Technical Note

Lesser Tuberosity Avulsion Fracture Repair Using Knotless Arthroscopic Fixation

William M. Cregar, M.D., Ian S. MacLean, M.D., Nikhil N. Verma, M.D., and Scott W. Trenhaile, M.D.

Abstract: Although some literature may suggest that acute nondisplaced lesser tuberosity fractures should undergo nonoperative management, there is a body of evidence that supports surgical stabilization of these injuries due to concern for fracture displacement, nonunion and malunion, anteromedial impingement, and possible biceps tendon subluxation or dislocation. In this Technical Note, we introduce a novel technique for arthroscopic fixation of lesser tuberosity avulsion fractures using a knotless repair. In the lateral decubitus position using standard arthroscopic portals, with the addition of the biceps accessory portal, 2 ULTRATAPE sutures are fixed to the avulsed fragment in luggage-tag fashion to create a secure, knotless fixation. These are used to mobilize and anatomically approximate the lesser tuberosity to the avulsion bed and are held in place with suture anchors placed immediately adjacent to the fracture bed. This technique provides good anatomic reduction with maximal surface area for bone-to-bone healing.

The subscapularis muscle is the largest and most powerful muscle that makes up the rotator cuff and plays an integral part in both the stability and biomechanical motion of the glenohumeral joint.[1] It arises from the anterior scapular fossa and terminates laterally onto the proximal humerus with a footprint of approximately 25.8 mm × 18.1 mm.[2] The tendinous portion of the subscapularis makes up the upper two-thirds of the muscle and attaches primarily onto the lesser tuberosity of the proximal humerus. The remaining third is muscular and attaches to the inferior aspect of the lesser tuberosity and inferiorly onto the anterior aspect of the proximal humeral metaphysis.[3] The superior fibers of the subscapularis tendon interlace with the anterior fibers of the supraspinatus tendon to form contributions to the rotator interval. These fibers intimately connect with the coracohumeral and superior glenohumeral ligaments to share a common insertion onto the lesser tuberosity and form the biceps "sling" or "pulley" with the main function of preventing dislocation or subluxation of the long head of the biceps brachii tendon anteromedially.[4-6] Tears of the subscapularis tendon can therefore cause disruption of the biceps sling and contribute to subluxation or dislocation of the biceps tendon that often needs to be addressed with either tenodesis or tenotomy during surgical repair of the subscapularis tendon.[3,7] The subscapularis serves many purposes; however, its primary role in shoulder mechanics is internal rotation.[8] During active shoulder movement, however, the subscapularis can aid in abduction, adduction, flexion, and extension.[9,10] Additionally, the subscapularis plays an integral role in anterior glenohumeral stability through a buttressing effect.[11]

Fractures of the lesser tuberosity are usually in association with Neer 3- or 4-part proximal humerus fractures or posterior fracture dislocations of the shoulder.[12] Isolated avulsion fractures of the lesser tuberosity of the proximal humerus are uncommon, with most being reported in the literature as case reports involving a limited number of patients,

From the Department of Orthopaedic Surgery (W.M.C., I.S.M.) and Midwest Orthopaedics at Rush (N.N.V.), Rush University Medical Center, Chicago; and OrthoIllinois (S.W.T.), Rockford, Illinois, U.S.A.

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Address correspondence to William M. Cregar, M.D., Department of Orthopaedic Surgery, Rush University Medical Center, 1611 W Harrison St, Ste 201, Chicago, IL 60612, U.S.A. E-mail: william_cregar@rush.edu

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mostly adolescents.[13-20] Robinson et al.[21] estimated the incidence of isolated lesser tuberosity avulsion fractures in adults to be 0.46 per 100,000 population per year, with a median age of 43 years. The mechanism of injury is usually an abduction and external rotation trauma to the shoulder, causing the subscapularis muscle to forcibly contract and resist motion, resulting in an avulsion injury.[13,22]

Literature suggests that nondisplaced fractures of the lesser tuberosity can be managed conservatively with satisfactory results.[13,14] However, some studies suggest that acute nondisplaced lesser tuberosity fractures undergo surgical stabilization due to concerns over fracture displacement, nonunion/malunion, anteromedial impingement, and the possibility of biceps tendon subluxation or dislocation.[14,16,23,24] Levine et al.[15] reports acceptable surgical criteria to include displacement of the lesser tuberosity > 5 mm or angulation $> 45°$, however, there is no consensus in the literature on the amount of fracture dislocation that can be tolerated before adverse outcomes become significant. Most studies seem to agree that any displacement of the lesser tuberosity is an indication for surgery.[13,14,21,23] Traditionally, open reduction and internal fixation using screw fixation represent the surgical treatment of choice for avulsion fractures of the lesser tuberosity.[13-15,17,21] Excision of the lesser tuberosity also exists as a treatment option.[25,26] There are several reported techniques of arthroscopically repaired subscapularis tendon tears[27-29]; however, there are few reports of arthroscopic repair of isolated subscapularis avulsion injuries. To our knowledge, only 2 arthroscopically assisted reduction and fixation techniques for lesser tuberosity avulsion fractures have been reported in the literature.[18,30] In this Technical Note, we introduce arthroscopic lesser tuberosity fixation using ULTRATAPE (Smith & Nephew, Memphis, TN) and a completely knotless repair (Video 1). Our technique is similar to that described by both Scheibel et al.[18] and Heyworth et al.[30]; however, several differences exist.

Surgical Technique

Operating Room Setup

The patient is brought back to the operating room following a safety protocol completed in the preoperative holding area, including surgical marking of the correct extremity. After undergoing an interscalene block, the patient is placed under endotracheal anesthesia in the operating room while in the supine position. We then place the patient in the lateral decubitus position for shoulder arthroscopy with all bony prominences well padded, as described by Jinnah et al.[31] A full preoperative shoulder examination is performed under anesthesia. The extremity is prepped and draped in a sterile fashion.

Portal Placement

We perform arthroscopic repair of lesser tuberosity avulsion fractures using a standard posterior viewing portal, a working anterior rotator interval portal, and a standard lateral portal, all well described by Burkhart and Brady[7] for subscapularis repair. We also use a biceps accessory (BA) portal described by Tarleton et al.[32] for mobilization of the subscapularis tendon and preparation of the footprint bone bed (Fig 1).

Operative Technique

Using a 30° arthroscope, access is gained through the posterior viewing portal and diagnostic evaluation of the entire glenohumeral joint is undertaken. An anterior rotator interval working portal is created using an outside-in technique after localizing the correct placement under direct visualization with a spinal needle. Attention is directed in particular to the subscapularis tendon, its humeral insertions, and the long head of the biceps tendon, which is often subluxed or dislocated with concomitant subscapularis pathology. Either tenotomy or tenodesis based on patient-specific factors should be carried out in such a scenario to provide better visualization of the subscapularis footprint and because relocation and stabilization of the biceps tendon can subsequently cause the subscapularis repair to fail.[7,33] Visualization of the subscapularis footprint can be maximized by internally rotating the arm. When dealing with simultaneous rotator cuff or labral pathology, we suggest prioritizing lesser tuberosity

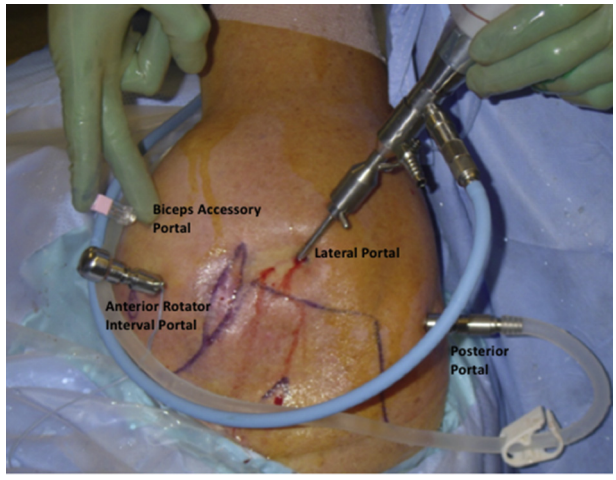

Fig 1. Intraoperative picture of a right arm with the patient in the lateral decubitus position demonstrating the portals used during lesser tuberosity repair. All portals are labeled. The lateral portal is the primary viewing portal. The posterior portal is used as an outflow tract. The anterior rotator interval portal and biceps accessory portal are the primary working portals during repair.

repair as the first step before iatrogenic swelling and fluid extravasation compromise the subcoracoid space.[7]

Lesser Tuberosity Repair

Using the posterior portal for viewing, a full bursectomy is performed in the subacromial space. The arthroscope is moved to the lateral portal to complete the standard bursectomy superiorly. During the lesser tuberosity repair, the lateral portal becomes the primary arthroscopic viewing portal. A BA portal is established approximately 3 finger breadths inferior and lateral to the anterior rotator interval portal using an outside-in technique (Fig 1). The biceps tendon is subsequently arthroscopically tenodesed in the suprapectoralis location. This BA portal is then used in conjunction with the anterior rotator interval portal to mobilize the lesser tuberosity and the avulsed subscapularis tendon. Preparation of the bone bed with a shaver and burr and adequate debridement of chondral debris surrounding the avulsed fragment are carried out using a working anterior rotator interval portal and a BA portal (Fig 2). Good bone bleeding within the fracture bed base signifies adequate preparation of the footprint with the goal of increased bone-bone healing potential. Next we mobilize the fractured fragment and bring it from its retracted position medially back to anatomic position ensuring adequate mobilization of the avulsed fragment (Fig 3). Using a suture passer, we pass 2 separate ULTRATAPE sutures through the inferior and superior aspects of the bone-tendon junction, in a luggage-tag fashion, creating a secure knotless fixation (Fig 4).

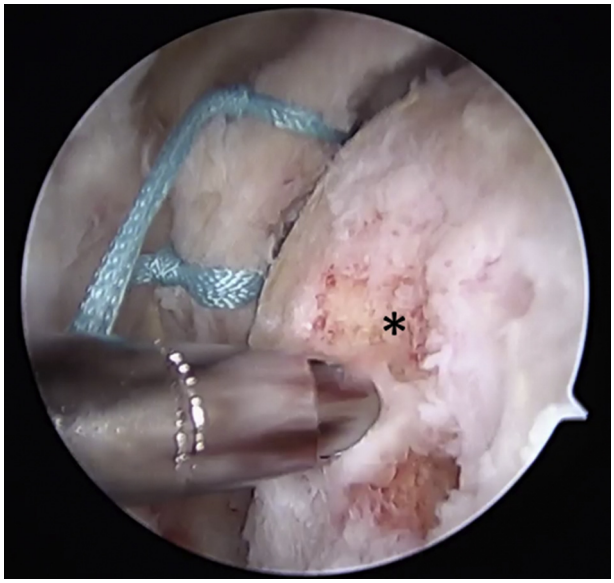

Fig 2. Arthroscopic view of the left shoulder viewed from the lateral portal with the patient in the lateral decubitus position. A shaver/burr is used to debride the fracture bed (asterisk). Bony bleeding at the base of the fracture bed signifies adequate preparation of the fracture bed.

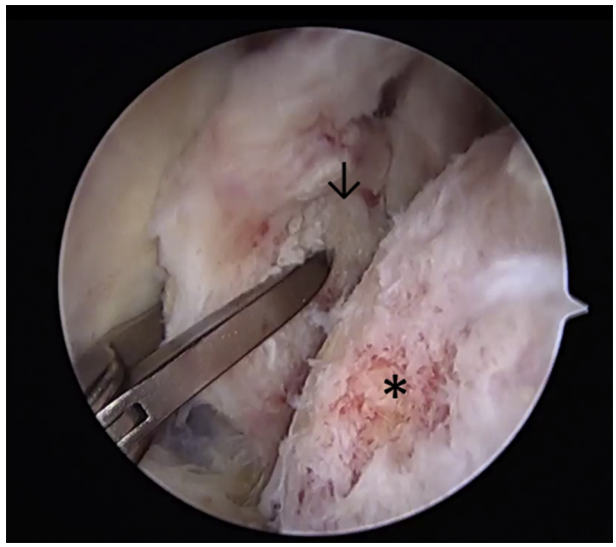

Fig 3. Arthroscopic view of the left shoulder viewed from the lateral portal with the patient in the lateral decubitus position. The lesser tuberosity avulsion fracture (arrowhead) as well as the avulsion bed (asterisk) are shown. This image demonstrates mobilization of the fracture fragment and attached tendon using an arthroscopic grabber through the biceps accessory portal.

Attention is then turned to the fracture bed, where 2 areas just lateral to it are debrided to create a superior and inferior footprint for suture anchor fixation. A bone tap is then used to create bone sockets within these footprints just beyond the lesser tuberosity fracture bed (Fig 5). Because of the nature of the fracture and the comminuted soft cancellous bone within the lesser tuberosity, an alternative location may be used for anchor

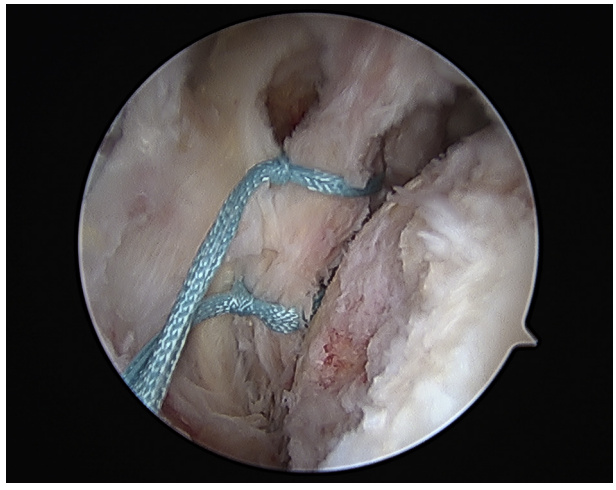

Fig 4. Arthroscopic view of the left shoulder viewed from the lateral portal with the patient in the lateral decubitus position. Two ULTRATAPE sutures have been placed around the lesser tuberosity avulsion fracture through the subscapularis tendon-bone junction in a luggage-tag fashion with the use of a suture passer through the biceps accessory portal.

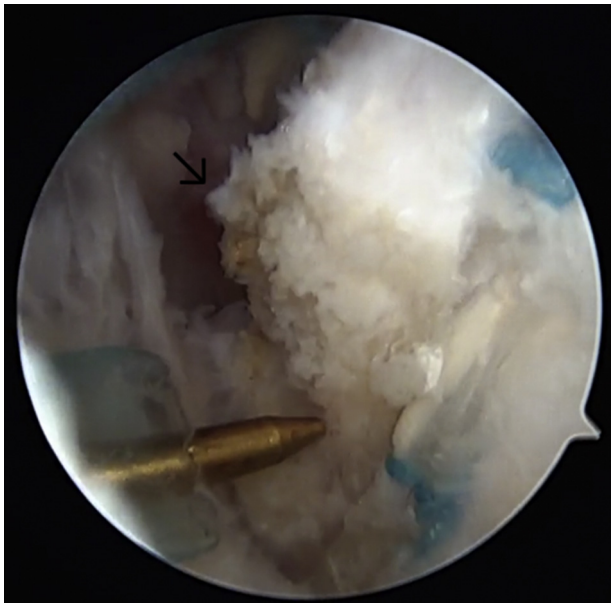

Fig 5. Arthroscopic view of the left shoulder viewed from the lateral portal with the patient in the lateral decubitus position. A bone tap is used to create superior and inferior (pictured here) bone sockets immediately lateral to the fracture bed (arrow) for suture anchor placement.

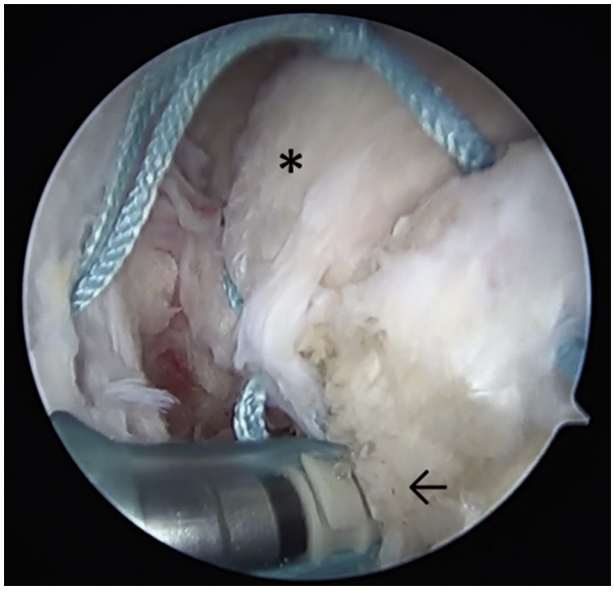

Fig 6. Arthroscopic view of the left shoulder viewed from the lateral portal with the patient in the lateral decubitus position. A 4.5 FOOTPRINT PK anchor is placed within the inferior bone socket (arrow) immediately lateral to the fracture bed. The avulsed fragment (asterisk) should be brought laterally via tension on the ULTRATAPE sutures such that anatomic reduction is achieved.

placement. The bone of the intertubercular groove is cortical bone in nature and an excellent point for anchor placement. Drill holes may be placed in the intertubercular groove using a drill bit to make a pilot hole that can subsequently be dilated with a bone tap. Traction is placed on the 2 ULTRATAPE sutures securely fixed to the subscapularis tendon and bone, allowing mobilization of the fracture fragment indirectly laterally into the fracture bed until complete bony apposition is obtained. A 4.5 FOOTPRINT PK anchor (Smith & Nephew) is placed within the inferior bone socket and fully seated after the ULTRATAPE suture has been adequately tensioned (Fig 6). Attention is then turned to the superior bone socket where another 4.5 FOOTPRINT PK anchor is placed and again taking care to adequately tension the ULTRATAPE sutures prior to fully seating the anchor. The finished repair should demonstrate the avulsed fragment positioned securely in anatomic position (Fig 7).

Discussion

Isolated lesser tuberosity fractures are relatively rare injuries, often difficult to diagnose, and frequently missed, which may cause prolonged delays in definitive treatment.[21,34] Small bony avulsion fragments may not be easily apparent on radiographs. While large fragments may be visible on standard anteroposterior imaging, anteroposterior imaging with maximal internal rotation or an axillary view is critical for detecting smaller fragments with minimal displacement

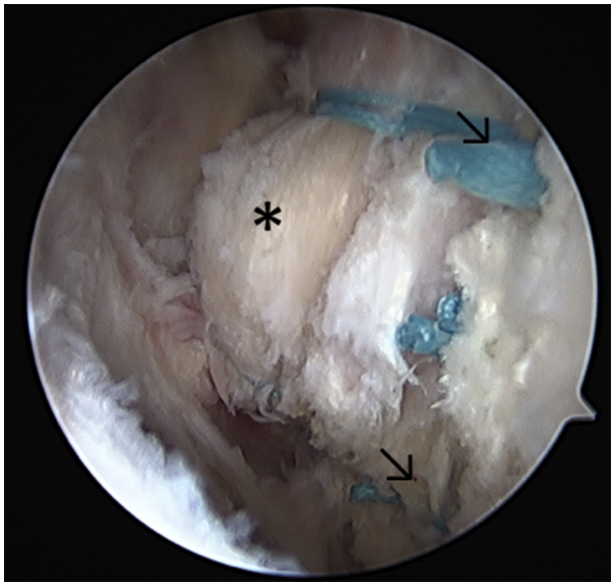

Fig 7. Arthroscopic view of the left shoulder viewed from the lateral portal with the patient in the lateral decubitus position. The 2 ULTRATAPE sutures placed around the lesser tuberosity avulsed fragment in a luggage-tag fashion are securely fixed to superior and inferior suture anchors (arrows) placed immediately adjacent to the fracture bed in a knotless fashion. The avulsed fracture fragment (asterisk) is anatomically reduced. With this repair, there is no instrumentation/fixation directly penetrating the avulsed fragment.

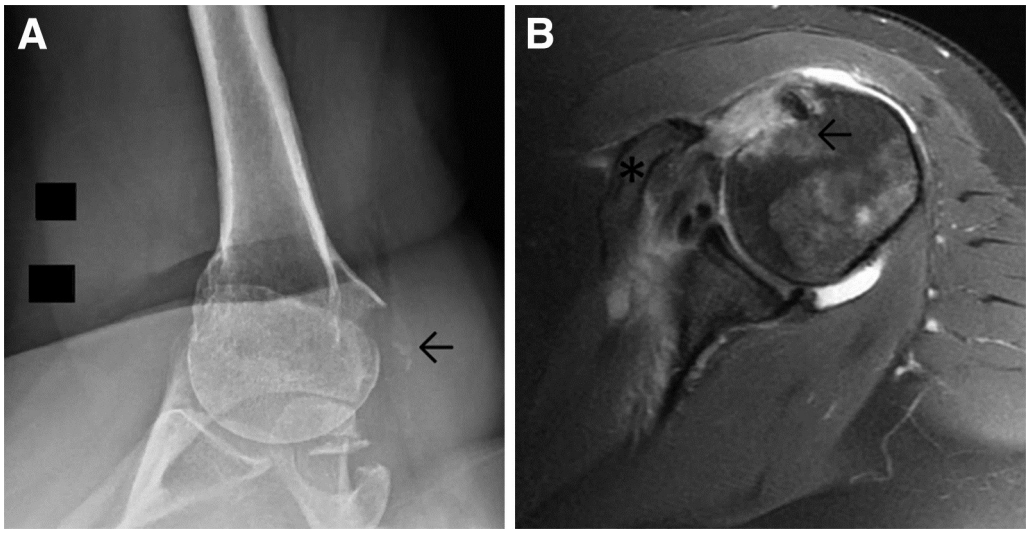

Fig 8. (A) Axillary view radiograph of a left shoulder demonstrating an avulsion fracture (arrow) of the lesser tuberosity. (B) Axial cut of T2-weighted magnetic resonance imaging of a left shoulder demonstrating an avulsion and retraction of the lesser tuberosity with the attached subscapularis tendon (asterisk) and associated humeral head bony edema (arrow).

(Fig 8A).[35] Advanced imaging with either computed tomography or magnetic resonance imaging can also be beneficial, as in the case detailed above (Fig 8B).

While some cases may adequately be managed nonoperatively, any amount of displacement is generally viewed as an indication for surgery.[13,21-23] Outcomes after surgical treatment are generally very good, while risks following conservative treatment include nonunion, loss of rotation, pain, and weakness.[14,24] Surgical techniques for repair range from open reduction internal fixation, to excision of the lesser tuberosity, to arthroscopically assisted repair. A recently published systematic review focusing on lesser tuberosity avulsion injury repairs in adolescents demonstrated good outcomes following both open and arthroscopic repairs, with no statistical difference between the 2 in terms of clinical results.[36] The benefits of many arthroscopic techniques over open reduction internal fixation include the fact that there is no instrumentation that penetrates the avulsion fragment, which could possibly cause fragmentation and loss of fixation. Arthroscopy is also less invasive, resulting in smaller postoperative scars and theoretically less postoperative pain and shorter rehabilitation periods. The technique reported in this paper differs from other arthroscopic repairs in that it features knotless fixation of the lesser tuberosity avulsion fragment down to the humeral bed. Furthermore, our anchor sites were placed just lateral to the avulsion site rather than directly into the fracture bed as described by both Scheibel et al.[18] and Heyworth et al.[30] These differences permit both an anatomic reduction as well as maximal bony interface between the 2 fragments for healing. Advantages and disadvantages of our technique as well as pearls and pitfalls can be found in Table 1 and Table 2, respectively.

Table 1. Advantages and Disadvantages of Arthroscopic Knotless Repair of Lesser Tuberosity Avulsion Fractures

Advantages	Disadvantages
Anchor sites positioned adjacent to the fracture bed allow maximal bony interference between the avulsed fragment and the fracture bed, promoting an anatomic reduction and a more ideal environment for bony healing.	May be more difficult to perform if avulsion injury is chronic in nature and the subscapularis and avulsion fragment are retracted.
Bridging technique using tape suture fixation as described avoids direct penetration of the avulsed fragment, which could possibly cause fragmentation and loss of fixation.	Lateral decubitus position may potentially make conversion to open repair more difficult if required as compared with the beach chair position.
An all-arthroscopic approach in the lateral position allows for treatment of other intra-articular pathology within the glenohumeral joint that would otherwise be missed or difficult to visualize in an open approach.	Arthroscopic fixation may be more technically challenging than open repair.
Arthroscopic repair may lead to less postoperative pain, shorter rehabilitations, and a smaller postoperative scar when compared with an open approach.	

Table 2. Pearls and Pitfalls of Arthroscopic Knotless Repair for Lesser Tuberosity Avulsion Fractures

Failure to address concomitant long head of the biceps tendon pathology with either tenodesis or tenotomy can lead to failure of the subscapularis repair.
Use of the biceps accessory portal described allows for arthroscopic treatment of biceps long head pathology with suprapectoralis tenodesis in addition to lesser tuberosity avulsion repair.
Using knotless anchors may not be feasible if the proximal humerus is highly comminuted, even if the fracture is nondisplaced, and may require open reduction and internal fixation with a plate and screw construct.
We suggest addressing subscapularis repair as one of the earlier procedures if other concomitant injuries are addressed arthroscopically because iatrogenic swelling and fluid extravasation can limit the ability to work in a tight subcoracoid space.
Anatomic understanding of the coracoid, strap muscles, vascular bundle, which lies medial to the coracoid region, and axillary nerve, which runs immediately inferior to the subscapularis tendon, is integral to avoiding complications during arthroscopic repair of lesser tuberosity avulsion fractures.

When planning treatment of a lesser tuberosity avulsion fracture, it is important to be aware of any other copathology that may require intervention. In addition to the lesser tuberosity avulsion fracture, in the case demonstrated in our video, there was also a SLAP tear type 2B, a Hill-Sachs lesion, and a long head of the biceps tendon that was noted to be subluxed into the lesser tuberosity footprint intraoperatively. The SLAP tear was not addressed in the case demonstrated in our video since both age greater than 40 and diabetes are risk factors significantly associated with SLAP tear repair failure.[37] The Hill-Sachs lesion was nonengaging and therefore was also not addressed. In this scenario, the long head of the biceps was managed with a biceps tenodesis, although a tenotomy would also be a reasonable option.[3,7]

A major limitation of our described technique involves situations in which the proximal humerus is comminuted, preventing the use of knotless suture anchors. Such a scenario may require open reduction and internal fixation using a plate and screw fixation. Also, with the patient in the lateral decubitus position, conversion to an open procedure may be more difficult, as opposed to with the beach chair position. Major risks include damage to surrounding neurovascular structures, including the vascular bundle, which runs just medial to the coracoid, as well as to the axillary nerve, which is intimate to the subscapularis tendon as it courses just inferior to it and the lesser tuberosity. A sound understanding of anatomic structures surrounding the shoulder girdle is integral to performing arthroscopic lesser tuberosity repairs.

In summary, it is important for clinicians to have a high index of suspicion for lesser tuberosity avulsion fractures as they are both rare and frequently missed. Operative intervention is generally indicated especially in cases with displacement. Our knotless arthroscopic technique provides a good anatomic reduction with maximal surface area for healing and provides patients with a good chance for an excellent outcome.

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