CURRENT CONCEPTS REVIEW

Disorders of the Proximal and Distal Aspects of the Biceps Muscle

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Proximal Aspect of Biceps

- Tenodesis of the long head of the biceps may offer improved cosmesis, improved strength, and diminished activity-related pain compared with tenotomy, although comparative studies have shown similar outcomes in some patient populations.

Distal Aspect of Biceps

- Operative treatment of both partial and complete distal biceps ruptures results in better outcomes compared with nonoperative care, although the optimal technique and fixation are yet to be determined.
- Nonoperative management is an acceptable treatment for patients willing to accept some loss of forearm supination and elbow flexion strength as well as changes in endurance and cosmesis.

Anatomy of the Biceps Brachii Muscle

The long head of the biceps tendon originates from the supraglenoid tubercle on the scapula and is an intra-articular structure continuous with the superior glenoid labrum¹ (Fig. 1). This triangular fibrocartilaginous region of the labrum attaches medially to the glenoid articular margin with the biceps anchor, which can create a subsynovial recess. Meniscoid variants may cover the superior aspect of the glenoid articular cartilage.

In a study of 100 cadavers, the bicipital insertion on the labrum was classified as entirely posterior in twenty-two, predominantly posterior in thirty-three, equally anterior and posterior in thirty-seven, and predominantly anterior in eight² (Fig. 2). Further delineation with use of light microscopy found that all biceps fibers superficial to the glenoid tubercle were oriented posteriorly¹.

Three distinct anatomic variants of the anterosuperior labrum have been described. Rao et al. found complete, normal labral attachments in 473 of 546 patients. Anatomic variants were present in the remaining seventy-three (13.4%), and consisted of an isolated sublabral foramen in eighteen (3.3%), a sublabral foramen with a cord-like middle glenohumeral ligament in forty-seven (8.6%), and an absent anterior superior labrum with a cord-like middle glenohumeral ligament in eight (1.5%). The presence of these variants has been associated with increased passive internal rotation of the arm, which may predispose individuals to further injury³ (Fig. 3).

Wahl and MacGillivray as well as Dierickx et al. described twelve variants in the long head of the biceps resulting from embryological development^{4,5}. Anatomic variants, specifically tendon adherence to the inferior aspect of the superior capsule

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Fig. 1

Arthroscopic image of normal insertion of the superior labrum anteriorly and posteriorly. A probe is retracting the long head of the biceps to visualize a normal insertion both anterior (to the right) and posterior (to the left). A normal glenohumeral articulation (with the humeral head at the top of the image and the glenoid at the center) is also visible. LHB = long head of the biceps, AL = anterior labrum, PL = posterior labrum, and G = glenoid.

or an abnormal double origin, may contribute to intra-articular bicipital or rotator cuff pathology⁵.

The long head of the biceps receives its blood supply from the ascending branches of the anterior humeral circumflex artery proximally and from the brachial and deep brachial arteries distally⁶. The suprascapular artery supplies the posterosuperior aspect of the glenoid, and the labrum is supplied separately by branches of the suprascapular, circumflex scapular, and posterior circumflex humeral arteries⁷. The anterosuperior labrum and glenoid represent a watershed region without a robust blood supply, leading to poor healing following repair.

After exiting the glenohumeral joint, the long head of the biceps travels in the bicipital groove, an hourglass-shaped corridor between the humerus tuberosities. The tendon is stabilized primarily by soft-tissue restraints known as the biceps pulley, which involves a complex interaction of the subscapularis tendon, supraspinatus tendon, coracohumeral ligament, superior glenohumeral ligament, pectoralis major insertion, and falciform ligament^{6,8}. Proximally, the most important constraints of the long head of the biceps are the osseous bicipital groove, coracohumeral ligament, and subscapularis tendon.

The short head of the biceps tendon originates from the coracoid process of the scapula and is the lateral aspect of the conjoint tendon, sharing an origin with the coracobrachialis. The short head of the biceps travels medial to the long head of the biceps to its distal insertion point.

The biceps rotates 90° externally before inserting distally on the bicipital tuberosity of the radius, defining its role as a forearm supinator and an elbow flexor. The long head of the biceps inserts more proximally than the short head, and the long head is the primary forearm supinator, whereas the short

head acts primarily as an elbow flexor. The bicipital tuberosity is approximately 22 mm long and 15 mm wide, whereas the inserting tendon is 22 mm long and 7 mm wide. Distally, the lacertus fibrosus runs from the short head of the biceps to the forearm fascia, allowing proper orientation and repair of the distal biceps on the tuberosity⁹⁻¹¹.

The biceps muscle is innervated by the musculocutaneous nerve, and its blood supply is from the bicipital branch of the brachial artery. The musculocutaneous nerve penetrates the conjoint tendon approximately 5 cm distal to the tip of the coracoid.

The Superior Labrum Anterior and Posterior

The term “superior labrum anterior and posterior” (SLAP) describes the superior aspect of the glenoid labrum, starting posteriorly and extending anteriorly, including the origin of the long head of the biceps. Pathology in this region was first classified by Snyder et al. in 1990 and includes degeneration or detachment with or without biceps tendon involvement. In a retrospective review of more than 700 shoulder arthroscopies, SLAP lesions were present in only twenty-seven cases (<4%)^{12,13}. There is no consensus regarding a single causal factor for SLAP lesions, and the multiple proposed entities are listed in the Appendix¹⁴⁻²¹.

The most commonly used classification system for SLAP lesions remains that proposed by Snyder et al.¹² with various modifications, which are described in the Appendix and depicted in Figure 4. The classification has been expanded to include SLAP lesion types V to X, although there is a paucity of evidence to guide their treatment²²⁻²⁸.

Diagnosing SLAP tears is challenging. Many patients have concomitant pathology, including acromioclavicular disorders,

Fig. 2

Figs. 2-A through 2-D Patterns of origination of the long head of the biceps from the glenoid labrum². **Fig. 2-A** The head originates entirely from the posterior labrum. **Fig. 2-B** The head originates mostly from the posterior labrum. **Fig. 2-C** The origin of the head is split between the anterior and the posterior labrum. **Fig. 2-D** The head originates entirely from the anterior labrum.

A

Fig. 3-A

B

Fig. 3-B

C

Fig. 3-C

D

Fig. 3-D

Figs. 3-A through 3-D Normal anatomy and variants of the superior labrum. MGHL = middle glenohumeral ligament, and IGHL = inferior glenohumeral ligament. **Fig. 3-A** Normal shoulder anatomy. The glenoid labrum is attached to the rim in the anterosuperior quadrant. The flat or sheet-like normal MGHL is present. **Fig. 3-B** Sublabral foramen only. A sulcus is visible between the normal anterosuperior labrum and the glenoid articular rim, and the MGHL is normal. **Fig. 3-C** Sublabral foramen with a cord-like MGHL. A sublabral foramen is present in the anterosuperior quadrant, and the MGHL is thickened. **Fig. 3-D** An absence of anterosuperior labral tissue with a cord-like MGHL. A thickened MGHL attaches to the superior labrum at the base of the biceps brachii tendon, and the anterosuperior glenoid labrum is absent. © JHU 2002, Department of Art as Applied to Medicine, The Johns Hopkins University School of Medicine. Reproduced with permission.

subscapularis tears, pathology of the long head of the biceps, labral pathology, or internal impingement. Various studies have found that physical examination tests for SLAP tears are neither sensitive nor specific and are rarely conclusive²⁹⁻³¹. The active compression test indicates the ability to distinguish between superior acromioclavicular joint pain and internal SLAP pathology with 100% sensitivity and 98.5% specificity³². Other examination findings associated with SLAP pathology may include resisted supination (Yergason test³³), resisted shoulder flexion with forearm supination and elbow extension (Speed test as described by Crenshaw

and Kilgore³⁴), increased external rotation in the abducted external rotation (ABER) position, and internal impingement signs^{33,34}. Multiple studies have supported arthroscopy as the gold standard for SLAP diagnosis; however, recent studies have demonstrated poor intrarater reliability of arthroscopic diagnosis, challenging the conventional diagnostic gold standard^{30,35-38}.

Recommended imaging includes standard shoulder radiographs^{39,40}. High-resolution, noncontrast magnetic resonance imaging (MRI) or a magnetic resonance arthrogram (MRA) can further evaluate patients for associated pathology, with MRA

Fig. 4-A

Fig. 4-B

Figs. 4-A through 4-D Arthroscopic images of SLAP tears. AL = anterior labrum, PL = posterior labrum, G = glenoid, and LHB = long head of the biceps. **Fig. 4-A** A type-I SLAP tear with superior labral fraying (large arrowhead) and an intact biceps anchor at the glenoid (small arrow). **Fig. 4-B** A type-II SLAP tear with detachment of the biceps anchor from the glenoid with erythema and inflammation (arrow).

having superior sensitivity and specificity compared with MRI⁴¹⁻⁴⁵. Advanced imaging may overdiagnose the presence of SLAP tears because of anatomic variation^{46,47}. A SLAP lesion is best visualized on coronal oblique sequences as an irregular cleft extending below the biceps anchor⁴⁸. A normal sublabral recess may exist at the biceps anchor but not medial to it⁴⁹. Optimal imaging techniques and guidelines for classifying subtle SLAP pathology have been well described^{39,40,47,49,50}.

Although standard glenohumeral arthroscopy is often utilized to diagnose SLAP lesions, surgeons studying the same pathology often disagree on the diagnosis; interobserver and intraobserver reliability are both poor⁵¹⁻⁵⁴. Type-II SLAP tears are particularly challenging to diagnose because of the aforementioned anatomic variation. These lesions may be charac-

terized on the basis of some or all of the following: abnormal laxity in the biceps anchor, evidence of erythematous tissue, fraying, hemorrhage, deep clefts, and gapping of >5 mm with medial traction of the labrum³⁹. A subgroup of SLAP lesions in throwing athletes may be revealed by placing the arm in the throwing position to observe for peel-back from the postero-superior glenoid while passively rotating the arm internally and externally¹⁵.

Nonoperative management of SLAP lesions relies on successfully identifying and treating associated pathology. Scapular dyskinesia and glenohumeral internal rotational

Fig. 4-C

Fig. 4-D

Fig. 4-C A type-III SLAP tear demonstrating a bucket-handle tear of the superior labrum displaced into the glenohumeral joint (large arrowhead). **Fig. 4-D** A type-IV SLAP tear demonstrating a bucket-handle tear of the superior labrum extending into the biceps tendon (large arrowhead).

deficit (GIRD) should be identified and addressed with targeted therapy, including improved posterior capsular flexibility in patients with GIRD. The so-called sleeper stretch has up to a 90% success rate in resolving GIRD^{17,24}. Failure of therapy often indicates intra-articular pathology, including SLAP lesions. Anti-inflammatory medication may decrease symptoms, and targeted injections may be diagnostic and potentially therapeutic. Although nonsurgical therapy is the first step in treatment, no studies have specifically addressed the efficacy of therapy alone for SLAP lesions^{40,55}.

Operative management of SLAP lesions is tailored to the type of lesion and typically follows failure of three months of nonoperative management. If symptoms are manageable, operative interventions are unnecessary. Earlier intervention may be indicated if suprascapular nerve compression is present because of an associated paralabral cyst causing supraspinatus and/or infraspinatus muscle atrophy⁵⁵. For type-I SLAP lesions, fraying is addressed by operative debridement, taking care to remove only abnormal tissue. Such lesions usually occur in older patients and are rarely an isolated source of shoulder pain²⁵.

Symptomatic type-II SLAP lesions may benefit from surgical treatment, especially in young or active patients. In patients undergoing repair, some authors advocate the use of two anchors, one anterior and one posterior to the biceps anchor, whereas others advocate a single double-loaded anchor, with sutures passed in a similar fashion. Alternatively, many advocate a single point of fixation posterior to the biceps anchor^{25,56,57}. For posterior lesions, a shift to an anterior viewing portal and deployment of the shaver via the posterior portal may assist with debridement⁵⁷. Suture anchors are placed at the superior glenoid articular cartilage margin at a 45° angle for maximum anchor security. Sutures are passed in a simple pattern or a horizontal mattress-type pattern, with careful placement of knots away from the chondral surface. For approximately the first three weeks postoperatively, patients are treated with a sling and with early protected biceps activity and pendulum exercises only, followed by progressive passive and active motion. Gradual return to throwing starts at ten to twelve weeks postoperatively, depending on the chosen rehabilitation protocol. Biceps tenotomy with tenodesis rather than isolated tenotomy is advocated by some authors in a younger patient population, although most studies have demonstrated similar outcomes. Complications of operative treatment include recurrent type-II SLAP tears, continued pain, implant failure, stiffness, decreased throwing velocity, and capsulitis.

If rehabilitation fails, these cases are addressed surgically by biceps tenotomy with or without tenodesis. Additionally, primary biceps tenodesis or tenotomy should be considered, although current literature does not clearly delineate which patients will do better with repair, tenodesis, or tenotomy. Simple tenotomy can relieve the pain, allowing early return to activity. Clinical data on type-II SLAP repairs are limited, and further research is needed to determine whether primary repair, tenodesis, tenotomy, or SLAP repair with concurrent tenodesis or tenotomy is the ideal treatment option⁵⁶.

Type-III SLAP lesions are treated by resection of bucket-handle tears or by repair of the middle glenohumeral ligament

when its insertion is compromised⁵⁷. Treatment of type-IV SLAP lesions depends on the amount of tendon involvement. For lesions with minimal tendon involvement, simple debridement may suffice. For lesions with tendon involvement, biceps tenotomy with tenodesis or isolated tenotomy is indicated. There is no consensus on repairing residual SLAP tears after biceps tenotomy or tenodesis⁵⁷.

To our knowledge, no long-term studies on the outcomes of nonoperative care have been published. Isolated debridement of unstable SLAP tears provides only short-term symptomatic relief, with deteriorating outcomes by two years following surgery^{58,59}. Outcomes after repair of type-II SLAP tears are summarized in the Appendix⁶⁰⁻⁸⁷. The current literature does not provide clear guidelines for the treatment of SLAP tears.

Disorders of the Proximal Aspect of the Biceps

The proximal aspect of the long head of the biceps has long been implicated as a pain generator in the shoulder^{88,89}. Pathology includes tendinitis, delamination, tears, subluxation, entrapment, and dislocation from the bicipital groove⁹⁰. Some authors have suggested a stepwise process of inflammatory degeneration of the long head of the biceps, leading from early tendinitis to late degeneration and rupture (Fig. 5). Most authors attribute tendinitis of the proximal aspect of the long head of the biceps to associated pathology, with only rare cases of isolated tendinopathy of the long head of the biceps^{91,92}.

Pathology of the proximal aspect of the long head of the biceps may be attributed to specific anatomic considerations. Soft-tissue structures and the osseous anatomy of the bicipital groove contribute to tendon tracking and stability of the

Fig. 5

Diagnostic algorithm for pathology of the long head of the biceps (LHB).

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proximal aspect of the long head of the biceps. The biceps tendon exits the joint through the biceps pulley and enters the bicipital groove⁹³⁻⁹⁵. Recent anatomic studies have revealed multiple congenital variants in the proximal aspect of the long head of the biceps and the variable presence of a vinculum, which can tether the tendon in the groove after its proximal attachment has been severed^{5,96,97}. Given the anterior location of the bicipital groove and the degree of humeral retroversion, the tendon is exposed to medial force in the groove, predisposing it to medial instability and/or degeneration⁹⁸. Normal variations in the osseous architecture of the groove, including the medial wall angle, the width and depth of the intertubercular sulcus, and the presence of any osseous spurs, may further contribute to tendon pathology⁹⁹⁻¹⁰¹.

Variations in osseous anatomy likely contribute to the infrequent cases of primary biceps tendinitis or tenosynovitis, which are worsened by subtle subluxation of the tendon or inflammation from increased friction within the bicipital groove¹⁰². Secondary biceps tendinitis is most commonly attributed to degenerative conditions of the rotator cuff and to impingement syndromes. Pain localized to the groove is commonly elicited in patients with rotator cuff pathology. Several large series (n = 122 to 847) have demonstrated an association between degeneration of the long head of the biceps and rotator cuff tears¹⁰³⁻¹⁰⁷. Furthermore, atraumatic rupture of the long head of the biceps tendon has been attributed to rotator cuff pathology^{90,105}.

Painful dislocation or subluxation of the long head of the biceps can arise as a result of rotator cuff pathology that compromises the integrity of the bicipital sling¹⁰⁸. An arthroscopic study of 200 shoulders with rotator cuff tears by Lafosse et al. showed that ninety shoulders (45%) had static or dynamically induced instability of the long head of the biceps tendon¹⁰⁹. Cases of instability of the long head of the biceps have also been reported in shoulders with an intact rotator cuff, implicating destabilizing injuries to the coracohumeral or superior glenohumeral ligaments¹¹⁰. The so-called hourglass-shaped long head of the biceps tendon refers to a unique pathological change in the tendon in which hypertrophic degeneration causes entrapment and enlargement of the biceps in the groove with forward flexion¹¹¹.

The typical history of patients with tendinitis of the proximal aspect of the long head of the biceps is one of progressive, worsening anterior shoulder pain, although the symptoms often present in conjunction with signs of rotator cuff tears or impingement syndrome. Less frequently, patients may complain of mechanical symptoms of tendon snapping or catching in the anterior aspect of the shoulder. In some instances, bruising and/or the so-called Popeye deformity herald a complete rupture of the proximal aspect of the long head of the biceps with loss of normal muscular tensioning. A meticulous physical examination of the cervical spine, shoulder girdle, and scapulothoracic joints is indicated. Tenderness with direct compression of the long head of the biceps tendon in the bicipital groove is common. The subpectoral test of the long head of the biceps tendon is performed with direct compres-

sion just medial to the pectoralis tendon insertion during resisted internal rotation¹¹². Tests, including the Speed test³⁴, the Yergason test³³, and the active compression test described by O'Brien et al.³², have little specificity⁸.

Use of imaging studies, including standard radiographs and MRIs, ensures a complete picture of all contributing pathology, such as the presence of a rotator cuff tear involving the upper aspect of the subscapularis, which is a potential cause of instability of the long head of the biceps. Standard MRI does not always detect lesions of the proximal aspect of the long head of the biceps that are evident arthroscopically. MRA is sensitive and moderately specific for lesions of the long head of the biceps, particularly when sagittal oblique cuts that can depict tendon flattening and degeneration are used¹¹³. Ultrasonography may be useful in confirming complete rupture, dislocation, or dynamic instability of the long head of the biceps tendon¹¹⁴.

Nonoperative treatment of tendinopathy involving the proximal aspect of the long head of the biceps includes rest, nonsteroidal anti-inflammatory drugs (NSAIDs), and direct ice massage. When appropriate, physical therapy should be used to address muscle imbalance and scapulothoracic dyskinesia. Many surgeons recommend a diagnostic and potentially therapeutic corticosteroid injection in the tendon sheath at the groove, although little has been reported on the results of such injections. Authors of recent studies have advocated ultrasonographic guidance for this injection, as such guidance achieved a greater than threefold increase in accuracy compared with a technique involving no guidance¹¹⁵.

Operative treatment consists of debridement, tenotomy, or tenodesis. Operative treatment is indicated for cases of primary or secondary tendinopathy in which a trial of nonsurgical care has failed as well as for cases of instability, partial rupture, or entrapment of the long head of the biceps. Arthroscopic debridement is reserved for cases with fraying of no more than 30% to 50% of the tendon⁸. Relative indications for surgical treatment include a high-grade SLAP tear and arthroscopically confirmed tenosynovitis visualized as the tendon is pulled into the joint¹¹². In younger or higher-demand patients, complete rupture is an indication for open tenodesis, which improves cosmetic results and strength, particularly strength in forearm supination (21% loss with rupture) and elbow flexion (8% loss with rupture)^{116,117}. Some surgeons advocate tenotomy or tenodesis of the long head of the biceps at the time of rotator cuff repair. Furthermore, studies (n = 72 to 307) have indicated that tenotomy or tenodesis of the long head of the biceps in addition to subacromial decompression may yield good results in cases of advanced or irreparable rotator cuff tears^{88,118}.

Surgeons still debate the overall merits of tenotomy compared with tenodesis. Most comparative studies have demonstrated no difference between the two treatments, although the represented tenodesis methods were only arthroscopic. Tenotomy may lead to decreased supination strength, and this should be considered in the treatment algorithm. Tenotomy is a simple procedure with rapid rehabilitation, whereas tenodesis involves greater operative time, an associated implant cost, and specific postoperative restrictions during early rehabilitation. The Appendix

highlights the results of studies comparing the outcomes of tenotomy and tenodesis¹¹⁹⁻¹²⁴.

The site of tenodesis—proximal to, distal to, or within the bicipital groove—is controversial. Arthroscopic or open suturing of the long head of the biceps to the transverse humeral ligament in the bicipital groove or to the conjoint tendon can provide proximal fixation^{91,102,125-127}. Suture anchors, bone tunnels, an interference screw, or suture button fixation can be used to anchor the released long head of the biceps against the proximal aspect of the humerus in tenodesis¹²⁸⁻¹³¹. Distal or subpectoral tenodesis has gained favor because of the low complication rate and the lower reported failure rate compared with proximal tenodesis. Sanders et al. reported a revision rate of 45% (five of eleven) with proximal arthroscopic tenodesis compared with 8% (four of fifty-two) with a distal or subpectoral technique¹³². Moreover, no revisions were needed in the proximal open tenodeses in which the bicipital sheath was opened ($n = 7$)¹³². The mini-open subpectoral tenodesis technique has been described in detail in several recent publications^{112,133}. In a recent series of over 350 patients treated with subpectoral biceps tenodesis, only seven experienced any reported complication¹³⁴. Our recommended postoperative rehabilitation entails four weeks of sling wear and passive elbow motion only. Full active motion is started at four to six weeks postoperatively.

Distal Biceps Tendon Ruptures

Distal biceps tendon ruptures typically occur in the dominant arm of men in the fourth to sixth decade of life. The mechanism of injury is an unexpected eccentric load that forces a flexed arm into extension, resulting in tendon avulsion from the radial tuberosity. Smokers have a 7.5-fold greater risk of rupture¹³⁵. Studies have also implicated anabolic steroid use and local corticosteroid injection^{136,137}. Distal biceps tendon ruptures are classified as partial or complete and as acute (presenting within three weeks of injury) or chronic¹³⁸.

Patients often report a painful “pop” at the time of injury and describe a sudden, sharp, tearing sensation in the antecubital fossa that generally subsides to a dull ache. A hallmark of injury is weakness and pain with forearm supination. Additionally, patients present with tenderness and ecchymosis in the antecubital fossa. A complete tear results in retraction of the muscle belly and an abnormal biceps contour. The differential diagnosis of anterior elbow pain also includes cubital bursitis, biceps tendinosis, and lateral antebrachial cutaneous nerve entrapment.

The hook test described by O’Driscoll et al. has been reported to have 100% sensitivity and 100% specificity¹³⁹. While the patient actively flexes the elbow to 90° with the forearm in maximum supination, the examiner uses his or her own finger to hook the lateral edge of the biceps tendon. If the tendon is intact, the examiner can completely insert a finger 1 cm beneath the tendon¹⁴⁰. It is necessary to be wary of an apparently normal hook test in cases of partial rupture as the lacertus fibrosus can mimic an intact tendon. An alternative test involves placing the elbow in 90° of flexion in a neutral position and then alternatively supinating and pronating the forearm. The biceps muscle belly is observed for motion; if it is intact, it moves proximally with supination and distally with pronation. If the biceps is rup-

tured at the radial tuberosity, the muscle belly does not move with passive supination and pronation¹⁴¹.

Radiographs should be obtained to rule out an avulsion of the radial tuberosity. Advanced imaging, including MRI, can aid in the diagnosis of partial tears; however, diagnosis of a distal biceps tendon rupture is a clinical diagnosis. In long-standing distal biceps ruptures, MRI is also useful for the assessment of tendon retraction. Ultrasonography has shown promise in facilitating the diagnosis. It has the advantage of decreased cost compared with MRI, but it is operator-dependent^{142,143}.

Historically, nonoperative treatment of a complete rupture is generally reserved for elderly, low-demand patients, although recent studies have questioned this. Hetsroni et al. found better subjective and objective outcomes in middle-aged individuals with a surgically treated distal biceps rupture, although patients treated nonoperatively also had good to excellent outcomes¹⁴⁴. Freeman et al. retrospectively reviewed nonoperatively treated distal biceps ruptures and found that patients had acceptable results despite a loss of supination strength¹⁴⁵. The altered cosmesis of the retracted muscle and decreased supination strength and endurance prompt most individuals to seek surgery. Partial ruptures are initially treated nonoperatively with NSAIDs and physical therapy; however, many patients ultimately elect surgical treatment. Expected outcomes with nonoperative treatment include decreased forearm strength and endurance along with activity-related forearm pain and fatigue¹⁴⁶.

Operative repair restores endurance, forearm supination, and elbow flexion strength¹⁴⁶. Options for single-incision surgery include a modified anterior longitudinal Henry approach as described by Mazzocca et al.¹⁴⁷ and a limited antecubital fossa incision through the interval between the brachioradialis and the pronator teres. Both require identification and protection of the lateral antebrachial cutaneous nerve and the posterior interosseous nerve, which can be afforded by maximum forearm supination and limited radial-sided retraction.

Dual-incision approaches include the Boyd-Anderson¹⁴⁸ and the Mayo modification as described by Failla et al.¹⁴⁹. These approaches are associated with lower rates of radial nerve injury¹³⁸. The most common complication associated with distal biceps tendon repair is paresthesia of the lateral antebrachial cutaneous nerve in 5% to 7% of cases, with less frequent dysfunction of the radial nerve and the posterior interosseous nerve.

Multiple options for tendon fixation at the radial tuberosity exist, including repair with suture over a bone tunnel¹⁵⁰, suture anchors^{142,150,151}, an interference screw¹⁵², and a cortical button¹⁵³. Regardless of technique, the repair must withstand the physiologic forces pulling on the tendon at the elbow. Biomechanical studies have demonstrated failure loads ranging from 232 N with suture anchor fixation to 440 N with cortical button fixation; both of these loads are well above the physiologic force of 50 N^{154,155}. Although the costs of the repair techniques vary widely, no high-quality evidence demonstrating clinical superiority of one technique over another has been published.

Additionally, many authors stress the importance of positioning the distal aspect of the biceps back at its anatomic footprint on the ulnar aspect of the radial tuberosity to avoid loss

Fig. 6
Sagittal T2-weighted magnetic resonance image demonstrating a complete distal tear of the biceps tendon. The small arrow illustrates the retracted tendon, and the large arrowhead illustrates the distal biceps sheath leading to the radial tuberosity.

of supination torque. Biomechanical studies comparing one-incision techniques (involving anterior placement of the tendon) with two-incision techniques (involving anatomic placement) are inconclusive with respect to restoration of supination function^{156,157}.

Partial tears may warrant a trial of nonoperative treatment, but outcomes with respect to pain and function suggest that these injuries are better addressed operatively^{158,159}. The operative approach is similar to that in a complete distal biceps rupture and the procedure involves completion of the rupture to assist with the repair.

Postoperative management varies but typically includes some variation of immediate sling treatment with early passive motion for two to three weeks followed by active-assisted

motion at between four to six weeks postoperatively. Gentle muscle strengthening begins at about eight to twelve weeks postoperatively, with full activity expected at about six months.

Outcomes of distal biceps repair are good to excellent with respect to the elimination of pain and the recovery of strength and endurance. Morrey et al. demonstrated recovery of 97% of elbow flexion strength and 95% of forearm supination strength, compared with the uninvolved extremity, following distal biceps tendon repair¹⁶⁰. A radioulnar synostosis, presenting with pain and limitation of forearm pronation and supination, occasionally complicates repairs and may require excision¹⁶¹.

Chronic distal biceps tendon ruptures present with retraction of the muscle and scarring to surrounding tissues, making anatomic repair challenging. Remaining tissue quality is often poor, with loss of elasticity. These patients rarely report pain but still demonstrate loss of supination strength and endurance. MRI evaluation is useful to confirm the diagnosis and to localize the tendon position for operative planning (Fig. 6). Indications for surgery mirror those for acute rupture, although the repair is much more challenging. An extensile anterior approach is used to locate the distal stump. Interposition grafting with autograft (usually semitendinosus tendon or fascia lata) or allograft (Achilles tendon) is frequently required because of muscle contractures, scarring, and inability to reach the footprint with the distal tendon. However, primary repair is preferable even if performed with 45° to 60° of elbow flexion. Postoperative management is more restrictive, with gradual extension starting at three weeks and full extension of the elbow by six weeks. Outcomes typically involve satisfactory improvement in both strength and function with the ability to return to heavy manual labor or sporting activities^{162,163}.

Appendix

eA Tables summarizing proposed SLAP tear injury mechanisms, SLAP lesion classifications, outcomes of type-II SLAP repairs, and studies comparing outcomes of proximal biceps tenotomy and tenodesis are available with the online version of this article as a data supplement at jbjs.org. ■

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