authors considered a subcritical “grey” area (between 17% and 25%), other factors should be considered: low demands/sedentary and non-contact sports patients may be considered good candidates for soft tissue repair alone, while for those with high demand and/or are involved in contact sports, a glenoid reconstruction would yield superior results and lower recurrence rates. In conclusion, in “simple” primary instability, evaluation of clinical factors and patient demands must be carried out thoroughly, along with appropriate determination of bone loss, performed with feasible and reliable imaging techniques. The presence and morphological parameters of a concomitant Hill-Sachs lesion should also be considered, even in presence of seemingly insignificant percentages of glenoid bone loss. In the absence of concomitant significant bony and soft tissue pathology, ABR alone (Fig. 3) can provide satisfactory clinical results on a long-term basis.

**Simple instability**

**Cartilage on glenoid rim – remove it or leave it on?**

There are two methods of repairing the detached Bankart lesion to the glenoid: (1) make a bony bed only on the anterior scapular neck or (2) make a bony bed not only on the scapular neck but also on the glenoid surface by removing the peripheral articular cartilage from the anterior to inferior rim of the glenoid. While the former is performed worldwide, the latter has become popular among some surgeons after Sugaya reported this cartilage removal technique in 2006 [35]. The basic concept of removing the articular cartilage is to increase the contact area of the Bankart lesion to achieve a stronger construct. However, removing the cartilage decreases the contact area between the glenoid and the humeral head, which may eventually lead to osteoarthritis in the long run. The key questions are: “is it really better to remove the cartilage in terms of outcomes?” and “is it really safe to remove the articular cartilage?”

**Basic science studies**

There are two patterns of attachment of the inferior glenohumeral ligament (IGHL)-labrum complex to the glenoid: (1) the complex attaches to both the glenoid bone and the articular cartilage and (2) the complex attaches only to the glenoid bone. According to an anatomical study, the complex attached to both the bone and the cartilage in 88% of the shoulders [36]. There have been no biomechanical studies comparing the pullout strength between these two types of attachment. In terms of the mechanical strength, there is no question that the attachment to the bone is far stronger than that to the cartilage. In other words, the main stabilising function of the IGHL is most likely to be provided by its attachment to the bone, not to the cartilage. Thus, what we need to achieve is to reconstruct the bony attachment of IGHL-labrum complex. During surgery, it is impossible to say whether the labral attachment is both to the glenoid neck and the cartilage or only to the glenoid neck because they have been detached already. As a result, those who remove the rim of the articular cartilage at the time of Bankart repair do so only to increase the contact area between the labrum and the glenoid bone, not to recreate the original anatomical structure.

Inoue et al. performed a finite element model (FEM) analysis of the contact load distribution of the glenoid comparing those with and without cartilage removal [37]. They found a significantly lower load on the anteroinferior rim of the glenoid after cartilage removal (Fig. 4). This stress shielding may be related to bone resorption after ABR with cartilage removal. They concluded that ABR without removing the cartilage is desirable.

**Clinical studies**

Shim et al. reported that cartilage removal did not change clinical outcomes or the rate of osteoarthritis (OA) at 5 years, although the rate of apprehension was significantly lower in the group with cartilage removal [38]. Are there any disadvantages of removing the cartilage? First, removing the cartilage decreases the contact area of the glenoid to the
humerus. There is no long-term study to prove or disprove this concern. Second, recent clinical studies showed that the width of the glenoid decreased after removing the cartilage (Fig. 5) [39], whereas there is no decrease in the glenoid width in shoulders without removing the cartilage (Fig. 6) [40]. This bone resorption of the glenoid seems to be caused by the loss of contact pressure on the anterior rim of the glenoid. The glenoid surface is only 1/4 of the humeral head. Making the glenoid even smaller would be a great concern not only increasing the risk of osteoarthritis but also increasing the risk of instability. As the surgical outcomes depend on various factors, we need high-level prospective randomised clinical trials comparing these techniques.

Conclusion on cartilage on glenoid rim

Because of the concerns mentioned above, we recommend that the articular cartilage should be kept in place when repairing the Bankart lesion back to the bone.

Anchors – knotless versus knotted?

Use of suture anchors has become the gold standard in labral repair surgery [41]. Tying arthroscopic knots are vital in a successful outcome for labral repair. Since arthroscopic knot tying may be cumbersome to learn and difficult to master, with more time to perform a knotted anchor [42] and time consuming in the operating room time, there has been a push to use knotless anchors.

The outcomes of knotted versus knotless anchors have been debated and remain controversial and surgeon's choice of which to use based on training and personal preference. Considerable variations in knot strength exist between arthroscopic knots tied by surgeons. A study by Hanysik et al. [43] revealed that surgeons were unable to tie 5 consecutive knots of the same type consistently; that for both ultimate load and clinical failure load, surgeons with <10 years in practice were able to tie knots more consistently than surgeons with >10 years; and

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Fig. 4. Finite Element Model (FEM) analysis. The FEM model (A, B) and its stress distribution (C) with the intact cartilage. The high stress distribution is observed at the anteroinferior portion of the glenoid. The FEM model (D, E) and its stress distribution (F) after removing the cartilage from the anteroinferior rim of the glenoid. The stress significantly decreases at the anteroinferior portion of the glenoid after cartilage removal. Reprinted and modified from Inoue et al. J Shoulder Elbow Surg 2021 [37], with permission from Elsevier.
that surgeons performing >200 arthroscopic shoulder cases annually failed to tie stronger or more consistent knots than their counterparts performing fewer cases.

**Biomechanical evidence**

There is conflicting biomechanical evidence surrounding the use of knotted and knotless anchors for anterior labral repair. Lacheta et al. [44] found in 6 match paired cadaveric shoulders that knotless anchors resulted in a similar stiffness, ultimate load, and load to failure compared with knotted anchors. In addition, there were fewer instances of suture slippage (loss of loop security) with knotless anchors. Similarly, Ranawat et al. [45] showed in 8 matched pairs cadaver shoulders with soft tissues intact, that knotless and knotted anchors had no significant difference in stiffness and ultimate load to failure, and that both anchor types failed most frequently at the suture-tissue interface. There was no difference in rate of failure by cut-through or pullout between knotted or knotless groups. However, Leedle and Miller [46] found in 15 cadaveric shoulders that knotless anchors resulted in a greater ultimate load to failure than the knotted anchors using a Duncan Loop knot. Nho et al. [47] compared anchor types in 30 cadaveric shoulders in two phases. The first phase, the specimens were tested without cyclic loading, and they found that there was no difference in ultimate load to failure or stiffness, between a knotted anchor with a simple stitch (SSA) and a knotless suture anchor (KSA). However, a lower load was required to create a 2 mm displacement in the KSA group. In the second phase, the specimens were tested with cyclic loading, for 100 cycles from 5 to 25 N at 1 Hz. There was a statistically significant difference in ultimate load to failure between the SSA and KSA groups, but there was no difference in load required to create a 2 mm displacement or in stiffness which the authors felt may be more clinically relevant than ultimate load to failure. Slabaugh et al. [48] compared labral height after ABR in 10 matched paired cadaveric shoulders and showed that both knotless and knotted anchors resulted in

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**Fig. 5.** Preop and 1-year postop 3D-CT (cartilage removal technique). A decrease in the glenoid width was clearly detectable 1 year after the surgery. Reprinted from Hirose et al. Arthroscopy 2020 [129], with permission from Elsevier.

**Fig. 6.** Preop and 2-year postop (cartilage preserving technique). No change in the glenoid width at 2-year follow-up.
Clinical evidence

Four studies evaluated knotless anchors compared with knotted anchors in patients undergoing arthroscopic Bankart repair [42,49–52]. The first study in the literature to compare knotted and knotless anchors clinically, is the only one that found inferior results for knotless anchors. Cho et al. [49] compared Bankart repairs in 61 patients treated with knotted anchors and 21 treated with knotless anchors. At a mean follow-up of 29 months (minimum of 24 months), the knotted group had significantly higher patient satisfaction rate and a lower pain score and re-dislocation rate than the knotless group. These findings may be due to outdated implants and technology may have been used at the time this study was conducted. With newer techniques and implants, all other recent studies have demonstrated that knotless anchors are equivalent clinically to knotted anchors. Kocaoglu et al. [50] reported on ABR in 31 patients treated with knotless anchors and 21 treated with knotted anchors. At a mean follow-up of 2.7 years (range 2–3.7 years), there was no difference in Constant score, visual analogue scale (VAS), patient satisfaction, range of motion, re-dislocation, or subluxations. Wu et al. [52] compared outcomes in 34 knotless and 68 knotted anchor ABRs. At mean follow-up of 4.8 ± 2.5 years (minimum of 2 years), they reported no difference between the two anchor types in re-dislocation and revision surgery rates as well as VAS with use. In addition, there was no difference in Single Assessment Numeric Evaluation (SANE), Quick Disabilities of the Arm, Shoulder and Hand Score (QuickDASH), the University of California at Los Angeles (UCLA) Shoulder scores or Rowe scores. However, the knotted group showed a higher re-subluxation rate. Shim et al. [53] compared 115115 knotted and 61 knotless repairs and at mean follow-up of 43 months (range: 24–99 months), found no difference in re-dislocation and apprehension rates, American Shoulder and Elbow Surgeons (ASES) and Rowe scores, VAS, or range of motion.

Conclusion on anchors

Based on clinical findings, as well as the biomechanical data, knotless anchors for ABR have shown similar outcomes for the treatment of anterior shoulder instability. Given the ease of use, quicker application, tensionability, lower profile repair (no knot stacks, which have been previously reported to cause abrasive wear on the rotator cuff and glenohumeral articular cartilage [54]), knotless anchors are a reasonable implant choice for ABR. Both knotless and knotted anchors are appropriate for ABR and should be used at the surgeon’s discretion.

Rotator interval closure – every time or never?

The rotator interval (RI) is a triangular anatomical space that resides in the anterior-superior aspect of the shoulder, first described by Charles Neer. The structures of the rotator interval (RI) have been shown to contribute to stability of the glenohumeral joint by maintaining negative intra-articular pressure and by resisting inferior and posterior glenohumeral translation of the adducted arm [55]. However, there is no clear consensus of the most critical structure contributing to these functions. Some authors argue that the coracohumeral (CHL) and superior glenohumeral ligament (SGHSL) work together as a unit to prevent inferior and posterior translation of the humeral head, whereas others emphasise that these structures function independently [56].

Harryman et al. [57] analysed the role of the RI by assessing glenohumeral motion and translation in eight cadaveric shoulders with three different testing conditions: (1) Intact RI, (2) sectioned coracohumeral ligament (CHL) in RI and (3) open CHL imbrication in a medial to lateral direction by 1 cm. They found that imbrication of the CHL decreased posterior and inferior translation of the humeral head in the scapular plane. Multiple biomechanical studies have been completed, attempting to replicate Harryman’s work arthroscopically with conflicting results. Mologne et al. [58] found that the addition of an arthroscopic RI closure provided enhanced anterior stability after an anteroinferior capsulolabral repair but had no effect on inferior or posterior stability. Improved anterior stability with arthroscopic rotator interval (RI) closure with negligible effect on posterior and inferior stability has been confirmed by other studies [59,60]. When performing RI closure arthroscopically, most techniques involve a superior to inferior shift of the middle glenohumeral ligament (MGHSL) or subscapularis tendon to the superior glenohumeral ligament (SGHSL). This contrasts with the initial open medial to lateral plication of the coracohumeral ligament (CHL) described by Harryman. This has called into question the utility of arthroscopic RI closure for posterior or multidirectional instability.

The implications of arthroscopic RI closure are variably reported in the literature with conflicting results with respect to stabilisation and postoperative stiffness. Clinical results in terms of shoulder stability have been satisfactory, leading multiple authors to advocate for the use of arthroscopic RI closure as an adjunct to ABR in anterior shoulder instability [61]. Only two comparative studies have been performed thus far comparing ABR with and without RI closure. Chechik et al. [62] performed a retrospective case control study of 83 patients with anterior shoulder instability. They found that 3/37 (8%) with RI closure had re-dislocation at 42 ± 16 months, all of which had joint hyperlaxity, and 6/46 (13%) without RI closure had re-dislocation at 13 ± 14 months. There was a greater loss of abduction, forward flexion and external rotation compared to the contralateral shoulder in the RI closure group, however this was not found to be significant. They concluded that the addition of RI closure to ABR improves stability in patients without systemic joint hyperlaxity and reduces recurrence in patients with hyperlaxity. To date, Maman et al. [63] has performed the only prospective randomised control study of 39 patients evaluating outcomes of acute ABR with and without acute RI closure (ARIC). They found that the re-dislocation rate was higher in the acute ABR + ARIC group at 16% versus 0% in the acute ABR alone group, concluding that the addition of RI closure showed no superiority in stability compared to ABR alone. However, a major limitation in their study was that significantly more remassage procedures were performed in the ABR alone group, which may represent a bias due to the contributing effect of a remassage procedure on stability. This highlights the need for further prospective comparative studies on RI closure and ABR procedures.

One of the most commonly reported complications associated with RI closure is postoperative reduction in external rotation. In a review by Coughlin et al. [64], eight studies observed a decrease in external rotation, however only one study observed a statistically significant decrease in external rotation with the addition of an RI closure [65]. Taverna et al. [66] and Smith [67] have recommended positioning the arm in 30° of abduction and 30° of external rotation while performing an RI closure to prevent postoperative loss of external rotation. Other surgeons have recommended maximum external rotation or greater than 60° to avoid external rotation limitation [68].

The indications for RI closure are not well delineated in the literature with inconsistencies in reporting of indicating factors. Multiple authors [69] have described indications for RI closure, which can be divided into instability characteristics and intra-operative evaluation. Indications for RI closure based on instability characteristics include patients with anterior instability with a positive sulcus test that persists in external rotation, a large sulcus in patients with significant multidirectional instability and in revision procedures. Intra-operative indications include patulous anterior joint volume, persistent anterior and/or inferior laxity after labral repair and the presence of a drive through sign.

Conclusion on rotator interval closure

It remains unclear what the benefit of RI closure is in shoulder instability surgery with conflicting results from clinical studies. Points
that many authors have consensus on regarding this topic are: (1) sulcus test that persists in external rotation is used to assess the integrity of the RI; (2) When interval closure is performed, tensioning should be performed with the arm in at least 30°, and preferably 60°, of external rotation to avoid external rotation limitations [66–68,70]; (3) The findings consistent with a lesion of the RI are redundancy/tearing of the capsule between the subscapularis and supraspinatus tendons, damage/flattening/subluxation of the long head of the biceps, tearing of superior glenohumeral ligament (SGHL) or fraying of the superior border of the subscapularis tendon [61].

**Complex ileac crest instability**

**Iliac crest bone graft**

Among the procedures of bone augmentation of the glenoid cavity, ICBG, along with coracoid autograft, is one of the most widely described. It was originally described at the beginning of the 20th century by German surgeon Rudolf Theis Eden (1883–1925) and Swedish surgeon Oscar Samuel Hybbinette (1876–1939). Both Eden and Hybbinette initially used a tibial cortical bone graft, but subsequently differed in autograft donor, although the change to iliac crest autograft is attributed to Hybbinette. Subsequent modification regarding the origin of the graft (autograft with iliac crest, allograft etc.), graft positioning and fixation (no fixation device, screws etc.), and the surgical approach (split of the subscapularis tendon in open surgery, arthroscopy etc.) have allowed this technique to remain a viable solution for anterior shoulder instability with significant glenoid bone loss [71].

ABR alone may not be sufficient in certain circumstances: in case of critical glenoid bone loss (15%–25%), a bone block procedure is recommended [11]. A Latarjet procedure is usually performed in these cases, with predictable and successful results. Yet, failure is still reported in the literature at variable rates (5%–12%) [72]. Such failure usually happens in the first postoperative year [73] and can be due to several reasons, most of them related to the graft itself (i.e., non-union, malpositioning and fracture) [74]. Inadequate patient selection, technical error and new trauma could also be a cause of failure. It is to be noted though, that reported complications and failures vary widely within the literature, which may be due to frequent overlap of the two terms and a certain inconsistency in their definition [75].

Contemporary use of ICBG for anterior shoulder instability is mostly indicated in cases with significant (i.e., critical) glenoid bone loss where previous bone block procedures (i.e., Latarjet) have failed and it is performed through fixation with either a combination of screws or plate/screws or “low-profile” implants (buttons, sutures, J-shaped implant-free bone graft), with mini-open or arthroscopic procedures [76]. Most grafts are taken from the patient’s ipsilateral iliac crest, but this can be dependent upon various factors (i.e., size of bone necessary to successfully reconstitute the deficient glenoid, graft viability, surgeon preference etc.). Gilat et al. [77] performed a systematic review comparing auto-versus allograft in the treatment of anterior shoulder instability with bone deficiency and found comparable outcomes in terms of postoperative result and incidence of complications. Yet, heterogeneity in the sample of studies analysed was a limitation (i.e., the inclusion of studies using both allograft and autograft). A potential and well-known disadvantage of the use of an autograft is donor site morbidity (infection, hypaesthesia, pain etc.) [78], although no significant difference in the pooled estimate of the number of complications between autograft and allograft was noted. A similar group of authors [79] also performed a systematic review of the same studies versus Latarjet, finding no significant differences between the procedures in rates of recurrent instability, other complications, osteoarthritis progression, and return to sports. Again, significant heterogeneity in the included studies was reported. To this date, only one study directly compares iliac crest allograft versus autograft for anterior shoulder instability: in their arthroscopically treated sample, Malik et al. [79] suggested that autograft may lead to significantly improved instability score, higher union rate and less bone resorption, suggesting better biological incorporation of autologous tissue at the base of this difference.

Different techniques and fixation devices have been described. A recent systematic review by Tahir et al. [80] included a sample of 15 studies analysing patients treated with arthroscopic bone block stabilisation procedures, of which 12 were performed using iliac crest grafts, fixed onto the glenoid with either titanium or bioresorbable screws, which showed good clinical and radiological results on a short-to midterm basis. Ernstbrunner et al. [81] were the only authors to date, who carried out a direct comparison between the two techniques (arthroscopic vs. open), although solely from a radiologic perspective: en-face view and axial plane CT-views showed comparably adequate positioning, with a significantly steeper impaction angle resulting from an arthroscopic technique. While most of the used techniques seem to involve an open repair [82], this aspect is also highly heterogeneous and ultimately depends upon the surgeon’s preference in the reported literature. The same concept applies to fixation devices, which describes the use of screws [83] (Fig. 7), endobutton [84], sutures [85], or even implant-free techniques [86].

Overall, clinical studies report good to excellent results within 4 years of the operation [87]. In the published series, about 2/3 of the patients were able to return to their previous level of sports [84], with relatively low incidence (3.9%) of osteoarthritis when this was reported [88]. In their series of 16 patients treated after Latarjet failure, Ernstbrunner et al. [76] found that iliac crest autograft failure was associated with mis-diagnosed multidirectional instability, subscapularis insufficiency, static inferior subluxation, uncontrolled seizures, or psychological disorders: because these factors have been previously described to be associated with inferior outcomes (or even posed as contraindications) for glenoid bone grafting [89], the authors recommend careful patient analysis and selection for further decision regarding their treatment.

**Conclusion on iliac crest bone graft**

ICBG for anterior glenohumeral instability is a viable option when significant bone loss is present or when previous bone block procedures have failed. Significant heterogeneity in techniques and bias in patient selection must be kept in mind when critically reviewing the literature, in order to achieve the best outcome and minimise potential pitfalls.

**Latarjet procedure**

The Latarjet procedure is best indicated for shoulders with a glenoid bone loss. The Hill-Sachs lesion is usually off-track when a glenoid bone loss is ≥25% [90], but typically not if bone loss is greater than 35%. The Latarjet procedure fills the glenoid defect with the coracoid process,

Fig. 7. ICBG used in case of critical (>20%) bone loss. In this case, the graft was fixed in place with two screws and a wedge plate (courtesy of Dr. G. Di Giacomo). G – glenoid; I – iliac crest bone graft.
which in turn makes the glenoid width greater and the glenoid track wider, which converts an off-track Hill-Sachs lesion to an on-track lesion. Instability severity index score (ISIS) is commonly used. Balg and Boileau reported that because of high recurrence rate, patients with the score >6 points should be treated by open procedure such as the Latarjet, whereas those with the score ≤6 points were successfully treated with arthroscopic Bankart repair [14]. Later, it has been suggested that this threshold should be lowered to 4 [91] or 3 [92]. One disadvantage of this scoring system is that the bony defects are assessed by plain X-rays, which is not accurate. Di Giacomo et al. proposed to use the glenoid track concept instead of X-ray assessment in the ISIS, which was proved to provide better assessment of the bony lesions [16]. If a glenoid bone loss is greater than the thickness (traditional method) or the width (congruent arc method) of the coracoid process, a larger bone graft such as iliac crest autograft or distal tibial allograft should be considered [93].

There have been several iterations of the Latarjet procedure. In the original technique, the subscapularis muscle was tenotomised, the coracoid process was fixed with a single screw, and the capsule was not repaired [94]. Later, two-screw fixation (Fig. 8), a capsular repair to the remnant coracocromial ligament attached to the coracoid process [95] and a subscapularis split approach were introduced and widely accepted [96]. Having said that, there are several technical variations available.

The congruent arc method is a method to align the coracoid so that the undersurface of the coracoid, which is more congruent to the humeral head than the lateral surface, would face the humeral head [97]. Potentially, it might decrease the long-term incidence of osteoarthritis. However, due to technical difficulty and a higher rate of non-union and a risk of coracoid fracture in the congruent arc method [98], the traditional method is preferred.

Regarding the screw types and fixation method, some studies showed superiority in biomechanical strength of one screw over the other: stainless steel screw was stronger than polyactic acid (PLLA) screw [99] or 3.75 mm cannulated screw was weaker than 4.5 mm solid screw in the unicortical configurations [100]. However, most studies showed that there was no significant difference in biomechanical strength in terms of screw types (cannulated vs. solid, cortical vs. cancellous) or fixation method (unicortical vs. bicortical) [101–103]. Thus, surgeons may select the screw type and method of fixation (unicortical or bicortical) based on preference.

Suture button technique was introduced for both iliac crest bone graft and Latarjet to avoid complications related to screws [104]. A biomechanical study showed that there were no significant differences in the biomechanical properties between these two fixation methods [105]. Regarding osseous healing and resorption, there were no significant differences in osseous healing rate and bone resorption rate between the suture button fixation and screw fixation [106].

Some repair the capsule to the remnant coracohumeral ligament attached to the coracoid process, creating an intra-articular bone graft [96], whereas others repair it to the native glenoid (Fig. 9), creating an extra-articular bone graft [97]. A cadaveric study showed that the range of external rotation was more restricted but the mid-range stability was greater when the capsule was repaired to the native glenoid [107]. A recent systematic review that there was an apparent trend toward higher rates of osteoarthritis among studies in which an intra-articular bone block technique was employed; however, it is possible that this was influenced by substantially different follow-up times between groups and other various sources of heterogeneity among the included studies [108]. Therefore, large-scale randomised controlled trials or comparative studies are needed to draw stronger conclusions comparing the 2 techniques.

Both open and arthroscopic Latarjet procedures are reliable treatment with low recurrence rate (6.9% in open vs. 6.7% in arthroscopic) and similar patient-reported outcomes [109]. A clinical study showed that the coracoid graft location by arthroscopic Latarjet was significantly more superior in the sagittal plane and more lateral in the axial plane than that by open Latarjet [110]. A systematic review comparing the traditional Latarjet procedure versus congruent arc modification showed that the traditional procedure demonstrated a lower incidence of non-union or fibrous union, and lower incidence of screw-related problems [98]. Other than that, the outcomes of traditional Latarjet and congruent arc modification were equivalent.

A systematic review of 2,560 Latarjet procedures revealed that the overall complication rate was 16.1% [111]. Intraoperative complications included nerve injuries (1.9%) and iatrogenic fractures (1.0%). The axillary nerve and musculocutaneous nerve are at risk during the Latarjet procedure, especially during glenoid exposure and graft insertion [112]. Postoperative complications were instability in 6.2% and non-union in 1.3%. A recent systematic review of 4 long-term studies (average follow-up of 17.6 years) [113] showed that radiological signs of development or progression of osteoarthritis were observed in 25.8%, of which 88.6% were mild. Overhanging of the coracoid or too-lateralized coracoid was the principal risk factor of osteoarthritis, whereas the hyperlaxity seemed to be protective. Although similar outcomes and

![Fig. 8. Coracoid fixation. The coracoid process (C) was fixed with two screws. Suture anchors (arrows) were inserted to the anterior rim of the glenoid for capsular repair. Reprinted from Eiji Itoi. Shoulderology [130], with permission from Igaku-Shoin. G – glenoid.](image1)

![Fig. 9. Capsular repair. The capsule (Ca) is repaired to the anterior rim of the native glenoid. C – coracoid; knots-arrows.](image2)
complication rates were reported between open and arthroscopic procedures, a systematic review suggests that the arthroscopic procedure may be advisable to perform only in high-volume centres with experienced arthroscopists because of its significant learning curve [114].

Moroder et al. compared open Latarjet with open iliac crest bone graft in a prospective randomised clinical trial [86]. They assigned 30 patients in each group. None of the WOSI score, Rowe score, Subjective Shoulder Value showed a significant difference between the groups. Postoperative traumatic subluxation occurred in 2 patients with iliac crest bone graft and 1 patient in Latarjet group. The only significant difference was a limited range of internal rotation in the Latarjet group. On the other hand, donor-site sensory disturbances were observed in 27% of the patients treated with iliac crest bone graft.

Conclusion on Latarjet procedure

The Latarjet procedure is most frequently used in patients with significant glenoid bone loss, instability severity index score (ISIS) ≥4, contact/collision athletes, and revision surgery for failed arthroscopic Bankart repair. The traditional orientation of the coracoid (non-congruent arc) and capsular repair to the native glenoid seems to be preferred (placing the coracoid in an extra-articular position) to reduce a risk of arthritis [108]. Excellent results in achieving stability have been reported but not without significant complications. Arthroscopic Latarjet should be performed at high volume centres by experienced surgeons.

Arthroscopic anatomic glenoid reconstruction

Although the Latarjet procedure has shown excellent results in treating shoulder instability, North American surgeons are slower to take up this technique due to the high complication rates and the resulting difficult revision surgeries due to the altered native anatomy [115]. Similarly, the arthroscopic Latarjet has shown to be a difficult surgical technique with a slow learning curve and has a similar rate of complications to open Latarjet [116]. The necessity of the sling effect achieved in coracoid transfer procedures via the conjoint tendon has been called into question recently, with free bone block reconstructions showing similar clinical results to the Latarjet procedure [86]. Compared with open Latarjet, free bone block procedures have shown similar excellent outcomes and recurrence rates [117]. However, violation of the subscapularis muscle in open techniques can lead to functional deficits and

Fig. 10. The preoperative (A) and postoperative (B) CT scans and postoperative 3D reconstruction (C) in a left shoulder.

Fig. 11. The outside view (A) and inside view (B) of the Halifax portal creation. The viewing portal is anterosuperior portal. H = Halifax portal.
has been shown to cause weakness in isometric subscapularis muscle strength [118].

To avoid open surgery, and the subsequent damage to the subscapularis muscle, arthroscopic anatomic glenoid reconstruction (AAGR) with a free bone block was developed to decrease severe neurovascular compromise and allow concomitant pathologies to be addressed. It has the advantages of preserving the integrity of the subscapularis muscle, coracoid process and conjoined tendon. It has been associated with good results, low recurrence rates, minimal complications, and a relatively easy learning curve [119].

Although multiple techniques have been described with autograft bone blocks, allograft offers certain advantages. These include avoidance of donor site morbidity and potentially decreasing the risk of osteoarthritis progression due to the precontoured shape of iliac crest allograft or by recreating a cartilage lined concave surface for humeral head articulation, when using distal tibial allograft. Concerns have been raised over accelerated graft resorption; however, this increased resorption has not been correlated with an increase in recurrence of instability [120]. This is possibly due to graft remodelling and scarring resulting in a robust capsulolabral structure on the anterior glenoid rim [77]. A recent systematic review that analysed fifteen papers on arthroscopic bone block procedures found that allograft union rates were high (>90%) in all but two studies [80].

Wong and Urquhart [121] described a subscapularis sparing arthroscopic anatomic glenoid reconstruction with distal tibial allograft in 2014. Frozen, non-irradiated distal tibial allograft is the preferred allograft (Fig. 10). The posterolateral corner of the DTA is used as it best replicates the native glenoid contour and provides three cortical surfaces for better fixation strength [122] (Fig. 11). The technique by Wong uses a novel far medial portal, also known as the Halifax portal. It is created using an inside out technique which allows for safe passage of the bone graft and for screws to be placed parallel to the glenoid and perpendicular to the glenoid defect. The subscapularis is retracted inferiorly, which avoids using a subscapularis split and minimises risk of neurovascular complications. To create the Halifax portal, the arm is placed in the adducted position and the elbow is flexed to 90° to release tension and medialise the conjoined tendon (Fig. 12). A switching stick is then advanced through the posterior portal (Fig. 13), parallel to the glenoid, proceeding superior to the subscapularis and lateral to the conjoined tendon before advancing the switching stick through the deltopectoral muscle fibres and penetrating the skin (Fig. 14) (Box 1–5).

The safety profile utilising the Halifax portal has been established, showing it to be a safe distance from neurovascular structures in a cadaveric study and having no intraoperative complications [123]. Furthermore, the learning curve associated with the arthroscopic anatomic glenoid reconstruction (AAGR) using the Halifax portal has been found to be shorter compared with the arthroscopic Latarjet [124]. Excellent short-term clinical outcomes, good graft positioning and healing rates on CT have been found with a recurrence rate of 3% [125]. Additionally, a recent cost analysis study showed that AAGR was less costly and led to an improvement in quality adjusted life years when compared to ABR in patients with subcritical glenoid bone loss [126]. It is important to note that the capsulolabral tissues are repaired to the native glenoid, leaving the graft in an extra-articular position.

AAGR has recurrence rates comparable to the Latarjet while minimising complications. Wong et al. [119] performed a retrospective cohort study to compare outcomes of AAGR with distal tibial allograft and arthroscopic Latarjet in 48 patients. At the minimum 2-year follow-up, radiographic and clinical results were comparable between the two groups. They observed that graft resorption rate was higher in the AAGR group, however the two groups had similar bony union rates and found no significant differences in the final graft surface area, the size of graft and the anteroposterior dimensions of the reconstructed glenoid. Additionally, there was no significant difference in recurrence rate and subluxation between the 2 groups at the two-year follow-up. The Latarjet group had a decreased step deformity than the Latarjet group, which could lead to a slower progression of osteoarthritis. These short-term findings suggest that the AAGR using distal tibial allograft may be used as an alternative to Latarjet.

Fig. 12. The graft is inserted and is maintained in the proper position using a switching stick from the posterior portal. The viewing portal is anterosuperior portal. G = glenoid, A = allograft, H = humeral head.

Fig. 13. Graft marking on the back table.

Fig. 14. The final view of the arthroscopic anatomic glenoid reconstruction with distal tibial allograft, viewing from the anterosuperior portal. G = glenoid, H = humeral Head, A = allograft.
et al. [80] that analysed 15 studies on arthroscopic anatomical glenoid graft union, significant improvement in clinical outcomes scores and a low rate of re-dislocation. AAGR provides radiological restoration of glenoid area, without the risks related to the coracoid osteotomy.

**Conclusion arthroscopic anatomic glenoid reconstruction**

AAGR provides an excellent method for restoring glenoid width in patients with critical bone loss. The frozen allograft eliminates donor site morbidity and the arthroscopic technique avoids damage to the subscapularis muscle and tendon. Excellent clinical satisfaction, radiographic graft union, low re-dislocation rates, and a relatively easy learning curve have been reported.

**Fresh distal tibial allograft**

In patients with chronic recurrent shoulder dislocations, high rates of anterior glenoid bone loss have been described, which if not addressed, can lead to high failure rates. “Bone loss” is a simplistic description of what occurs in these cases, as it is not only bone, but hyaline articular cartilage that is lost. While several bone grafts such as iliac crest, acromial spine, distal clavicle, and coracoid transfer have been described, none address the cartilage loss that occurs. These grafts do provide mechanical stability to the shoulder; however, there is a growing concern of glenohumeral joint arthritis with these non-anatomic procedures. In 2009, Provencher et al. [122] described a novel technique using fresh osteochondral DTA transplantation to the anterior glenoid. The authors noted that the curvature and concavity of the postero-lateral distal tibia to be highly congruent and nearly matching the native curvature of the glenoid (Fig. 15). In addition, the fresh DTA contains dense weight-bearing corticocancellous bone, allowing for excellent screw fixation and host-graft incorporation (Fig. 16). This novel technique has allowed for complex, anatomic reconstructions of the anterior glenoid in cases of recurrent anterior instability with the restoration of the osteo-articular surface by placing the graft in an intra-articular position (Fig. 17A and B). The results thus far have been very promising.

Provencher et al. [127] reported on the results of their initial series of 27 patients, all males, and 67% in active military duty, with an average age of 31 ± 5 years and an average follow-up of 45 months (range, 30–66) who were treated with fresh distal tibial allograft (DTA). There were significant improvements in American Shoulder and Elbow Surgeons (ASES) score, Western Ontario shoulder instability index (WOSI) and Single Assessment Numeric Evaluation (SANE) score. Computed tomography (CT) was obtained at an average 1.4 years in 25 patients and demonstrated an allograft healing rate of 89%, average allograft angle of 14.9°, and average allograft lysis of 3%. They noted that grafts with lesser allograft angles (<15°) were better opposed to the anterior glenoid had superior healing and graft incorporation rates as opposed to those with higher allograft angles. They reported no cases of recurrent instability.

Frank et al. [117] compared outcomes of fresh distal tibial allograft (DTA) to Latarjet at a single institution by a match cohort study. There...
**Text Box 4**
Tips and tricks for Eden-Hybinette procedure

- **ILIAC CREST**
  - An iliac crest graft (a.k.a. Eden-Hybinette procedure) is the most widely used salvage procedure for cases of previously failed bone block procedure for anterior shoulder instability with significant bone loss (i.e., Latarjet).
  - There is significant heterogeneity in the published literature regarding graft origin (auto-versus allograft), surgical technique (arthroscopic vs. open) and fixation methods (screws, buttons, sutures, implant free) which make direct comparison challenging.
  - Overall, standing the correct indications, it can provide good results with few relative adverse effects which are peculiar to the procedure (i.e., donor site morbidity, graft non-union etc.).
  - When used as a salvage procedure, care must be taken in ascertaining the exact (and possibly overlooked) causes of previous failure and treat them accordingly.

**Text Box 5**
Major pitfalls and advantages of each procedure

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Advantage</th>
<th>Pitfalls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latarjet</td>
<td>1. Long track record</td>
<td>1. High complication rate</td>
</tr>
<tr>
<td></td>
<td>2. Autologous</td>
<td>2. High graft resorption rate</td>
</tr>
<tr>
<td></td>
<td>3. No added cost</td>
<td>3. Long-term may lead to arthropathy</td>
</tr>
<tr>
<td></td>
<td>5. Very low re-dislocation rate</td>
<td></td>
</tr>
<tr>
<td>Iliac crest bone graft (ICGB)</td>
<td>1. Autologous</td>
<td>1. Donor site morbidity</td>
</tr>
<tr>
<td></td>
<td>2. No added cost</td>
<td>2. Non-anatomic</td>
</tr>
<tr>
<td></td>
<td>3. Available worldwide</td>
<td>3. Extra-articular</td>
</tr>
<tr>
<td></td>
<td>4. Good for massive bone loss or salvage cases</td>
<td></td>
</tr>
<tr>
<td>Arthroscopic anatomic glenoid...</td>
<td>1. No donor site morbidity</td>
<td>1. Cost</td>
</tr>
<tr>
<td></td>
<td>2. High union rates</td>
<td>2. Not available worldwide</td>
</tr>
<tr>
<td></td>
<td>3. Highly conforming with humeral head</td>
<td>3. No viable cartilage (Frozen)</td>
</tr>
<tr>
<td></td>
<td>4. Extra-articular</td>
<td>4. Extra-articular</td>
</tr>
<tr>
<td>Fresh DTA</td>
<td>1. Viable cartilage</td>
<td>1. Cost</td>
</tr>
<tr>
<td></td>
<td>2. Highly conforming with humeral head</td>
<td>2. Not available worldwide</td>
</tr>
<tr>
<td></td>
<td>3. Intra-articular</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. High union rates</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Biologic Joint restoration</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 15.** A fresh distal tibia graft seen en face and lateral aspect marked for harvest.

**Fig. 16.** A postoperative CT scan 3 years after surgery demonstrating healed and incorporated graft, fixated with 2 screws and a wedge profile plate (Arthrex, Naples, FL).
were 50 patients in each of the groups and had comparable demographic information. However, there was a significantly larger glenoid bone loss in the DTA group (28% bone loss) compared to the Latarjet group (22% bone loss). They reported similar clinical outcome measures in both groups at a mean follow up of 45 months (Range 24–111 months). There were no differences in visual analogue scale (VAS), American Shoulder and Elbow Surgeons (ASES) scores, Western Ontario shoulder instability index (WOSI) scores, and Single Assessment Numeric Evaluation (SANE) scores, but the Latarjet group had a better Simple Shoulder Test (SST) outcome. Both groups had similar complication and recurrent instability (1%) rates. Since most Latarjets are intra-articular as well, with the difference being there is no cartilage on coracoid, longer term follow-up is needed to see if the DTA group will have a lower post-instability arthroplasty due to the intra-articular placement of the fresh osteochondral graft.

Fresh distal tibial osteochondral allograft is also a viable option for failed Latarjet procedures in a revision setting. Provencher et al. [128] reported on 31 males with a mean age of 25.5 years, who had failed a Latarjet procedure and were treated with DTA. In this cohort, 35% were having re-dislocation and 65% subluxation. The mean glenoid bone loss of 30.3%. There was a mean of 78% coracoid resorption. At a mean follow up of 47 months (range 36–60 months), there was significant improvement in ASES, SANE, and WOSI scores, with no cases of recurrent instability. A computed tomography (CT) scan demonstrated that there was union of the allograft to the native glenoid in 92% of patients.

**Conclusion distal tibial allograft**

Fresh DTA reconstruction of the glenoid with substantial bone loss has several advantages including matched contour to the humeral head, restoration of bone and cartilage that is lost with repeated dislocations, being placed intra-articularly, restoring bone stock for future arthroplasty procedures, and can act as an alternative for a failed Latarjet. The disadvantage includes cost and lack of availability in certain parts of the world.

When comparing an arthroscopic anatomic glenoid reconstruction-distal tibial allograft (AAGR DTA) to fresh DTA, one must consider the following. The AAGR graft is frozen, making the chondrocyte viability questionable. The graft is placed in an extra-articular position with a Bankart repair placed over it, as it is repaired to the native glenoid rim. The AAGR graft is essentially acting as a more anatomic bone block procedure that better contours with the glenoid compared to an iliac crest bone graft (ICBG) or a non-congruent coracoid transfer. The current average cost in the United States is $1000 for a frozen DTA and $6500 for a fresh DTA. The cost difference could be justified because fresh DTA maintains chondrocyte viability and is placed intra-articularly, rendering it a true joint restorative procedure.

**Conclusion**

ABR has been accepted as a standard procedure for anterior shoulder instability with a minimum or no glenoid bone loss and an on-track Hill-Sachs lesion if present. Several controversies were addressed including removal of cartilage from the glenoid edge for potentially better healing, knotless versus knotted anchors and rotator interval closure were presented and discussed to aid surgeons in their decision-making process. Furthermore, several procedures for cases of significant bone loss were also discussed to assist surgeons. We believe this international perspective addresses controversial topics in shoulder instability to better allow surgeons to make the best decisions around the globe.

**Declaration of competing interest**

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Raffy Mirzayan, MD reports a relationship with Arthrex Inc that includes: speaking and lecture fees.

Ivan Wong reports a relationship with DePuy Mitek Inc that includes: consulting or advisory and speaking and lecture fees. Ivan Wong reports a relationship with Smith and Nephew Inc that includes: consulting or advisory and speaking and lecture fees. Ivan Wong reports a relationship with CONMED Corp that includes: consulting or advising and speaking and lecture fees. Ivan Wong reports a relationship with Stryker Orthopaedics that includes: consulting or advising and speaking and lecture fees. Ivan Wong reports a relationship with Arthrex Inc that includes: consulting or advisory. Ivan Wong reports a relationship with Bioventus LLC that includes: speaking and lecture fees.

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