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INJURIES IN OVERHEAD ATHLETES (J DINES AND C CAMP, SECTION EDITORS)

Diagnosis and Treatment of Injuries to the Biceps and Superior Labral Complex in Overhead Athletes

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Abstract

Purpose of Review This review discusses the diagnostic and treatment challenges presented by injuries to the biceps and superior labral complex.

Recent Findings A focused patient history, numerous physical examination maneuvers, and appropriate advanced imaging studies must be utilized to reach an accurate diagnosis. Nonoperative management, even in overhead athletes, has demonstrated relatively good outcomes, while operative outcomes have yielded mixed results. The surgeon must take into account a number of variables when choosing the appropriate surgical procedure: labral repair versus biceps tenodesis. Rehabilitation, either as nonoperative management or as a postoperative protocol, should focus on restoring glenohumeral and scapulothoracic strength, endurance, and full, pain-free range of motion, while correcting any deficiencies in balance or rhythm throughout the overhead motion.

Summary Despite the operative treatment challenges that SLAP tears present, with new techniques and proper patient selection, overhead athletes with injuries to the biceps and superior labrum complex can return to sport at a high level.

Keywords Biceps · Labrum · Superior labrum from anterior to posterior tear · SLAP · Long head of the biceps tendon · Overhead athlete

Introduction

Injuries to the proximal long head of the biceps tendon (LHBT) and superior labrum in overhead athletes provide a diagnosis and management challenge for orthopedic surgeons. Recent literature has pointed towards the importance of approaching the superior labrum and the proximal LHBT as a unit, known as the biceps and superior labral complex. With increased focus towards treatment of these injuries as a continuum of disease, recent trends in the treatment of superior labrum anterior and posterior (SLAP) tears have pointed towards a decrease in primary SLAP repair and an increase in biceps tenotomy and tenodesis procedures [1]. This review article aims to provide a basic understanding of these challenging injuries, both from a diagnostic and treatment standpoint, while reviewing the recent literature pertaining to the pathomechanics, presentation, diagnosis, and management of biceps and superior labral complex injuries.

This article is part of the Topical Collection on *Injuries in Overhead Athletes*

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Basic Anatomy and Pathogenesis

The glenoid labrum is a fibrocartilagenous structure that runs circumferentially around the rim of the shallow bony glenoid fossa, deepening the socket and acting as a passive stabilizer to prevent humeral head subluxation [2–4]. The labrum also serves as an attachment site for capsuloligamentous structures, such as the glenohumeral ligaments and the LHBT [5,6].

Numerous mechanical changes have been postulated for the pathogenesis of injury to the biceps and superior labral complex. For instance, Andrews et al. first theorized that biceps and superior labral injuries may occur as a result of traction during the deceleration phase of throwing [7,8]. Underlying anterior instability may increase the fractional

forces generated by the biceps brachii, leading to higher rates of superior labral complex injuries in these patients [9,10].

Burkhart et al. suggested that the initiation of a superior labral tear is secondary to posteroinferior capsular contractures, which drives the humeral head posterosuperiorly, increasing shear forces on the LHBT [11]. Additionally, torsional forces have been implicated in injury to the superior labral complex through the "peel-back" mechanism, as described by Burkhart and Morgan [12].

Other mechanisms of injury include labral degeneration secondary to compressive grinding forces generated on the labrum by internal rotation [13,14], altered scapular mechanics [15,16], and acute traumatic events such as direct blows to the shoulder and forceful traction injuries [17]. Given the wide spectrum of potential etiologies of injury, it is likely that a majority of cases of injury to the biceps and superior labral complex are multifactorial and driven by the specific inciting injury and the underlying anatomy of the patient.

Diagnosis

Presentation and History

Overhead throwers complaining of anterior shoulder pain should be closely evaluated for biceps and superior labral complex pathology. Injuries to this complex typically occur as a result of repetitive microtrauma through overuse, although acute injuries are possible [12]. Many throwers present complaining of a decrease in velocity and often note pain and mechanical symptoms such as clicking and popping during the late cocking phase of the throwing motion, while tennis or volleyball players may complain of pain during the cocking phase of the serve [18–21]. Concomitant injuries can occur with relative frequency, such as rotator cuff pathology and instability [22].

Physical Examination

Physical examination is an important element in the diagnosis of biceps and superior labral pathology, while ruling out other possible causes for shoulder pain in the overhead athlete. The first component of the examination should be a comprehensive evaluation of the glenohumeral and scapulothoracic range of motion. Overhead throwers often have glenohumeral internal rotation deficit (GIRD), which is defined as a lack of internal rotation of at least 20° compared to the contralateral side [23,24]. With the patient supine, anterior and posterior stability of the glenohumeral joint also should be assessed. Evaluation of the scapula must be done both with the arm at rest and throughout elevation. SICK scapular syndrome, defined by scapular malposition, inferior medial border prominence, coracoid pain and malposition, and dyskinesis of scapular motion, is often present to some degree in overhead athletes with shoulder pathology [15]. Restoration of normal scapular motion and mechanics is an important component of rehabilitation preoperatively or postoperatively.

In addition to range of motion, there are a number of special tests that can be utilized including the "3-Pack" examination (O'Brien active compression test, resisted throwing test, and palpation of the bicipital tunnel) [25•], as well as the Dines modification of the O'Brien active compression test [26], the crank test [27], Speed's test, dynamic labral shear test [28], and Yergason's test, among others. Knesek et al. compiled a summary of these clinical tests and their ability to diagnose SLAP pathologies [23]. One addition in the past few years is the Dines modification to the O'Brien active compression test as described by Urch et al. [26]. Similar to the active compression test, the patient's arm is flexed to 90°, adducted to 10° to 15°, and internally rotated with the thumb pointed down. The modification occurs when the patient places the contralateral arm in the same position adjacent to the involved arm. A downward force is applied by the examiner to both arms and is then repeated with the palms facing up. The test is considered positive when the patient has pain in the affected shoulder with the thumb pointing down that is relieved when the humerus is externally rotated and the palms are up. This modification standardizes the arm position and provides reproducibility, while preventing the patient from attempting to compensate by changing arm position [26].

Taylor and colleagues evaluated the 3-Pack examination (O'Brien active compression test, resisted throwing test, and palpation of the bicipital tunnel) for its diagnostic value in the identification of biceps and superior labral complex disease [25•]. This case control study, examining 116 chronically symptomatic patients indicated for subdeltoid biceps tendon transfer and 29 control patients, demonstrated that the 3-Pack tests are more sensitive (73 to 98%), but less specific (46 to 79%) compared to the traditional examination maneuvers of Speed's test, Yergason's test, and the full and empty can tests, which overall were less sensitive (20 to 67%) and more specific (83 to 100%). Palpation of the bicipital tunnel and O'Brien's active compression test carried negative predictive values of 96.4 and 92.6%, respectively, for lesions in the bicipital tunnel. The 3-Pack examination proved much more reliable, with a high inter-rater reliability (kappa 0.7 to 0.85), compared to the traditional tests that had much wider variability (kappa 0.25 to 0.56) [25•]. Therefore, the 3-Pack is a reliable screening tool that can be used to predictably rule out biceps and superior labral complex disease.

Kibler et al. performed a systematic review on the current practice in the diagnosis of SLAP tears [29]. In the 26 articles that were reviewed, the most commonly reported components for diagnosis were a positive active compression test (65%), magnetic resonance imaging or arthrography (65%), and a

history of shoulder pain (42%), with arthroscopic findings making or confirming the diagnosis in 95% of cases.

Imaging Studies

Establishing a clear diagnosis of disease of the biceps and superior labral complex can prove difficult with examination alone, and therefore, imaging studies can play an important role in the diagnosis of pathology. Initial imaging evaluation of a patient with shoulder pathology should begin with orthogonal plain radiographs of the shoulder, including anteroposterior, outlet, axillary, and Grashey views.

Advanced imaging with magnetic resonance imaging (MRI) remains the gold standard in diagnostic imaging for intra-articular shoulder pathology, including of the biceps and superior labral complex. A recent systematic review and meta-analysis by Symanski and colleagues evaluated 32 studies, with a total of 3524 imaging examinations, to determine the diagnostic accuracy of MRI and magnetic resonance (MR) arthrography for diagnosis of SLAP tears [30•]. They found that MR arthrography carried the highest sensitivity (80.4%) and specificity (90.7%), while MRI had a sensitivity of 63% and specificity of 87% in the included studies. Additionally, they found 3-T magnets to be superior to lower power 1.5-T imaging in the diagnosis of superior labral tears [30•]. Therefore, MR arthrography continues to be the gold standard in the diagnosis of superior labral tears (Fig. 1). When comparing MRI results to arthroscopy for diagnosis of shoulder pathologies, Bhatnagar et al. found MRI to be least reliable (kappa 0.7) in the diagnosis of SLAP lesions compared to its ability to diagnose other intra-articular pathologies such as osteochondral lesions, rotator cuff tears, and Bankart lesions [31].

Taylor et al. described the inability of MRI to completely evaluate the proximal LHBT. While they found MRI to have a sensitivity of 77.3% and specificity of 68.2% for the diagnosis of intra-articular biceps lesions, the ability to diagnose junctional (sensitivity 43.3 and specificity 55.6%) and bicipital tunnel (sensitivity 50.4 and specificity 61.4%) lesions is notably lower [32]. Additionally, Taylor et al. found that traditional glenohumeral arthroscopy only evaluates 55% of the LHBT proximal to the pectoralis major tendon and therefore did not identify lesions along the extra-articular portion of the tendon, which are present in 47% of symptomatic patients [33]. These studies highlight the difficulty in properly diagnosing a specific pathology along the biceps and superior labral complex and further emphasize the importance of a comprehensive history and physical exam combined with these imaging studies.

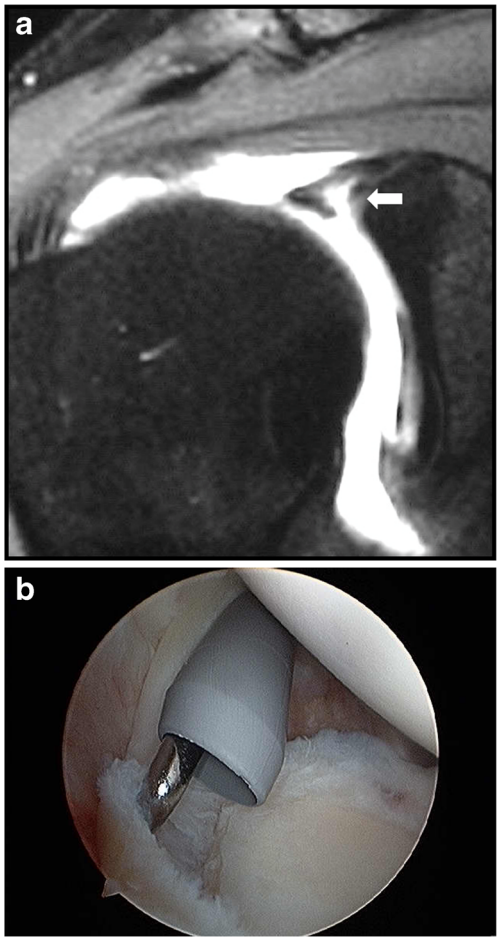

Fig. 1 **a** Magnetic resonance arthrogram demonstrating a type II superior labrum from anterior to posterior (SLAP) tear (white arrow). **b** Intraoperative photograph showing a type II SLAP tear

Nonoperative Management

Many injuries to the biceps and superior labral complex in the overhead athlete can be successfully treated nonoperatively. Edwards and colleagues demonstrated successful return to sport at the same or higher level in 66% of overhead athletes with SLAP tears following a nonoperative management protocol of nonsteroidal anti-inflammatory drugs (NSAIDs) and physical therapy consisting of posterior capsule stretching and scapular stabilization exercises [34]. While the initial phase of nonoperative management focuses on decreasing inflammation, a successful rehab protocol for an overhead athlete with a biceps and superior labral complex injury has the ultimate goal of restoring muscle strength, endurance, and normal, pain-free glenohumeral and scapulothoracic motion [35•].

In a patient with GIRD, stretches should address the posterior capsular contracture. One such stretch is the sleeper stretch where the patient lies on the affected side with the shoulder and elbow flexed at 90°, while the contralateral hand passively internally rotates the shoulder [15, 23]. Stretching of the posterior capsule is particularly important in baseball players, who commonly develop internal rotation deficits (GIRD) secondary to posterior capsule contracture [36]. Rotator cuff exercises, both closed and open chain with light dumbbells and bands, can be performed. Scapular

stabilization exercises help to restore normal scapular motion and improve strength. This is followed by progressive, higher intensity scapular stabilization and rotator cuff resistance exercises as outlined by Jang et al. [35•]. Shoulder exercises can be supplemented with core and lower extremity strengthening in order provide stability, balance, and rhythm throughout the throwing motion or overhead activity [37•].

When motion is restored, a throwing program can be initiated with a focus on proper alignment, posture, and motion, while the timeline for this varies [19, 23, 37•]. Using a specific nonsurgical protocol incorporating the above points in the treatment of professional baseball pitchers with SLAP tears, Fedirow et al. demonstrated a return to play (RTP) rate of 40%, which was similar to the RTP rate of 48% in the operative group [37•]. Nonoperative intervention is typically continued for 3 to 6 months. If the patient continues to complain of pain and dysfunction with overhead activities at 3 to 6 months or is not progressing well through nonoperative management, it is deemed a failure and operative intervention should be considered.

Jang et al. studied the potential predictive factors leading to failure of nonoperative management of SLAP tears [35•]. In a series of 63 patients treated nonoperatively for type II SLAP tear, 45 patients (71.4%) noted significant improvements in their pain (visual analog scale (VAS), 4.6 to 1.7) and function (American Shoulder and Elbow Surgeons (ASES), score 54.2 to 86.4) at an average follow-up of 21 months. The 18 patients (28.5%) that failed nonoperative management were more likely to participate in overhead sports, had a history of traumatic event, and had a positive compression-rotation test as described by Kim et al. [35•, 38]. Nonoperative management has demonstrated success, including in overhead athletes, and therefore should be the first line of treatment for athletes with biceps and superior labral complex injuries.

Operative Management

Once nonoperative management in overhead throwers is deemed a failure, operative intervention is indicated. As previously mentioned, injury to the superior labrum and LHBT should be considered pathologies of different zones of the biceps and superior labral complex. Consequently, when approaching an overhead athlete with a superior labral tear from an operative standpoint, it is important to evaluate for pathology along the LHBT, while taking into account the quality of labral tissue, extent of biceps injury, condition of glenohumeral joint cartilage, presence of other symptomatic shoulder pathology, and the age of the patient. In young (< 35 years), active patients with healthy labral tissue and glenohumeral cartilage, or a history of traumatic injury or instability, primary SLAP repair is often preferred, while biceps tenodesis is typically favored in older patients (> 40 years) with chronic symptoms, proximal LHBT lesions, degenerative labral tissue, notable glenohumeral cartilage wear, or the presence of concomitant shoulder pathology. These factors, among others, are accounted for in the multiple treatment algorithms for SLAP tears [39–41]. Notably, in a survey of Major League Baseball (MLB) team orthopedic surgeons, a vast majority (93%) said that they would repair a type II SLAP tear that failed nonoperative management in an MLB pitcher rather than perform an arthroscopic debridement, while none said they would perform a simultaneous biceps tenodesis [42].

Superior Labral Repair

There have been a number of proposed techniques for repairing superior labral tears, including knotless suture anchors, transosseous sutures, and bioabsorbable suture tacks. The patient may be positioned in the beach chair or lateral position, depending on surgeon preference. When accessing the glenohumeral joint for superior labral repair, three portals are typically utilized including the standard posterior viewing portal, an anterior portal immediately superior to the subscapularis tendon, and a high rotator interval portal, adjacent to the LHBT at the leading edge of the supraspinatus tendon using a spinal needle for localization [23]. Additionally, transrotator cuff portals have been previously described and are commonly used by various surgeons [43].

There are various options available to the surgeon when repairing superior labral tears, including anchor choice. Bioabsorbable anchors have fallen out of favor due to concerns for potential glenoid osteolysis, anchor pull-out, synovitis, and chondral damage [44, 45]. Knotless suture anchors made with polyetheretherketone (PEEK) have demonstrated high load to failure strength, improved biocompatibility, and fewer anchor-related complications [46–48].

When performing superior labral repairs in overhead throwers, bulky suture knots (Fig. 2) should be avoided as they may impinge during overhead motion, leading to pain and chondral injury. Park and colleagues reported a case series of 11 patients that underwent reoperation for suspected knot-induced pain at an average of 21 months after SLAP repair with knot-tying techniques [49]. They noted that patients complained of sharp pain and clicking, with a positive O'Brien's active compression test at the time of presentation. After removal of the suture knot, all patients noted significant pain relief [49].

Suture configuration is another topic that has been debated in labral repairs. Dines and ElAttrache described a technique using a horizontal mattress configuration with a knotless suture anchor to anatomically repair the superior labrum and recreate the labrum's meniscoid shape [50]. Yang et al. presented the outcomes of SLAP repair comparing knotless horizontal mattress sutures to vertical knot fixation, and they

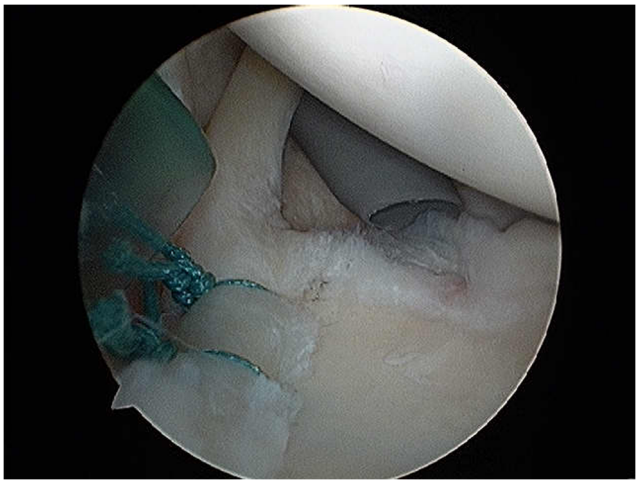

Fig. 2 Arthroscopic images of a superior labrum from anterior to posterior (SLAP) tear repaired with suture anchors and traditional knot-tying techniques

found no significant difference in the functional outcome scores between the two groups [51]. However, the authors noted that the group that underwent knotless horizontal mattress repair had significantly better range of motion compared to those that underwent conventional vertical knot repair. Newer sutures, such as LabralTape (Arthrex, Naples, FL), are flatter and stronger than traditional sutures and have been shown to restore labral height, while providing a broader surface area of compression and limiting tissue "cut through," all with knotless fixation (Fig. 3) [52]. Additionally, anchors placed anterior to the LHBT should be placed with caution as this may have a tendency to overconstrain the shoulder through closure of a sublabral foramen or tightening of the middle glenohumeral ligament, resulting in a loss of external rotation [23, 53].

Outcomes of Superior Labral Repair

The literature on the outcomes of the treatment of superior labrum and biceps complex injuries has demonstrated mixed results, and recent studies demonstrate that achieving a return to high level, preinjury status in elite overhead athletes has proven difficult. In a review of the diagnosis and management of SLAP tears, Knesek and colleagues provide a comprehensive overview of the outcomes in the treatment of overhead athletes with SLAP tears [23]. In the past few years, there have been a number of studies reporting RTP in overhead athletes treated for biceps and superior labrum complex injuries.

A recent retrospective study that included 133 baseball players who underwent SLAP repair found an overall RTP rate of 62%, 59% for pitchers and 76% for position players [54•]. For both pitchers and position players, the Kerlan-Jobe Orthopedic Clinic (KJOC) scores (75.3 vs. 76.2) were below 90 (the minimum score for a healthy baseball player). Therefore, the authors recommended that surgical intervention should only be considered when nonoperative measures have failed, as 38% of baseball players were unable to RTP after surgical SLAP repair [54•].

Interestingly, a recent case series by Fedirow and colleagues looked at the ability of 68 professional baseball players treated for SLAP tears to not only RTP but also return to prior performance (RPP) using baseball statistics such as innings pitched, earned run average (ERA), and walks plus hits per inning pitched (WHIP) [37•]. Of the 68 players with documented SLAP tears, 48 were pitchers and the remaining 20 were position players. The 21 pitchers treated nonsurgically had an RTP rate of 40% and RPP rate of 22%, while the other 27 that underwent a total of 30 procedures had an RTP rate of 48% and RPP rate of only 7%. Overall, pitchers had an RTP rate of 62% and RPP rate of 26%, while position players had a higher RTP rate (87%) and RPP rate (57%), demonstrating how difficult this injury can be to successfully treat in overhead throwing athletes, especially in pitchers [37•].

The presence of concomitant injuries may result is worse outcomes in the operative management of biceps and superior labrum complex tears. Neri et al. demonstrated significantly worse outcomes in patients that underwent type II SLAP repair in the setting of an associated rotator cuff repair in their series of 23 elite overhead athletes [55]. The athletes that had an associated partial thickness rotator cuff tear had an RTP rate of 12.5% (KJOC 66.0, ASES 90.4), while those with isolated SLAP tears had an RTP rate of 80% (KJOC 82.8, ASES 95.5) [55].

Biceps Tenodesis

Addressing the biceps tendon as a part of the biceps and superior labral complex in patients with superior labral tears is important and has been shown to be a viable surgical option for certain patients. Importantly, in a cadaver study by Strauss et al., biceps tenodesis in the setting of a SLAP injury resulted in no significant worsening of glenohumeral stability [56]. The biceps tendon can be tensioned and fixed to the proximal humerus using a variety of arthroscopic or open techniques. Arthroscopic suprapectoral biceps tenodesis can be performed with a suture anchor [57], interference screw [58], or can be a soft tissue repair in the case of a biceps tendon transfer [59, 60].

Alternatively, many surgeons favor an open subpectoral technique for biceps tenodesis using an interference screw [61], suture anchor [62], unicortical button [63], or bicortical button for fixation [64]. A recent study by Green et al. demonstrated good results in a technique that involves docking the tendon into a socket in the humerus without the use of an interference screw [65]. Regardless of the technique chosen, biceps tenodesis has demonstrated positive outcomes in the general population; however, there is relatively limited data

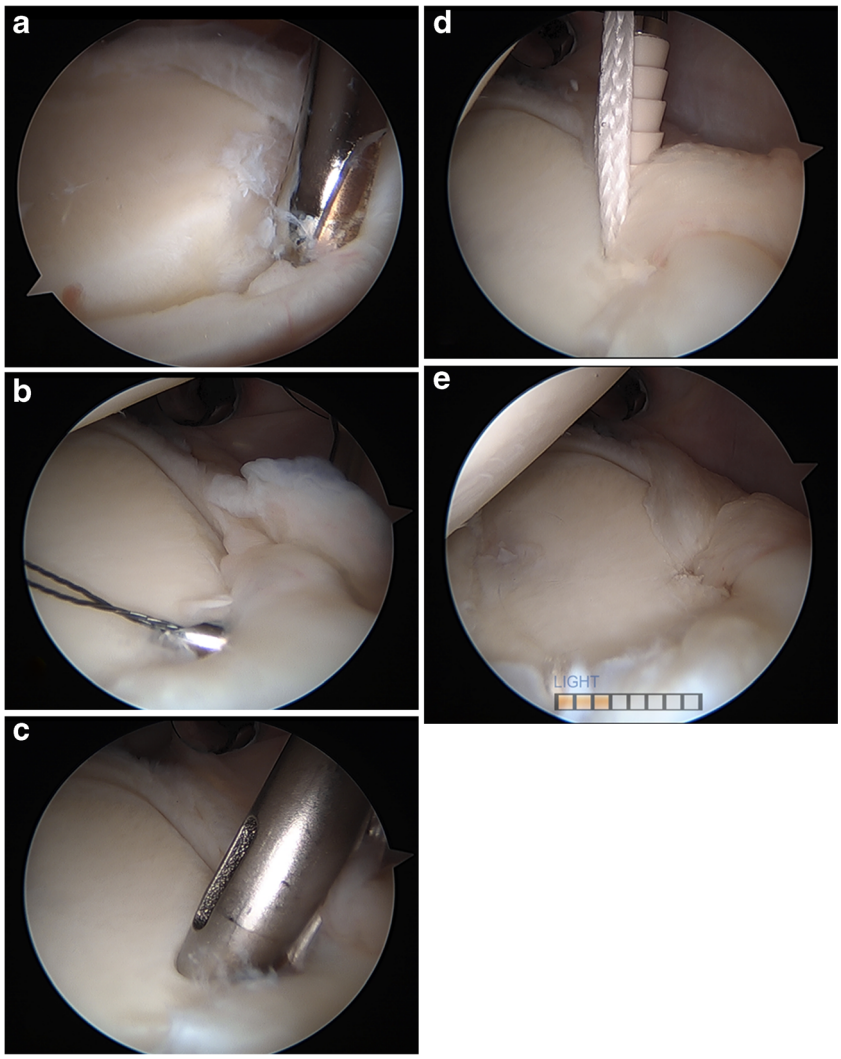

Fig. 3 Arthroscopic images of a superior labral repair with a knotless suture anchor technique. The superior labrum is debrided, and the bed is prepared (**a**); a suture passing device is used to pass the LabralTape (Arthrex, Naples, FL) around the labrum (**b**); the hole is drilled (**c**), and the anchor is inserted (**d**) to secure the knotless LabralTape repair (**e**)

regarding return to play following biceps tenodesis in overhead athletes.

Outcomes of Biceps Tenodesis

With the increased focus on the proximal LHBT, a handful of studies have compared surgical treatments for SLAP tears: superior labral repair, biceps tenodesis, or both. However, it is important to acknowledge that there is limited data on biceps tenodesis in overhead athletes as many of the studies below do not specify if the patients are overhead athletes. Notably, one factor that many studies have in common is that patients who underwent biceps tenodesis were older with degenerative changes to the superior labrum, while younger patients with healthier labral tissue underwent SLAP repairs.

Ek and colleagues retrospectively reviewed all patients that underwent surgical intervention for isolated type II SLAP tears over a 3-year period [66•]. They found that both groups (SLAP repair and biceps tenodesis) did remarkably well, with no significant difference between the two groups in ASES score or patient satisfaction, with a rate of RTP of 73% in the biceps tenodesis group and 60% in the SLAP repair group. An additional study by Gottschalk et al. demonstrated a significant improvement in ASES and VAS in 33 patients (average > 46 years old) with type II and IV SLAP tears treated with subpectoral biceps tenodesis and debridement of the superior labrum [67]. A combination of SLAP repair and biceps tenodesis in patients with biceps and superior labral pathology, as presented by Chalmers et al., demonstrated worse outcomes in ASES scores and VAS scores when compared to those that underwent isolated biceps tenodesis or SLAP repair [19].

Griffin et al. presented their experience with biceps tenodesis in patients under 25 years of age. In 33 athletes (22 overhead athletes), with a mean age of 19.8 years, who underwent biceps tenodesis for biceps tendinopathy or injuries to the biceps labral complex, the authors found a 66% rate of RTP (76% in overhead athletes) with 48% returning to their prior level of play [68]. Notably, 19 were revision surgeries. Chalmers et al. recently presented the incidence and RTP rates of professional baseball players (major and minor leaguers)

that underwent biceps tenodesis [69•]. Their case series included 17 professional baseball players (71% pitchers), 47% who had prior shoulder surgery and 47% who had a concomitant labral repair at the time of tenodesis. Players that underwent isolated biceps tenodesis had a 44% rate of RTP, while those that had concomitant biceps tenodesis and labral repair had a 25% rate of RTP; overall, the RTP rate was 35%. RTP rates were much higher in position players (80%) than pitchers (17%) [69•].

In the setting of failed primary SLAP repair, biceps tenodesis remains a viable option in order to eliminate the pull of the LHBT on the superior labrum. McCormick et al. presented a case series of 42 patients with an average age of 39 years old, who failed primary repair of a type II SLAP tear that underwent subpectoral biceps tenodesis [70•]. After biceps tenodesis, these patients had an RTP rate of 81% and showed significant improvements preoperatively to postoperatively in ASES (68 to 89), Western Ontario Shoulder Instability Index (WOSI, 65 to 81), and Single Assessment Numeric Evaluation (SANE, 64 to 84) scores as well as in range of motion in forward flexion (135° to 155°) and abduction (125° to 155°). Therefore, the authors concluded that biceps tenodesis is a safe and effective procedure for patients who failed primary SLAP repair with persistent pain and dysfunction [70•].

Conclusions

Overall, lesions to the biceps and superior labrum should be evaluated and treated as a continuum of pathology that exists along different points in the biceps and superior labral complex. These injuries often pose a diagnostic challenge as various shoulder pathologies can manifest as shoulder pain, especially in the overhead athlete. A focused history and physical examination incorporating multiple special tests, in combination with appropriate advanced imaging studies, must be utilized to reach an accurate diagnosis. Outcomes of nonoperative management, even in overhead athletes, are relatively positive, and therefore, nonoperative treatment should be exhausted prior to operative intervention in most cases. The surgeon must take into account a number of variables when determining the appropriate surgical procedure, technique, and implants. Despite the operative treatment challenges that SLAP tears present, with new techniques and proper patient selection, overhead athletes with injuries to the biceps and superior labrum complex can return to sport at a high level. Rehabilitation, either as primary nonoperative management or as a postoperative protocol, should focus on restoring glenohumeral and scapulothoracic strength, endurance, and full, pain-free range of motion, while correcting any deficiencies in balance or rhythm throughout the overhead arc of motion.

Compliance with Ethical Standards

Conflict of Interest Joshua S. Dines reports personal fees from Arthrex, personal fees from Trice, grants from Arthrex, and personal fees and others from Conmed Linvatec, outside the submitted work. He is on the editorial board for the American Journal of Orthopedics and the Journal of Shoulder and Elbow Surgery.

All other authors declare that they have no conflict of interest.

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

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