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CLINICAL FEATURE
REVIEW

Surgical management of type II superior labrum anterior posterior (SLAP) lesions: a review of outcomes and prognostic indicators

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ABSTRACT

A Type II SLAP (superior labrum anterior posterior) lesion is a tear of the superior glenoid labrum with involvement of the long head of the biceps tendon insertion. In patients that do not improve with conservative treatment, there is a great deal of variability in the surgical management of these injuries that includes arthroscopic SLAP repair, arthroscopic SLAP repair with biceps tenodesis, biceps tenodesis alone and biceps tenotomy. Each surgical technique has specific effects on a patient's postoperative course and functional recovery. Rehabilitation strategies may be best formulated on an individual basis with an open line of communication between the operating surgeon and the physical therapist. Despite an increased incidence in treatment, there is currently no consensus on the optimal surgical procedure or treatment algorithm for Type II SLAP injuries. However, in middle-aged or older patients (>35) with Type II SLAP tears, either arthroscopic suprapectoral or mini-open subpectoral biceps tenodesis is recommended due to the higher failure rates observed with arthroscopic SLAP repair in this patient group. Although more patients present with a 'Popeye' sign after biceps tenotomy, long-term functional outcome is similar between biceps tenodesis compared to tenotomy. However, more patients will experience biceps fatigue or cramping after the tenotomy procedure. Biceps tenodesis is preferred in younger, more active patients, while tenotomy is preferred in the middle-aged or older and lower demand patients. The aim of this paper is to provide a brief description of the different surgical techniques employed to address Type II SLAP lesions (arthroscopic repair, biceps tenodesis, and biceps tenotomy) and provide a review of available literature regarding outcomes and prognostic factors associated with each technique.

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SLAP lesion; arthroscopic SLAP repair; biceps tenodesis; biceps tenotomy; post-op rehabilitation

Introduction

Superior labral tears of the shoulder can be significant contributors to pain and disability for patients of all ages and activity levels. Superior labral tears were described in 1985 by Andrews [1], and later coined SLAP (superior labrum anterior posterior) lesions in 1990 by Snyder et al. [2]. These injuries are classified into different subtypes based on the extent of the labral tear and biceps tendon involvement. In a Type II lesion, there is a detachment of both the superior labrum and the origin of the long head of the biceps tendon insertion from the glenoid, with or without associated fraying of the biceps tendon. There is a bimodal distribution in patient age with two distinct patient age groups of 20–29 years and 40–49 who most commonly present with symptomatic SLAP tears [3]. It is imperative to consider these groups as separate entities due to varying biological factors (including healing capacity and the presence of tissue degeneration), mechanism of injury, chronicity of symptoms, activity level and patient expectations between the two groups. Patients that fall outside of these age categories may warrant individualized consideration in terms of surgical treatment options.

Although the mainstay of treatment has traditionally been non-operative, the role of surgery in the management of Type II SLAP lesions has become increasingly popular in the last 10 years. Onyekwelu et al. [4] reported a 464% increase in the number of arthroscopic SLAP repairs performed in the northeastern United States and Zhang et al. [3] reported a 105% increase at the national level. Despite the increasing frequency of surgical intervention, there is no consensus on optimal surgical management for Type II SLAP lesions. Arthroscopic repair has been proposed as the standard of care for these injuries as it is believed to restore normal shoulder anatomy and joint mechanics [5–7]. However, more recent studies are beginning to challenge the role of arthroscopic repair, especially in overhead athletes and older patients [8]. A study by Erickson et al. [9] evaluated trends in arthroscopic shoulder surgery performed by four experienced sports or shoulder/elbow fellowship-trained orthopedic surgeons from 2004 to 2014. The findings reflected a progressive decrease in the number of SLAP repairs performed during shoulder arthroscopy; there was a preponderance of repair in Type 2 lesions, a coincident increase in tenodesis procedures and a general trend towards treating younger patients. Overall, the findings reflected a general shift in the provision of care for SLAP lesions towards select SLAP repair in younger patients with Type II lesions and the popularization of biceps tenodesis or

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tenotomy procedures in older patients with less favorable tear characteristics or biceps tendon involvement that has subsequently played out in the wider literature.

Biceps tenodesis and tenotomy provide surgical alternatives to SLAP repair by alleviating pain and facilitating accelerated rehabilitation of the injured shoulder; both procedures may also be successfully employed following failed, symptomatic SLAP repair [10–12]. Shoulder rehabilitation protocols, essential in the success of both operative and non-operative approaches, are procedure dependent [13,14]. Overall, while non-operative management remains the mainstay of treatment, controversy exists regarding the role of specific surgical strategies in distinct patient populations. This was further complicated recently by a study Schroder et al. [15] that suggested SLAP repair or biceps tenodesis had no significant clinical benefit over sham surgery in final functional outcome at 24 months in middle-aged patients (mean age of 40) presenting with a Type II SLAP tear. However, a significant limitation in their study is that 14 out of 39 patients (36%) in the sham group crossed over to surgery with either arthroscopic SLAP repair or biceps tenodesis during the follow-up period.

Therefore, the purpose of this paper is to provide a comprehensive review of the surgical management of patients with Type II SLAP tears with an emphasis on surgical technique and clinical outcome.

Overview of surgical technique

The three most common options for surgical intervention in Type II SLAP lesions are arthroscopic SLAP repair, biceps tenodesis alone (suprapectoral or subpectoral), or biceps tenotomy. In select patient populations, arthroscopic SLAP repair with biceps tenodesis or tenotomy has also been described. The type of surgical intervention is based on several factors including goals of the patient, mechanism of injury, age, concomitant injuries, and surgeon preference.

Arthroscopic SLAP repair

Arthroscopic SLAP repair is performed with the goal of restoring normal shoulder anatomy and joint biomechanics [16]. Successful surgical repair requires healing of the labrum to the glenoid, and a successful outcome is defined by restoration of pain-free glenohumeral range of motion (GH ROM), especially with overhead motions without over-constraining the shoulder. Of note, the healing response of the fibrocartilagenous labrum is contingent on its tissue quality; much like the meniscus, degenerative tissue is thought to have a lower regenerative capacity. Uggen et al. [17] found this requires excellent initial fixation strength to prevent labral displacement during gentle, passive ROM. The length–tension relationship of the long head biceps muscle tendon unit will be maintained in SLAP repair, allowing for recovery of pre-injury functional strength and mechanics of the entire muscle. Despite the controversial role of the long head biceps tendon at the shoulder, repairing this complex attempts to normalize shoulder kinematics and function and ultimately optimize recovery [16,18].

Prior to surgical intervention, examination under anesthesia is essential to assess the GH ROM and stability, specifically in the anterior and posterior direction with humeral elevation in 90 degrees. Translation of the humeral head in relation to the glenoid rim is graded on a scale of 1–3 [19]. Intraoperatively, the articular surfaces of the humeral head, labrum, rotator cuff, and biceps tendon are evaluated. Specifically, the biceps tendon anchor must be examined for laxity, fissuring, and separation of the tendon from the superior rim of the glenoid (Figure 1(a)). A peel back test is used to determine whether or not the biceps tendon anchor is intact. This is performed with the patient's upper extremity in 90 degrees of abduction and maximal external rotation. With a Type II SLAP lesion, the biceps/labrum anchor will peel back and displace medially onto the glenoid neck when the shoulder is stressed in this position. Contextually, it is also important to consider that a SLAP lesion may be the result of traction injury and may manifest differently, intraoperatively during provocative testing.

During the surgical procedure, the labrum is debrided of non-viable tissue and the superior glenoid is debrided with a shaver establishing a bleeding bony bed (Figure 1(b)) to optimize the healing environment for tissue repair [20]. This is a critical stage as the blood supply to the superior labrum is very poor, and providing an appropriate healing environment will provide an optimal biological stimulus for tissue healing and recovery. After debridement of any scarring or fraying of the biceps, the tendon and superior labrum are fixated to the glenoid surface using bioabsorbable suture anchors (Figure 1(c)). The number of suture anchors will often depend on the extent of the lesion, but most Type II tears can be repaired with 1–2 anchors. The superior labrum is then sutured to the glenoid to firmly secure the biceps anchor and any areas of labral instability, reestablishing the anatomic footprint. The sutures are then tied and secured to complete the surgery (Figure 1(d)).

Variations of this technique have been described in the literature and can include knotless anchors, as well as posterior and trans-rotator cuff approaches [17,21,22]. The clinician should be aware of these as each has implications for the rate of recovery and postoperative rehabilitation. The orthopedic surgeon should communicate these clearly to the physical therapist. Specifically, knotless techniques may restore the anatomy without over-constraining the shoulder and are less likely to result in postoperative irritation of the humeral head and superior labrum (Figure 2(a–c)) [17,21]. In the immediate postoperative period, the ability of the intrascalene nerve block to provide adequate pain relief may be limited following an incision in the posterior capsule and additional measures should be taken into account to limit the pain cascade in these patients. Posterior capsular stiffness and limited range of motion need to be considered specifically in the overhead athlete [7]. Therefore, early intervention for individuals undergoing this technique should focus on addressing posterior capsule mobility, within orthopedic restrictions and protocols [23]. The trans-rotator cuff approach involves placing a portal in line with the rotator cuff [22]. There is conflicting evidence as to whether or not this approach will have an effect on rotator cuff pathology or patient outcomes, however physical therapists need to recognize the potential need for active healing

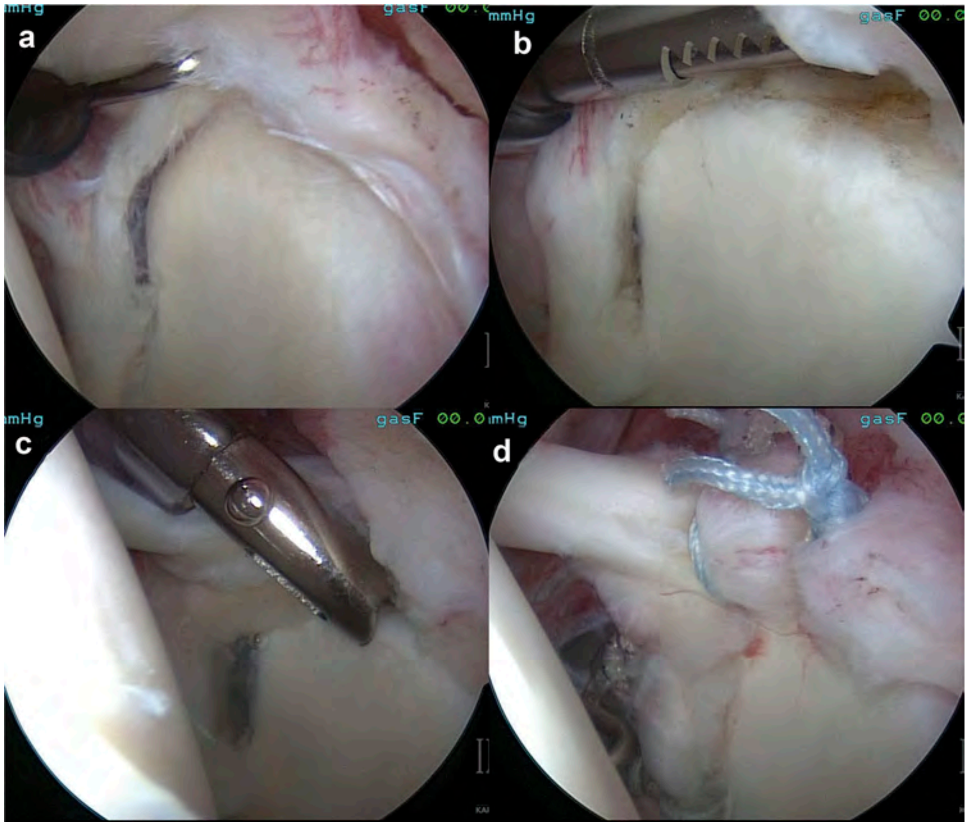

Figure 1. (a). Arthroscopic view of the left shoulder showing a Type 2 SLAP tear. (b). Arthroscopic shaver is inserted into the anterior portal to debride the superior glenoid to a bleeding bone bed in preparation for repair. (c). First anchor is placed posterior to the biceps anchor insertion footprint. (d). Final arthroscopic repair with two anchors and the knots tied down.

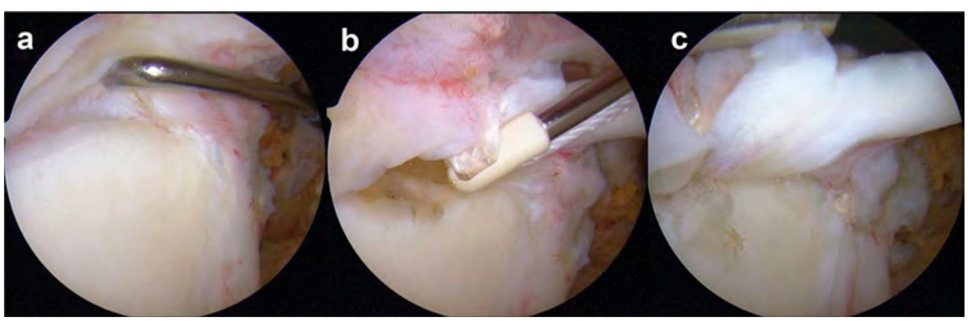

Figure 2. (a). Arthroscopic view of the right shoulder with SLAP tear. (b). A knotless anchor is inserted with a labral tape to repair the SLAP tear. (c). Final arthroscopic repair with knotless fixation.

that may be required following a trans-rotator cuff approach [22].

Biceps tenodesis

In a biceps tenodesis procedure, the biceps tendon is removed from its insertion and reattached on the proximal humerus. The location of fixation can be either suprapectoral or subpectoral. The supra location is typically done arthroscopically while subpectoral is done with a mini-open technique. The association between the biceps tendon and the labrum has been described with some anatomic variation within the normal population. Careful consideration should be given to biceps tenodesis where excursion of the biceps tendon results in destabilization of the labral tear and is a potential mechanism of failure of attempted labral repair [24]. Tenodesis is generally recommended to treat SLAP lesions with obviously associated biceps pathology including partial tears of the biceps tendon and macroscopic evidence of tendinitis. Both mechanisms may contribute to pain generation within the shoulder joint or the biciptial groove. In select patients, there is evidence to suggest that biceps tenodesis represents a potential standard of care for SLAP lesion management in older patients >35 years of age due to the higher failure rates of SLAP repair. Biceps tenodesis can also be undertaken in the setting of failed Type II SLAP lesion repair [16,25,26].

Several locations have been described for fixation of the long head of biceps including superior to the bicipital groove, into the groove, or below the groove (subpectoral biceps tenodesis). While the exact approach is typically dependent on a surgeon's preference, older evidence indicates that more proximal tenodesis may dispose some patients to residual shoulder pain from residual biceps tenosynovitis within the groove necessitating further intervention. However, recent prospective trials comparing suprapectoral versus subpectoral biceps tenodesis for type 2 SLAP tears demonstrate no difference with 2-year follow-up in terms of residual groove pain and patient outcome [27,28]. The surgical goal of biceps tenodesis is to remove the biceps as a source of pain in the shoulder while maintaining the length–tension relationship of the biceps. This will help to prevent atrophy and maintain functional biceps strength in elbow flexion and forearm supination. It is currently understood that the biomechanical disadvantage of removing the long head of biceps from the shoulder joint is minimal based on *in vivo* shoulder kinematics [29]. In general, a biceps tenodesis may allow a more expedient recovery, as there is less time required for immobilization and protection postoperatively compared to a SLAP repair.

Following examination under anesthesia, a thorough arthroscopic assessment of the shoulder is performed. The biceps tendon is identified and is released from its insertion on the labrum. The labrum is then debrided to create a smooth surface at the old tendon insertion point. To facilitate the mini-open subpectoral approach, the arm is maneuvered, placing the shoulder in 60° to 70° of abduction and 30° of external rotation to put the pectoralis major tendon on stretch. A 2–3 cm vertical incision is carried approximately 1 cm below the palpable pectoralis major tendon in the axillary fold. Blunt dissection is carried out under the pectoralis major tendon to the humerus avoiding the medial neurovascular structure and the cephalic vein. A sharp homan retractor is placed under the pectoralis major tendon over the humerus to retract it superiorly. The biceps tendon is palpated manually within the bicipital groove. Using the index finger, the biceps tendon is delivered out of the groove and prepared for tenodesis. A bone tunnel is drilled at the desired level of reattachment or a suture anchor is inserted into the humeral shaft, and then the biceps tendon is inserted into the tunnel and fixed with an interference screw or tied to the anchor, respectively. Tendon to bone fixation and tensioning is examined. Typically, to restore the proper length and tension relationship, the musculotendinous junction of the biceps should be at the inferior border of the pectoralis major tendon.

Alternatively, an above the groove arthroscopic biceps tenodesis may be performed in the intra-articular position with labral tape and a knotless anchor which is the preferred technique of the senior author (XL) (Figure 3(a–d)). Two threaded cannulas (6.5 mm) are established anteriorly in the rotator interval and anterolaterally, next to the anterior leading edge of the supraspinatus tendon, respectively. An 18-gauge spinal needle is used to pierce the biceps tendon at the top of the groove (Figure 3(a)). A PDS suture is shuttled into the joint and used to pass the labral tape (1.5 mm, Arthrex, Naples, FL) into the biceps tendon. A lasso loop technique is used to place the labral tape around the biceps tendon (Figure 3(b)). Using a 2.9 mm push lock anchor (Arthrex, Naples, FL), the biceps tendon is tenodesed at the top of the biceps groove within the glenohumeral joint (Figure 3(c)). Superior labrum is debrided with a shaver and bleeding

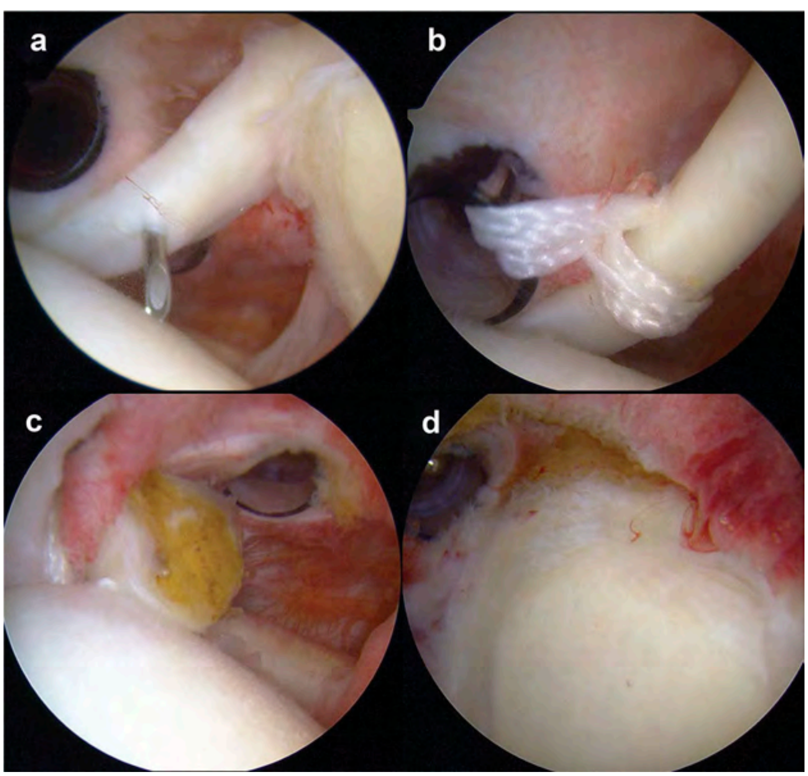

Figure 3. (a). Arthroscopic view of the left shoulder with two cannulas placed into the glenohumeral joint. An 18-gauge spinal needle is used to penetrate the biceps tendon. (b). Labral tape is shuttle around the biceps in a lasso loop fashion. (c). Arthroscopic biceps tenodesis above the pectoral insertion and intra-articular at the top of the groove. (d). Biceps tendon is released from the top of the glenoid.

controlled with an RF device (Figure 3(d)). Please see the entire technique and video published in Arthroscopic Techniques by the senior author (XL) [30].

Variability in this technique is primarily in the location of reattachment for the biceps tendon, the approach and the fixation device for the tendon itself. If the reattachment is above or at the level of the intertubercular groove, the biceps maintains an optimal or near-optimal length–tension relationship; however, it may remain vulnerable to pathology (tenosynovitis) within the groove which may result in residual pain and may lead to higher risk for tendinopathy and possible revision surgery [31]. Fixation distal to the groove removes the potential for pain generation in the bicipital groove; however, care must be taken to maintain the length–tension relationship of the biceps at this level using anatomic tensioning techniques. Mini-open subpectoral approaches allow easier access to the shoulder and have an advantage of either direct fixation of LHBT to short-head (biceps transfer) or to the humerus [32,33]. The biceps transfer technique is thought to be effective in preventing the Popeye deformity compared to tenotomy however can shift the trajectory of the biceps in the direction of the coracoid process and therefore may be more suitable for lower demand patients [33].

Fixation techniques to attach the biceps to the humerus remain surgeon dependent employing a variety of suture anchors, cortical buttons and interference screws with each modality demonstrating adequate time 0 pullout strength [34–37]. Healing of the tendon to bone is achieved using a bone tunnel or direct fixation to a prepared cortical surface. Bone tunnels are believed to increase tendon bone healing area with delivery of endogenous stem cells and growth factors to the surgical site; however, a recent rabbit study from Tan et al. [38] comparing bone tunnel fixation and cortical fixation demonstrated equivocal healing, *in vivo*.

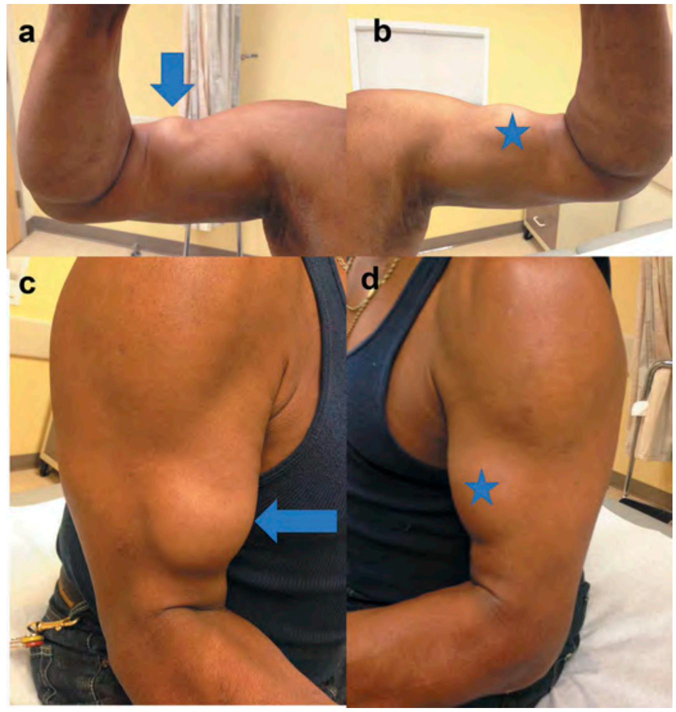

Figure 4. (a,c). Patient that presents after arthroscopic biceps tenotomy with residual 'Popeye' sign and retraction of the biceps tendon (arrow). (b,d). Contralateral normal side showing good biceps tension (star).

Biceps tenotomy

Biceps tenotomy is generally considered for older, sedentary or obese patients with concomitant shoulder pathology and less need for functional biceps strength. Biceps tenotomy has a reported 13–50% incidence of a cosmetic 'Pop-eye' deformity postoperatively (Figure 4(a–c)), which is when the biceps tendon slips inferiorly out of the groove when the muscle contracts in the brachium [39]. The biceps short head is still attached and functional at the coracoid process, so although there will be minimal change in the normal shoulder kinematics, the biceps muscle will experience a diminished level of functional strength. Specifically, Bertram et al. [40] observed a decrease in both peak flexion torque of 7.0% (confidence interval [CI] 1.2–12.8), and peak supination torque of 9.1% (CI 1.8–16.4) relative to the contralateral arm. In addition, total work carried out through the full range of joint motion was reduced in elbow flexion by 5.1% (CI −1.3–11.4) and in forearm supination by 5.7% (CI-2.4–13.9) accounting for high patient satisfaction. Biceps tenotomy is often performed on an individualized basis (older and lower demand patients) and the context of additional procedures because it is expedient and permits significantly accelerated rehabilitation following surgery. Patients may experience fatigue and cramping as a result of the altered mechanics and loss of muscle function; however, these symptoms are uncommon and often well tolerated with favorable clinical outcomes seen in the majority of patients overall.

Biceps tenotomy is generally performed arthroscopically using a similar method as described for biceps tenodesis. Arthroscopic diagnosis and assessment of the biceps tendon are performed, as well as evaluating surrounding structures such as the labrum and rotator cuff. The biceps tendon is probed to determine mobility and then cut at its insertion into the glenoid labrum with an arthroscopic radiofrequency device (Figure 5(a)), and the labrum is debrided to create a smooth surface with no tissue fraying (Figure 5(b)).

Outcomes following surgical technique

Patient outcomes after SLAP repair

There is considerable variability in reported outcomes following surgical repair of Type II SLAP lesions, however generally favorable results have been reported in terms of UCLA, ASES, and L'Insalata scores as well as patient satisfaction. Good to excellent outcomes have been reported in terms of patient satisfaction with most studies in the literature reporting 80–90% patient satisfaction (Table 1). For example, in a systematic review, Li et al. [41] report a range of 87–94% of the patients reporting good to excellent outcomes after repair using suture anchors, indicating that many patients can achieve positive outcomes after repair.

Age also should be considered a prognostic indicator of successful outcomes after SLAP repair. A systematic review by Erickson et al. [44] found that age greater than 40 was an independent risk factor for failure and surgical complications

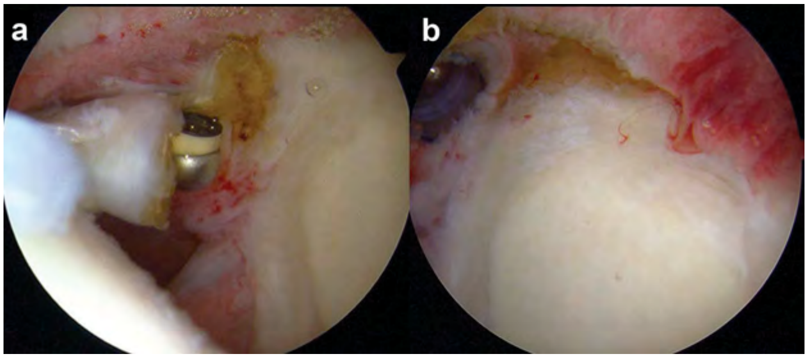

Figure 5. (a). Arthroscopic view of the left shoulder. An arthroscopic radiofrequency device is used to tenotomize the biceps tendon from the insertion at the top of the glenoid rim. (b). The residual superior labrum is debrided with a shaver.

after SLAP repair. A prospective study by Provencher et al. [45] also reported that age greater than 36 was the only variable associated with a statistically significant increased risk of failure, with a relative risk of 3.45. In contrast to these studies, Alpert et al. [46] reported no difference in clinical outcomes comparing arthroscopic type II SLAP repair in patients older or younger than age 40. There was however a trend in ASES scores and SF-12 scores favoring outcomes in the under 40 cohort, and the authors stated that it was their clinical impression that it took longer for older patients to regain their full ROM.

Alternatives to arthroscopic SLAP repair

Comparison of outcomes based upon the surgical approach is very new with only a few studies published to date [11,47]. In 2009, Boileau et al. [11] examined 25 consecutive patients with an isolated Type II SLAP lesion at an average follow up of 35 months and found that arthroscopic biceps tenodesis with an interference screw can be considered an effective alternative to arthroscopic repair. Patients in the tenodesis group had a much higher rate of satisfaction and return to sport when compared to the repair group; however, conclusions and results must be considered with caution as patients treated with tenodesis were significantly older (mean age 52 yrs) than patients who were treated with repair (mean age 37 yrs). A comparison of outcomes between Type II SLAP repair versus biceps tenodesis is included in Table 2.

Ek et al. [47] in 2014 evaluated 25 patients who underwent either arthroscopic repair or biceps tenodesis for an isolated Type II SLAP lesion. They reported no significant differences between groups for ASES scores, patient satisfaction, or return to sport, and concluded that both techniques can provide significant improvements in functional outcomes. However, this study also had some discrepancy in age between groups, where the authors state that it was their preference to perform SLAP repair on younger patients (mean age 31 yrs) and tenodesis on older patients or patients with a degenerative or frayed labrum (mean age 47 yrs). Denard et al. [48] also recently evaluated outcomes after each procedure in patients over the age of 35. They reported that patients who underwent tenodesis had shorter postoperative recovery, a more predictable functional outcome, higher rate of satisfaction and return to activity compared to patients who underwent SLAP repair. The results of these studies suggest that while there is an opportunity for successful outcomes with both techniques, tenodesis may be the more favorable surgical option in treating patients over 35–40 years of age compared to SLAP repair.

It is also important to make note of a recent randomized controlled trial, which found that neither SLAP repair nor biceps tenodesis had any significant clinical benefit over sham surgery for middle-aged patients with type II SLAP lesions [15]. This double-blind, sham-controlled study randomized patients with a diagnosis of type II SLAP lesion into one of three categories: arthroscopic repair, biceps tenodesis, or sham surgery (standard diagnostic arthroscopy). The study found significant improvement in all groups at 6 and 24 months and reported no significant differences by age in function, patient satisfaction, or complications. The authors caution the possible overtreatment of SLAP lesions and recommend that patients be informed about the long recovery and possible complications after surgery. A significant limitation of the study, however, is the cross over rate from the sham group to surgical intervention, with 14 out of 39 patients (36%) requiring either SLAP repair (12) or biceps tenodesis (2) during the follow-up period (patients had the opportunity to be 'unblinded' after 6 months). The authors also did not perform the numbers needed to treat analysis taking this crossover into account. These major limitations should be considered when evaluating the results of this study.

Treatment for failed arthroscopic SLAP repair

Biceps tenodesis or tenotomy are both considered viable revision procedures in the setting of failed SLAP repair. Boileau et al. [11] reported successful results and return to play for four patients treated with revision tenodesis after failed SLAP repair. A case series by McCormick et al. [10]. found significant improvement in ROM, ASES, SANE, and WOSI scores at a minimum 2-year follow-up for patients treated with subpectoral tenodesis revision after a failed SLAP repair. The return to active duty and sport rate was 81%, which is consistent with the return to sport rates following arthroscopic repair. Common causes of failure in this study were synovitis of the rotator interval, loose knots, and lack of healing at the glenoid surface.

Table 1. Outcomes following SLAP repair. Western Ontario Shoulder Instability Index (WOSI); Single Assessment Numeric Evaluation (SANE); American Society of Shoulder and Elbow Surgeons (ASES); Kerlan Jobe Orthopaedic Clinic (KJOC); Simple Shoulder Test (SST); UCLA Shoulder Score (UCLA).

Study	Description	Procedure	Outcomes	Conclusions
Systematic Reviews				
Erickson et al. 2015 [44]	14 Studies with at least 1 group who underwent arthroscopic type II or IV SLAP repair Min 2 year f/u Mean patient age ≥40 yrs	Arthroscopic Repair	Several authors reported equivalent outcomes for patients over and under 40 yrs Others demonstrated significantly higher failure rates >40 yrs Decreased satisfaction and increasing complications occur at higher rates in >40 yrs cohort	While satisfactory outcomes may be obtained in SLAP repair in an older cohort, age >40 yrs and Worker's compensation status are independent risk factors for increased surgical complications Current evidence supports labral debridement or biceps tenotomy over labral repair with concomitant rotator cuff injury
Sayde et al. 2012 [56]	Type II SLAP repairs with 2-year f/u 14 articles Level 3–4 evidence	Arthroscopic Repair	83% good to excellent satisfaction 73% Overall return to sport 63% Overhead athlete RTP Anchor repair in overhead athletes: 88% vs 74% good to excellent satisfaction 63% vs 57% return to sport	Repair of type II SLAP tears leads to return to prior level of play in most athletes. Overhead athletes have lower return to sport rates Anchor fixation appears to be most favorable fixation for overhead athletes
Gorantla et al. 2010 [7]	Outcome Studies of repair of Type II SLAP Min 2 year f/u Level IV or higher	Arthroscopic Repair	40%-94% Good to Excellent outcome 20%-94% returned to prior level of activity 64% of all overhead athletes in the review returned to sport	Arthroscopic repair results in overall excellent results for individuals not involved in throwing or overhead sports (based on Level III and IV studies)
Prospective Cohort Studies				
Boesmueller et al. 2017 [42]	n = 11 patients mean age: 31.8 yrs 72.7% male 4 Traumatic, 7 atraumatic	Arthroscopic Repair Suture Anchors	6 month f/u: Significant improvement in function according to Constant Score, ASES, and SF-36 compared to pre-op CS: 91.89 ASES: 90.8	Arthroscopic repair with suture anchors leads to satisfactory functional outcome and return to sport level, with significant pain relief, observed 6 months after surgery. Return to sport should not be allowed earlier than 6-month post-op. Limitations: Small study size, no comparison group, homogenous level of activity
Brockmeier et al. 2009 [5]	n = 47 SLAP II tear Mean age: 36 yrs	Arthroscopic Repair Bioabsorbable or metal suture anchors	Avg 2.7 year f/u Median ASES: 97 Median L'Insalata: 93 Median Satisfaction: 9/10 87% rated Good to Excellent Overall 74% preinjury level return to play	Favorable outcomes in majority of patients after arthroscopic SLAP repair. 11/12 (92%) of athletes with discrete traumatic event able to return to competition Limitations: No control or comparison group, some patients managed by multiple surgeons, patients with coexisting pathology
Provencher et al. 2013 [45]	Prospective case control study, n = 179 Active duty patients Mean age 31.6 (18–45) 47.4% traumatic event	Arthroscopic Repair Suture anchors	Significant improvement in all outcomes and ROM WOSI: 82% SANE: 85% ASES: 88 37% Failure rate (ASES>75, no revision surgery, full military duty) 28% revision rate after surgery	Arthroscopic repair provides significant improvement in shoulder outcomes. Reliable return to previous level of activity is limited in an active population. Age >36 yrs associated with higher chance of failure Relative Risk: 3.45 Mean age Failed Case: 39.2 yrs Mean age Successful Case: 27.9 yrs Limitations: Only active military population, selection bias, 20% did not complete, 2 surgeons
Retrospective Studies				
Alpert et al. 2010 [46]	Cohort study, n = 52 patients with type II SLAP Group 1: Age >40 yrs Group 2: Age <40 yrs	Arthroscopic repair Single surgeon, suture anchors	Min 2 year f/u: Group 1: Satisfaction: 84% VAS: 1.68 SST: 10.867 ASES: 86.026 Group 2: Satisfaction: 95% VAS: 0.947 SST: 11.278 ASES: 93.119	Arthroscopic repair of type II SLAP can yield good to excellent results in patients both older and younger than 40. Clinical Impression: Longer for older patients to regain range of motion-recommend early, supervised rehabilitation program. Limitations: Retrospective, small sample size
Case Series				
Neuman et al, 2011 [43]	n = 34 overhead athletes Mean age 24 yrs	Arthroscopic Repair Suture anchors	Consistent improvement with prior studies ASES: 87.9 KJOC: 73.6 Athlete Perception: 84.1% of prior level Mean return to sport 11.7 months Overall Satisfaction 93.3%	Arthroscopic repair shows excellent results and high rate of overall satisfaction. Consistent return to elite throwing sports may still remain problematic. Limitations: Retrospective cohort, small sample size

(*Continued*)

Table 1. (Continued).

Study	Description	Procedure	Outcomes	Conclusions
Friel et al. 2010 [6]	n = 48 patients Mean age 33.1 yrs 80% male	Arthroscopic Repair Suture anchors	Mean f/u 3.4 years Significant improvement in all outcomes and range of motion ASES: 83.37 SST: 10.2 80% Good to Excellent UCLA score 89% would have surgery again Overhead athletes and laborers also showed improvement in subjective scores	Arthroscopic repair of Type II SLAP provides significant improvement in functional capacity and pain relief No differences between outcomes of non-athletes, non-overhead athletes, suggesting that SLAP II repair is successful independent of activity level Limitations: No pre-operative strength score, small sample size

Table 2. SLAP repair vs Biceps tenodesis. Western Ontario Shoulder Instability Index (WOSI); Single Assessment Numeric Evaluation (SANE); American Society of Shoulder and Elbow Surgeons (ASES); Kerlan Jobe Orthopaedic Clinic (KJOC); Simple Shoulder Test (SST); UCLA Shoulder Score (UCLA).

Study	Description	Procedure	Outcomes	Conclusions
Randomized Controlled Trial				
Schroder et al. 2017 [15]	3-armed n = 118 18–60 yrs	Double-blind, sham-controlled RCT 1. Labral Repair 2. Biceps Tenodesis 3. Sham Surgery	All groups showed improvement after 6 and 24 month follow ups No significant between-group differences at any follow-up in any outcome (Rowe score, WOSI, Oxford)	Neither labral repair nor biceps tenodesis had any significant clinical benefit over sham surgery for patients with SLAP II lesions in the population studied No significant differences in function, satisfaction, or complication by age Limitations: Small sample size, possible to un-blind after 6 months, No non-operative group
Prospective Cohort Study				
Boileau et al. 2009 [11]	Level 3 Cohort Study n = 25 consecutive patients Repair: 10 male, mean age 37 yrs Tenodesis: 15 (9 male/6 female), mean age 52 yrs	1. SLAP repair 2. Biceps tenodesis	Repair Group: CS: 83 60% disappointed secondary to pain or inability to return to sport Tenodesis Group: CS: 89 93% Satisfied or very satisfied Return to Sport: Repair: 20% Tenodesis: 87%	Arthroscopic biceps tenodesis is an effective alternative to the repair of a type II SLAP lesion. The results of biceps reinsertion (repair) are disappointing compared with tenodesis. Biceps tenodesis may provide viable alternative for a failed SLAP repair. Limitations: age between the 2 groups varied (37 yrs vs 52 yrs), small sample size
Retrospective Studies				
Denard et al. 2014 [48]	n = 37 patients with isolated Type II SLAP 22 Repair, mean age 45.2 yrs 15 Tenodesis, mean age 52 yrs	1. SLAP repair 2. Biceps tenodesis	Significant improvements observed for both groups ASES: 87.4 vs 89.9 UCLA 31.2 vs 32.7 Full range of motion delayed by 3 months in repair group Patient Satisfaction Repair: 77% Tenodesis: 100%	Biceps tenodesis is preferable to biceps repair for isolated type II SLAP lesions in non-overhead athletes over 35 years. Limitations: Retrospective study, additional procedures that did not require repair, small sample size
Ek et al. 2013 [47]	Retrospective cohort study: treatment study, n = 25 patients 15 biceps tenodesis mean age 47 yrs 10 SLAP repair mean age 31 yrs	1. SLAP repair 2. Biceps tenodesis	Both groups showed significant improvement in subjective shoulder value and pain scores ASES: 93.0 vs 93.5 Satisfaction: 93% vs 90% Return to prior sport level: 73% vs 60%	Both biceps tenodesis and SLAP repair can provide good to excellent results Tenodesis primarily performed in older patients (>35 yrs) and patients with degenerative/frayed labrums Repair performed in younger and more active patients with healthy-appearing labral tissue Limitations: Retrospective, non-randomized, small sample size, only isolated type II SLAP
Revision Tenodesis				
McCormick et al. 2014 [10]	Case series, n = 42 patients with failed SLAP Repair Mean age 39.2 yrs 85% male	Subpectoral Tenodesis Revision	Mean f/u 3.5 years Significant improvement across all outcomes and ROM after revision ASES: 89 SANE: 84% WOSI: 81% Rate of return to active duty/sports: 81%	Biceps tenodesis is a predictable, safe, and effective treatment for failed arthroscopic SLAP tears at minimum 2 year follow up. Limitations: Entirely military personnel, 2 surgeons at 1 center, no randomization

Regarding reoperation following isolated SLAP lesion, Mollon at al. [49]. identified a 10.1% incidence of subsequent surgery in their study that included over 2,500 SLAP repairs performed in New York State between 2003 and 2014. They attributed their high reoperation incidence to additional diagnoses cautioning that pain generation in the shoulder is often multifaceted and the isolated diagnosis of a SLAP tear should continue to be challenged in the perioperative period. The authors also observed the shift towards biceps tenodesis or tenotomy over revision repair of the SLAP lesion in more recent years coincident with general trends. Contextually the need for reoperation can be distinguished from the incidence of re-tear which is often asymptomatic and does not necessarily correlate with clinical outcome scores [50].

Concomitant injuries

A high proportion of SLAP injuries occur with concomitant injury (Table 3). It is also important to recognize that SLAP lesions are being increasingly diagnosed which results in a shift from a predominance of overhead athletes to an older patient population with concomitant intra-articular injuries. As such, the literature supports biceps tenodesis and tenotomy over SLAP repair in the presence of concomitant cuff tears, particularly in middle-aged patients [8]. Specifically, a 2008 study by Franceschi et al. [12] reported that there were no advantages in repairing a type II SLAP lesion when associated with a rotator cuff tear when compared to biceps tenotomy in patients older than 50 years old. Additional studies by Kim et al. [51] and Abbot et al. [52] similarly found that in an older population, SLAP repair with concomitant rotator cuff repair did not perform as well as a biceps tenotomy or SLAP debridement.

It may also be important to distinguish those patients who require combined SLAP repair and a biceps procedure from those who require either isolated labral or biceps procedures based on the degree of pathology within the shoulder joint. Chalmers et al. [53] report significantly worse outcomes in those patients that required combined procedures rather than isolated labral repair or biceps tenodesis. The results suggest that the technical success of the procedures to alleviate pain and promote a return to normal function may be dependent on the level of burden of host surgical shoulder pathology at the outset.

There is some evidence to support arthroscopic SLAP repair with concomitant injury in a younger patient population. Levy et al. [54] found no significant effect of a coexistent rotator cuff injury on short-term outcomes for arthroscopic SLAP repair in patients younger than 50 years old. Another study by Beyzadeoglu & Circi [55] evaluated elite athletes with SLAP lesions and associated rotator cuff tear or Bankart lesion, and found that 88% of the patients were able to return to their prior level of activity at an average of 6.4 ± 1.5 months. The authors suggest that anatomic repair and aggressive rehab may facilitate a high rate of return to the sport in athletes following SLAP repair with a concomitant procedure. Of note, both of these studies were retrospective in nature, and with no comparison to alternative management techniques such as tenodesis/tenotomy or conservative treatment.

Return to the sport and overhead activity

Overhead athletes present a challenge in rehabilitation following SLAP repair. There are a number of studies that report overall positive outcomes in patients after SLAP repair; however, overhead athletes had inferior patient satisfaction and return to sports compared to the non-overhead athletes. This contrast suggests that there is still significant room for improvement in managing these patients who are returning to a high level of overhead activity. A systematic review by Sayde and colleagues [56] in 2012 included 506 patients and found that 83% reported good to excellent patient satisfaction; however, only 73% of these patients returned to their prior level of play, including only 63% of overhead athletes. While all studies were retrospective in nature and included relatively small sample sizes, the authors felt that the results were fairly consistent in exemplifying difficulty for overhead athletes to return to their previous level of sports activity after SLAP repair which may be attributed to the decrease in range of motion post-surgery affecting the throwing arc of motion.

There is also evidence that return to sports outcomes is less than optimal after biceps tenodesis in the overhead athletes. A study by Chalmers et al. [57] evaluated return to play rates in professional baseball players following biceps tenodesis between 2010 and 2013. Of the 17 baseball players who underwent biceps tenodesis, only 35% (6 players) returned to their prior level of activity. Eighty percent (4/5) of position players returned to play; however, this number was much lower in pitchers (17%, 2/12). There were no significant differences in performance among pitchers who did return to play. The authors note that biceps tenodesis is an uncommon procedure in professional baseball; however, the current outcomes are not meeting the demand of this population and should be further evaluated.

In a controlled laboratory study, Chalmers et al. [29] investigated postoperative restoration of motion and neuromuscular control during overhand pitching comparing pitchers who had undergone either biceps tenodesis or arthroscopic repair of SLAP lesions. Overall, 18 pitchers participated (7 controls, 6 post-SLAP repair and 5 post-subpectoral biceps tenodesis) undergoing simultaneous surface electromyographic (EMG) measurements and *in vivo* motion analysis. Interestingly, biceps tenodesis appeared to more closely approximate normal muscle activation patterns within the long head of biceps compared to SLAP repair. Overall those pitchers who underwent SLAP repair exhibited altered thoracic rotation during pitching when compared to the controls on the biceps tenodesis group.

Conclusion

A recent rise in the incidence of surgical management of Type II SLAP lesions has been reported in the literature with a shift towards older patients with concomitant injuries. Current surgical options for the treatment of these injuries include arthroscopic repair, biceps tenodesis, and biceps tenotomy. There are many varieties of surgical techniques including arthroscopic or mini-open and location of the tenodesis reported in the literature. Thus, surgical management for SLAP lesions is often individualized based on patient-specific factors including the preinjury level of activity, type of sports (non-overhead vs overhead), age, symptomatology, concomitant injuries, and patient expectation. Indeed, conservative non-surgical treatment should be initiated first in the majority of patients particularly in lower demand middle-aged and older patients [1]. Given the significant variation in these surgical strategies and approaches, clear and ongoing communication between physicians, physical therapists and athletic trainers throughout the rehabilitation period is essential to optimize patient care. In fact, the authors would advocate for direct communication between the surgeon and therapists, where possible to advance early milestones and determine appropriate

Table 3. SLAP lesion with concomitant injury. Western Ontario Shoulder Instability Index (WOSI); Single Assessment Numeric Evaluation (SANE); American Society of Shoulder and Elbow Surgeons (ASES); Kerlan Jobe Orthopaedic Clinic (KJOC); Simple Shoulder Test (SST); UCLA Shoulder Score (UCLA).

Study	Description	Procedure	Outcomes	Conclusions
Randomized Controlled Trial				
Franceschi et al. 2008 [12]	n = 63 patients >50 yrs with rotator cuff (RC) tear and type II SLAP 31 SLAP repair 32 Biceps tenotomy	1.Arthroscopic SLAP and RC repair 2.Biceps tenotomy with RC repair	Mean followup 5.2 yrs Group 1: UCLA: 27.9 Return to sport: 3/8 Group 2: UCLA: 32.1 Return to sport: 6/6	No advantages in repairing type II SLAP when associated with a RC tear in patients >50 Lower risk of developing post-op stiffness at 5 years Limitations: No "non-repair" group, only UCLA score
Prospective Cohort Study				
Kim et al. 2012 [51]	n = 36 patients with type II SLAP and large to massive rotataor cuff tear 16 SLAP repair and RC repair Mean age: 61.1 yrs 20 Tenotomy and RC repair Mean age: 63.3 yrs	1. SLAP repair and RC Repair 2. Biceps tenotomy and RC repair	2-year followup Repair Group: SST: 7.8 ASES: 80.4 UCLA: 26.0 Tenotomy Group: SST: 9.3 ASES: 88.6 UCLA: 29.6	Outcomes of SLAP and cuff repair were less satisfactory than arthroscopic tenotomy and cuff repair. Limitations: Not randomized, small sample size
Abbot et al. 2009 [52]	n = 48 patients >45 yrs with RC tear and type II SLAP Randomized into 2 groups: 24 SLAP debridement 24 SLAP repair	1. RC repair and SLAP debridement 2. RC repair and SLAP repair	2 year f/u Group 1: UCLA: 34 Tegner: 5.6 Internal Rotation (IR): 69.3 degrees External rotation (ER): 84.3 degrees Group 2: UCLA: 31 Tegner: 5.1 IR: 36.1 degrees ER: 68.6 degrees	Patients >45 yrs with arthroscopic RC repair and SLAP debridement have better function, pain relief, and range of motion compared to SLAP repair. All operations performed by single surgeon Limitations: 10 patients lost to followup (20%)
Retrospective Study				
Levy et al. 2010 [54]	Cohort study: n = 93 patients <50 yrs Type II SLAP repair 44 SLAP with normal RC 49 SLAP with partial/full thickness RC tear	1. Arthroscopic SLAP Repair 2. SLAP repair plus RC repair if >50% tear	Mean f/u 2.54 yrs Group 1: UCLA: 32.9 Group 2: UCLA: 33.3 Return to Activity: 92.4% Between groups not reported	No effect of coexistant rotator cuff tears on short-term surgical outcome of arthroscopic SLAP repair in patients <50 yrs. Rotator cuff injury common in setting of type II SLAP (52.7%) Limitations: Retrospective nature with short-term follow up, only used UCLA score
Case Series				
Beyzadeoglu & Circi, 2015 [55]	n = 35 34 Elite Athletes Mean age: 25 yrs	Arthroscopic Repair of SLAP with Bankart or RC repair	Isolated SLAP: 17.1% Partial Cuff Tear: 25.7% Bankart: 37.1% Full Cuff Tear: 8.6% Bankart and Post labrum: 8.6% Bankart and Full Cuff Tear: 2.9% Mean follow-up: 4.3 yrs ASES: 89.6 KJOC: 80.9 Return to Sport: 6.4 months, 88%	Depending on injury mechanism, SLAP lesions may frequently occur with Bankart or posterior labral lesions and rotator cuff tears. Anatomic repair and aggressive rehab facilitate high rate of return to sport. Limitations: Retrospective, small sample size

return to full activity or sport. Overhead or throwing athletes are particularly susceptible to the development of Type II SLAP lesions and present the greatest challenge in terms of return to prior level of activity after surgery.

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Declaration of interest

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