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The SLAP Tear: A Modern Baseball Focus

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Background

From the commencement of sports in the United States, baseball has been known as the country's greatest pastime. For over a hundred years, faithful fans everywhere have packed stadiums to watch the men of their communities play the game. At its basic structure, baseball is played with nine players per team, and the core of the battle lies in a pitcher's duel with each hitter. Therefore, in order to become a successful ball club, a team must be able to rely on their pitcher for both his talent and ongoing health.

For the past 30 years, the role of medicine and injury prevention in baseball has largely been emphasized in what's known as Tommy John surgery, a common procedure on a pitcher's damaged elbow ligament. Once a career ending injury, the torn ligament (ulnar collateral ligament) can now be routinely reconstructed by almost any orthopedic surgeon, thus allowing a pitcher to return to the field. However, over the past decade, a new pitching injury has gained notoriety and become somewhat of an obscurity to team athletic trainers and doctors. This injury, a torn shoulder labrum, stands as a dark reminder of what a torn elbow ligament used to mean to a pitcher's career.

The shoulder labrum is a thin layer of cartilage that lies between the humerus (bone of the upper arm) and the glenoid fossa, the small groove which the humerus fits into. It functions as a shock absorber and a part of the shoulder joint's connective structure. Therefore, it cushions the joint when the humerus collides with the glenoid fossa in activities such as throwing a baseball- a violent action that rips at the tissues of the shoulder. Sometimes this aggressive motion can cause the labrum to tear. The most common type of labral tear in baseball is a superior lesion anterior to posterior or "SLAP". Like most other injuries, a SLAP tear is initially thought to be only minor pain and tenderness. In addition, it is quite difficult to diagnose without exploratory surgery due to its concealed location between two bones. Frequently, the tear goes unnoticed for weeks to months until the tenderness and ensuing loss of pitching quality add up. Thus, it is interesting to figure how many great pitchers of the past had their careers ended by the injury. Even today, it often takes a team of orthopedists and radiologists to examine a patient and MRI to conclude that a labral tear is present. Once diagnosed, the only treatment other than mild rehabilitation is surgery.

Once surgery is decided, there are a few ways to correct the problem. A few years ago, it was common for a surgeon to merely enter the shoulder joint housing the tear and perform a routine "clean up." This led to an 18-month rehabilitation program with slim odds of the patient being able to pitch at the same standards as before the injury. A newer operation involves this same clean up along with a reattachment of the labrum with sutures- a procedure which shortens the rehabilitation time to about 6-8 months. Still, the chances of being able to pitch at the same level as before the injury are small. Whereas the long celebrated Tommy John surgery has an 85% success rate of getting a pitcher back to a high level, the SLAP tear operation once only had a 3% chance of putting a pitcher back on the mound with the quality of performance he had prior to the injury (Carroll, 2004). For the other 97% of pitchers who tore their labrum, it was essentially a death sentence (or at least a major hindrance) to their career. Even today, the SLAP repair procedure only has a 33-66% success rate in putting athletes back on the field. For these reasons, I find the SLAP tear to be an exciting modern and growing issue in baseball- one that may soon lead to a medical breakthrough with the same distinction as Tommy John surgery.

This discussion includes extensive research of the SLAP tear including descriptions of the anatomy and physiology of the shoulder, diagnostic tools to detect the injury, surgical procedures to repair the tear, information on how throwing a baseball influences the occurrence of the injury, and, finally, an analysis of a group of collegiate baseball players who have had the injury.

Shoulder Labrum Anatomy and Physiology

The shoulder capsule consists of several aspects of bone, muscle, nerves, tendons, and ligaments that function in the ball and socket joint. In regards to the labrum, the two most important anatomy are the humerus (upper arm bone) and the glenoid fossa (shallow depression cradling the humeral head). Between these two bones resides the shoulder labrum- a thin, fibrocartilaginous (rigid) matrix that acts as a cushion when the humerus and glenoid collide (FIGURE 1a) (Carroll, 2004). Typically, the labrum is smooth and triangular or rounded; however, the morphology can alter with various motions. The primary characteristic of the cartilage is to provide shoulder stability in movements such as throwing, swimming, or even under traumatic stress.

FIGURE 1a- Basic Shoulder Anatomy

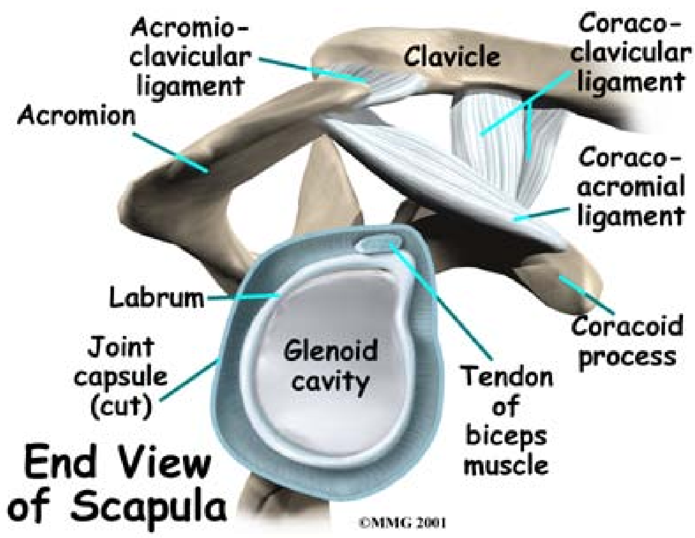


FIGURE 1a- The above image shows the basic anatomical aspects of the shoulder. As viewed, the labrum encapsulates the glenoid socket and serves as an origin for the biceps tendon.

The shoulder labrum serves as an origin for several ligaments and tendons (FIGURE 1b). Anteroinferiorly, the labrum attaches to the inferior glenohumeral ligament (IGHL) while, superiorly, it blends with the superior glenohumeral ligament (SGHL) and long head of the biceps tendon (Chang, 2008). The IGHL is the primary stabilizer of the shoulder complex beyond 60^o of abduction as well as in external rotation, and the SGHL provides stability specifically to the glenohumeral complex. Aside from these two ligaments, the middle glenohumeral ligament (MGHL) can arise from the anterosuperior labrum, although it usually arises directly from the glenoid. In fact, the MGHL is the most variable structure in the shoulder and can even be absent (30% of shoulders) (Chang, 2008).

FIGURE 1b- Shoulder Socket and Ligament Attachments

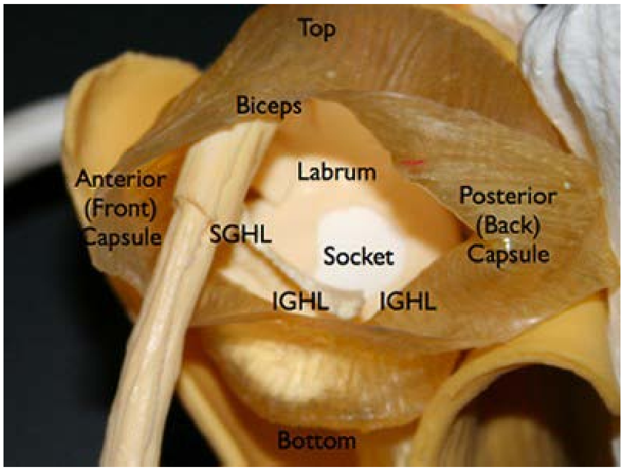


FIGURE 1b- The above picture shows a representation of the shoulder joint and the various ligaments which have origins in the socket. As viewed, the labrum (tan) is a thin sheet of cartilage that encases the shoulder socket (white). The biceps tendon originates at the superior aspect of the labrum along with the superior and middle glenohumeral ligaments. Along the inferior anteroposterior aspect of the labrum, the inferior glenohumeral ligaments originate (Portland).

In terms of describing the location of anatomy within the shoulder (especially with the labrum), there are two methods to consider (FIGURE 1c). First, standard anatomical vocabulary can be used whereby upwards is known as "superior"; forwards is "anterior", etc. In addition, a "clock" analogy can be used in which "12 o'clock" represents a superior aspect; "3 o'clock" corresponds to anterior; "9 o'clock" describes posterior, etc. This method is practical for its specificity in accurately describing the location of a tear or lesion. The standard vocabulary, however, can pose only a range of tissue where an injury may be found.

FIGURE 1c- Labrum Tears: Shoulder Aspects

FIGURE 1c- The above figure shows two methods of identifying the shoulder. The clock method (left) looks at the shoulder from the lateral perspective as if it were the face of a clock, with 3 o'clock being the anterior shoulder and 9 o'clock being the posterior shoulder. The standard anatomical identifying method (right) can also be used to describe the location of a labrum tear. Both images describe the lateral view of the right shoulder (Mohana-Borges, 2003).

Aside from the typical morphology of the shoulder labrum and its corresponding attachments, variable positions can sometimes occur. Most of this variability occurs between the 11 and 3 o'clock region. Included in this region can be the presence of a sublabral recess, sublabral foramen (hole), or an absence of the anterior superior labrum- a condition known as a Buford complex (Chang, 2008). These deviations in anatomy often lead to difficult analysis of the shoulder via imaging or physical examinations because they reside in a location of common pathology. For example, in the case of a Buford complex, the MGHL attaches directly onto the glenoid and may appear to be a sublabral hole or labral lesion. If this confusion leads to a surgical reattachment of the ligament onto the glenoid cartilage, the patient will face severe pain and resistance in arm rotation and elevation. Similarly, anatomical variants can appear as SLAP lesions in diagnostic imaging. A "pseudo-SLAP" lesion is found when there is a recess between the superior labrum and the origin of the biceps tendon. Even with magnetic resonance arthrography, a deep recess can be easily mistaken for as a SLAP tear. This sublabral recess, the most common deviation in shoulder anatomy, is the most difficult variant to differentiate from a SLAP tear (Chang, 2008).

Shoulder Labrum Tears

Considering the various ligaments and tendons that attach to it, the labrum is susceptible to physical stress in almost all directions whenever the arm is in motion. Sometimes, these tensions overcome the strength of the fibrocartilage, causing it to tear. Based on which ligament or tendon caused the injury, the labrum can tear at any location around the glenoid. If tension in the inferior glenohumeral ligament is the source of injury, a tear will arise in the anteroinferior (or 4-5 o'clock) portion of the labrum. This type of tear, commonly known as a Bankart lesion, typically occurs when the humeral head translocates outside of the glenoid fossa- a dislocated shoulder (Portland). Similarly, posterior labral tears occur from shoulder dislocations, falls on outstretched arms, or sometimes from overhead sports. Most commonly, however, labrum injuries occur superiorly, where the biceps tendon originates from the labrum. When this powerful tendon pulls at the labrum- either in falls or in overhead sports such as baseball, swimming, or volleyball- its origin can tear the top of the cartilage away from the glenoid. This injury is known as a superior lesion anteroposterior or superior labral anteroposterior lesion (SLAP).

There are ten different types of SLAP tears depending on the characterization of the injury. Types I-IV are frequently found in overhead athletes (baseball players, swimmers, volleyball players) while Types V-X are typically not found in these patients. Still, dislocations and falls on an outstretched arm can lead to any of the SLAP types.

A Type I SLAP injury (FIGURE 2a) refers to a fraying of the superior labrum without tearing off from the glenoid fossa. Also, the biceps tendon remains attached to the labrum. A Type II injury includes this fraying along with detachment of the superior labrum (and biceps tendon) from the glenoid. Further, this type of tear can be subdivided: a Type IIA tear is in the anterosuperior (12-3 o'clock) position; a Type IIB lesion is in the posterosuperior (9-12 o'clock) position; and a Type IIC lesion is in the superior labrum and extends both anteriorly and posteriorly. The Type II SLAP is the most common type of labrum tear (41-55%) and is typically caused by repetitive mild trauma to the shoulder capsule (as in pitching) (Chang, 2008). A Type III SLAP is a "bucket handle" tear of the superior labrum with the middle portion of the injury extending into the joint. Similarly, a Type IV injury is a bucket handle tear extending into the biceps tendon (Chang, 2008). These last two forms (III and IV), although sometimes occurring in overhead athletes, are commonly caused by falls on outstretched arms; throwers are more likely to have either a Type I or II injury).

FIGURE 2a- Classification of Throwing-Related SLAP Tears (Types I-IV)

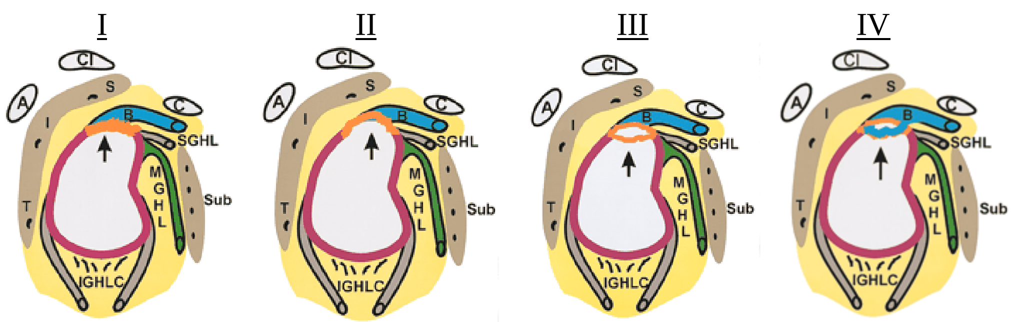


FIGURE 2a- The above images illustrate the nature of the shoulder in each of the most common types of SLAP tears, I-IV. In a **Type I** injury, the superior labrum is merely frayed; **Type II** injuries are characterized by a detached superior labrum and biceps tendon from the glenoid; **Type III** injuries correspond to a bucket-handle tear in which the biceps tendon is fully intact; **Type IV** tears include bucket-handle tears in which the biceps tendon is also partially torn (Mohana-Borges, 2003).

Legend: CL= clavicle, A= acromion, C= coracoid process, B= biceps tendon, SGHL= superior glenohumeral ligament, MGHL= middle glenohumeral ligament, IGHL= inferior glenohumeral ligament

SLAP Types V-X are generally non-throwing-related and mostly occur from falls or dislocations. A Type V (FIGURE 2b) is a tear in the anteroinferior (3-6 o'clock) position, also known as a Bankart lesion, along with partial tearing of the superior labrum and biceps tendon. Type VI injuries involve a tearing of the flap of the labrum either anteriorly or posteriorly, along with detachment of the biceps tendon from the superior labrum. Type VII tears are characterized by detachment of the biceps tendon from the superior labrum with the tear extending into the middle glenohumeral ligament. Type VIII SLAPs are superior tears extending posteriorly (similar to Type IIB). Type IX lesions are superior tears with vast extension of the tear both anteriorly and posteriorly.

In this tear, the labrum is almost fully separated from the glenoid. Last, a Type X SLAP is a superior labrum tear with extension into the rotator cuff (Chang, 2008).

FIGURE 2b- Further Classification of SLAP Tears (Types V-X)

FIGURE 2b- The above images illustrate the nature of the shoulder socket in Types V-X SLAP injuries (typically not associated with baseball). **Type V** injuries involve a Bankart Lesion along with partial tearing in the superior labrum and biceps tendon; **Type VI** injuries are characterized by an anterior or posterior tear in the flap of the labrum, along with separation of the biceps tendon from the superior labrum; **Type VII** injuries involve a tear in the biceps-labrum complex, along with partial tearing in the middle glenohumeral ligament; **Type VIII** tears are located in the superior labrum with partial tearing in the posterior labrum; **Type IX** injuries involve complete detachment of the labrum; **Type X** tears are typical SLAP tears which extend to rotator muscles or other structures (Mohana-Borges, 2003).

Legend: CL= clavicle, A= acromion, C= coracoid process, B= biceps tendon, SGHL= superior glenohumeral ligament, MGHL= middle glenohumeral ligament, IGHL= inferior glenohumeral ligament

Diagnosis: Examinations and Imaging Techniques

Due to the location of SLAP injuries as well as the intricate surrounding anatomy, lesions are extremely difficult to diagnose. In fact, it is widely suggested that a shoulder arthroscopy is the only method to definitively determine the presence of a SLAP tear. Still, traditional diagnostic methods are used to assist an orthopedist in making the decision to surgically repair a torn labrum. These include a patient history, physical examinations, and imaging techniques. The patient history and examinations have been found to be approximately 70% accurate in determining the presence of a SLAP lesion while traditional magnetic resonance imaging (MRI) is 50-70% accurate. MR arthrogram, a procedure in which a contrast dye is injected into the shoulder, has been deemed 70-90% accurate in diagnosing SLAP tears (Portland). Still, imaging tools do not allow a physician to distinguish the type of lesion; only the location, morphology, or supplemental injuries may be characterized (Chang, 2008). Therefore, these different diagnostic methods can be studied for further analysis of shoulder labrum injuries.

Patient History

The SLAP lesion diagnostic process begins with a thorough patient history evaluation designed to determine the mechanism of injury. This involves questioning the patient for details about their symptoms. Patients with SLAP injuries will commonly complain of general shoulder pain and a clicking or popping felling when performing overhead activities. This pain and dysfunction also ceases when the patient is at rest. Further, throwers and other overhead athletes typically complain severe pain during a specific stage of throwing such as arm-cocking or decelerating. On the other hand, if the patient complains of shoulder weakness, a secondary injury might be present (such as rotator cuff inflammation) (Dodson, 2009).

When determining the exact mechanism of injury, several possible explanations exist. The two most common of these is a gradual wearing down of the labrum and compression of the shoulder brought about by trauma. Wearing down, or traction, of the shoulder is frequently found in throwers who have tired the capsule over time with too much overhead activity. Compression, on the other hand, is frequently caused by a fall on an outstretched arm. This would force the humeral head powerfully into the glenoid fossa, rupturing the labrum in the process.

Physical Examinations

Once a patient history is obtained and the mechanism of injury can be estimated, a physical examination is conducted. This begins with range of motion tests in areas around the cervical spine in order to rule out any neurological problems. Next, the injured shoulder goes through several passive and active mechanical tests and is compared to the healthy shoulder in the same tests. In general, the physician pays attention mostly to the tests that produce pain in the patient's affected shoulder. In addition, the physician examines for secondary injuries (in areas such as the rotator cuff) before moving onto SLAP lesion physical tests (Dodson, 2009).

There are numerous physical tests that have been shown to indicate the presence of a SLAP tear; however, orthopaedists speculate over the effectiveness of each in determining labrum lesions. Still, a few tests exist that are widely accepted by the medical community. These include O'Brien's test, the crank test, Neer's test, the Hawkins test, the biceps load test, and the passive compression test.

One of the most widely used tests to indicate the presence or absence of a SLAP lesion is the active compression test, or O'Brien's test (FIGURE 3a, A). In this procedure, the patient arranges his or her arm at 90^{o} forward elevation, 20^{o} adduction, and in the pronated position. The physician then applies a downward force on the forearm while the patient resists. Once complete, the same procedure is done with the forearm in the supinated position. If the patient experiences pain while the arm is pronated and pain relief when the arm is supinated, the test is positive for the presence of a SLAP tear. However, if pain locates in the acromioclavicular joint, the test is negative for a SLAP lesion and a different injury can be suspected. This examination has been found to have a 90% sensitivity and a 98% specificity (O'Brien, 1998) in determining shoulder pathology.

The crank test (FIGURE 3a, B), or compression rotation test, is also a commonly used procedure to suggest the presence or absence of a SLAP lesion. In this examination, the patient's arm is abducted 90^{o} and internally and externally rotated. Meanwhile, the physician applies an axial compressive force in order to push the humeral head into the glenolabral complex. This test is useful for identifying the location of a labrum tear depending on when the patient experiences pain while the shoulder is rotated (Funk, 2009).

The biceps load test II (FIGURE 3a, C) can further characterize the possibility and nature of a SLAP tear. This test begins with the patient lying down in the supine position. The arm is abducted 120^{o} and externally rotated, the elbow is flexed 90^{o}, and the forearm is placed in a supinated position. Next, the patient is asked to actively flex the elbow while the physician applies resistance. If pain occurs during active flexion, then the presence of a SLAP lesion can be concluded. The examination is based on the idea that shoulder abduction with external rotation and elbow flexion causes the biceps tendon to produce a torsional force on the superior labrum. If a tear is present, this torsion will peel at the labrum and enhance pain (Kim, 2001; Funk, 2009).

FIGURE 3a- Physical Examination Tests for SLAP Tears

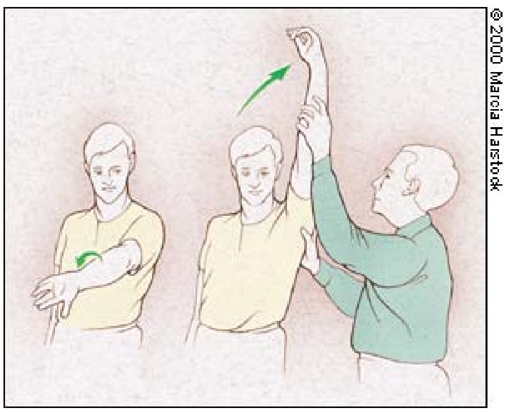
A- O'Brien's Test   B- Crank Test   C- Bicep's Load Test II

FIGURE 3a- The above figure shows a few physical examination tests, among others, that can be used to determine if a patient has a SLAP lesion. Each attempts to reproduce either a torsional or compressive force on the superior labrum (Funk, 2009; Woodward, 2000).

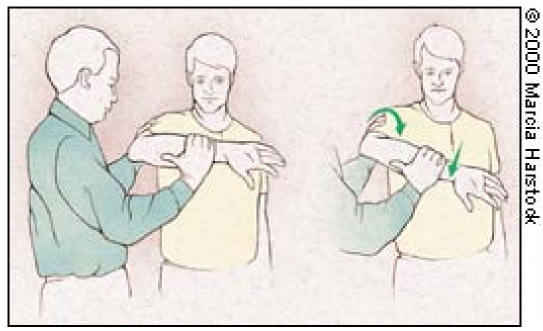
Neer's test (FIGURE 3b, A) and the Hawkins test (FIGURE 3b, B) are two procedures used to supplement initial physical examinations. In Neer's test, the patient's arm is forwardly flexed and passively elevated. If pain occurs, then a SLAP lesion can be suggested. This is because the test produces an impingement of the humeral head on a labrum tear as the arm is elevated. In the Hawkins test, the injured arm is forwardly flexed, adducted, internally rotated, and the elbow is flexed 90^{o}. Like Neer's test, this procedure will produce pain if there is impingement of the humeral head on a labrum tear as the shoulder is internally rotated (Parentis, 2006).

<u>FIGURE 3b- Supplemental Tests for Shoulder Impingement</u>

<u>A- Neer's Test</u>



<u>B- Hawkins Test</u>



<u>FIGURE 3b</u>- The above image shows two secondary tests used to diagnose SLAP tears. Neer's test and the Hawkins test are used to produce impingement of the humeral head or glenoid on the superior labrum (Parentis, 2006).

A final physical examination that is commonly implemented in the diagnosis of SLAP lesions is the passive compression test (<u>FIGURE 3c</u>). This procedure begins with the patient lying on his or her side with the injured shoulder up while the physician passively coordinates all movements. The arm is abducted 30^{o}, externally rotated, and a proximal compressive force is applied to the acromioclavicular joint by the examiner as the humerus is extended. The compressive force is designed to push the superior labrum onto the glenoid. A positive test produces pain or a popping feeling in patients with a SLAP lesion (Kim, 2007).

The value of the passive compression test has been studied for its ability to specifically identify superior labrum tears. This has been considered significant to the study of SLAP tears since most other physical tests cannot precisely detect the location of a labrum tear. In 2007, a study examined 61 patients- who eventually underwent arthroscopic surgery- with the passive compression test.

FIGURE 3c- Passive Compression Test

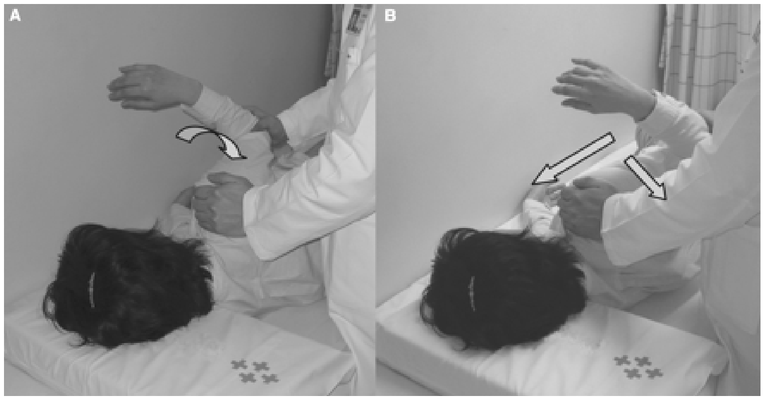


FIGURE 3c- The above image shows use of the passive compression test in which the physician rotates the patient’s arm externally while abducting the arm 30^{o}. The arm is also pushed proximally in order to compress the superior labrum onto the glenoid (Yang-Soo Kim, 2007).

Imaging Techniques

Imaging for labrum abnormalities typically includes magnetic resonance imaging (MRI), magnetic resonance (MR) arthrography, and computed tomography (CT) arthrography. While MRI and CT arthrography can be useful for assisting in the diagnosis of labrum tears, MR arthrography is almost unanimously regarded as the strongest diagnostic tool. In this technique, a contrast dye fluid (gadolinium or gadopentetate dimeglumine) is injected intra-articularly into the patient’s affected shoulder (Dodson, 2009). Typically, the patient’s arm is also placed in an abducted and externally rotated position (ABER). When subjected to magnetic resonance imaging, a distinguishable “spotlight” appears in any pathogenic area in which the fluid can collect- such as in a labral tear (FIGURE 3d).

FIGURE 3d- MR Arthrograms of Normal vs. Abnormal Labrum

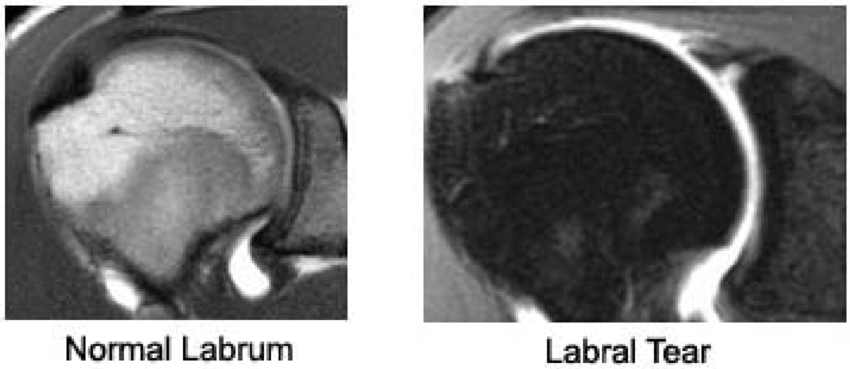


FIGURE 3d- The above images display differences in magnetic resonance arthrograms. With this imaging technique, a contrast dye is injected into the injured shoulder and allowed to collect in open spaces (such as a tear). The image on the left is of a normal shoulder labrum while the shoulder on the right has a labral tear- the bright outline around the shoulder socket is the contrast dye being magnified (Shoulder, 2008).

Most current literature estimates that the MR arthrogram is 80-85% effective in identifying labrum tears (McFarland et al.). Although this value may seem somewhat low, it is significantly higher than other diagnostic tools such as patient history, physical examinations, and traditional MRI. In addition, its superiority amongst diagnostic tools is especially recognized in young, athletic patients with chronic instability leading to SLAP lesions (FIGURE 3e) (Chang, 2008). A study in 2010 found that MR arthrograms are 85% accurate in predicting the presence of a superior labrum tear and 96% accurate in predicting the absence of one (Iqbal et al., 2010). In this study, 124 patients with previously diagnosed SLAP tears underwent an MR arthrogram procedure. Of these patients, 54 had normal arthrograms and 36 tested positive for a superior labral tear (FIGURE 3e). All other participants showed some other shoulder dysfunction. Of the 54 with normal arthrograms, 10 underwent arthroscopy in which one patient proved to have a SLAP tear. Of the 36 patients with positive arthrograms, 26 underwent an arthroscopic procedure in which 22 were found to have a superior labrum tear. In all, the study found that the MR arthrogram is falsely negative in only 4% of patients who have the procedure and is falsely positive in 15%. In addition, arthrograms are significantly more accurate in predicting the absence of a SLAP tear (96%) than the presence of one (85%). Considering these statistics, MR arthrograms are a helpful diagnostic technique in examining the shoulder, especially in preventing patients from undergoing unnecessary arthroscopic surgery (Iqbal et al., 2010).

FIGURE 3e- MR Arthrogram Image of a Superior Labral (SLAP) Tear

FIGURE 3e- The above MR arthrogram image of the anterior-superior [right] shoulder shows a tear in the superior labrum (indicated by the arrow) (Musculoskeletal, 2009).

Although MR arthrography is widely regarded as the best indicator of deep shoulder pathology, traditional MRI and CT arthrography have also been used in some cases. To investigate the effectiveness of each, a study in 1993 compared the three imaging techniques in patients with glenoid labrum tears. Thirty patients with symptoms of shoulder instability and pain underwent all three imaging techniques followed by arthroscopy of the shoulder. In all, 28 patients had labrum tears and a detached labral fragment was found in 26. Of the imaging methods, traditional MRI was 93% accurate, MR arthrography was 96% accurate, and CT arthrography was 73% accurate. In identifying the detached fragment, however, MRI was only 46% accurate, MR arthrography was 96% accurate, and CT arthrography was 52% accurate (Chandnani et al., 1993). As concluded in the study, MRI and MR arthrography are similarly effective in identifying labrum tears; however, MR arthrograms are far more specific in regards to identifying detached fragments. CT arthrograms, on the other hand, are relatively ineffective and, thus, inefficient for use in diagnosing labrum tears.

A primary reason for MR arthrography's prevalence in diagnosing SLAP tears involves the clarity of the image that is produced (FIGURE 3f). Because the patient's arm is in an ABER position, the joint expands and exposes all synovial surfaces to imaging. In addition, this allows the contrast dye to spread throughout the capsule and accumulate in abnormal areas, thus, producing obvious pathology upon imaging (Chang, 2008).

FIGURE 3f- Traditional MRI vs. MR Arthrogram Images of SLAP Tears

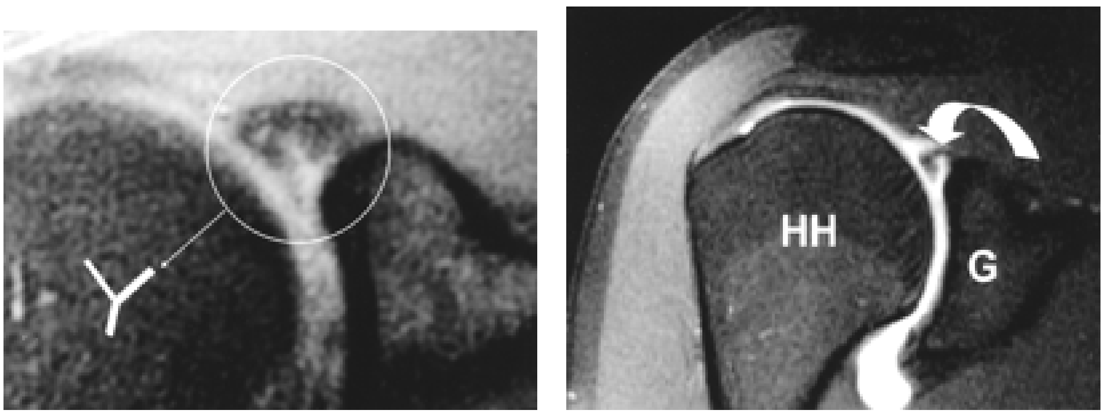


FIGURE 3f- The figure above allows for comparison between traditional MRI and MR arthrogram imaging techniques. The MRI image (left) of the shoulder shows a Type II superior labral anteroposterior lesion which has been circled. The MR arthrogram image (right) also shows a Type II SLAP tear indicated by the arrow, yet this image provides more precision in imaging. This allows for a better and more comprehensive diagnosis of the shoulder (Mohana-Borges, 2003).

Legend: HH= Humeral Head; G- Glenoid Fossa

Non-Surgical Treatment

Once diagnosis of a SLAP lesion is made, a patient is presented with the option of undergoing a surgical repair of the tear or attempting to let the injury heal without invasive treatment. Although non-operative treatment is usually unsuccessful- especially in throwing athletes- it may be opted for in patients with Type I SLAP tears (since these are characterized by mere fraying of the labrum). The initial step of this conservative treatment is a total stop of all overhead and throwing activities along with use of antiinflammatory medication. Once most pain has subsided, a physical therapy program can be implemented. This focuses on increasing the stability, flexibility, and strength of the shoulder joint. Stretching concentrates on the posterior capsule so that internal rotation can be improved (as most overhead athletes with SLAP injuries face a loss of internal rotation). Once stable and flexible, the shoulder can begin a strengthening phase which aims at boosting core, trunk, rotator cuff, and scapular muscles (Dodson, 2009). Finally, the patient, if a throwing athlete, can start an interval throwing program at three months post-injury.

Although non-surgical treatment is beneficial in reducing pain and restoring function, it has generally proven unsuccessful in keeping overhead athletes' shoulders healthy in the long-term. This is because it aims to treat the symptoms of a torn labrum rather than facilitate an environment for the injured labrum to reattach and heal alongside the glenoid. For this objective, surgical repair of the labrum is a necessity.

Surgical Treatment

Repair of the Glenolabral Complex

Surgical repair of a torn labrum is usually necessary with Types II-X since the labrum has detached from the glenoid fossa (Type I, fraying, typically does not need an invasive procedure). The best way to accomplish this is via a shoulder arthroscopy rather than an open operation. An arthroscope is a tiny camera that the surgeon can maneuver inside the shoulder socket to locate a tear (FIGURE 4a) (Shoulder, 2008). Once identified, the surgeon can repair the injury with several other tiny instruments. This method is valued because it saves much more healthy tissue in the patient than an open procedure would. Once the physician and patient agree upon arthroscopy, an appointment is made for the outpatient procedure.

FIGURE 4a- Arthroscopic View of Labral Tear

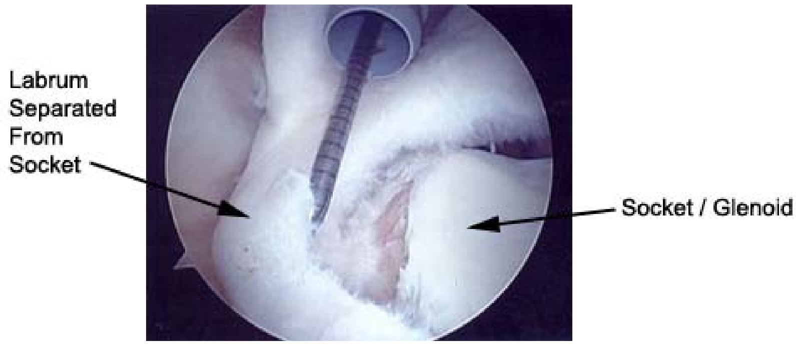


FIGURE 4a- The above figure provides an arthroscopic view of a shoulder socket with a labral tear (Shoulder, 2008).

To begin the surgical procedure, general anesthesia is given to the patient along with a nerve block to further numb the area around the shoulder. Once asleep, the patient is positioned on his/her side (decubitus position) so that the injured shoulder is upwards. The surgeon then makes incisions along the shoulder joint for entry of the arthroscope. Typically, the surgeon enters the shoulder through a posterior portal and circumferentially examines the joint to locate the labrum and determine the extent of injury (Nofsinger, 2010). The arm is then positioned in such a way that the biceps tendon pulls on the labrum (FIGURE 4b, A). This is performed to determine if the labrum has detached from the glenoid. Next, damaged and excess tissue is removed from the injured area (FIGURE 4b, B) so that the labrum will be able to heal directly onto the glenoid bone without interference (Portland). [This step is known as a debridement and, in some patients, can be the extent of a surgical procedure on a torn labrum. In these patients, the labrum will be allowed to naturally heal onto the glenoid over a course of approximately 18 months. More recently and with younger patients, however, further repair is necessary]. Once cleaned of excess tissue, bioabsorbable anchors- screws with attached sutures- are inserted deep into the glenoid (FIGURE 4b, C). These sutures are then knotted around the labrum so that it can grow against the fossa (FIGURE 4b, D) (Portland).

FIGURE 4b- Surgical Repair of a Torn Labrum

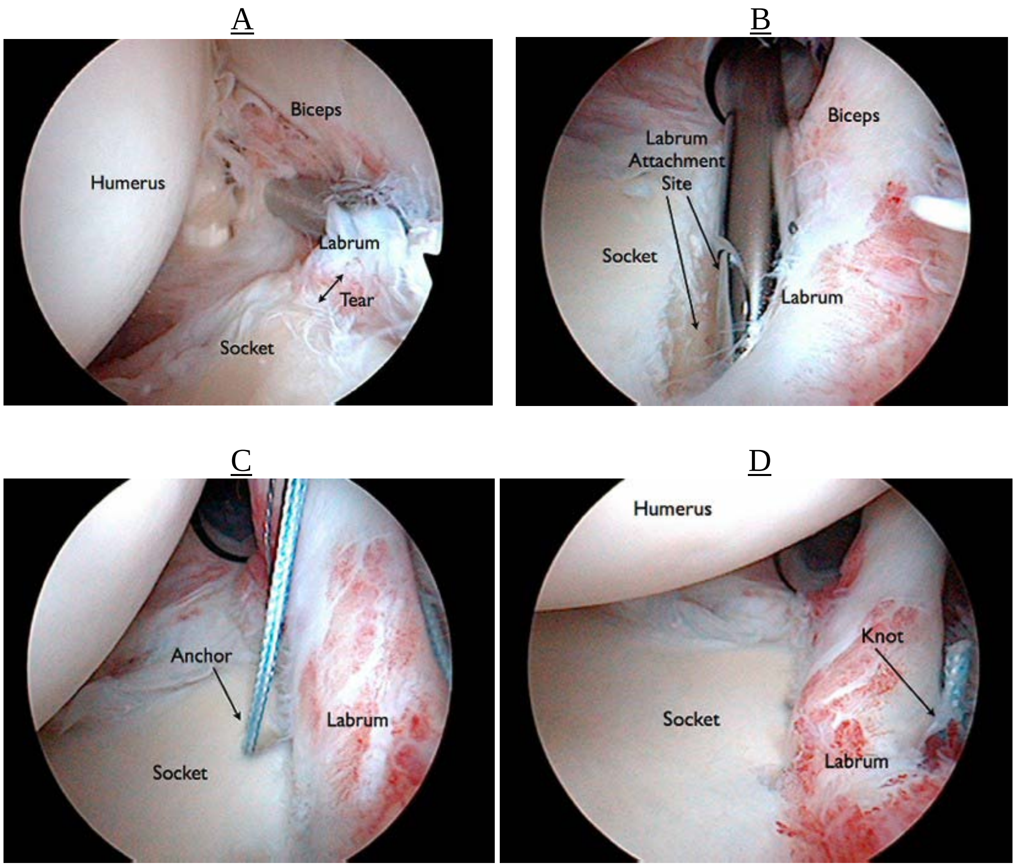


FIGURE 4b- The above arthroscopic images show the major steps of a labral repair. Image (A) displays the identification step of the labral tear. Image (B) displays debridement of the excess dead tissue around the shoulder socket. Image (C) shows sutures arising from anchors within the glenoid socket and being tied around the labrum. Image (D) shows knots being tied in the sutures to secure the labrum against the prepped glenoid socket (Portland).

Once the bioabsorbable sutures have tied the labrum alongside the glenoid, the area is profusely irrigated and examined circumferentially to confirm proper attachment of the labrum (FIGURE 4c). Auxiliary anatomy can also be probed to ensure there is no remaining tissue damage (Nofsinger, 2010). Last, nylon stitches are used to close the incisions, and the patient is taken to a recovery room and awoken. On the whole, SLAP surgical repairs are 90-95% successful in restoring a patient's shoulder to normal function. In overhead athletes, however, this statistic may drop in regards to returning a player to his or her previous level of performance (Portland).

FIGURE 4c- Arthroscopy of Labral Tear: Before and After

FIGURE 4c- The above figure shows the shoulder before and after surgical repair of a torn labrum. Postoperatively (right), the labrum has been tied against the glenoid socked with sutures inserted into anchors within the socket (Shoulder, 2008).

Debridement

Aside from the intricate shoulder labrum reconstruction operation, a simpler procedure exists which merely "cleans" the shoulder socket where a tear locates. This is known as a debridement and is characterized by identification of the tear and a corresponding removal of all damaged and excess tissue (FIGURE 4b, A-B). As a result, the labrum is allowed to reattach and grow naturally alongside the glenoid.

Though the debridement is much simpler than the repair procedure, it requires much more recovery time for overhead athletes (18 versus 6 months). In addition, it can only be performed on SLAP tears in which the biceps tendon is not involved- Types I and III (Dodson, 2009). Still, a full labrum repair can be performed on a Type III SLAP lesion with added long-term benefits. That is, the debridement procedure has been found insufficient upon post-operation follow-ups. A retrospective study in 1992 examined the shoulders of 40 overhead athletes who had a debridement procedure on labrum tears. At a minimum two-year follow-up, only 7% of patients presented with no shoulder pain. 72%, however, indicated that they had symptom relief in the first year after surgery, but this relief declined over time (Altchek et al., 1992). As a result, it was determined that the debridement procedure is an ineffective long-term treatment for labrum tears in overhead athletes.

Biceps Tenodesis

Aside from the standard shoulder labrum surgical repair operations (debridement or reconstruction), a new procedure has gained some popularity recently. This procedure, known as biceps tenodesis, aims at preventing the biceps tendon from being able to pull on the superior labrum by excising it and attaching it to the head of the humerus. The operation is based on the proposal that the biceps tendon- either present or absent- does not have an effect on the stability of the shoulder. Thus, by removing its origin on the superior labrum, the prevalence of SLAP tears will decline (since these tears often occur when the tendon jerks on the labrum). In addition, the surgery has been found to alleviate pain caused by labrum tears without affecting the biomechanics of the shoulder (Dodd, 2010). Still, many doctors are unsure of the exact function of the biceps tendon and caution patients, especially baseball players, who consider having a tenodesis operation. This is because throwing and, specifically, pitching puts a huge amount of stress on all aspects of the shoulder. Until an exact characterization of the biceps tendon is made, many sports medicine physicians will continue to question the benefits of a biceps tenodesis (Dodd, 2010).

Rehabilitation

Rehabilitation for shoulder surgery focuses on a few goals: allowing the repaired anatomy to heal, restoring range of motion, rebuilding strength in the shoulder, and returning to previous levels of activity and performance (Shoulder, 2008). Further, the rehabilitation program depends on several factors such as SLAP type, surgical procedure performed, and the presence of any other pathology (rotator cuff tears, for example).

Generally, following surgery, the patient’s repaired arm is placed in a sling for one month to limit motion. During this time, the sling prohibits external rotation and limits abduction. This allows optimal healing of the glenolabral complex as bone ingrowth can take place without interference (Portland). In addition, the patient is advised to ice the affected shoulder for 20-30 minutes every few hours in order to minimize inflammation. Follow-up visits are also scheduled for two weeks post-operation so that the physician may check the morphology and repair of the shoulder (Shoulder, 2008). At four weeks, the patient begins physical therapy including passive and active exercises to restore range of motion. At eight weeks, the patient can begin strengthening exercises that focus on the scapular muscles. Meanwhile, the biceps muscle remains in an idle, healing process so as to not disturb the newly repaired biceps anchor in the superior labrum (this time period may be extended for Type IV SLAP tears). Finally, at four-six months post-surgery, the patient can fully return to work or sports.

For baseball players who have had a surgical repair of a SLAP tear in their shoulder, rehabilitation is far more extensive and rigorous. During weeks one-three in which mobility is still restricted, the thrower begins wrist and elbow range of motion exercises and mild strengthening. Once removing the sling at four weeks, he or she goes through passive shoulder range of motion exercises and continues elbow flexion mobility. Week five consists of body-weight prone-position back rows and scapular retraction exercises to begin strengthening the muscles of the trunk and rotator cuff. In addition, the thrower begins internal and external rotation movements against gravity. At week six, a Swiss-Ball workout is introduced. This consists of the patient lying in a prone position on top of an abdominal ball and performing shoulder extensions in the posterior, anterosuperior, and superior directions. In addition, the patient begins weighted shoulder shrug exercises and rice bucket workouts to strengthen the forearm. In week seven, the patient begins protraction, standing internal and external rotation, and shoulder flexion exercises to expand shoulder stability and range of motion. With week eight, the strengthening portion of the rehabilitation is vastly increased. The thrower begins chest press movements and supine overhead latissimus dorsi pullovers. In addition, protracted rhythmic stabilization maneuvers are introduced. Weeks nine and ten include a progression of all range of motion and strength exercises as well as an exercise consisting of the patient swinging an unweighted stick for enhanced rotational trunk stability. In weeks eleven, twelve, and thirteen, the patient (if a position player) can begin hitting off of a tee and throwing tennis balls with a coordinated quantity and distance of throws. Finally, in week fourteen, an interval throwing program is instituted in which the distance and quantity of throws in gradually increased with each day (Herran, 2010). Finally, at approximately six months post-operation, the thrower is prepared for a full return to sports. Still, however, the exact time it takes for a full recovery depends on several factors such as personal rate of healing, extent of injury, post-surgical complications, and work level in the rehabilitation program (Shoulder, 2008).

SLAP Tears and Baseball

Biomechanics and Physical Stresses of Pitching

While all pitchers differ slightly in their throwing motion, there are a few general stages that each goes through in an effort to exert the baseball towards his target at home plate. Some of these stages may or may not occur depending on whether the pitcher is in the “wind-up” (six stages) or the “stretch” (five stages) motion. A pitcher typically throws using the wind-up motion when there are no base runners present and uses the stretch motion with runners on base.

The wind-up begins at rest as the pitcher stands on the mound rubber and prepares to throw a pitch. Next, the wind-up (FIGURE 1, 1) involves a slight step-back followed by a raising of the non-dominant leg towards the abdomen. In the stride (FIGURE 1, 2), the raised leg extends towards home plate, and the throwing arm begins to abduct and externally rotate upwards. In the arm-cocking phase (FIGURE 1, 3), the non-dominant foot is firmly planted on the ground, and the throwing arm reaches optimal abduction, external rotation, and elbow flexion. Next, the acceleration stage (FIGURE 1, 4) is characterized by a rapid increase in arm motion towards home plate. During this stage, the shoulder reaches maximal external rotation while abduction and elbow flexion remain relatively constant. In the later part of this stage, the shoulder begins to internally rotate in order to direct the baseball towards home plate. This phase ends with a release of the baseball. After acceleration and release, the deceleration stage (FIGURE 1, 5) involves a rapid deceleration of arm motion via shoulder adduction and elbow extension. Also, the planted leg straightens as the pitcher’s momentum pushes him toward home plate. Finally, in the follow-through (FIGURE 1, 6), the dominant leg is pulled off the ground, and the trunk returns to an upright position in an effort to counteract the momentum generated by throwing (Whiteley, 2007).

The stretch or "set" motion includes all of the above stages with the exception of the wind-up (stage 1). In order to prevent runners from easily advancing to the next base, the pitcher must begin his motion at a state of rest on the mound rubber, ready to activate the stride stage immediately from this rest. The physical stress that each of these motions have on the shoulder will be discussed next.

FIGURE 5a- Stages of a Pitcher's Throwing Motion

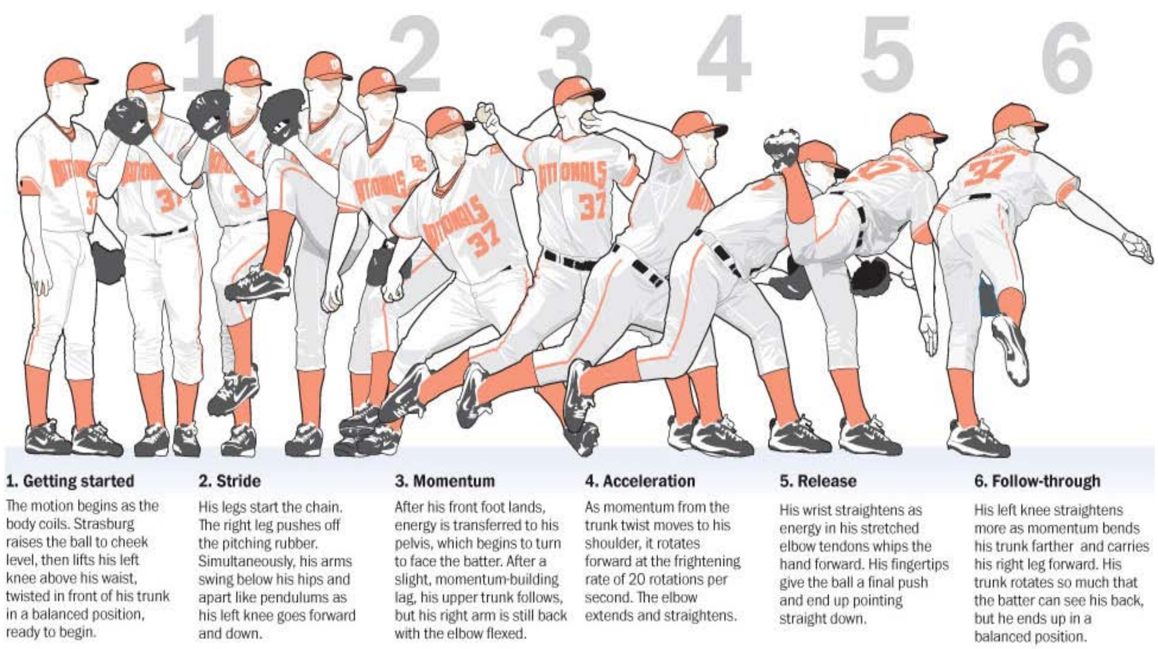


FIGURE 5a- The above figure shows the stages of a pitcher's throwing motion. The process starts at rest, followed by the wind-up (1), stride (2), arm cocking (3), acceleration (4), deceleration (5), and follow-through (6) (Adair, 2010).

The sport of baseball can be viewed as one with periods of idleness interspersed with brief moments of extremely aggressive body kinetics. These violent motions include the forceful trunk rotation that occurs in hitting as well as the maximized shoulder and elbow angular velocities that take place in throwing. The latter movements are of great significance when considering frequent injuries that arise from the sport. That is, now-famous procedures such as "Tommy John" surgery or the increasingly prevalent SLAP repairs have become routine operations in the sports medicine field. In addition to perfecting these procedures, however, there must be a closer examination into the physical stresses which cause the injuries they repair. As such, there are several physical forces that must be accounted for during the pitching motion (or general throwing motion). This discussion will focus only on the forces that are applied to the shoulder and can influence the occurrence of a labrum tear.

Several extreme movements that the human body can endure peak during the throwing motion. For example, the highest recorded angular velocities of any movement- $10{,}000^{o}/_{sec}$ in the acceleration stage of throwing- occur when a pitcher throws a baseball. In addition, while accelerating during throwing, the anterior shoulder can experience a force that peaks at 350 Newtons (N)- near the threshold of injury. These shocking values, along with several others, have been calculated through several studies of the kinematics of the pitching motion.

For the sake examining only the key factors than can lead to injury in pitching, the rest and wind-up phases can be neglected since they impart no force on the shoulder. Beginning with the stride stage, pitchers have a stride length of approximately 87% of body height which is directed toward home plate within a 10cm gap to the left or right. In addition, the stride (non-dominant) foot is closed (slightly angled toward the throwing arm) by $10\text{-}15^{o}$ in reference to a line drawn directly towards home plate. Throwers who deviate from this average technique often face increased forces on the shoulder. For example, an additional 3N of anterior shoulder force occur for every centimeter the stride foot lands toward the open side. Similarly, an extra 2N of anterior shoulder force occurs for every degree the stride foot lands at an open placement (Fleisig, 1994). This supplemental stress could explain why position players (non-pitchers) also face a risk of torn labrums. That is, many throws in a live game, especially those made by infielders, are done so while off-balance or in an open body position (leading foot away from the throwing arm side). This lack of proper technique, though necessary, causes additional forces on the anterior shoulder. By landing with the stride foot deviated towards a closed position, however, a pitcher or player does not face any increased shoulder stress (Fleisig, 1994).

A frequent mechanism of injury involving SLAP occurs during the arm-cocking phase of throwing. This is known as the "peel-back" mechanism and takes place while the arm is abducted and maximally externally rotated. At this point in the throwing motion, the shoulder rotational force couples with increased biceps flexion and creates both a pulling and torsional force on the superior labrum where the biceps tendon anchors to it. As a result, the anterior aspect of the biceps anchor can begin to "peel-back" and tear on the superior labrum (Dodson, 2009). This can create either Type II or IV SLAP lesions. Further, maximal external rotation can pose a risk for injury as the humeral head is forced to translate anteriorly. As a result, the posterior rotator cuff may become impinged between the humeral head and the labrum. Over time, this continuous impingement can lead to fraying of both the labrum and rotator cuff (Pathomechanics). Type I SLAP tears might be explained in this manner.

The acceleration phase of throwing, though commonly examined for its stress on the ulnar collateral ligament which possibly leads to Tommy John surgery, can present additional strain on the shoulder as well. First, longitudinal distraction of the glenohumeral joint during the acceleration stage can lead to shoulder instability. This distraction occurs at the point of stride foot contact while the elbow is flexing. It has been found that pitchers who maintain a more flexed elbow at the points of stride foot contact and ball release (close to 90^o) experience less longitudinal distraction than those with less flexed elbows (less than 70^o) (Werner et al., 2001). As a result, these groups observe less frequent shoulder pain and injury. Continuing, external rotation is a key variable in the acceleration stage as figures up to 210^o have been recorded during pitching (Werner et al., 2001). It has been found that a decreased amount of external rotation at the point of stride foot contact boosts the longitudinal compressive force on the humerus by $1.5N/^o$. This additional compressive force, coupled with rotation, is often associated with labrum injuries (Fleisig, 1994). Finally, it is common for throwers to have increased passive external rotation flexibility with decreased internal rotation flexibility. For those whose decreased internal range of motion surpasses their increased external flexibility, the risk for labrum injury rises. Therefore, proper stretching and avoidance of decreased internal rotation can be restorative and preventative of shoulder injuries (Burkhart, 2003).

The deceleration and follow-through phases, though insignificant to the quality of pitch thrown, are perhaps the most important mechanical aspects of shoulder health. The force that is required to slow and stop the rapidly rotating arm is provided by a combination of several muscles and other anatomical aspects. One of these, the posterior inferior glenohumeral ligament, can gradually wear down throughout years of throwing. This results in a shortening and thickening of the ligament which, then, can translocate the humeral head during different phases of throwing. It is believed that this translocation directly influences the presence of SLAP tears due to fraying of the posterior superior shoulder (Burkhart, 2003). A second common cause of SLAP tears is the pulling of the proximal biceps tendon on the superior glenoid labrum during arm deceleration. The force of the flexing biceps- in order to prevent hyperextension and to slow internal rotation and horizontal adduction- jerks at the muscle's anchor on the superior labrum, leading to a fraying or detachment of the biceps from the labrum (Andrews, 1985). This type of injury characterizes Type I-IV SLAP tears and is more prevalent in pitchers with improper mechanics (Pathomechanics).

While the throwing of curveballs and other non-fastball pitches is frequently suspected as a source of shoulder and elbow pathology, it does not have an effect on injury occurrence. It might, however, influence the amount of pain present. That is, curveballs have been found to increase the risk of shoulder pain while sliders have been associated with more elbow pain (Lyman, 2002). Nonetheless, the frequency of both pitches as well as the age at which they are thrown show no correlation to injury. Instead, the greatest promoters of shoulder and elbow injury are pitching with high frequency, pain, and fatigue (Olsen, 2006).

Impact of SLAP Tears in Baseball

Although most focus lies on the elbow, the importance of a healthy shoulder labrum is a necessity to baseball players, especially pitchers. While a torn ulnar collateral ligament (UCL) once served as a death sentence to a player's career, the advent of "Tommy John" surgery nullified this injury with an 85% success rate in returning pitchers to the mound (Carroll, 2004). The labrum, however, does not have such a proven procedure. This may lie in the foundational location of the injury- the shoulder-which is the central worker in throwing. In other words, when a player receives Tommy John surgery for an elbow UCL tear, the rehabilitation focuses on shoulder strengthening and flexibility to take the stress off of the elbow. When the labrum tears, however, there's no other anatomical structure to assist in carrying the stress load. As a result, a previously injured shoulder must be relied upon for the remainder of a pitcher's career. These points may be considered when reviewing current literature on the success rates of SLAP repairs in baseball players.

A study in 2008 examined the success rates of SLAP repairs in over 40 Major League Pitchers. In considering statistics such as earned-run-average (ERA), innings pitched (IP), and walks and hits per inning pitched (WHIP), the group showed a postoperative decline in pitching performance in comparison to their pre-injury levels. Of the 42 pitchers, 69% returned to the Major Leagues for one year, but only 29% lasted for up to three years. In terms of statistics, most showed no difference in ERA or WHIP but there was a sharp decrease in IP throughout the group (Cerynik, 2008).

A similar study in 2010 examined the performance of 23 elite overhead athletes at three years postoperative of a SLAP repair. Of the 23, 13 (57%) had returned to their previous levels of performance without pain. In addition, six were playing with pain and four were not playing because of pain (Neri, 2010).

An Analysis of SLAP Tears in Collegiate Baseball Players

Background

In order to relate to the presence of SLAP injuries in baseball, a study was conducted which surveyed seven collegiate baseball players who had labrum tears and/or reconstructive surgeries within the past two years. This study consisted of a questionnaire that inquired into the details of each subject's case including pre-injury shoulder strengthening, the moment of trauma or tear, post-injury stress, and post-recovery mental outlook. All subjects volunteered for the study, and their responses to the prompts will remain anonymous.

Methods and Materials

A questionnaire consisting of eight prompts regarding the subjects' injuries was created and distributed to seven collegiate baseball players. The subjects consisted of both pitchers and position players who had injured their labrum and either received surgical reconstruction or a physical therapy program for it. The questionnaire was comprised of two prompts regarding pre-injury shoulder identity that inquired into any previous arm injuries and previous shoulder strengthening mechanisms. One prompt regarded the moment of trauma or stress which lead to the injury. Three prompts regarded post-injury diagnosis, surgical reconstruction, and treatment. Finally, two prompts inquired into the subjects' mental outlook about their injury (how confident they are in their shoulder, what stage of recovery they are at).

All of the subjects completed the questionnaire at their leisure and returned it to the examiner within a month. In addition, the subjects were informed that their responses and participation in the study would remain confidential and anonymous. After reading the responses in each questionnaire, a statistical analysis of each prompt was performed and the results listed below.

Results

Of the seven baseball players who had a shoulder labrum injury within the past two years, five (71%) of them indicated that they had previous throwing arm injuries and/or surgeries. Two (29%) of them informed that this injury consisted of shoulder impingement accompanied with tendonitis. Another two subjects indicated that they had previous ulnar collateral ligament (UCL) reconstructive surgeries (or "Tommy John surgery"). One subject had previously dislocated his shoulder.

All subjects (100%) indicated that they were doing shoulder strengthening/rehabilitative work on their shoulder at the time of their labrum injury. Five (71%) subjects indicated that this consisted of shoulder band (Thera-Band) workouts including internal and external shoulder capsule strengthening. The extent and intensity of this strengthening, however, was not specified. One separate subject did, in fact, specify that his shoulder band work was quite limited. Last, one subject was recovering and rehabilitating from an ulnar collateral ligament surgical repair when he injured his labrum.

The majority of the subjects (57%) described the moment of their injury as a "pop" with ensuing pain whenever they performed an overhead or throwing motion. One subject (14%) felt no pain, yet he indicated that he could not move his arm after tearing it. Another described his injury feeling as general tenderness with moderate to severe pain when reenacting a throwing motion. Finally, one subject expressed the moment of injury as an intense pain as if his "shoulder detached from [his] body." The clinical severity of each subject's injury, however, was not included in these descriptions.

All subjects (100%) underwent range of motion examinations as well as magnetic resonance imaging in order to diagnose their shoulder labrum tears. In regards to the range of motion exams, two subjects (29%) felt pain when performing external rotation movements, one (14%) felt pain when any resistance was applied to a movement, and one (14%) felt pain in each range of motion exercise conducted. Six of the seven subjects (86%) had surgery on their shoulder labrums. Of these six, five (83%) had a surgical repair of their labrum including the insertion of anchors and sutures to reattach the labrum to the glenoid socket. One of the six (17%), however, had a debridement of his shoulder socket whereby any loose or damaged tissue was removed without reattachment of the labrum to the glenoid. Last, one subject declined receiving surgical treatment on his torn labrum. Post-surgical treatment for the injury was mostly the same for each subject. All subjects included extensive stretching, shoulder band strengthening workout programs, icing, and physical therapy modalities in their description of the treatment and rehabilitation they underwent post-surgery. The stretching and shoulder strengthening focused mainly on external and internal rotation with the intention of maximizing stabilization and strength within the shoulder. In addition to this rehabilitation, six subjects (86%) were put on an interval throwing program at four months post-surgery whereby they exercised the throwing motion by gradually increasing the distance and/or amount of throws each day. One subject, who declined surgical repair, took time off to allow his shoulder to heal naturally while icing and performing minimal shoulder band strengthening exercises.

When prompted to state the stage of recovery they felt they were at, all of the subjects indicated that they were above 50% rehabilitated. One subject, who declined surgery and did not resume collegiate athletics, stated that he was at a full recovery with the exception of throwing competitively. He felt he could physically perform any other task without pain. One subject felt that he was between a 90-100% recovery, three (43%) felt they were between 70-90% rehabilitated, and one subject felt between 50-70% recovered. When asked to rate their confidence level in regards to their reconstructed labrum maintaining its proper physiology, three subjects (43%) feel very confident in the health and future maintenance of their shoulder. One subject described his status as "hopeful" but did not express his level of confidence in his shoulder. Two subjects (29%) indicated that they are still somewhat scared that their labrum might get injured again. Both described the injury as "lingering in the back of [their] minds since getting hurt. Last, one subject, who had described the moment of his injury as his "shoulder detaching from [his] body" and had undergone only a debridement surgical procedure, felt doubtful and hesitant that his labrum would remain injury-free in his future career.

Discussion

Considering that five of the seven subjects had arm injuries prior to their torn labrum, it might be concluded that there is a correlation between a player's specific throwing mechanics and his risk for injury. This could involve unfavorable stride length, foot placement, and/or poor shoulder flexibility in external or internal rotation. Also, the treatment for each of the listed prior injuries includes shoulder strengthening programs (even ulnar collateral ligament reconstruction). Should this rehabilitation be performed incorrectly, the stabilization and strengthening muscles of the shoulder might not heal or perform properly in a movement such as throwing. Further, if any shoulder rehabilitation was performed to an insufficient extent, capsular laxity could develop which would make the shoulder susceptible to injury. This capsular laxity is often seen in the anterior shoulder prior to Type II labrum lesions (Mihata, 2008). As a result, instability occurs at 90^o abduction of the shoulder- a necessary arm location in throwing. This laxity could explain at least one subject's (who indicated he was performing only minimal shoulder band workouts) labrum injury. Similarly, several subjects (71%) listed shoulder band strengthening as their only pre-injury treatment. If the band workouts were performed insufficiently, it is possible that capsular laxity could explain their injuries as well.

Based on the subjects' descriptions of the specific moment of injury, it is reasonable to conclude that most baseball-related torn labrums present as a "pop" with ensuing pain, especially when attempting to perform a throwing motion or other overhead movement. Since all subjects are baseball players, and Type II lesions are the most common labrum injuries to throwers, it is reasonable to conclude that all subjects who felt this "pop" with ensuing pain experienced a Type II tear. This is supported by the fact that Type II lesions include a detached labrum which could account for the "pop" these subjects felt. Similarly, subjects whose tears presented as general tenderness or immobility could have had different types of lesions, most likely Type I which is characterized by mere fraying of the labrum without detachment from the glenoid.

Considering that all subjects underwent range of motion examinations and magnetic resonance imaging to successfully diagnose their labrum injuries, it can be concluded that the combination of these two diagnostic tools is a useful method for determining the presence and extent of a labrum lesion. Although the study did not probe into the type of MRI used (traditional or arthrogram with contrast dye), prevailing literature indicates that MR arthrogram is more up to 90% accurate in determining the extent of a shoulder injury- see FIGURE 3f, Diagnosis: Examinations and Imaging Techniques (Bencardino, 2000). Continuing, six of the seven subjects had decided to undergo surgery to correct their labrum injuries while one subject declined surgical repair. The one subject who declined did so because he did not wish to continue with competitive athletics and, thus, did not find the operation necessary. Further, in five of the six subjects who had surgery, a reconstructive operation was performed to reattach the labrum to the glenoid via anchors and sutures. One subject had only a debridement to remove excess or damaged tissue, allowing the labrum to naturally reattach to the glenoid. The five subjects who underwent reconstructive surgery were able to begin throwing again at four months post-operation and were healed or are on pace to heal at approximately six months post-operation. On the other hand, the subject who had merely a shoulder debridement is currently two years out of surgery and still experiencing frequent setbacks in his rehabilitation program. Based on this information, it is a plausible claim that the reconstructive surgical procedure is far more efficient than a debridement for torn labrums in baseball players. That is, it can be reasoned that a naturally healing labrum is more vulnerable to future detachment from the glenoid than a surgically repaired one. Finally, based on the subjects' responses, the most efficient rehabilitation of a SLAP lesion is extensive stretching and shoulder strengthening in the rotator cuff and capsular muscles. Upon completion of this initial treatment, an interval throwing program is useful for easing a player's shoulder back to a competitive level. This is because the program is a gradual process to reinforce the throwing motion by a step-wise increase in distance or quantity of throws each day.

When asked to indicate the stage of recovery they felt they were at, almost half (43%) of the subjects felt that they were between 70-90% of normal function. These subjects are either still on a rehabilitation program or are in a state of maintaining their repaired shoulder. As one can understand, these subjects generally expressed a feeling of anxiety and uncertainty in the present and future health of their shoulder. They did, however, indicate that they are hopeful and confident in their rehabilitation despite feeling a bit of fear in the whole process. Continuing, two subjects felt that they were between 90-100% recovered and were very confident in the future health of their shoulders. These subjects have witnessed the benefits of a successfully repaired labrum and the efficiency of a proper rehabilitation program including stretching, strengthening, and interval throwing. One subject, who had declined surgery, indicated that he has seen a 100% recovery and is able to do any activity he wants with the exception of competitive pitching. Because baseball is the one activity this subject cannot take part in, the magnitude and prevalence of labrum tears in the sport must continue to be examined by the athletic and sports-medicine community. Finally, one subject, who had a debridement procedure on his torn labrum, indicated that he is between 50-70% of normal function. This subject also indicated that he is hesitant and doubtful that his shoulder will return to a level in which he can successfully throw again. Considering his minimal surgical procedure and consistently hindered rehabilitation, it can be concluded that a debridement procedure, while perhaps useful for non-athletes, is insufficient for throwers and other overhead athletes. Further, should a debridement be performed in an overhead athlete, ample recovery time (far more than with a reconstructive surgery) must be included in the rehabilitation process.

Conclusion

Of the ten different forms of SLAP tears, Types I-IV are the most common to baseball players, and the mechanism for each type can vary. First, improper stride foot placement in an open position can create supplemental force on the anterior shoulder. This could explain the presence of SLAP lesions in position players (non-pitchers) in baseball since they are frequently forced to throw off-balance and in an open position during a game. Second, in the arm-cocking phase, maximum external rotation coupled with biceps flexion can create a pulling and torsional force, causing the biceps anchor to peel back on the superior labrum. This would be common in Type II, III, and IV lesions. In addition, humeral head translation can occur in this phase leading to impingement of the rotator cuff on the labrum. With acceleration, flexibility in both external and internal rotation is key to maintaining a healthy shoulder. For example, decreased external rotation can create excess longitudinal force of the humeral head on the labrum. Also, throwers with decreased internal rotation are more prone to shoulder injuries. Finally, in the deceleration phase of throwing, biceps flexion coupled with adduction is an important movement that affects the health of the labrum. In shoulders experiencing capsular laxity, the force of the biceps can rip at its tendon anchor on the superior labrum, thus, creating Type II or IV lesions.

When a patient presents with the symptoms of a SLAP tear (pain, clicking, dysfunction), a definitive diagnosis is often very difficult. A patient history may allow a physician to rule out certain injuries based on the mechanism of injury and presence of certain symptoms. Next, a wide range of physical examinations exist that can suggest a labral lesion. A few of the more prevalent of these include the active compression test (O'Brien's test), the crank test, the biceps load test II, and the passive compression test. In addition, Neer's test and the Hawkins test can supplement the physical examination to investigate shoulder impingement. Continuing, imaging is often the most dependable tool used to diagnose a SLAP lesion. Although MRI and CT arthrography can be implemented to study the shoulder joint, MR arthrography is recognized as the most precise imaging technique for determining the presence (or absence) of a SLAP tear. This can be explained by its enhanced clarity in illustrating the shoulder capsule and presence of any abnormalities (Figure 3f). Together, a thorough history, positive physical tests, and indicative imaging results can allow a physician to diagnose a patient's SLAP tear and recommend a surgical repair of it.

Although three surgical procedures exist for treatment of a SLAP tear, only a full repair has been thoroughly accepted as a successful route in returning an athlete to his or her full level of performance. This is because the operation (Figure 4b) provides for immediate, healthy re-growth of the labrum to the glenoid via anchors and sutures that connect the two. A debridement procedure, however, merely removes damaged and excess tissue from the capsule. Therefore, as a patient rehabilitates, the labrum is much more vulnerable to re-injury. Further, a biceps tenodesis, though suggested to remove the possibility of the biceps pulling on the superior labrum, is insufficiently studied at this point and is, therefore, only an experimental operation on a thrower's shoulder. That is, the exact function of the biceps tendon has not been thoroughly evaluated and defined by orthopaedists. Thus, by undergoing the innovative procedure, a thrower is taking a big risk in his long-term health and career.

Rehabilitation is the final step in getting an athlete back to his or her sport. Advances in range of motion, stability, and strength characterize this developmental stage. Typically, these advances begin distally with the wrist and elbow while the shoulder is immobilized for up to four weeks. Then, once the labrum has had ample time to grow onto the glenoid, range of motion and strength exercises can target the stabilizing muscles of the shoulder- the rotator cuff and trunk muscles. Only when the shoulder has sufficient stability, the patient can begin strengthening the muscles involved in throwing. Finally, at approximately four months postsurgery, the patient can start an interval-throwing program. This is designed to step-wisely increase the load of throwing that the shoulder can tolerate by gradually raising the quantity of throws or distance with each day. This extensive rehabilitation should put a patient back on the field at about six months post-operation.

Though diagnosis, surgery, and rehabilitation of the SLAP tear has gradually improved over the past decade, there is still a need for further study into prevention and potential treatments of the injury, specifically in the sport of baseball. For example, shoulder maintenance and strengthening programs could be mandated in all healthy players in order to prevent capsular laxity. This "pre-habilitation" would not only increase the stability of the shoulder joint, but it would decrease the amount of stress that gets put on the labrum while throwing. Similarly, range of motion workouts aimed at increasing internal and external rotation could be included in these programs. This would be beneficial considering that throwers whose gains in external rotation outweigh their losses in internal rotation are more prone to shoulder injuries. Last, the biceps tenodesis procedure should be further investigated as a potentially successful treatment for SLAP tears. Though the operation has had success in football players and lower-level baseball pitchers, it needs more appeal amongst Major League Baseball team physicians. Before this can happen, however, the exact physiology of the biceps tendon (or other concealed anatomy) must be determined. Nonetheless, despite once being a mysterious, career-ending injury for pitchers at all levels of baseball, the SLAP tear has become an exciting point of focus amongst sports orthopaedists over the past two decades.

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