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Chapter Offprint

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DOI: 10.5772/intechopen.108711

Chapter

SLAP Lesions in Overhead Athletes

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Abstract

Superior labral anterior to posterior (SLAP) tears in overhead athletes can be a career-ending injury because of the high failure rates with surgical intervention. There are many factors for this including the failure to establish the correct diagnosis, inadequate nonoperative management, the repair of normal variants of the superior labrum by inexperienced surgeons, and improper poor surgical technique. SLAP lesions rarely occur in isolation and can be associated with other shoulder disorders. The mechanism of injury can be an acute episode of trauma or a history of repetitive overhead use as in baseball pitchers or volleyball players. The physical exam findings can be confusing as these injuries often occur with other shoulder pathology. There is no single physical exam finding that is pathognomonic for SLAP tears. Nonoperative treatment should always be undertaken for a minimum of 3 months before surgery is recommended. If this fails to return the overhead athlete to competitive participation, a diagnostic arthroscopy with SLAP repair can yield excellent results if the proper technique is employed. The technique that we describe can be technically demanding but can be reproduced and give excellent results with a predictable return to play for overhead athletes.

Keywords: SLAP tears, overhead athletes, shoulder, arthroscopy

1. Introduction

Superior labral tears anterior to posterior, the so-called SLAP lesion, coined by Snyder and colleagues, are a common injury in overhead athletes. Snyder described four different types of SLAP lesions and found that they were uncommon [1]. In a retrospective review of more than 700 shoulder arthroscopies at the Southern California Orthopedic Institute (SCOI), Snyder et al. identified 27 patients who had significant pathology of the superior labrum at the time of arthroscopy [1]. Although SLAP tears can be rare, they can be a source of significant disability [1, 2]. Andrews, Carson and McLeod [3] first reported on a group of athletes who had tears of the anterosuperior labrum not extending posterior to the biceps. The authors felt that this injury pattern was due to repetitive traction of the biceps on the labrum as a result of repeated throwing motions.

The Snyder classification system presents an organized approach to defining SLAP pathology, the challenge is to diagnose these lesions properly and to differentiate significant superior labral pathology from the many normal anatomic variations that exist [4].

With the advent of shoulder arthroscopy in the late 1980s and early 1990s, it became possible to diagnose these injury patterns, which were difficult to diagnose with radiographic methods at that time. Shoulder arthroscopy has helped delineate specific injury patterns of the superior labrum [5].

The SLAP lesion injury pattern involves the superior aspect of the glenoid labrum in which the tear begins posteriorly and extends anteriorly, stopping at or above the mid-glenoid notch. The superior labrum is functionally important as it serves as the "anchor" for the insertion of the long head of the biceps tendon [1]. Injuries to the biceps tendon attachment to the superior glenoid labrum can be acute or chronic.

The incidence of SLAP tears varies. Maffet et al. [6] reported 84 of 712 patients or a 12% incidence of SLAP tears, whereas Handelberg et al. [7] reported a 6% incidence (32 of 530 patients). Snyder and colleagues [1] reported a 4% incidence of SLAP tears in their original description in 1990.

The etiology of SLAP lesions remains uncertain, but there are many theories on its pathogenesis including acute trauma or repetitive overhead activities.

SLAP lesions have been identified in association with shoulder instability but can occur in association with diagnoses other than instability [1, 6–9]. The difficulty lies in the preoperative diagnosis and differentiation symptomatic superior labral pathology from normal anatomy [10]. The difficulty is compounded by the degenerative changes that occur in the labrum with advanced age [4, 11].

The diagnosis of isolated SLAP lesions has historically been difficult. This has been attributed to several reasons such as the high incidence of other associated pathology. Studies of SLAP lesions suggest that most patients have pain, mechanical symptoms, notably, loss of range of motion, or inability to perform at their previous activity level [5, 6]. The poor sensitivity and specificity of clinical examination tests and difficulties with the interpretation of advanced imagery [2, 12–14] make the clinical diagnosis difficult.

When occurring in throwing athletes, SLAP lesions present an additional layer of complexity when evaluating the throwing shoulder. Through repetitive stress, elite throwers develop osseous and ligamentous adaptive changes, allowing them to reach extremes of external rotation [15].

Many surgeons including the senior author (WBS) believe that too many overhead athletes are undergoing arthroscopic SLAP repairs and that many athletes can be managed nonoperatively [16]. The operative treatment of SLAP tears remains controversial [17, 18]. SLAP repair in overhead athletes has yielded poor results and does not return the majority of athletes to their previous level of play [17, 19–22].

We must ask ourselves why the poor results and high failure rates in overhead athletes with Type II SLAP repairs Is it the failure to establish the diagnosis these athletes preoperatively and not treat them with an adequate nonoperative regimen before considering surgery? Or at the time of surgery, is it the inability of the operating surgeon to differentiate normal anatomic variants from SLAP lesions? Or is it the surgical technique that violates the rotator cuff or the improper placement of suture anchors that restricts range of motion postoperatively and disrupts overhead throwing mechanics [16]? These are all factors that will be explored in this chapter on the SLAP lesions in overhead athletes. We will discuss the anatomy and biomechanics of the glenoid labrum and its role in stability of the glenohumeral joint. This will be followed by the clinical evaluation, diagnosis, nonoperative and operative treatment of SLAP lesions in overhead athletes with tips on the surgical techniques of repairing SLAP lesions.

2. Anatomy and biomechanics

The shoulder is a mobile ball-and-socket joint with both static and dynamic stabilizers, including the glenoid with its concave surface, labrum, capsule, and its ligamentous thickenings, negative intra-articular pressure, and adhesion-cohesion of synovial fluid [23]. The glenoid labrum is fibrocartilaginous tissue with the superior labrum primarily triangular in cross section, allowing for deeper seating of the humeral head relative to the glenoid socket [24]. There is variability in this anatomy, and Higgins and Warren [25] reviewed approximately 70 peer-reviewed articles on superior labral lesions and concluded that significant anatomic variability of this region exists.

The normal superior labrum plays an essential role in providing concavity compression and thus maintaining biomechanical stability as demonstrated by the anteroinferior labrum [26]. The glenoid labrum represents the fibrocartilaginous rim between the joint capsule and the glenoid. It functions to increase the depth of articulation and, hence, the stability of the glenohumeral joint [27]. By effectively increasing the surface area available for articulation, the labrum decreases the impact stresses in the joint, especially posteriorly and inferiorly [28].

This superior labrum and biceps anchor are mobile structures during shoulder elevation, abduction, and rotation [17]. The medial rolling of the biceps anchor during abduction/external rotation (i.e., a throwing movement) may be lost after a rigid superior labrum repair resulting in shoulder pain. The long head of the biceps tendon has been suggested to have a role as a head depressor [29] or as a static stabilizer of the glenohumeral joint [30, 31]. Sakurai et al. [32] suggested that the long head of the biceps can act as a humeral head stabilizer in superior and anterior directions.

Alpantaki et al. have shown that the tendon of the long head of the biceps is innervated by a dense network of sensory sympathetic fibers, particularly in this proximal portion of the tendon, which may play a role in the pathogenesis of shoulder pain [33]. This nerve density may explain the residual pain after arthroscopic SLAP repair.

Biomechanical studies have shown that the long head of the biceps tendon acts to depress the humeral head, limit shoulder rotation, and confer anterior stability of the glenohumeral joint [34].

Other biomechanical studies have shown that destabilizing the biceps anchor leads to increased translation of the glenohumeral joint [34, 35]. When a tear of the superior labrum occurs, it is likely that symptoms are related to this increase in translation, mechanical catching of the unstable labrum within the shoulder joint, and increased forces placed on the destabilized areas during athletic activities. Previous studies have shown that SLAP lesions increase translation of the glenohumeral joint [36–38] and that those abnormal mechanics can be restored by labral repair [39]. When the labral bicipital complex is disrupted, the shoulder is allowed to go into extreme external rotation, putting increased stress on the inferior glenohumeral ligament and eventually leads to subtle instability and continued pain [40, 41].

The overhead throw motion is an extremely skillful and complex movement that is very stressful on the shoulder joint complex. The overhead throwing athletes place extraordinary demands on this complex. Excessively high stresses are applied to the shoulder joint because of the tremendous forces generated by throwers. The thrower's shoulder must be lax enough to allow excessive external rotation, but stable enough to prevent symptomatic humeral head subluxation, thus maintaining a delicate balance between mobility and functional stability. Wilk and Andrews referred to this as the "thrower's paradox," and this balance is frequently impaired, which leads to injury [42].

There are tremendous forces placed on the shoulder joint during the throwing motion. In vitro research has shown that the superior labrum must be able to withstand 262 N of shear force in the position of abduction and external rotation [43]. The arm internally rotates during the arm-acceleration phase, and the biceps force is produced to both resist shoulder distraction and elbow extension [44]. The biceps-labrum complex must be able to withstand 508 N of tensile force [43]. Fleisig et al. [45] first suggested that the tensile force produced by the biceps tendon at the ball release can lead to a SLAP tear. The forces of elite throwers approach the fatigue strength of the soft tissues of the shoulder [46]. At ball velocities of 90 MPH, the angular velocity of the shoulder approaches 7000 deg./s and the distractive force of the shoulder 950 N [47].

Numerous types of injuries may occur to the surrounding tissues during overhead throwing [42]. These superior labral tears may occur near the time of ball release, as the biceps contract to both resist glenohumeral distraction and deceleration of elbow extension [3]. Alternatively, the bicipital-labral complex may tear because of a "peel-back" mechanism as the abducted and shoulder externally rotates during the arm-cocking phase of throwing [48]. Shepard et al. [43] measured in vitro strength of the biceps-labral complex during both the distal force and peel-back mechanisms and concluded that SLAP lesions most likely occur from the repetition of both peel-back and distal forces. Other authors have demonstrated an association between posterior-superior labral lesions and contact of the rotator cuff with the arm in a cocked position [49, 50].

Assuming that in a thrower, there is an inherent adaptive increase in external rotation, it may be undesirable to restrict external rotation with surgical repair. If pitchers are unable to reach this external rotation set point or "slot," they are unable to throw with maximal velocity [15].

SLAP repair may also affect elbow function and may compromise the ability to generate elbow flexion torque in throwers to help to decelerate the elbow extensively during pitching [51]. In a study of baseball pitchers after SLAP repair versus a control group that did not have surgery, the SLAP repair group exhibited significantly less abduction and shoulder external rotation than those in the control group [51].

There is controversy as to the proper surgical technique and anchor placement for repair of type II SLAP lesions. Several biomechanical studies of Type II SLAP lesions have investigated various techniques of suture anchor placement to determine the correct repair construct. There remains no consensus on the most ideal technique for type II SLAP repairs [52]. However, looking at the biomechanical studies that have been performed and then the clinical studies, it is apparent that some anchor and suture configurations are less efficacious than others.

Bacdini et al. [53] compared single-loaded suture anchor versus double-loaded suture anchor repair and found no difference in pull-out strength. Yoo et al. determined that a mattress suture technique was inferior to a simple suture technique regarding clinical failure [54]. In contrast, the mattress suture was noted to be biomechanically superior to simple suture configurations for biceps anchor repair by Domb et al. [40]. Several studies have shown the one well-placed anchor is biomechanically sufficient [40, 53] and multiple anchors usually are not necessary. Domb et al. [40] concluded that a single anchor with a mattress suture may be the most biomechanically advantageous construct for the repair of type II SLAP lesions. The most secure knot configurations are also achieved by reversing the half-stich throws and alternating the posts [55].

Previous cadaver studies have shown an increase in external rotation with the creation of a type II SLAP tear that was correctable with a repair including anchors both anterior and posterior to the biceps anchor [39].

Cadaveric and biomechanical studies by McCulloch, Andrews, and colleagues determined that an anchor anterior to the biceps tendon had the greatest effect in decreasing external rotation [15]. The avoidance of the use of an anchor anterior to the biceps should be considered especially in baseball players and other overhead athletes where even such a small loss of external rotation would be detrimental [15]. Decrease external rotation in pitching after SLAP repair [56] is consistent with previous cadaver research that demonstrated that anchors placed anterior to the long head of the biceps tendon during SLAP repair can limit shoulder external rotation [15].

Burkart, Morgan, and colleagues suggested that in type II SLAP repairs, a suture anchor just posterior to the biceps insertion is the most important in resisting peel back forces during late cocking [57]. This is supported by a biomechanical study that shows a single anchor placed just posterior to the biceps eliminated the peel-back of the labrum [58].

The advantage of knotless versus simple repairs is still unclear. Uggen et al. [59] compared the knotless versus simple suture and found no biomechanical differences.

There is controversy and no consensus on the role of the biceps tendon in shoulder stability. One electromyographic study showed no relationship between biceps activity and active shoulder motion, suggesting that biceps muscle activity does not contribute to shoulder stability [60]. However, the absence of the long head of the biceps has been shown to result in increased shoulder instability, especially in the anterosuperior and anterior planes [30, 34]. This has been supported by Patzer et al. [30], who showed in a biomechanical study that the stabilizing effect of the superior labral complex is dependent on the attached long head of the biceps tendon. As such, there has been an emphasis on repairing lesions involving detachment of the superior labrum, especially in younger patients and high-level throwing athletes [61].

Biceps tenodesis has been proposed as an alternative or adjunct to SLAP repair [17, 62, 63]. The kinematic consequences of biceps tenodesis within the pitching motion remain largely unknown [63]. A SLAP repair preserves the glenohumeral function of the long head of the biceps tendon (LHBT), whereas biceps tenodesis removes the intra-articular portion of the LHBT and with it any function that this tendon may cause in glenohumeral kinematics [64].

3. Classification system

With the advancement of arthroscopy equipment and improved techniques, SLAP lesions have been better delineated from normal anatomy [4]. In 1990, Snyder and colleagues published their observations of superior labral tears and proposed the name SLAP lesions to indicate a more complex range of pathology related to the superior labrum extending from anterior to posterior in relation to the biceps tendon anchor [1]. The classification system proposed by Snyder et al. consisted of four subgroups of lesions categorized by the condition of the labrum and the attachment of the biceps anchor to the superior labrum and superior glenoid tubercle [65].

Type I SLAP lesions consist of fraying and fragmentation of the free edge of the superior labrum. This is often a relatively minor problem that is commonly encountered during routine arthroscopy in middle-aged and older patients [65]. Snyder considered this to be akin to a degenerative meniscus in the knee and a possible but uncommon source of clinical symptoms. In their original description, Snyder classified 21% of SLAP lesions as type I [1].

Type II lesions are by far the most common, occurring in 55% of the study patients of Snyder in their original description of SLAP lesions in 1990 [1]. In the type II SLAP lesion, the biceps anchor is significantly detached from the superior glenoid tubercle. There is usually associated fraying of the edge of the labrum, and it must be differentiated from a type I. The middle glenohumeral ligament may be considered unstable when it has a high attachment in the superior labrum and must be evaluated for security [27].

Type III SLAP lesions consist of a bucket-handle tear of a meniscoid superior labral with an otherwise normal biceps tendon attachment. This occurred in only 9% of Synder's cases in 1990 [53]. The fragment of labrum is usually mobile like a bucket handle tear of the meniscus in the knee, but it may be split in two, leaving a stub of labral tissues on either end [27]. Rarely, the middle glenohumeral ligament may be confluent with this free fragment of labrum and consequently rendered unstable [65].

Type IV SLAP lesions constituted 10% of lesions first described by Snyder in 1990 [1]. This lesion is similar to type III and includes a bucket handle tear of a meniscoid superior labrum but with the tear extending in the biceps tendon. The tendon split may be minimal or quite significant. Like the Type III lesion, the attached site of the MGHL to the labrum in the area of the tear determines the significance of the lesion regarding stability of the shoulder [65].

Snyder also described cases of combined or complex SLAP lesions. Most often, these are type III or IV lesions combined with a significantly detached biceps anchor or type II lesion. This is classified as a complex type II and III or type II and type IV lesions [65].

Moffet et al. [6] and Morgan [66] et al. and others [67] have expanded Snyder's classification scheme to include various other entities involving variations of instability patterns with congenital variations and capsular damage. Regardless of the system used, the important task of the surgeon is to carefully evaluate the superior labrum and biceps anatomy, recognize significant pathology, and be prepared to repair the SLAP lesion and associated injuries [65].

Morgan et al. [66] further subclassified type II lesions into 3 distinct subtypes—anterior, posterior, and combined anterior-posterior lesions. The clinical implications of this distinction were that superior labral tears that extend posteriorly can lead to posterior superior glenohumeral instability that overtime leads to cuff tearing [66].

The challenge with any classification system is reproducibility. Even among experienced shoulder arthroscopists, there is a lack of consensus on making a SLAP diagnosis [4]. Gobezie et al. [68] studied the inter and intra-observer reliability in the diagnosis and treatment of SLAP tears with 73 "expert surgeons." Video clips containing 22 vignettes of approximately 15 seconds duration were sent 73 shoulder surgeons and each was asked to classify the superior labral anterior posterior type using Snyder's classification system (types I–IV). The same video clips were sent again 12 months later to obtain data on intraobserver reliability. Several significant trends were noticed regarding the diagnosis and treatment responses. These included the difficulty distinguishing type III lesions from type IV lesions and the difficulty distinguishing normal shoulders from type II SLAP tears. Regarding type II SLAP tears, only 52% of surgeons made the correct diagnosis of distinguishing normal shoulders from type I and from type II SLAP lesions and making the appropriate treatment recommendations. This is a significant study and further, prospective studies need to be performed in this area and possibly better surgical education.

4. Clinical evaluation

4.1 History

The proper diagnosis of SLAP lesions can be very difficult as the clinical picture may mimic other shoulder pathology. SLAP lesions rarely occur in isolation and are often associated with other shoulder conditions such as impingement, rotator cuff tendinitis, instability, and rotator cuff tears. When occurring in throwing athletes, SLAP lesions present an additional layer of complexity when evaluating the throwing shoulder. Studies of SLAP lesions suggest that most patients have pain, mechanical symptoms, notably, loss of range of motion, or inability to perform at their previous activity level [5, 6]. The diagnosis of isolated SLAP lesions has historically been difficult, and this has been attributed to several reasons including the high incidence of other associated pathology especially in an athlete's shoulder.

It is important first to determine whether there was an acute episode of trauma or a history of repetitive use as in overhead athletes. Many others have described a fall on an outstretched arm [1, 6] as a common mechanism of injury that can cause SLAP tears. This fall can cause impaction of the shoulder with a superiorly directed force driving the humeral head against the superior labrum and the biceps anchor [65]. If the force is severe enough, a "SLAP fracture" can occur, which appears as a divot in the superior dome of the humerus more anterior that the usual posterior lateral Hill-Sachs-type instability lesion [65].

Maffet et al. [6] suggested that the most common etiology was traction on the biceps tendon. The shearing forces on the superior biceps labral complex with the long head of the biceps acting as a decelerator of the arm during the follow through phase of throwing have also been proposed as mechanism for type II SLAP tears [57, 69]. Burkhart et al. described the contracture of the posterior-inferior glenohumeral ligament in throwers causing a shift of the glenohumeral contact point posterior and superiorly, increasing the shear forces on the posterior-superior labrum, generating the "peel-back" effect and a SLAP lesion [57].

The most common complaint of symptom of patients with a SLAP lesion is some type of mechanical catching or locking of the shoulder. This occurs when the unstable labrum is trapped between the humeral head and glenoid. In case of chronic SLAP lesions, there is history of an insidious onset of shoulder pain, especially in overhead athletes. The pain may increase in severity and limit sports performance with mechanical symptoms with forceful overhead movements as in throwing or overhead sports such as volleyball and the spiking maneuver.

The biggest difficulty is differentiating a symptomatic SLAP lesion from degenerative changes of the labrum or even normal variants. Most SLAP lesions occur in the dominant arm of male, high level, overhead athletes who are younger than 40 years old [70]. Patients older than 40 years of age often have degenerative changes of the labrum, which may or not be clinically significant or pathologic [4]. Pfahler and associates [11] described the normal aging pattern of the superior labrum with normal microscopic and macroscopic changes. Significant glenohumeral arthritis or full-thickness rotator cuff tears typically do not accompany a symptomatic type II SLAP tear but rather are just a part of the entire degenerative process of the shoulder joint.

SLAP tears can also occur in the presence of a shoulder dislocation and are found as the anterior labral tear progresses superiorly to the biceps anchor and posteriorly to create a SLAP with an associated Bankart lesion.

4.2 Physical examination

The symptoms of a SLAP lesion can mimic those of impingement syndrome, pathology of the rotator cuff or the AC joint, or other shoulder disorders. It is important to remember that no single physical examination finding is pathognomonic for SLAP tears [71]. SLAP tears rarely occur in isolation and are often associated with other shoulder pathology [1, 3, 5, 6, 72–74]. Even when seen in isolation, SLAP tears may mimic impingement (52%) or even anterior instability (39%) [71, 75]. Very few studies have examined the clinical signs and symptoms of isolated SLAP lesions. In 1997, we retrospectively examined 2375 patients who underwent shoulder arthroscopy and SLAP lesions were identified in 140 shoulders. Of these 140 SLAP lesions, only 26 had no other pathology. In 23 patients who had adequate postoperative follow-up, all patients had nonspecific shoulder pain, which increased with overhead activity and mimicked rotator cuff pathology. Nine patients (39%) had a positive apprehension test with only one (4%) positive relocation test. Of the 23 patients, over one half (52%) had a positive Neer test and 35% had a positive Hawkins test. A positive Speed's test (biceps tension test) was seen in 35% and 43% who had mechanical popping and snapping in their shoulder. It is apparent that even with isolated SLAP lesions, the clinical picture can be confused with rotator cuff symptomatology.

Many studies have evaluated the sensitivity, specificity, and positive and negative predictive values as well as inter-observer and intra-observer reliability of various clinical exams with limited success [68]. In a previous study of isolated SLAP lesions of the shoulder, we found no sensitive clinical test for their detection [71]. Snyder and colleagues also determined that no single or combination of tests could conclusively and reliably predict when and what type of lesion would be found at arthroscopy [5]. They determined that the most accurate test was Speed's biceps tension test [65]. Although this test is much more suggestive for damage to the biceps tendon proper than the labrum or anchor, it may be helpful when the anchor is unstable [65].

In 1996, Liu et al. [76] described the crank test and found it to be 91% sensitive in detecting glenoid labral tears, including SLAP lesions. In 1998, O'Brien et al. [77] described the active compression test, the so-called "O'Brien test" to clinically diagnose labral tears and pathologic conditions of the acromioclavicular joint. Of 56 patients who had a positive O'Brien test result and underwent subsequent operation, 53 (95%) were found to have a labral tear.

We conducted a prospective study in 2002 to determine whether the crank or O'Brien tests were reliable tools for detecting superior glenoid labral tears. Results of diagnostic arthroscopy were compared with those of the preoperative tests and determined that the crank test had only had 46% sensitivity and was only 56% specific and the O'Brien test had only a sensitivity of 54% and 31% specificity. We determined that the O'Brien and crank tests were not sensitive clinical indicators for detecting glenoid labral tears [2]. The poor sensitivity and specificity of these clinical examination tests and others combined with difficulties with the interpretation of advanced imagery [12–14] make the clinical diagnosis of SLAP tears extremely challenging.

Cook et al. [12] conducted a prospective study to determine the accuracy of five orthopedic clinical tests for the diagnosis of SLAP lesions. The purpose of the study was to identify the diagnostic utility of the Active Compression (O'Brien's test), the biceps load II test (Kim's test), the dynamic labral shear test (O'Driscoll's test), Speed's test, and the labral tension test when diagnosing isolated SLAP lesions. Physical exam findings were compared to the findings at the time of diagnostic arthroscopy. No tests demonstrated diagnostic utility when diagnosing any SLAP lesion, including those with concomitant diagnoses. The findings suggested that each of the five stand-alone tests and clusters of tests provide minimal to no value in the diagnosis of a SLAP lesion.

Several investigators have questioned the role of SLAP lesions in shoulder stability [78]. Some have reported that SLAP lesions occur without associated glenohumeral instability [9, 60, 72, 74] while others feel that SLAP lesions are directly related to instability. The relationship between a physical finding of laxity or instability and a superior labral lesion has not been fully elucidated [78].

At the present time, there is no sensitive clinical examination test for SLAP lesions as many other pathologic conditions are associated with SLAP lesions. A high index of suspicion is necessary to accurately diagnose and treat these injuries.

4.3 Imaging

The first step in evaluating any shoulder pain is proper X-rays of the shoulder joint. This includes an anteroposterior view of the glenohumeral joint (not the shoulder as this will not give a proper view of the joint), an axillary view, and a supraspinatus outlet view. This will help rule out bony abnormalities including glenohumeral osteoarthritis, an os acromiale, or even a rare locked posterior dislocation if there is a history of significant trauma or a seizure disorder. The supraspinatus outlet view will help determine the acromial morphology (types I–III) and the thickness of the acromion, which can be important if an arthroscopic subacromial decompression is ever performed.

An MRI or an MR arthrogram is the next imaging study in evaluating shoulder pain in overhead athletes. Although a routine MRI will show significant rotator cuff pathology and glenohumeral osteoarthritis, it is not highly sensitive for detecting subtle abnormalities of the labrum such as SLAP tears or partial rotator cuff tears. An MRA is recommended as it has shown to increase the sensitivity and specificity for detecting labral tears and also partial articular sided rotator cuff tears, which is important in evaluating the overhead athlete with shoulder pain [79]. An MRI or an MRA that shows a SLAP lesion is not an automatic indication for surgery [16]. In our prospective study of U.S. Olympic Volleyball athletes, 46% of asymptomatic elite volleyball players had MRI evidence of SLAP tears but no history of complaints of shoulder problems [80]. SLAP tears are also identified on MRI in up to 48% of pitchers who are asymptomatic [23, 81]. These studies show that pathologic MRI findings in elite overhead athletes can be present. However, they are often asymptomatic. In competitive overhead athletes such as volleyball players or baseball pitchers, an MRI or MRA evidence of a SLAP lesion may not be the cause of their shoulder pain and can initially treated with nonoperative management.

5. Nonoperative treatment

Frequently, injuries of the superior labrum can be successfully treated with a well-structured and carefully implemented nonoperative rehabilitation program. The key to successful nonoperative treatment is a thorough history, clinical examination, and accurate diagnosis [42]. Typical nonoperative treatments have centered on posterior capsular stretching while maintaining glenohumeral and periscapular strength and stability [19].

The repetitive micro-traumatic stresses placed on the athlete's shoulder joint complex during the throwing motion challenges the physiologic limits of the surrounding tissues. Athletes often exhibit numerous adaptive changes that develop from the repetitive micro-traumatic stresses during overhead throwing. Alterations in throwing mechanics, muscle fatigue, muscle weakness or imbalance, and excessive capsular laxity may lead to tissue breakdown and injury [42].

Little information is available on these patients who had a successful result after nonoperative treatment [19] for SLAP lesions. Edwards et al. [19], using validated, patient-derived outcomes, showed that successful nonoperative treatment of superior labral tears results in improved pain and functional outcomes.

An overhead athlete with significant shoulder pain in their dominant arm should first be rested for 4–6 weeks and be prescribed a short course of a non-steroidal anti-inflammatory medication. During this time, a stretching program emphasizing the posterior capsule stretching should be implemented with no resistance. At 6 weeks, a structured physical therapy program is instituted working on scapulothoracic mechanics with rotator cuff strengthening. At 3 months, a gradual return to throwing or overhead activities begins, which is closely monitored by the physical therapist or athletic trainer. If the athlete is not able to return to their previous level, surgical intervention is then recommended in the hopes of returning them to their preinjury level.

6. Operative treatment

SLAP repair technique results have varied widely in the many studies reported in the literature. This is most likely explained by the variety of techniques, which have been used to address and repair the biceps labral complex/SLAP lesion to the glenoid. This includes arthroscopic debridement, the use of arthroscopic suture anchors, staples, metal screws, absorbable sutures, and biodegradable implants [5, 10, 73, 74, 82], and also biceps tenodesis and tenotomy. The high frequency at which labral injuries involve associated pathology [83] of the shoulder makes it difficult to compare the results of studies.

6.1 Debridement

Arthroscopic debridement of SLAP lesions and in particular type II SLAP lesions was originally described by Andrews and colleagues in 1985 [3]. Altchek and colleagues also reported on the arthroscopic debridement of SLAP lesions in 1992. Interestingly, at 1 year, 72% of patients noted improvement, but by 3 years, that number had dropped significantly to only 7%. They concluded and we agree that arthroscopic labral debridement is not an effective long-term solution for symptomatic relief in the overhead athlete [84].

6.2 Arthroscopic repair

Suture anchors with both simple and mattress repair techniques have been utilized with success for Type II SLAP repair [85]. Morgan et al. [66] reported that stabilization of the detached biceps anchor in shoulders with a Type-II SLAP lesion provided satisfactory clinical results and eliminated the drive through sign [86]. A mattress repair for type II SLAP repairs creates a labral bumper compared with simple repairs while both techniques result in similar biomechanical characteristics [52].

In the surgical treatment of the elite throwing athlete's shoulder with a symptomatic Type II SLAP tears, surgeons are concerned about overtightening the shoulder resulting in a loss of the necessary external rotation [15]. For this reason, it is common practice among some surgeons who treat throwers to use suture anchors placed posterior to the insertion of the long head of the biceps and to avoid anchors placed anterior to the biceps. This practice is an attempt to restore stability without compromising external rotation [15].

6.3 Tenodesis

Biceps tenodesis has been proposed as an alternative procedure to SLAP repair for overhead athletes. However, some of the results have been disappointing, with an overall return to play rate of 35% in professional baseball players and only 17% in professional baseball pitchers [62]. Boileau et al. [17] conducted a prospective study to evaluate and compare the results of biceps tenodesis and repair of isolated type II SLAP lesions. In the biceps tenodesis group, 93% (14/15) were satisfied or very satisfied and 87% (13/15) were able to return to their previous level of sports participation. Only 20% (2/10) were able to return to sports participation after SLAP repair. They concluded that arthroscopic biceps tenodesis can be considered an effective alternative to repair of a type II SLAP lesion allowing patients to return to a pre-injury level of activity of sports participation. Reviewing this paper, it is unclear what type of sports they participated in and whether or not they were overhead athletes. Also, the technique of SLAP repair, which placed an anchor anterior to the biceps tendon, which can limit external rotation, may be one of the reasons for the poor results in the SLAP repair group.

Gottschalk et al. [87] also proposed biceps tenodesis as an alternative to repair for type II and type IV SLAP tears, especially in older athletes. There remains some doubt regarding the efficacy of repairing SLAP lesions versus a biceps tenodesis in middle-aged patients [87]. In a group of 26 patients and 29 shoulders available for follow-up with an average age of 46.7 years, 89.6% were able to return to their previous level of activity. However, the vast majority of the patients in their study group were not overhead athletes.

Ek et al. [88] retrospectively reviewed 25 patients comparing type II SLAP repair versus biceps tenodesis. The 15 patients who underwent biceps tenodesis had an average age of 47 years while the 10 patients who underwent type II SLAP repair were 31 years. Both groups showed significant improvement and there was no difference in patient satisfaction, ASES scores, or return to preinjury level of sports. Tenodesis was performed in older patients who showed degenerative or frayed labrums, whereas SLAP repairs were performed in the younger group and more active patients with healthier labrums.

6.4 Tenotomy

In general, tenotomy is reserve for older, lower demand patients. With a significantly torn and degenerative SLAP lesion in an older patient, this is a very easy and quick procedure. The risk of a "Popeye" deformity in a younger, more active patient and the resultant cramping and cosmetic deformity, which can result, makes tenotomy a poor choice in overhead athletes.

6.5 Author's preferred technique

Before surgery, it is important that a long course of conservative management with a structured physical therapy and return to overhead sports program has been tried before surgery is performed in the overhead athlete. When this fails and using the proper surgical techniques, most patients can be treated successfully and return to their previous level of play. It is important that a surgeon develop a preoperative "check list" [89] to make sure that all imaging studies are up to date and available and that all the proper equipment is also available in the operating room suite. Besides having the proper anchors for a SLAP repair, the surgeon must be ready and able to address other shoulder pathology including rotator cuff tears, which can also be present at the time of surgery. **Table 1** lists all the equipment that are needed to perform the procedure. In 2019, we described the details of our preferred surgical technique along with a surgical technique video [16], which can be helpful to learn all the many steps that we will describe.

Building the proper surgical team is critical to success. This includes a skilled anesthesiologist who is comfortable with hypotensive anesthesia to control bleeding and allow for adequate visualization at the time of arthroscopy. Visualization is key to any arthroscopic surgery and excessive bleeding can prolong the procedure. A dependable circulating nurse and a skilled assistant are also critical for the procedure. It is not necessary to have another surgeon to assist but rather a good surgical technician can be trained to be an excellent assistant to hold the arthroscope in position and handle other surgical instruments.

The lateral decubitus position is preferred as it allows easier access to the anterior and anterior inferior aspect of the shoulder with less risk of cerebral hypoperfusion. We prefer general endotracheal anesthesia to maintain a secure airway, and this also allows the anesthesiologist better control of the blood pressure. All equipment should be in front of the surgeon so that he can easily check the status of all equipment including shavers, pump, and arthroscopic fluid bags to make sure everything is working properly. We also prefer a suprascapular nerve block, which is easy to administer after the patient is asleep and before beginning the procedure. We feel it is a safer block with less risk than an interscalene block.

Portal placement is key for any arthroscopic shoulder procedure. We first establish a posterior portal two finger breadths down and two finger breadths medial from the posterolateral aspect of the acromion in the interval between the infraspinatus and teres minor muscles. A 30-degree arthroscope is inserted using a 5.5 mm x 8.5 cm "J-lock" metal cannula system (Smith and Nephew/Dyonics). The shorter type of cannula is better for shoulder procedures and easier to maneuver within the shoulder

• Lateral decubitus positioning device (Hip-Grip System or Bean Bag Device)
• Shoulder suspension device with STARR Sleeve (Arthrex)
• 4.5 mm 30-degree arthroscope
• 5.5 mm x 8.5 cm metal "J-lock" arthroscopic cannula system (Smith and Nephew/Dyonics).
• 5.75 mm x 7.0 mm arthroscopic disposable cannulas (2) (Arthrex)
• Clear crystal cannula (Arthrex)
• Clear crystal cannula with a ring at end (Arthrex)
• 2.8 mm non-absorbable suture anchor (Twin-Fix/Smith and Nephew/Dyonics; Mini-Revo/Conmed/Linvatec; Fast-Fix/Arthrex) with single-loaded high-strength suture
• Crescent-shaped suture device (Conmed/Linvatec)
• #1 PDS suture-shuttle relay (Ethicon)
• 4.0 mm full radius shaver (Smith and Nephew/Dyonics)
• 4.5 mm round burr (Smith and Nephew/Dyonics)
• Shaver system (Smith and Nephew/Dyonics)
• Arthroscopic pump (Smith and Nephew/Dyonics) with lactated ringer's solution with no epinephrine

Table 1.
Proper equipment.

joint compared to the longer cannula used for knee arthroscopy. It is important to have a 5.5 mm cannula for adequate inflow through the arthroscope, which allows for adequate joint distension compared to a smaller diameter cannula (3.5–4.5 mm).

After entering the glenohumeral joint, the glenoid should be parallel to the floor and the biceps tendon is identified. Next, an anterosuperior portal needs to be created in the rotator interval between the subscapularis and supraspinatus tendons. This portal needs to be high enough in the rotator interval to allow anchor placement in the superior glenoid. If the portal is too low, the angle for anchor placement is compromised. This can be done using an outside-in technique or inside out, depending on surgeon preference. The vast majority of the time I create this portal using an inside-out technique by driving the arthroscope up into the rotator interval, removing the arthroscope but keeping the cannula in place, and then placing a smooth switching stick or rod through the posterior cannula up into the rotator interval where it then tents the skin. A small incision is then made anteriorly over the rod, and it exits out the skin. The assistant then holds the shoulder while a metal 5.5 cannula is inserted over the rod and into the glenohumeral joint.

Using an outside in technique, a spinal needle is placed percutaneously and anteriorly in the rotator interval at approximately 45 degrees to the superior tubercle under the labrum. A small skin incision is made, and the 5.5 metal cannula with a smooth obturator is used to follow the direction of the needle into the glenohumeral joint. This anterior superior portal is then hooked up to outflow (not suction!) to tubing leading to a bucket on the floor. The outflow is controlled by a clamp that the assistant periodically opens to "clear the picture" of blood or debris. The position of this portal is critical for the success of the operation and must not damage the supraspinatus tendon, which can cause postoperative pain and weakness leading to a substandard result.

After the two portals have been established, we then perform a complete 15-point diagnostic shoulder arthroscopy of the glenohumeral joint [65]. The superior labrum is part of this diagnostic examination, and careful attention needs to be made to differentiate a meniscoid-type of labrum from a type II SLAP tear (**Figure 1**). Even among experienced shoulder surgeons, this has proven to be difficult with poor inter and intra-observer reliability with only 48% of them correctly identifying type II SLAP tears [68]. Repairing a meniscoid-type of labrum or a normal labral variant can lead to a loss of external rotation, which can limit the ability of an overhead athlete to return to peak form.

Once the type II SLAP tear is properly identified, preparation for repair begins by replacing the metal 5.5 cannula in the rotator interval with a working portal, a clear, smooth 5.75 mm x 7 cm cannula (Smooth Crystal Cannula/Arthrex). This is done using a switching stick technique to maintain portal placement and avoid damage to the surrounding musculature. This working cannula has a diaphragm, which does not allow water out and therefore keeps joint distension. A 4.0 mm full radius shaver (Smith and Nephew/Dyonics) is then inserted through the anterior-superior portal for debridement of the superior glenoid of all soft tissues extending from the biceps anchor posterior to the extent of the tear.

Decortication of the superior glenoid is then performed using 4.5 mm round burr (Smith and Nephew/Dyonics) via the anterior superior portal with care not to damage the articular surfaces of the glenoid or humeral head. The burr is carefully placed between the labrum and the superior glenoid and decortication of the superior glenoid is performed (**Figure 2**) to punctate bleeding bone (**Figure 3**) and verified with the fluid being turned off. This creates a bleeding surface of growth factors from the marrow, which can enhance healing. The surgeon should stay posterior to the biceps anchor as there is no need to decorticate anteriorly.

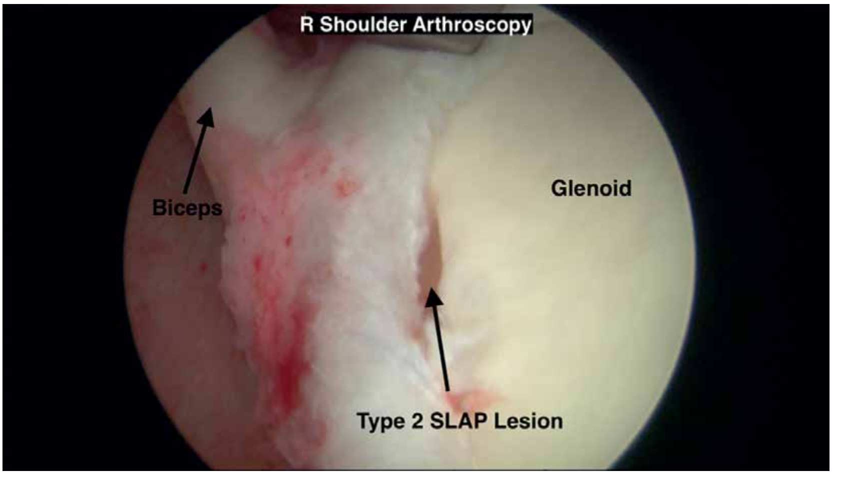

Figure 1.
A right shoulder viewing from the posterior portal in the lateral decubitus position, a type II SLAP lesion is seen here with the superior labrum along with the biceps anchor pulled away from the superior glenoid.

Once adequate decortication of the superior glenoid is performed with the burr and a bleeding bone bed has been created, a second anterior portal needs to be created for suture passage. This is created at the leading edge of the subscapularis tendon and is referred to as the mid-glenoid portal. Using an outside-in technique with a spinal needle, it is inserted at the leading edge of the subscapularis tendon high enough to allow easier passage of suture and instruments. A 5.75 mm x 7.0 mm clear cannula (Clear Crystal Cannula/Arthrex) with a ring at the end is inserted for twin anterior cannulas (**Figure 4**). This ring at the end of the cannula prevents it from "squirting" out inadvertently during the procedure.

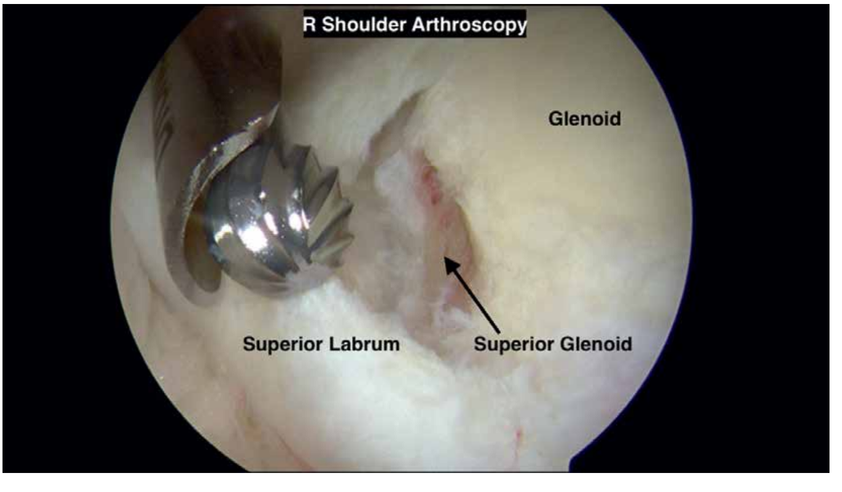

Figure 2.
A right shoulder viewing from the posterior portal in the lateral decubitus position, decortication of the superior glenoid is performed using a 4.5 mm round burr (Smith and Nephew/Dyonics) via the anterior superior portal. Care is taken not to damage the articular surfaces of the glenoid or humeral head and the burr is carefully placed between the labrum and the superior glenoid and decortication of the superior glenoid is performed.

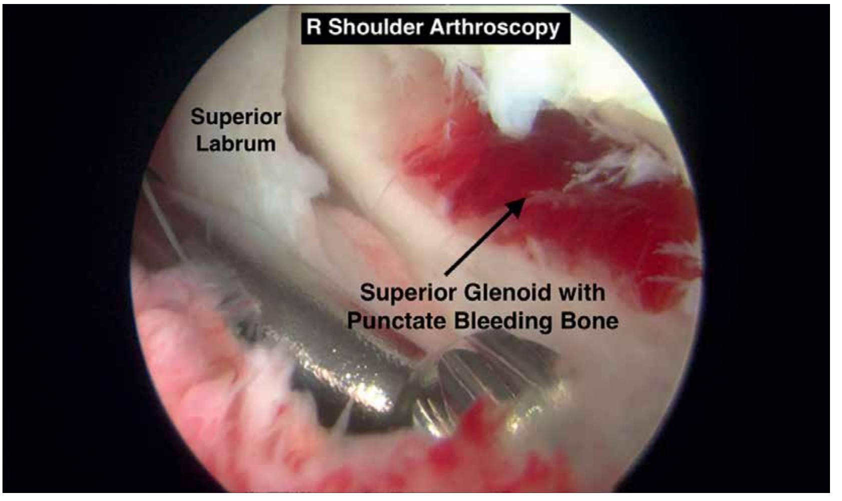

Figure 3.
A right shoulder viewing from the posterior portal in the lateral decubitus position, decortication of the superior glenoid is done until punctate bleeding bone can be seen. This is verified with the fluid being turned off and creates a bleeding surface of growth factors from the marrow, which can enhance healing. The surgeon should stay posterior to the biceps anchor as there is no need to decorticate anteriorly.

Proper anchor placement is one of the keys to success for this procedure. The anchor should be placed posterior to the biceps anchor at approximately the 12 o'clock position. There are multiple steps to anchor placement, and we recommend using them in the order described. The anterior superior portal cannula is placed just below or inferior to the biceps tendon (not above it), and 2.0 mm mini-Revo punch (Conmed/Linvatec) is inserted at a 45-degree angle into the bony bed of the area of decortication. This creates a pilot hole for the anchor. The arthroscope needs to be rotated downward to

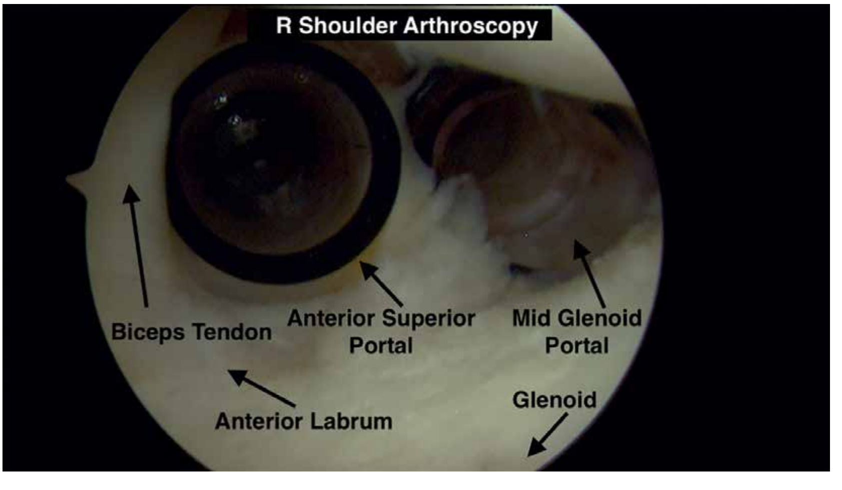

Figure 4.
A right shoulder viewing from the posterior portal in the lateral decubitus position, a second anterior portal is created for suture passage at the leading edge of the subscapularis tendon and is referred to as the mid-glenoid portal. A 5.75 mm × 7.0 mm clear cannula (Clear Crystal Cannula/Arthrex) with a ring at the end is inserted to create twin anterior cannulas. This ring at the end of the cannula prevents it from "squirting" out inadvertently during the procedure.

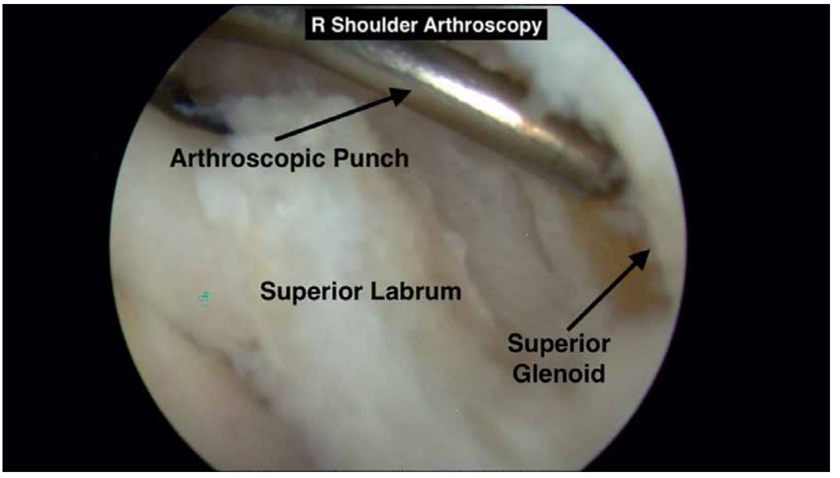

Figure 5.
A right shoulder viewing from the posterior portal in the lateral decubitus position, the arthroscope is rotated downward to the 5 o'clock position in order to adequately visualize the instruments properly. For anchor placement, a pilot hole is created at approximately the 12 o'clock position just posterior to the biceps anchor. The anterior superior portal cannula is placed just below or inferior to the biceps tendon (not above it), and a 2.0 mm mini-Revo punch (Conmed/Linvatec) is inserted at a 45-degree angle into the bony bed of the area of decortication. This creates a pilot hole for the anchor. It is important to adequately visualize the tap going into the bone and not do it blindly and skive posteriorly.

the 5 o'clock position for a right shoulder in order to adequately visualize the tap going into the bone and not skiving posteriorly (**Figure 5**) and needs to be done under direct visualization and not done blindly. Once the pilot hole has been created, the punch is removed and a 2.5 mm mini-Revo tap (Conmed/Linvatec) is inserted into the pilot hole (**Figure 6**) to create threads for the screw. We have found that in younger patients, the glenoid bone can be quite hard and self-tapping screws do not always seat properly into

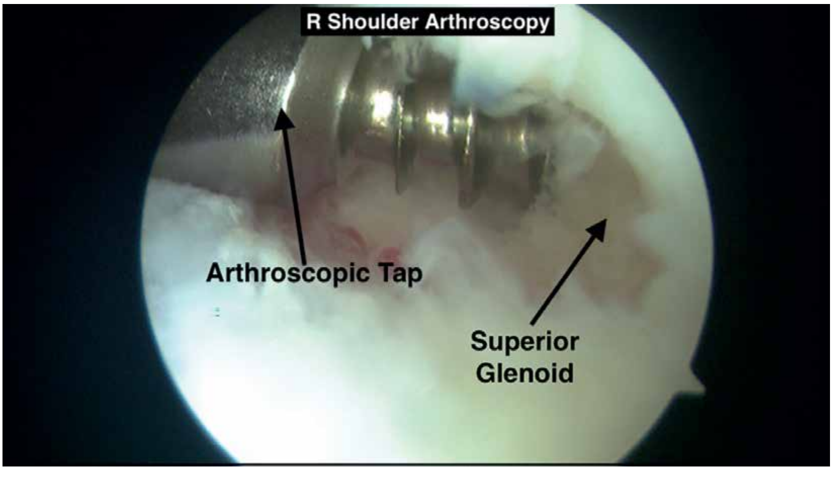

Figure 6.
A right shoulder viewing from the posterior portal in the lateral decubitus position, the pilot hole has been created and a 2.5 mm mini-Revo tap (Conmed/Linvatec) is inserted into the pilot hole to create threads for the screw. We have found that in younger patients, the glenoid bone can be quite hard and self-tapping screws do not always seat properly into the bone.

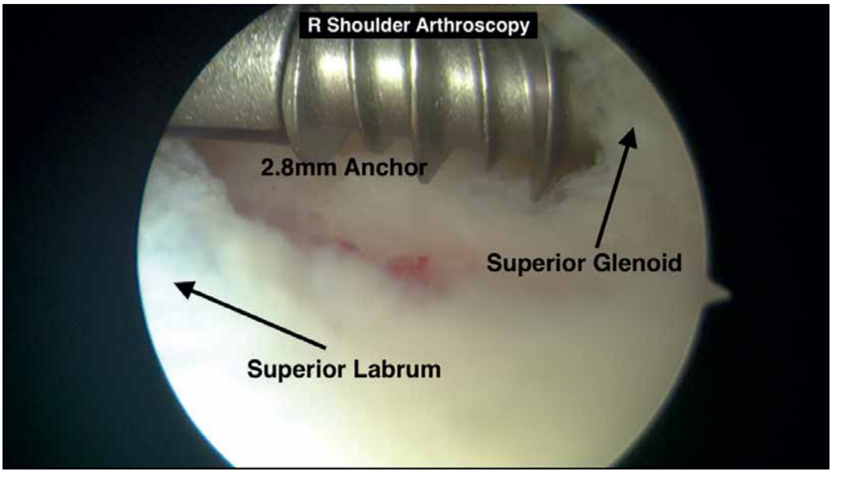

Figure 7.
A right shoulder viewing from the posterior portal in the lateral decubitus position, the tap is then removed and under direct visualization, the 2.8 mm metal anchor single loaded with a high strength suture (Twin Fix 2.8 mm/Smith and Nephew; Fast-Fix 2.8 mm/Arthrex; or Mini-Revo 2.8 mm/Linvatec/Concept) is inserted via the anterior superior portal into the superior glenoid.

the bone. A proud anchor can cause significant problems to the articular cartilage of the humeral head, so it is imperative that these anchors are well embedded into the superior glenoid. The tap is then removed and under direct visualization, the 2.8 mm metal anchor single loaded with a high strength suture (Twin Fix 2.8 mm/Smith and Nephew;

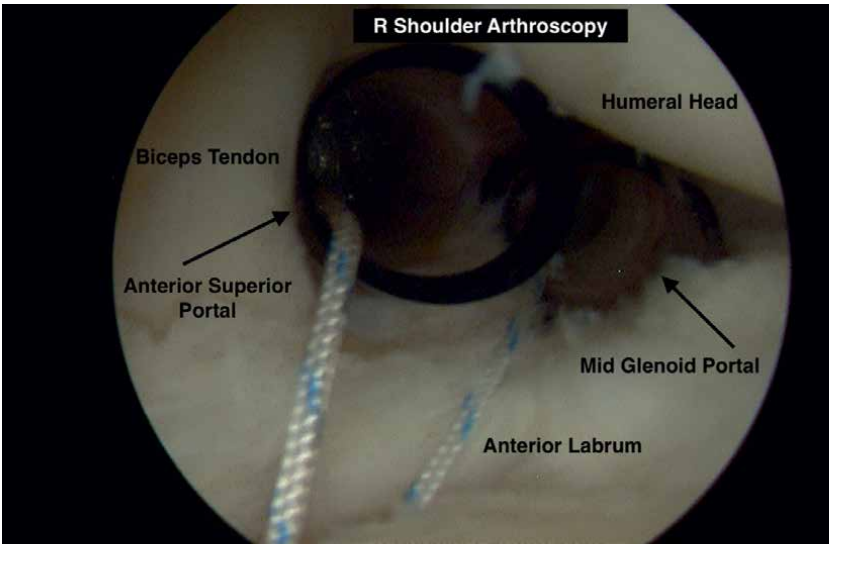

Figure 8.
A right shoulder viewing from the posterior portal in the lateral decubitus position, the arthroscope is rotated up to approximately the 1 o'clock position. A crochet hook is used for gently pulling one limb of the suture into the mid-glenoid portal. There is now one suture limb through the mid-glenoid portal and the other limb through the anterior superior portal. Suture management is also critical for a good repair. Without proper suture management, the sutures can become entangled and twisted. It is very important to keep the suture limbs separate in each portal for this part of the procedure.

Fast-Fix 2.8 mm/Arthrex; or Mini-Revo 2.8 mm/Linvatec/Concept) is inserted via the anterior superior portal into the superior glenoid (**Figure 7**). We prefer a metal anchor and have abandoned the use of bioabsorbable anchors or other plastic types of anchors because of the risk of fragmentation, synovitis, and chondrolysis.

We then test for anchor security, which is also a key step. After the anchor has been placed into the superior glenoid, the sutures are released from the driver and the driver is gently tapped out to disengage it from the anchor only a few millimeters. The sutures are then visible in the anchor and the sutures are then tugged to ensure "anchor security" and to make sure that the anchor does not come loose or become "proud." If the anchor is not secure and pulls out even a few millimeters, this can damage the articular surface of the humeral head. If by pulling on the sutures the anchor becomes loose or becomes proud, the driver can easily be slid down on top of the anchor again, re-engaged, and the anchor is seated deeper for full engagement and to make sure it will not come loose or become proud again.

Suture management is also critical for a good repair. Without proper suture management, the sutures can become entangled and twisted. After the anchor is secured into the bone, the arthroscope is rotated up from the 5 o'clock position to approximately the 1 o'clock position to view the two suture limbs coming out of the anchor. A crochet hook (not a grasper, which can damage the suture) is for gently pulling one limb of the suture into the mid-glenoid portal. There is now one suture limb through the mid-glenoid portal and the other limb through the anterior superior portal (**Figure 8**). It is very important to keep the suture limbs separate in each portal for this part of the procedure.

For suture passage and stitching, there are many devices on the market, many of them are one time use, which can be expensive. The Spectrum Soft Tissue device (Conmed/Linvatec) has different reusable attachments depending on the procedure being performed and the angle that is necessary. For a SLAP repair, we prefer the medium-sized crescent attachment, which easily fits through the 5.7 mm cannula. A #1 PDS suture (Ethicon) loaded into the back of the device, which keeps it out of the way when use the

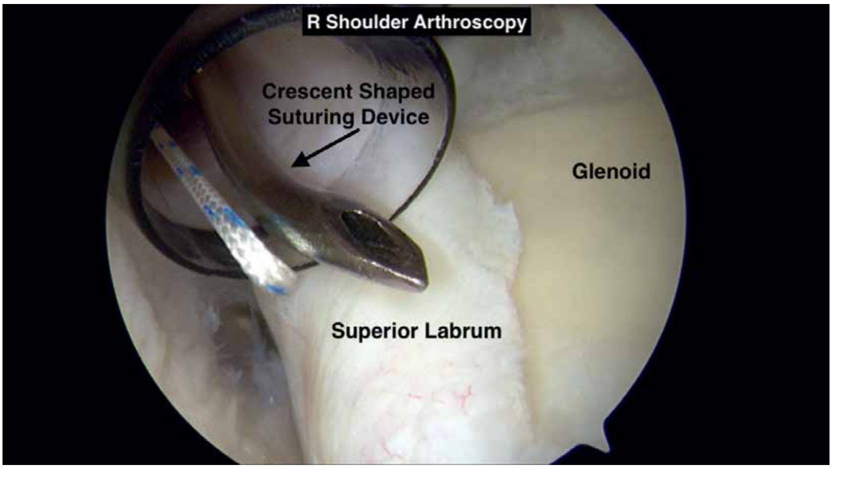

Figure 9.
A right shoulder viewing from the posterior portal in the lateral decubitus position, the Spectrum Soft Tissue device (Conmed/Linvatec) is used for a SLAP repair. We prefer the medium-sized crescent attachment, which easily fits through the 5.7 mm cannula. A #1 PDS suture (Ethicon) loaded into the back of the device, which keeps it out of the way when using the wheel to deploy the shuttle. The rotator interval portal is then placed above or superior to the biceps tendon and the Spectrum device is placed through this portal and just above the labrum. The arthroscope is rotated down into the 4 o'clock position in order to better visualize the superior labrum.

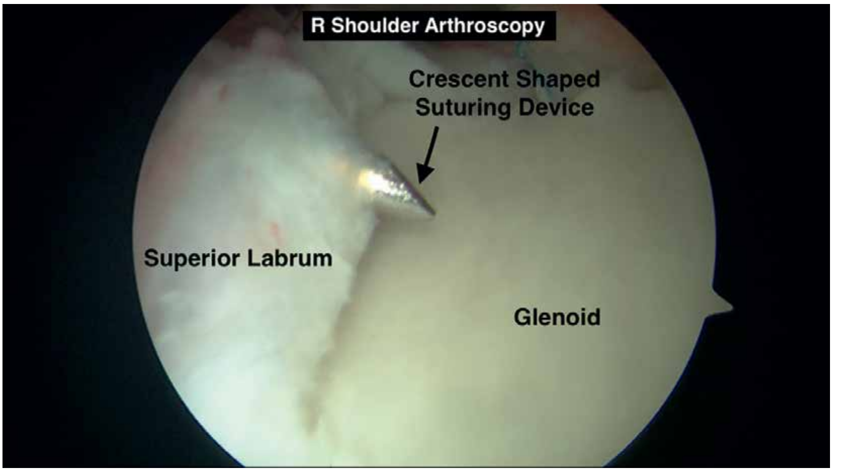

Figure 10.
A right shoulder viewing from the posterior portal in the lateral decubitus position, with careful attention not to damage the articular surface of the glenoid, the tip of the device pierces the superior labrum just posterior to the biceps tendon.

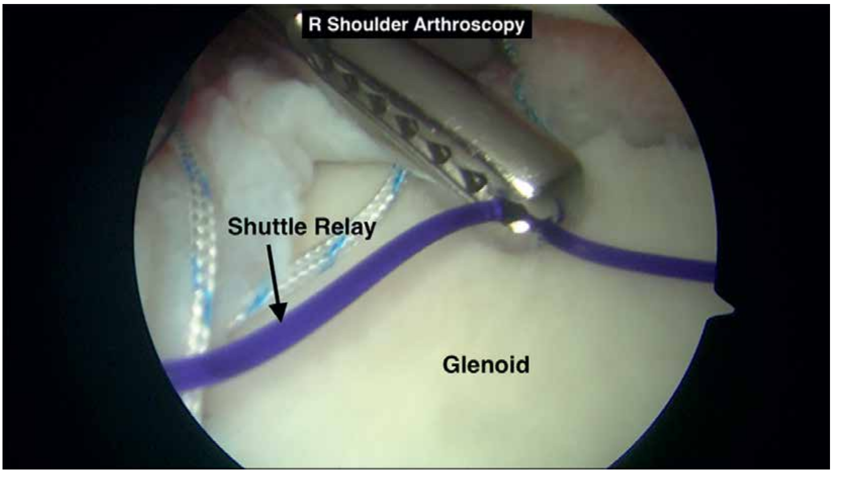

Figure 11.
A right shoulder viewing from the posterior portal in the lateral decubitus position, after the tip pierces the superior labrum the shuttle is deployed. The suture grasper via the mid-glenoid portal grasps the shuttle and pulls it out the mid-glenoid portal. A shuttling technique is used to then shuttle the mid-glenoid suture through the labrum.

wheel to deploy the shuttle. The rotator interval portal is then placed above or superior to the biceps tendon and the Spectrum device is placed through this portal and just above the labrum. The arthroscope is rotated down into the 4 o'clock position in order to better visualize the superior labrum (**Figure 9**). With careful attention not to damage the articular surface of the glenoid, the tip of the device pierces the superior labrum just posterior to the biceps tendon and the shuttle is deployed (**Figure 10**). The suture grasper via the mid-glenoid portal grasps the shuttle and pulls it out the mid-glenoid portal (**Figure 11**).

The shuttle is pulled out into the mid-glenoid portal and then clamped with a Kelly clamp to keep it from inadvertently being pulled out. The shuttle relay or PDS

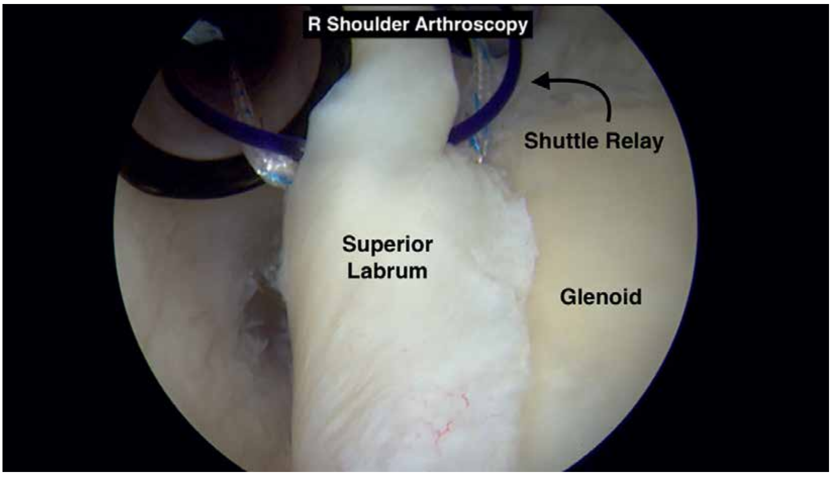

Figure 12.
A right shoulder viewing from the posterior portal in the lateral decubitus position, the PDS shuttle with the suture attached is pulled from the anterior superior portal and the suture is shuttled from the mid-glenoid portal, through the labrum, and then out the anterior superior portal.

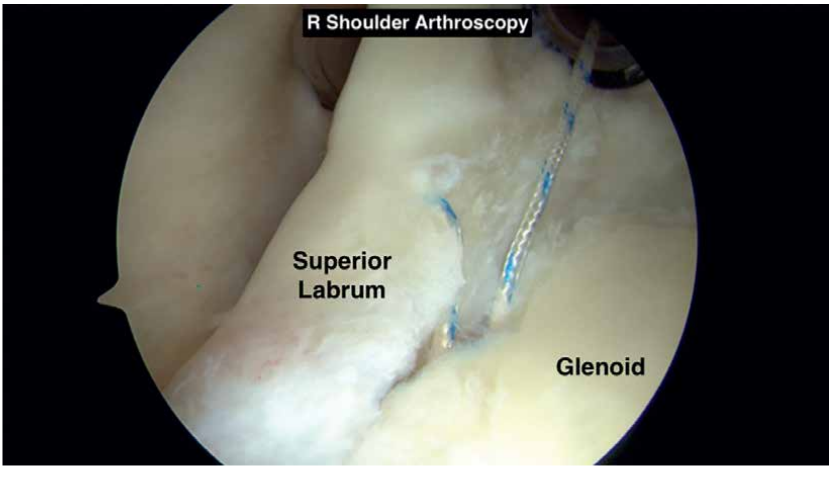

Figure 13.
A right shoulder viewing from the posterior portal in the lateral decubitus position, the first suture has been shuttled through the superior glenoid and this creates a simple knot with one limb through the labrum.

suture is then used to shuttle the first limb of the suture from the mid-glenoid portal, through the labrum, and out through the anterior superior portal. This is done by creating a "dilator knot" first on the PDS and then proximal to that creating a second knot and passing the limb of the suture through it, securing it, and then pulling on the PDS limb that is in the anterior superior portal to shuttle the first limb of the suture through the labrum (**Figures 12** and **13**). This creates a simple knot, but we prefer to repeat the process to create a mattress stitch.

Using the crochet hook placed into the mid-glenoid portal, the second limb of the suture that has not been passed through the labrum and is in the anterior-superior portal is grasped and brought into the mid-glenoid portal. The PDS suture is used again

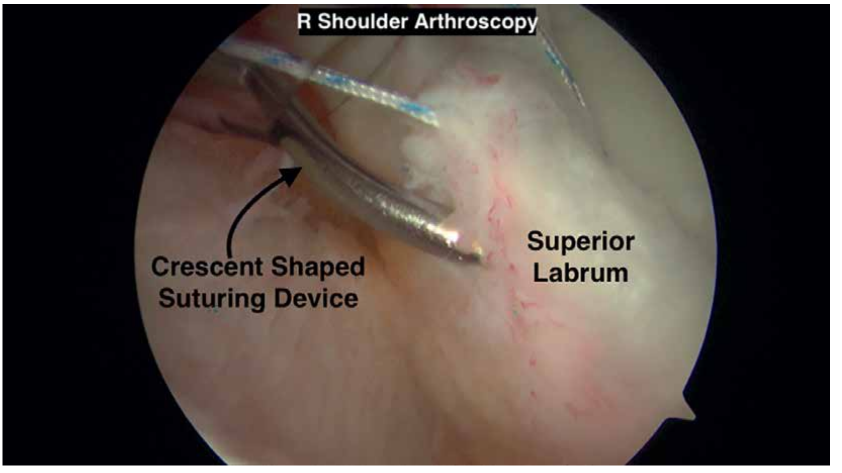

Figure 14.
A right shoulder viewing from the posterior portal in the lateral decubitus position, the arthroscope is rotated down to the 4 to 5 o'clock position and the Spectrum device with the crescent attachment is again placed into the anterior-superior portal just above the labrum. The tip of the device pierces the labrum approximately one centimeter posterior to the other limb of the suture, which has already been shuttled through the labrum.

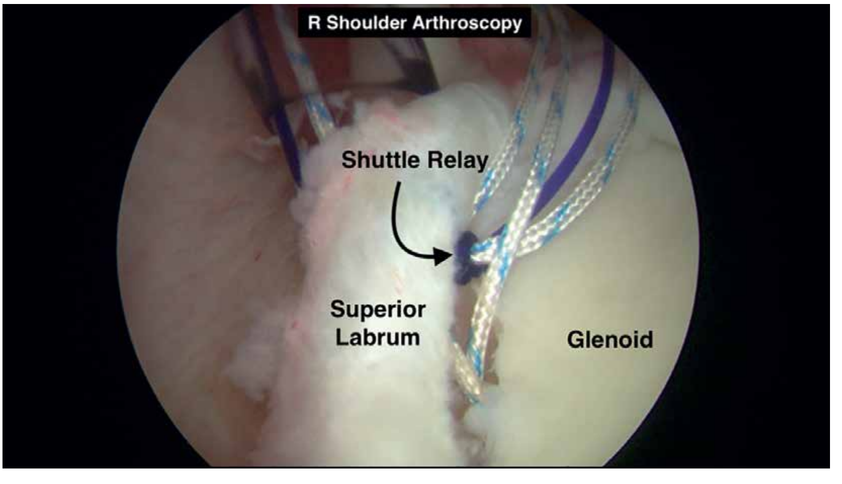

Figure 15.
A right shoulder viewing from the posterior portal in the lateral decubitus position, the process is then repeated with grabbing the shuttle from the mid-glenoid portal, bringing it out the cannula, securing the second limb of the suture outside the mid-glenoid portal with the PDS suture and shuttling the second limb through the labrum and out the antero-superior portal.

and loaded into the Spectrum device. It is important to cut away the previous knots on the PDS as these knots will prevent the PDS from sliding through the Spectrum device. The Spectrum with the crescent attachment is again placed into the anterior-superior portal just above the labrum. The tip of the device pierces the labrum approximately 1 centimeter posterior to the other limb of the suture, which has already been shuttled through the labrum (**Figure 14**). The process is then repeated with grabbing the shuttle from the mid-glenoid portal (**Figure 15**), bringing it out the cannula, securing the second limb of the suture outside the mid-glenoid portal, and shuttling the second

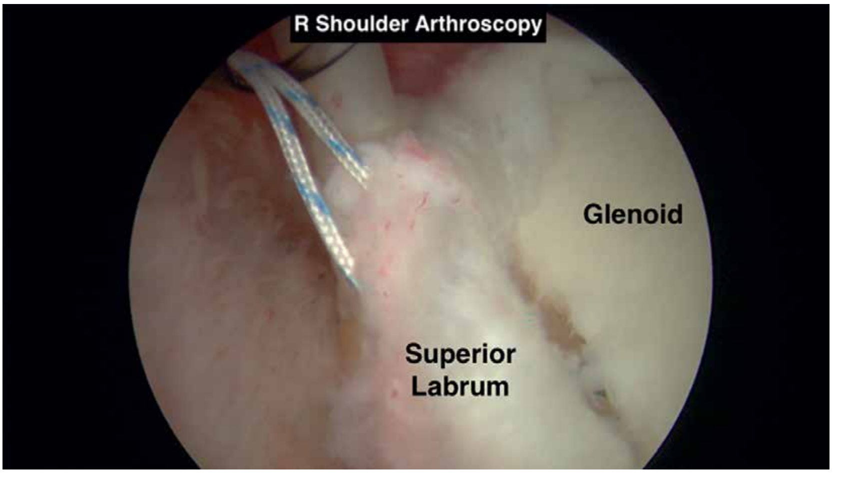

Figure 16.
A right shoulder viewing from the posterior portal in the lateral decubitus position, a mattress stitch has been created. This keeps the suture away from the articular surface and has been shown to be biomechanically stronger than a simple stitch [52, 56].

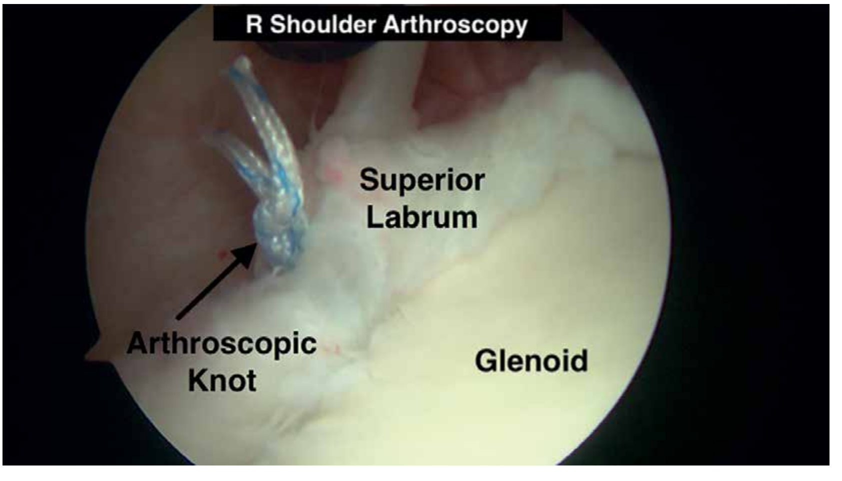

Figure 17.
A right shoulder viewing from the posterior portal in the lateral decubitus position, the knot is posterior to the biceps and the arthroscopic knot cutter cuts the suture after five half-hitches have been placed leaving a small tail at the end. With the mattress configuration, the knots are tied behind the labrum, off the articular surface, where it will not contact the humeral head or pinch between the glenoid and the humeral head.

limb through the labrum and out the antero-superior portal creating a mattress stitch (**Figure 16**). The mattress stitch keeps the knot off the articular surface and has been shown to be biomechanically stronger than a simple stitch [52, 56].

Knot tying is the final key step to a good repair. With the mattress configuration, the knots are tied behind the labrum, off the articular surface, where it will not contact the humeral head or pinch between the glenoid and the humeral head. A sliding knot is not used as sliding knots can damage and tear the labrum, which can be thin

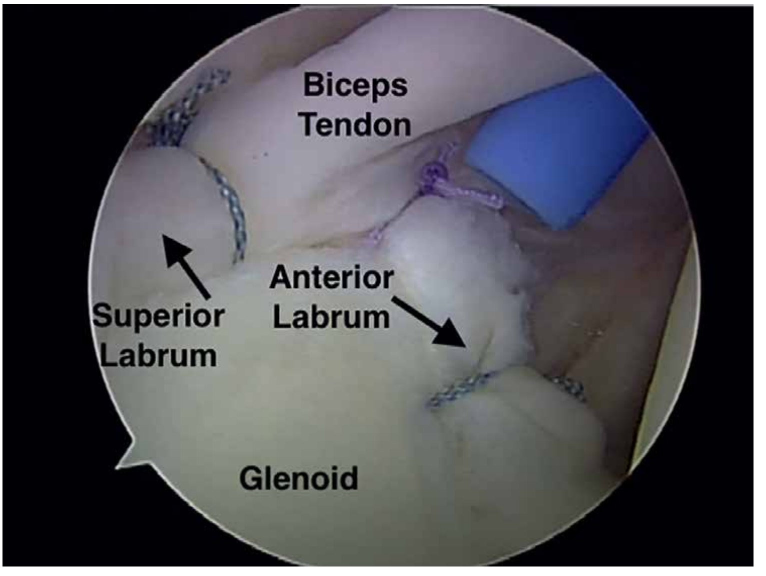

Figure 18.
A right shoulder viewing from the posterior portal in the lateral decubitus position, a different type of SLAP is depicted with anchors and sutures both posterior and anterior to the biceps anchor. Placing anchors and knots anterior to the biceps may limit external rotation by capturing the superior glenohumeral ligament which can be detrimental to the overhead athlete.

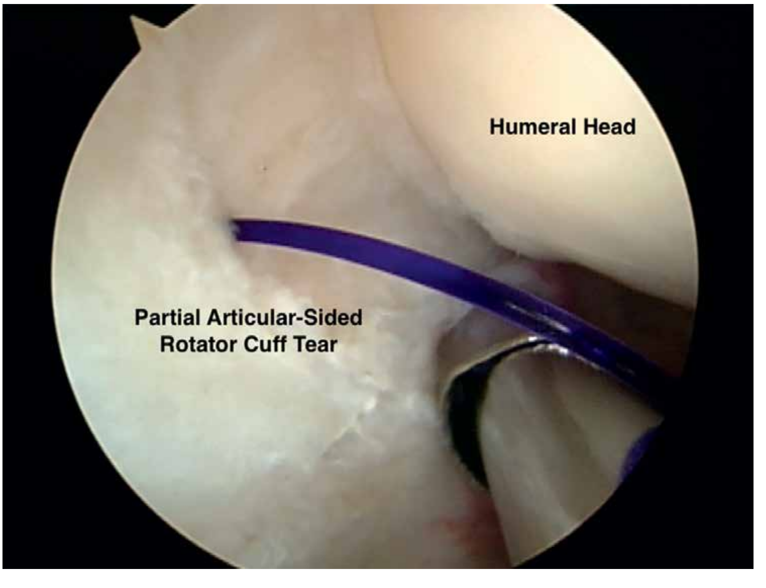

Figure 19.
A right shoulder viewing from the posterior portal in the lateral decubitus position, the arthroscope is rotated upward to about the 10 – 11 o'clock position to view the articular side of the supraspinatus tendon. If a partial articular sided cuff tear is identified in the glenohumeral joint, a marker suture technique [65] using a spinal needle can be used to place an absorbable PDS suture into the partial articular sided rotator cuff tear. This helps localize the area of the tear in the subacromial space.

in some patients. Also, sliding the knots through the anchor can damage the suture and weaken its strength. We recommend a "Revo Knot" [65] popularized by Snyder, which is a series of half-hitches. The arthroscopic knot pusher is placed via the anterosuperior portal, which is above the biceps tendon. It takes two hands to create a good arthroscopic knot so the trained assistant must be able to hold the camera in a steady position or "freeze the frame" to enable the surgeon to use two hands to create a stable knot. The knot is posterior to the biceps and the arthroscopic knot cutter cuts the suture after five half-hitches have been placed leaving a small tail at the end (**Figure 17**).

This mattress knot configuration of placing the knot behind the biceps tendon, off the articular surface, will help resist the peel back mechanism in the late phase of throwing (late cocking) [57]. Only one anchor placed posterior to the biceps is necessary [58]. Placing anchors and knots anterior to the biceps may limit external rotation by capturing the superior glenohumeral ligament (**Figure 18**), which can be detrimental to the overhead athlete.

Once the SLAP repair has been performed, it is important to address other issues inside the glenohumeral joint and the subacromial space including partial rotator cuff tears. If a partial articular sided cuff tear is identified in the glenohumeral joint, a marker suture technique [65] using a spinal needle can be used to place an absorbable PDS suture into the partial articular sided rotator cuff tear (**Figure 19**). The arthroscope is then positioned into the subacromial space. The arm holding suspension device in changed from abduction to adduction to easily facilitate entry into the subacromial space by bringing the humeral head away from the acromion. Once in the subacromial space, it is very important to evaluate for an impingement lesion and any amount of subacromial bursitis. In overhead athletes over the age of 30, it is not uncommon for them to have a significant amount of subacromial bursitis, and we recommend performing an arthroscopic subacromial decompression or "smoothing" in these athletes. We then recommend evaluating the bursal side of the rotator cuff. If a marker suture had been placed, finding the marker

• Anterior superior portal placement in the rotator interval high enough to place an anchor in the superior glenoid
• Second anterior portal at the leading edge of the subscapularis tendon created using an outside-in technique
• Decortication of the superior glenoid surface with a 4.0 mm burr to create a bleeding surface with "punctate" bleeding bone
• Never violate the supraspinatus tendon with a cannula as this can lead to residual pain and weakness in the postoperative period
• Never place an anchor anterior to the biceps tendon as this can capture the superior glenohumeral ligament and middle glenohumeral ligament leading to loss of external rotation and also tethering of the biceps tendon
• A single anchor centered at approximately the 12 o'clock position of the glenoid with a single high-strength suture is almost always adequate enough for repair
• A "Portal of Wilmington" is rarely necessary for anchor placement. If this portal is used, a cannula should not be used as this can substantially damage the rotator cuff tendon
• Always use a mattress stitch with the knot tied behind the labrum
• Always use a half-hitch knot and not a sliding knot as a sliding knot can damage the labrum

Table 2.
Key points for arthroscopic repair.

suture on the top or bursal side of the rotator cuff will help evaluate this side of the rotator cuff. If there is any significant damage to the bursal side of the rotator cuff, the surgeon has different options including debridement, a PASTA repair [65], or completing the tear and converting to a full thickness tear and repairing it. The details of this procedure are being the scope of this chapter, but shoulder surgeons who treat overhead athletes must be experienced in all of these techniques as no one technique is used all the time.

The key points for this procedure are outlined in **Table 2**.

7. Postoperative rehabilitation

Postoperatively, the SLAP repair needs to be protected for a minimum of 4 weeks before any resistive biceps is allowed. A sling is used postoperatively for only 2 weeks, but patients are asked to come out of the sling on postoperative day #1 and do elbow flexion and extension exercises along with gripping of a ball to reduce hand swelling. Pendulum exercises are started on postoperative day #2 and a formal exercise program is started 7–10 days postoperatively. Progressive resistance exercises are started at 6 weeks and a return to sports and throwing program is started at 3 months if motion is normal and patients have regained 80% of their strength. Return to sports including unrestricted overhead sports is allowed at 6 months.

8. Discussion

The published literature reveals that a significant percentage of athletes are unable to return to their prior level of athletic participation after repair of type II SLAP lesions, which is especially true for overhead athletes such a baseball players [10, 21, 22, 83, 90–92]. In baseball pitchers, the success rates for those who have undergone arthroscopic repair of Type II SLAP lesions are even poorer, ranging from 7 to 62% [10, 21, 22, 32, 83, 93–95]. Gorantla et al. [96] in a systematic review of the literature found that only 63% of overhead athletes who underwent type II SLAP repairs were able to return to sports at their previous level of competition.

Shoulder injuries in overhead athletes, especially those who throw, can be a debilitating condition that can severely limit and end the ability to participate [93]. SLAP tears can be challenging to treat in the overhead athlete. Nonoperative and operative treatments have been discussed with nonoperative treatment being the mainstay of treatment for the overhead athlete with a clinical diagnosis of a SLAP tear. As we have seen, SLAP tears can be seen in asymptomatic overhead athletes so initial nonoperative treatment will return most overhead athletes back to their pre-injury level of competition without surgery. When nonoperative treatment fails, which it can, arthroscopic surgical intervention can return most athletes to competition at or near their pre-injury level if the proper surgical techniques are used.

There have been unsuccessful outcomes with debridement alone for Type II SLAP lesions [5, 44, 84]. Arthroscopic debridement was initially recommended by some authors [3, 84], but the long-term results were disappointing. Cordasco et al. reported that arthroscopic debridement of Type II SLAP lesions was not effective with deteriorating results over 3 years. Their initial success rate was 78% at 1 year, 63% at 2 years, and only 45% at 3 years [44].

Initially, high rates of return to play were reported [97–99]. However, in these early studies of SLAP lesions, the outcome data are based largely in retrospective studies consisting of small numbers of patients using various surgical techniques and fixation options [61]. Many reports of the treatment of SLAP lesions have included patient who had other associated abnormalities making it difficult to clarify the clinical efficacy of treatment of the superior labral lesion alone [22].

Wilke, Andrews, and Meister [42] described the delicate balance of the thrower's shoulder, which has sufficient laxity to allow excessive external rotation and stability provided by the glenohumeral articulation and scapula can be easily disrupted. This has been described as the so-called "Thrower's Paradox" and disruption of this fine balance disables the throwing shoulder. The return to play (RTP) at an athlete's previous level of competition is a measure of the success of the operation.

The overhead athlete has had poor outcomes following the surgical repair of SLAP lesions reported by many different surgeons. The return to play has varied with only 63% of overhead athletes able to return to their pre-injury level [85, 96]. Other authors including Kim et al. [22] in 2002 also reported poor results of shoulder function with overhead athletes with only 22% able to return to their same level of competitiveness in their sport. Sayde et al. [85] reported that 73% of athletes were able to return to their previous level of play, but only 63% of the subset of 198 athletes who were baseball players returned to their previous level. Smith et al. [100] identified 24 major league baseball pitchers reported to have had surgery for a SLAP tear and found that 63% returned to play in the major leagues.

For baseball pitchers, the results are even worse with rates varying from 7 to 62% [10, 21, 22, 32, 83, 93–95]. Fedoriw et al. [93] reported on a case series of professional baseball players with SLAP lesions and found out that the rate of return to their previous level of play was 24% (16/68) after conservative treatment and only 23% (9/40) for those who progressed to surgery. For baseball pitchers, the results were worse and only 7% of baseball pitchers were able to return to play with surgical treatment The reasons for the high failure rates and poor results in this subgroup of overhead athletes are multifactorial and include a lack of a proper diagnosis not only preoperatively but also intra-operatively with a possible normal meniscoid variant being inadvertently repaired. Other nuances of the surgical technique could also be the explanation including anchors placed anterior to the biceps anchor, restricting external rotation, which can decrease the ability of the baseball pitcher to reach maximum torque in their pitching delivery.

Biomechanists and pitching coaches often observe that pitchers returning from injury or from surgical repair of a SLAP lesion look like they are "holding back" [51]. Pitchers in this situation demonstrate a smaller shoulder stride, less forward trunk tilt, and/or are "pushing the ball" [51]. Pushing the ball is a colloquial expression of increased shoulder horizontal abduction and increased elbow flexion seen in pitchers after SLAP repair, most likely due to the loss of external rotation.

Using electromyogram and motion analysis, it has been shown that baseball pitchers after SLAP repair have altered biomechanics including a loss of maximal external rotation of their throwing shoulder with less horizontal abduction causing a decrease in pitching velocity [51, 62]. What is it about SLAP repair that alters the pitching biomechanics resulting in a loss of pitching velocity? More likely than not, it is the technique of placing anchors anterior to the biceps anchor, overtightening the shoulder resulting in a loss of external rotation.

An MRI/MRA finding of a SLAP is not uncommon in overhead athletes and is not an indication for immediate surgery. In our prospective study of 26 elite Olympic volleyball players with no history of any shoulder problems, MRIs of their dominant shoulders showed that 17 had evidence of partial rotator cuff tears, 6 had labral tears including 4 with SLAP tears. The dominant shoulder of overhead athletes undergoes a tremendous amount of repetitive stress and is at risk for damage. However, this damage can remain asymptomatic throughout the athlete's career and any overhead athlete with shoulder pain should also initially be treated with nonoperative management [80]. Nonoperative treatment is the mainstay in overhead athletes and surgery should only be done after a long course of conservative management ranging from 3 to 6 months.

The study of Gobezie et al. [68] of 73 "expert surgeons" who were queried with video clips had a difficult time distinguishing type I from type II SLAP lesions. Only 52% make the correct diagnosis and recommended the appropriate treatment of labral repair. The poor results in the literature of arthroscopic SLAP repair may be a failure of not only diagnosis but also repair of normal variants or SLAP tears that are mistakenly misdiagnosed as normal at the time of surgery [9].

Reviewing the literature of the results of the SLAP repairs, examining the arthroscopic techniques used by different surgeons may help explain the poor results. The techniques have evolved since the original description of SLAP tears in 1985 and we now have a better understanding of the ligamentous anatomy and biomechanics of the shoulder joint. However, many surgeons did not have the benefit of these studies when they first started treated SLAP tears. With any procedure, proper portal placement, anchor placement, and knot tying are keys to a successful surgery.

In 2002, O'Brien and colleagues [90] used a trans-rotator cuff portal for surgical repair of SLAP lesions posterior to the biceps anchor. They describe the use of a cannula but state that to minimize the degree of damage to the rotator cuff, the procedure can be performed without a cannula. However, it is unclear how many patients had a cannula placed. This portal placement with a cannula referred to as the "Port of Wilmington" can damage the musculotendinous portion of the supraspinatus tendon and may explain the poor results. Using this technique, O'Brien et al. reported that only 16 of 31 patients (44%) were able to return to their preinjury level of sports. Despite the poor results, O'Brien stated that "the trans-rotator cuff technique is an effective and safe modality to address superior labral pathology." We would disagree considering the poor results reported and do not recommend violating the rotator cuff with a large cannula for anchor placement. If it is necessary to use the "Port of Wilmington" for posterior superior anchor placement, then it should be done percutaneously without the use of a cannula and using a spinal needle for direction.

Other authors have also reported poor results using a rotator cuff penetrating or trans-rotator cuff portal. In 2006, Cohen and colleagues [83] reported on isolated SLAP lesions treated with arthroscopic fixation using a bioabsorbable tack. Only 48% were able to return to their preinjury level of athletics. In those patients in which the rotator cuff was penetrated for cannula and anchor placement, only 12 of 22 patients (55%) rated their satisfaction as good or excellent. All 10 patients who reported postoperative night pain had undergone a cuff-penetrating surgical approach.

Neri et al. [10] also described a trans-rotator cuff portal for posterior SLAP lesions and reported only a 57% return to their pre-injury level of competition. They also found that the presence of a partial articular sided rotator cuff tear significantly correlated with ability to return to sport and only 13% with a partial cuff tear were able to return to their prior level of play. We do not recommend this technique of violating the rotator cuff for anchor placement, especially with a large diameter cannula but rather prefer our technique of a single anchor placed via a cannula through the rotator interval.

As we have seen from the numerous biomechanical studies that have been performed, placing an anchor anterior to the biceps tendon (**Figure 19**) can entrap the superior glenohumeral ligament (SGHL) and the middle glenohumeral ligament

(MGHL) causing a small but significant loss of external rotation [15, 61]. The biomechanical study by Morgan and colleagues in 2008 showed no advantage of placing an anchor anterior to the biceps tendon to prevent the peel-back mechanism [101].

Tension in the ligaments after SLAP repair may resolve shoulder instability but could negatively impact and affect a pitcher's ability to attain the shoulder external rotation and longitudinal abduction necessary to throw effectively [51]. The most common complication of the symptomatic type II SLAP repair has been reported as refractory post-op stiffness in forward flexion and external rotation, reported at 8.5% [15, 51]. When Katz et al. [102] looked at a cohort of failed SLAP repairs, they found out that 75% of these patient's complained of decreased range of motion.

Other authors have also noted poor results secondary to a loss of external rotation when an anchor is placed anterior to the biceps tendon. Indeed, the majority of failed SLAP repairs complain of not only pain but loss of motion [102]. Chalmers et al. in their analysis of return to play for professional baseball pitchers detected a trend toward a decrease in maximal external rotation in pitchers after SLAP repair as compared to normal controls [62].

Another key point in the arthroscopic technique of type II SLAP repair is the type of stitch configuration used. The mattress stitch with one anchor has shown to be stronger biomechanically than the use of a simple stitch with one or even two anchors [40]. This is also helps re-create the normal superior labral anatomy [52, 56].

With a mattress configuration, the knots are away from the articular surface, are less bulky, and can cause less irritation in the thrower's shoulder, reducing the risk of postoperative pain and mechanical-like symptoms in the thrower's shoulder. Even in experienced hands, these simple knots can be bulky causing significant irritation in the overhead athlete's shoulder reducing their ability to return to their normal level of play [55]. In an analysis of 11 failed SLAP repairs by Park and colleagues [103], patients complained of persistent pain and mechanical clicking in their shoulders when they returned to throwing after surgery. At the time of repeat arthroscopy in five patients, all had the knot positioned on the glenoid and caused damage the articular surface of the humeral head. Arthroscopic removal of the stitches provided pain relief and improved their ability to return to throwing. Rhee and Ha [104] described a case report of knot-induced glenoid erosion after arthroscopic suture anchor repair of a Type II SLAP lesion. The knot can be a source of continued pain after surgery so that is why we recommend a mattress configuration.

SLAP tears rarely occur in isolation [71] and other associated shoulder pathology such as chondral lesions, Bankart lesions with instability, impingement lesions, and partial or complete rotator cuff tears, which are present, may be another reason why SLAP repairs do so poorly. It is important to take a close look at the literature in that some studies that look at only the results of isolated SLAP lesions of the shoulder also have other pathology, most commonly partial rotator cuff tears, which are a confounding variable in looking at surgical results. Brockmeier et al. [61] had 24 of their 47 study patients with partial rotator cuff tears and 24 of 47 had signs and symptoms of impingement requiring a subacromial decompression. SLAP tears rarely occur in isolation and all pathology must be addressed at the time of surgery.

In an analysis of 23 elite collegiate or professional overhead athletes, Neri et al. [10] found that the presence of a partial articular sided rotator cuff tear correlated with inability to return to pain-free preinjury levels of competition. The group of patients with concomitant partial thickness rotator cuff tears demonstrated only 13% return to prior level of play, compared with 80% return in the group without tears. Brockmeier et al. [61] noted no difference in the ability to return to sporting activities in their group of 47 patients, 23 of which had a partial rotator cuff tear treated with debridement. Coexistent partial thickness rotator cuff tears did not appear to have an effect on the outcome parameters but only 74% were able to return to their preinjury level but the majority of these patients were recreational non-overhead athletes. The presence of a rotator cuff tear, even if only a partial tear, can significantly limit the ability of an overhead athlete to return their preinjury level of competition when they have an associated SLAP tear and repair.

Because of the poor results of SLAP repairs in overhead athletes, arthroscopic biceps tenodesis has been proposed as an alternative treatment to SLAP repair in the overhead athlete [17, 63, 87, 88]. In 2018, Chalmers et al. [62] reported on 17 professional baseball players who had a biceps tenodesis for a SLAP tear. Only 35% were able to return to their prior level of play and with baseball pitchers, the results were worse with only 17% able to return to their prior level of pitching.

Some studies have also implicated age as a risk factor for failure of repairs and ultimately worse activity upon return to play [17, 51]. Denard et al. [105] reported that increasing age (>40) may be a factor associated with poorer outcomes after repair of type II SLAP lesions, but the results were not statistically significant. Many of the patients in their study were worker's compensation cases. However, the results of those greater than 40 years old who had a repair of a type II SLAP lesion were 81%, similar to other studies. Among the overhead athletes in their study, 88% (15/17) were able to return to normal activities, but it does not state if they were overhead athletes or what sports they played. Worker's compensation cases had worse results with only 64% of patients (9/14) reporting satisfactory results and return to normal activities.

These results are in similar to the results of Alpert et al. [106], who showed no difference in clinical outcomes after type II SLAP repairs in patients older and younger than 40 years (surgical techniques/suture anchors placed posterior to the biceps anchor) using a technique similar to ours. Provencher et al. [107] found that type II SLAP repair in patients older than 36 years of age was associated with a significantly higher rate of failure. In their study they had a 37% failure rate and 28% revision rate. The relative risk for failure for patients older than 36 years was 3.45. However, the technique used is different from our recommended technique in that they used a transtendinous technique through the rotator cuff for anchor placement. They also used a simple stitch configuration (not a mattress stitch), which may have influenced results.

Schroder et al. [108] reported on patients who had isolated superior labral type SLAP II lesions with long-term follow-up and found no difference was observed between older patients (>40 years) and younger patients (<40 years) in terms of overall satisfaction and functional outcome scores. We have not found this to be true in our patients, and we do not use age as a factor for repairing type II SLAP lesions but rather the quality of the labrum and the activity of the patient.

We have described the technique of the arthroscopic repair of type II SLAP lesions, which has given excellent results in our patients for over 20 years. The procedure can be technically demanding but with attention to all details of the procedure, it can be reproduced and provide excellent results in overhead athletes. The two important points of not violating the rotator cuff with cannula placement and placing an anchor with a mattress suture behind the biceps are key components of a successful surgical repair. However, before proceeding with surgery, it is important to remember that not all overhead athletes with a clinical diagnosis of a SLAP by physical exam, MRI or both, need to have surgery and nonoperative measures should always be exhausted before surgery is performed.

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Chapter published: November 2022
Book available Winter 2023
Book DOI: intechopen.102227
Online ISBN: 978-1-83768-200-3
Print ISBN: 978-1-83769-982-7
eBook (PDF) ISBN: 978-1-83768-201-0