Technical Note

Lesser Tuberosity Osteotomy Combined with Anteroinferior Capsulectomy for Anatomic Shoulder Arthroplasty

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Abstract: Adequate subscapularis tendon mobilization and glenoid exposure are critical to a successful anatomic total shoulder arthroplasty. A lesser tuberosity osteotomy allows for direct bone-to-bone healing while maintaining the strong tendon-to-bone attachment of the subscapularis tendon insertion. Excision of the typically thickened and contracted anteroinferior capsule in osteoarthritic shoulders can help mobilize the subscapularis, theoretically allowing for optimal soft-tissue balance, decreased tension on the subscapularis repair, improved glenoid exposure, and anatomic repair. In this Technical Note and accompanying video, we describe our technique for lesser tuberosity osteotomy with anteroinferior capsulectomy for anatomic total shoulder arthroplasty. This technique reliably and reproducibly produces good results in terms of glenoid exposure, soft-tissue balance, and postoperative subscapularis function.

Careful management of the subscapularis tendon is crucial in anatomic total shoulder arthroplasty (TSA) because of its critical role in preserving anterior stability, postoperative function, and survival of the glenoid component.[1] There are multiple techniques commonly employed to mobilize the subscapularis tendon during anatomic TSA through a deltopectoral approach, including subscapularis tenotomy, subscapularis peel, or lesser tuberosity osteotomy (LTO).[2-4] LTO has multiple potential benefits, including bone-to-bone healing of the repair, a bony fragment that decreases pull-through of the sutures, easy postoperative repair surveillance with radiographs, and decreasing the anterior–posterior dimension of the humerus, which may aid in glenoid exposure.[5] Stemless and mini-stem arthroplasty was initially felt to be a contraindication to this technique, but this been shown not to be the case.[6,7] Despite these theoretical benefits and a host of retrospective and case–control data,[2,8-13] prospective, Level I studies have shown no difference compared with subscapularis peel or tenotomy.[4,5,14,15]

Another key component of anatomic TSA is thorough release of the contracted anterior and inferior capsular tissues.[16,17] In the past few years, a growing body of evidence has shown these tissues to be pathologically thickened—containing multiple contractile, biologically active and proinflammatory mediators, affecting the pattern of osteoarthritis on the humeral head, and affecting posterior subluxation and posterior glenoid erosion in the pathogenesis of glenohumeral osteoarthritis.[18,19] Other potential benefits of capsulectomy

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The authors report the following potential conflicts of interest or sources of funding: G.R.W. reports board or committee member: American Academy of Orthopaedic Surgeons; stock or stock options: Aevumed, Coracoid solutions, CrossCurrent Business Analytics, OBERD, Parvizi Surgical Innovations; paid speaker/consultant: DJO, Mathys; research support: DePuy; publishing royalties: Wolters Kluwer Health; and unpaid consultant: MiCare path. G.E.G. reports editorial or governing board: Journal of Shoulder and Elbow Surgery *and* Techniques in Orthopaedics*; paid consultant: Additive Orthopaedics, DJO, Mitek, and Tornier; board or committee member: American Shoulder and Elbow Surgeons and AANA; other financial or material support: Arthrex, DJO, and SouthTech; and stock or stock options: CultivateMD, Genesys, Patient IQ, ROM 3. Full ICMJE author disclosure forms are available for this article online, as supplementary material.*

Received February 20, 2022; accepted March 22, 2022.

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2212-6287/22252
https://doi.org/10.1016/j.eats.2022.03.037

include a low rate of subscapularis insufficiency, due to the decreased tension on the repair with a highly mobilized tendon. Furthermore, excellent postoperative external rotation and abduction, and—in conjunction with correcting for bony erosion—allow for correction of posterior humeral-head subluxation.[7,20] While these same benefits may be achievable with thorough capsular releases from both the glenoid and humeral sides—also known as a capsu*lotomy*—some shoulder surgeons, including the authors (G.R.W. and G.E.G.) resect the entire anteroinferior capsule—a capsul*ectomy*—with every primary anatomic TSA for glenohumeral arthritis.

The purpose of this Technical Note and accompanying video is to describe the technique for LTO with anteroinferior capsulectomy during anatomic TSA. This technique was developed by the senior author (G.R.W.) and modified slightly by (G.E.G.). This technique has been used by (G.E.G.) for nearly all anatomic TSA procedures—estimated to be approximately 3,200 TSA procedures since the current technique solidified in 1995. We have found it consistently produces good results in terms of glenoid exposure, soft-tissue balancing, range of motion, as well as subscapularis postoperative monitoring, healing, and function (Video 1).

Surgical Technique (With Video Illustration)

Preoperative Evaluation and Surgical Decision-Making

Patients with chronic debilitating shoulder pain due to end-stage primary glenohumeral osteoarthritis who have an absence of infection, no neurologic deficit of the shoulder girdle, a bony glenoid with either no erosion or erosion that is correctable with an

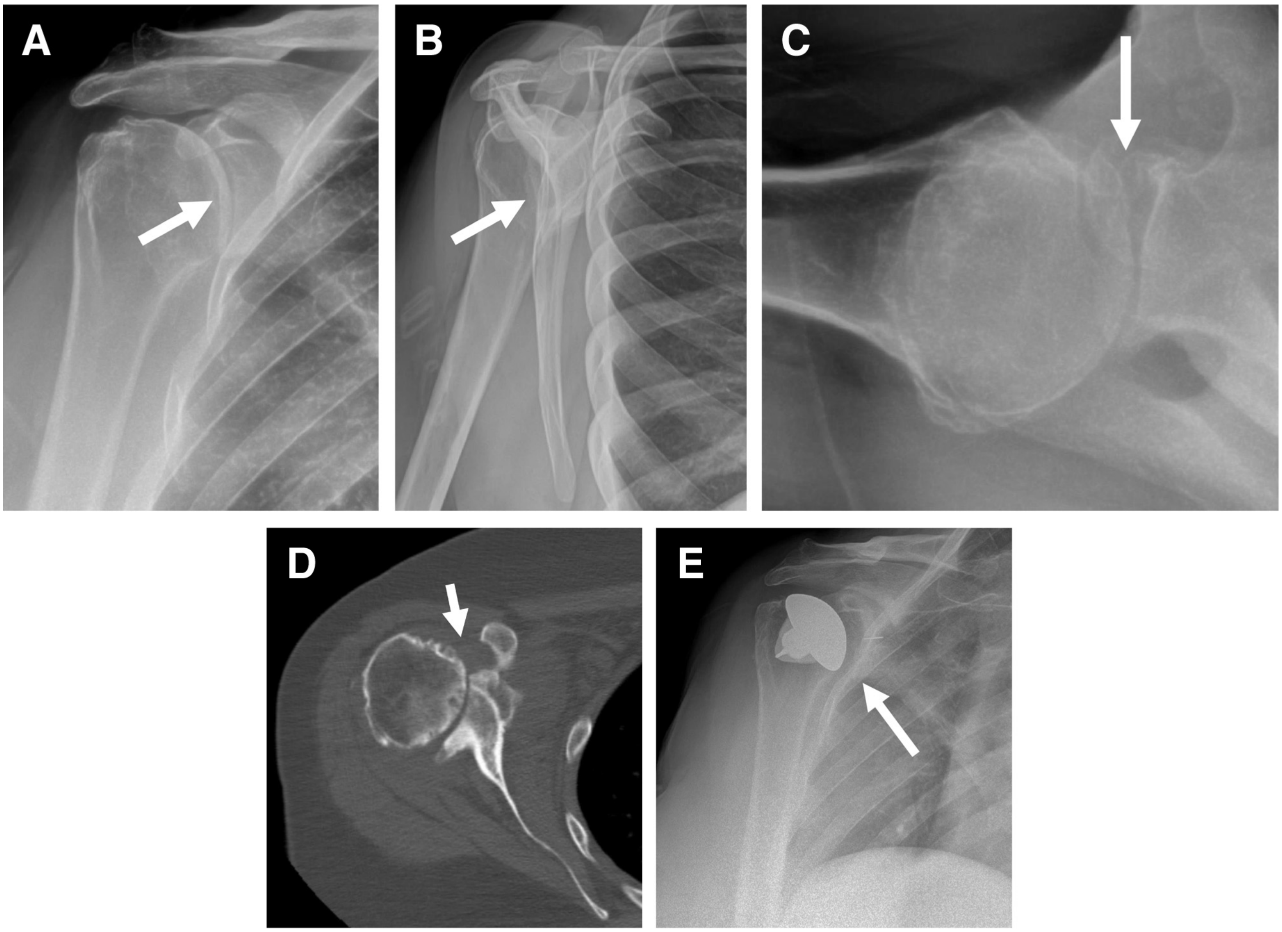

Fig 1. Pre/postoperative radiographs and preoperative CT scan of the right shoulder. (A) Preoperative radiographs at initial clinic visit of the right shoulder demonstrating end-stage primary glenohumeral osteoarthritis in the true anteroposterior view (Grashey), (B) outlet view, and (C) axillary lateral view of the glenohumeral joint. (D) Preoperative axial CT scan illustrating end-stage osteoarthritis with associated osteophytes and no evidence of fatty infiltration of the rotator cuff muscles. (E) Postoperative radiographs in the Grashey view at 2 weeks after surgery illustrating appropriate placement of the canal-sparing anatomic total shoulder arthroplasty implant (Simpliciti Shoulder System; Tornier, Bloomington, MN). (CT, computed tomography.)

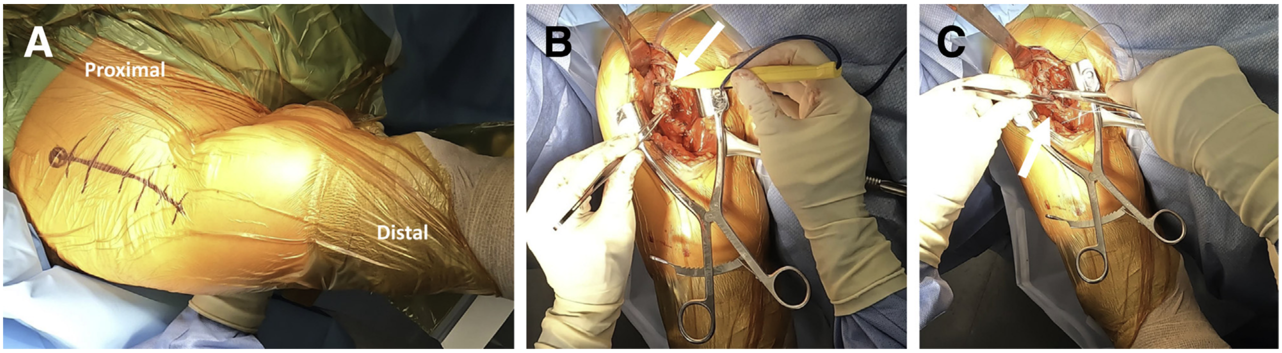

Fig 2. Intraoperative right shoulder positioning and surgical approach. (A) Patient is positioned supine on a standard operating table with an attached shoulder positioner (T-Max Shoulder Positioner; Smith & Nephew, London, United Kingdom). The back of the bed is raised approximately 30° to allow for sufficient intraoperative visualization and the operative extremity is then prepped and draped in the usual sterile fashion. The operative extremity is attached to a limb positioner (Spider2; Smith & Nephew, London, United Kingdom). (B) The long head of the biceps tendon is released from its sheath, through the rotator interval and cut from its attachment at the superior aspect of the glenoid labrum near its attachment at the supraglenoid tubercle. (C) The long head of the biceps tendon is then tenodesed to the pectoralis major tendon with two #2 ETHIBOND sutures and subsequently transected just proximal to the margin of the pectoralis major tendon.

augmented anatomic glenoid component, an intact functioning rotator cuff, and who are unresponsive to nonoperative treatment are indicated for anatomic TSA. The only contraindications to the capsulectomy procedure are for inflammatory arthritis in cases in which the capsule is not thickened, frequently seen in rheumatoid arthritis. The Magnuson Stack procedure, a lateral and distal transfer of the subscapularis for anterior instability that has fallen out of favor due to high rates of capsulorrhaphy arthropathy, is a contraindication, as the anatomy is altered in a way that makes the LTO and capsulectomy not predictable. In the senior author's experience (G.R.W. and G.E.G.), other previous, nonanatomic instability procedures are not necessarily contraindications and the technique can be modified. For example, in the setting of previous Latarjet where the conjoint passes through the subscapularis, the conjoint can be divided deep to the subscapularis muscle where it dives through the neocapsule. This leaves the conjoint adherent to the subscapularis and the capsule can still be excised. The Putti-Platt operation, in the senior author's experience, remodels in a way in which a distinct plane between the subscapularis tendon and capsule is evident, even in this nonanatomic operation, and thus is not a contraindication. Previous subscapularis tenotomy, peel, or even LTO are not contraindications.

Radiographs should be obtained, including views in the true anteroposterior plane (Grashey), axillary lateral, and outlet views (Fig 1 A-C). Unless a satisfactory magnetic resonance imaging scan has already been obtained by an outside provider, a computed tomography scan with coronal and sagittal plane reformatting and 3-dimensional volume rendering are obtained as part of preoperative implant planning and for potential application of patient-specific instrumentation if desired for highly deformed cases (Fig 1D).[21]

Patient Positioning and Anesthesia

A preoperative interscalene block is performed and general anesthesia subsequently induced. The patient is positioned supine on a standard operating table with an attached beach-chair positioner (T-Max Shoulder Positioner; Smith & Nephew, London, United Kingdom), with the head of the bed raised to 30°. The operative extremity is then prepped and draped in the usual sterile fashion and subsequently secured to a limb positioner (Spider2; Smith & Nephew).

Surgical Approach

A standard deltopectoral approach is used (Fig 2A). The incision is placed over the coracoid tip extending toward the anterior deltoid insertion overlying the deltopectoral interval. After subcutaneous exposure, the cephalic vein is carefully dissected and retracted laterally. The deltopectoral interval is then developed and the subacromial and subdeltoid bursa are released or excised. The clavipectoral fascia is incised lateral to the conjoint tendon, and the axillary nerve is located and palpated on both sides of the humerus using the tug test—laterally where it exits the quadrilateral space and anteriorly where it dives between the anterior humeral circumflex artery and the subscapularis.[22] Next, the anterior circumflex humeral artery and its 2 venae comitantes ("three sisters") are coagulated. Subsequently, the biceps tendon is released from its sheath, through the rotator interval and cut from its attachment at the superior aspect of the glenoid labrum near its attachment at the supraglenoid tubercle

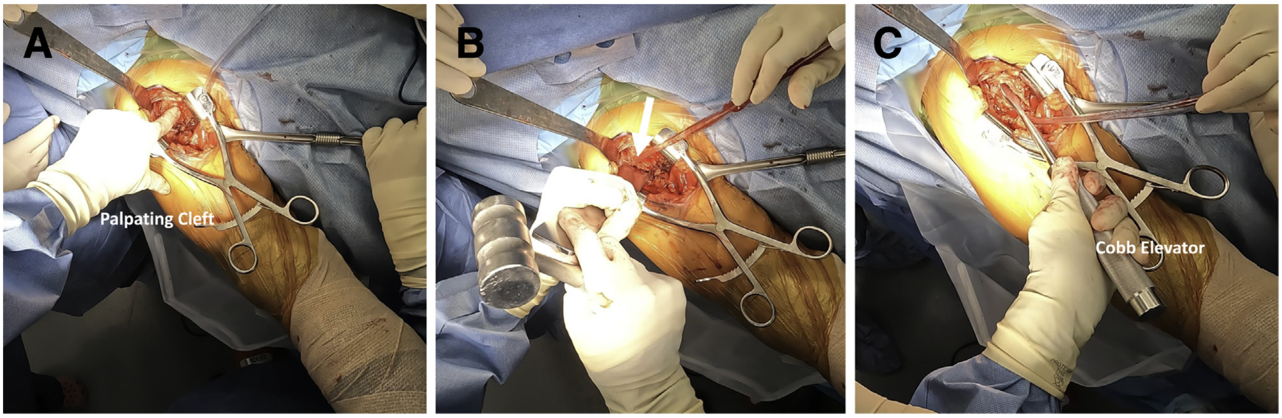

Fig 3. Lesser tuberosity osteotomy of the right shoulder. (A) With the right arm in external rotation, a cleft between the lesser tuberosity and humeral head osteophytes is palpated beneath the subscapularis tendon. (B) A wide, curved osteotome is placed low inside the biceps groove, and aimed medially toward the cleft. The osteotomy is completed and should resemble an oval of approximately 2 cm in diameter. (C) The remaining attachments to the rotator interval are sharply released with a Cobb elevator to create tension. These remaining attachments include the "comma sign" tissue (coracohumeral ligament and superior glenohumeral ligament).

(Fig 2B). The tendon is then tenodesed to the pectoralis major tendon with two #2 permanent sutures (ETHIBOND; Ethicon, Raritan, NJ), and subsequently transected just proximal to the margin of the pectoralis major tendon (Fig 2C). The rotator interval is released to the base of the coracoid and the biceps tendon is cut free from the superior labrum.

LTO and Capsular Release

At this point, the bicipital groove and subscapularis tendon are exposed. A small trapezoid of soft tissue between the inferior portion of the lesser tuberosity/three sisters superiorly, the bicipital groove laterally, and the upper border of the clavicular head of the pectoralis inferiorly is excised to demarcate the inferior portion of the lesser tuberosity. The arm is externally rotated to bring the lesser tuberosity into view. At this point, the lesser tuberosity anatomy is defined on 3 sides—superiorly through the rotator interval release, inferiorly through the resected trapezoid of soft tissue just superior to the three sisters, and laterally deep in the biceps groove. A cleft between the lesser tuberosity and humeral head osteophytes is palpated beneath the subscapularis tendon (Fig 3A). A wide, curved osteotome is placed in the nadir of the biceps groove and aimed medially toward the cleft (Fig 3B). The osteotomy is completed with the osteotome and should resemble an oval of approximately 2 cm in diameter and approximately 1 cm in thickness. The remaining attachments to the rotator interval are then sharply released using a Cobb elevator to create tension (Fig 3C). These remaining attachments include the comma sign tissue (coracohumeral ligament and superior glenohumeral ligament) described by Burkhart and colleagues.[23] Next, the subscapularis is tagged with two #2 ETHIBOND sutures (Ethicon) at the musculotendinous

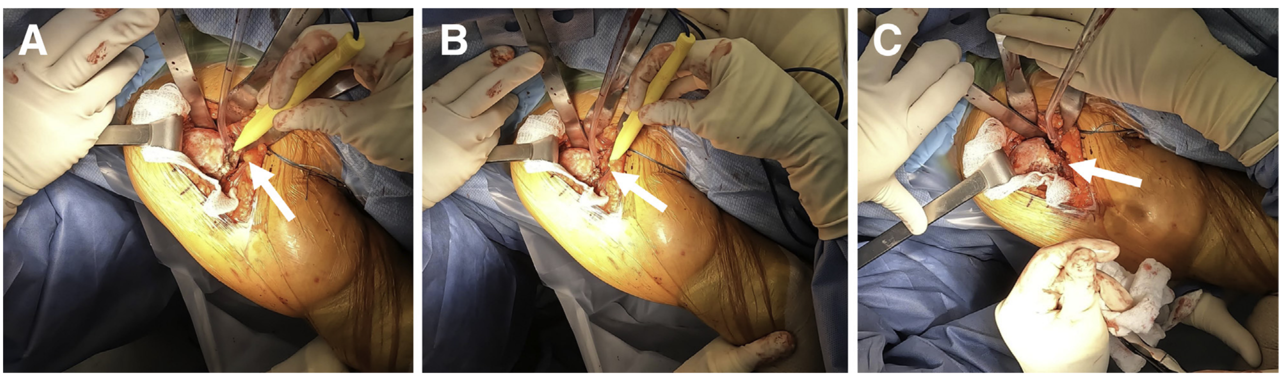

Fig 4. Approach for capsular release of the right shoulder. (A) A plane is developed between the subscapularis and anterior capsule. (B) The capsule is carefully released along the inferior humeral metaphysis using electrocautery, with blunt retractors placed to protect the axillary nerve. (C) The capsule is released as the arm is adducted and externally rotated to allow for complete circumferential capsular release along the humeral neck.

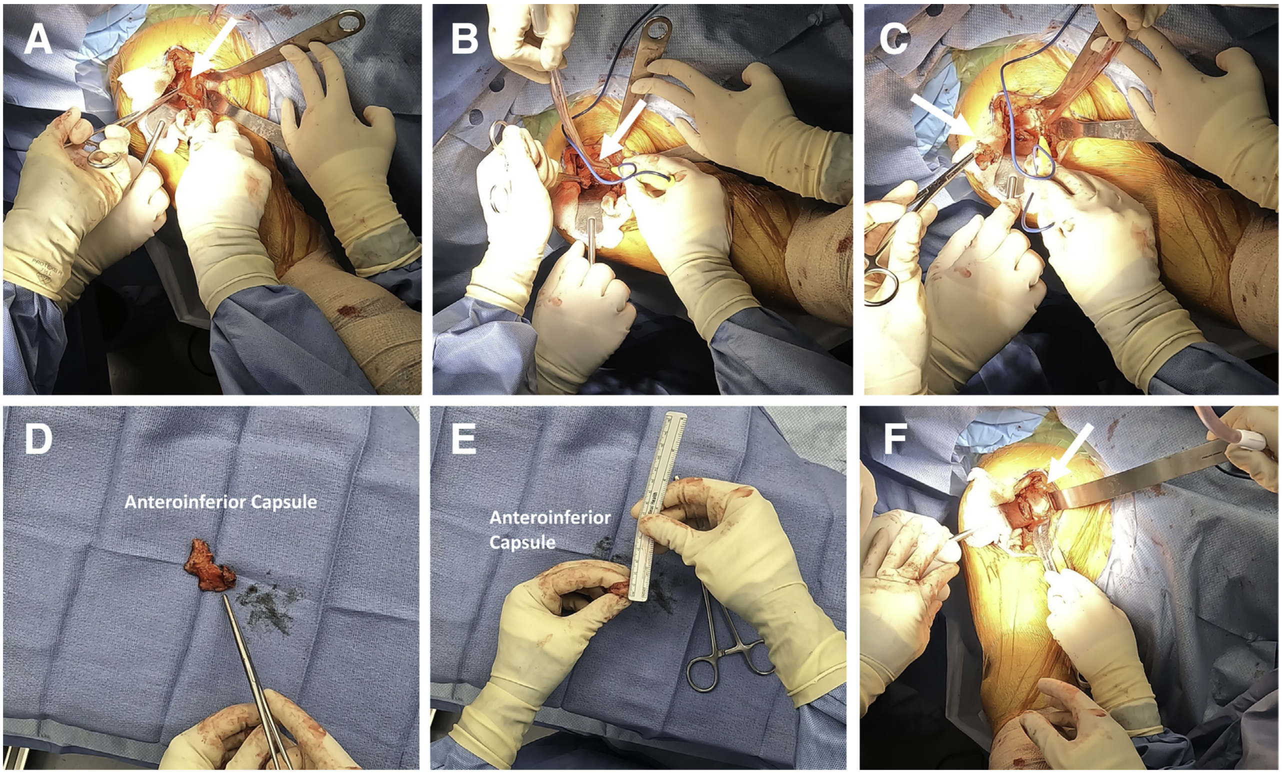

Fig 5. Anteroinferior capsulectomy approach of the right shoulder. (A) A Fukuda retractor is placed to retract the humeral head posterolaterally, and 2 blunt Hohman retractors are placed inferomedially to protect the axillary nerve, while a Kocher forceps is used to grasp the capsule. Using Metzenbaum scissors, the interval between the subscapularis muscle and the anteroinferior capsule is further developed. (B, C) A square-shaped section of the anteroinferior capsule is then resected using electrocautery. (D, E) The resected capsule is typically thickened and hypertrophic in nature. (F) After the capsulectomy is performed, the labrum is circumferentially excised, the capsule is released circumferentially, and the glenoid exposure can then be obtained.

junction. A plane is then developed between the subscapularis and the anteroinferior capsule. If done properly, the lesser tuberosity and subscapularis muscle tendon complex will be freed up while the anterior—inferior capsule remains attached to both humerus and glenoid. Next, the capsule is released from the humerus using electrocautery, with blunt retractors placed to protect the axillary nerve. The capsule is released as the arm is adducted and externally rotated to allow for complete circumferential capsular release along the humeral neck (Fig 4 A-C).

Anteroinferior Capsulectomy

After osteophytes are removed and the humeral head cut is made, anteroinferior capsulectomy is the first step in glenoid exposure. A Fukuda retractor is placed posterior to the glenoid to retract the humeral head posterolaterally, and 2 blunt Hohman retractors are placed in the plane previously developed between the capsule and the subscapularis, deep to the axillary nerve, while a Kocher clamp is used to securely grasp the capsule (Fig 5A). With the capsule clearly visualized, to ensure that the axillary nerve is not in danger, the capsule is divided from lateral to medial at approximately the 6-o'clock position on the glenoid using scissors or electrocautery. This anteroinferior capsule is then removed from inferior to superior all the way to the rotator interval. (Fig 5 B and C). The resected capsule is typically thickened and severely hypertrophic in nature (Fig 5 D and E). After the capsulectomy is performed, the labrum is circumferentially excised, and the posterior and remaining inferior capsule is released to complete the glenoid exposure (Fig 5F). The amount of posterior capsular release is determined by the presence of posterior subluxation and posterior glenoid deformity.

LTO Repair

After the glenoid and humeral components of the prosthesis are fully implanted, the LTO is repaired using a double-row construct. The medial row consists of one #5 ETHIBOND (Ethicon) suture that is passed around the implant before insertion, and both suture limbs are then passed from deep to superficial through the subscapularis medial to the LTO and eventually will be tied to each other in horizontal mattress fashion at the end of the repair. The lateral row consists of 4 alternating #5 FiberWire (Arthrex, Naples, FL) and ETHIBOND

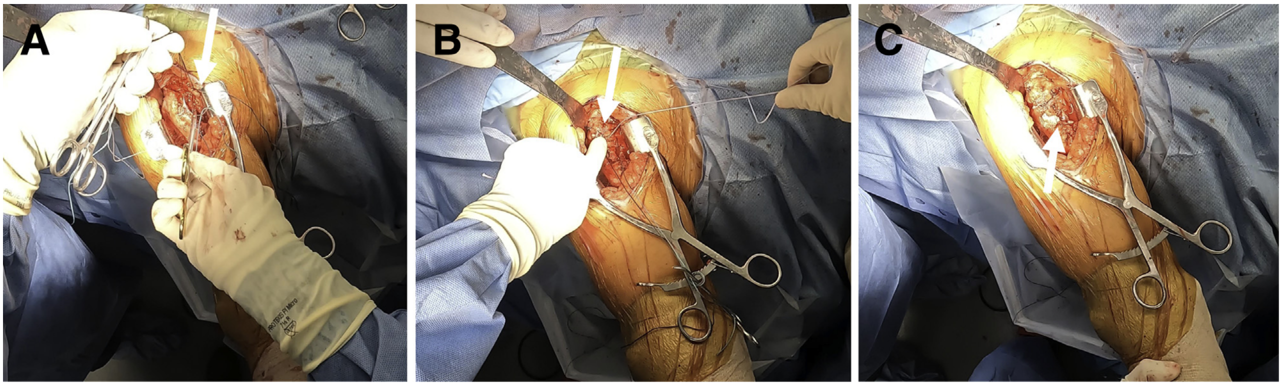

Fig 6. Lesser tuberosity osteotomy (LTO) repair of the right shoulder after placement of the prosthesis. The medial row consists of the one #5 ETHIBOND (Ethicon, Raritan, NJ) limbs, which are both passed from deep to superficial through the subscapularis medial to the LTO. (A-B) The lateral row consists of 4 alternating #5 FiberWire (Arthrex, Naples, FL) and ETHIBOND (Ethicon) sutures going through the subscapularis tendon, and then passed through the anterolateral cortex of the humerus in a transosseous fashion and sequentially hand tied. (C) The repair is assessed for security, full range of motion, and soft-tissue balance of the prosthesis is confirmed.

(Ethicon) sutures going through the subscapularis tendon insertion and then passed through the lateral part of the osteotomy bed, around the bicipital groove. After placing a figure of 8 stitch with #5 ETHIBOND (Ethicon) in the rotator interval, while holding the reduction, the transosseous stitches are sequentially tied (Fig 6 A and B). The repair is assessed for security, full range of motion, and soft-tissue balance of the prosthesis is confirmed (Fig 6C).

Rehabilitation

Upon conclusion of the case, the operative extremity is placed in an abduction sling, which is worn the first 2 weeks postoperatively. Patients starts exercises on postoperative day 0, consisting of 3 to 5 times per day supine, passive, well-arm, or wand-assisted forward flexion (maximum 140°) and external rotation (maximum 40°). The sling is then weaned over the next 4 weeks, with the goal to discontinue it completely at 6 weeks postoperatively. Active and active assisted range of motion as well as rotator cuff and periscapular strengthening are begun at 6 weeks. No resisted internal rotation is permitted until 6 weeks postoperatively. No activities that involve sudden, forceful resisted internal rotation (such as golf, wood splitting, or swimming) are permitted until at least 3 months postoperatively. Radiographs are obtained several times in the postoperative period to evaluate for hardware placement (Fig 1E) and LTO healing (Fig 7 A-C).

Discussion

The LTO subscapularis management technique in anatomic TSA takes advantage of bone-to-bone healing and is advocated by many owing to improved biomechanical strength and its high rates of healing.[13] A recent meta-analysis comparing the 3 subscapularis management techniques for anatomic TSA found that

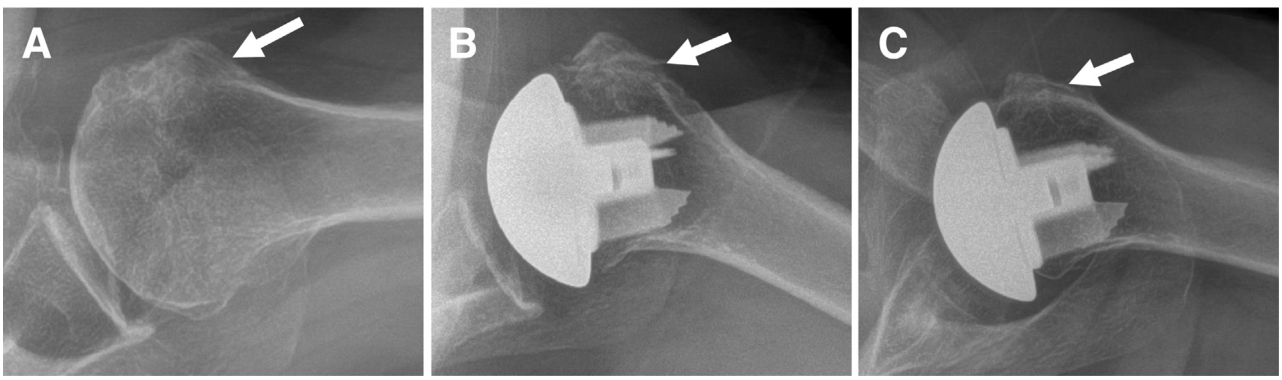

Fig 7. Representative radiographic surveillance of a lesser tuberosity osteotomy repair for a left shoulder in anatomic shoulder arthroplasty. (A) Axillary—lateral view preoperatively of a left shoulder with glenohumeral arthritis before undergoing an anatomic replacement. (B) Axillary—lateral view 2 weeks postoperatively after lesser tuberosity osteotomy. (C) Axillary—lateral view 10 months postoperatively after lesser tuberosity osteotomy showing well-healed osteotomy site.

Table 1. Pearls and Pitfalls

Pearls
• With the arm in external rotation and slight abduction, the cleft between the lesser tuberosity and humeral head osteophytes must be palpated beneath the subscapularis tendon to determine the site of the LTO with a total of 2 cm bone block removed
• During the capsulectomy procedure, electrocautery should be followed along the humeral shaft rather than following the osteophytes to avoid injury of the axillary nerve
• Axillary nerve should be palpated several times during the capsulectomy and always protected with blunt retractors to avoid injury
• Curved scissors should be used to assist in developing the plane between the capsule and subscapularis
• A Cobb elevator can be useful in creating tension between the capsular and subscapularis plane.
• Release and excise the capsule from the subscapularis before performing the humeral head cut
Pitfalls
• Creating an LTO that is too large increases the risk of fracture and a small LTO can inhibit sufficient bone-to-bone healing resulting in failure
• Injury to the axillary nerve if not continuously protected or in the incorrect plane
• Beginning active internal rotation too early in the postoperative period can damage the LTO repair and result in subscapularis failure

LTO, lesser tuberosity osteotomy.

LTO was associated with superior healing (98.9%) and physical examination tests compared with tenotomy and peel, although no differences were found in postoperative patient-reported outcomes or range of motion between the groups.[24] Comparatively, a prospective randomized controlled trial by Levine et al.[15] assessing subscapularis tenotomy and LTO showed that there were no differences in functional outcomes scores or range of motion at 1-year follow-up. The authors did find that LTO showed more consistent healing (93.1% vs 86.7%) over the same time period. Aibinder et al.[25] performed a multicenter comparative study and found there was no radiographic, patient-reported outcomes, or complication differences between subscapularis peel, tenotomy, and LTO at 2 years' follow-up. Interestingly, the authors did conclude that at final follow-up external rotation at 0° of abduction was statistically greater in the peel group compared with tenotomy (55° vs 45°) but was not different compared with LTO (48°).[25] While some variation exists in management, short- and mid-term results are consistent with the effectiveness and safety profile of these 3 subscapularis management techniques during anatomic TSA.[4,9,12,14,26-29] An added benefit of the LTO is that this repair can be closely monitored radiographically during the perioperative healing process.

Regardless of the technique used for subscapularis management, release of the capsule from the subscapularis during TSA is a pivotal step to ensure adequate glenoid exposure and tendon excursion for lateral repair, as well as restoration of range of motion in the arthritic shoulder.[5] Lovse et al.[17] performed a cadaveric analysis to understand how various soft-tissue releases impacted glenoid exposure. They found that release of the long head of the biceps increased glenoid exposure to 69%, which subsequently increased to 83% after pectoralis major release and finally to 93% exposure after inferior capsular release. Williams[30] described the importance of anteroinferior capsule excision in addition to release, as this part of the capsule is pathologic and contracted in patients with arthritis, and excision may allow for better glenoid exposure and range of motion. Furthermore, the pattern of glenoid wear in many patients with primary osteoarthritis occurs posteriorly, which can be exacerbated from an internal rotation contracture, increasing the contact of the humeral head with the posterior glenoid.[31] In the presence of this abnormal anatomy, it is critical to know where the axillary nerve is in space by palpating it while exposing and excising the capsule. We prefer a complete capsulectomy excision of the anteroinferior capsule, as we believe this consistently and thoroughly provides the appropriate level of release while eliminating the pathologic tissue.

Several pearls and pitfalls to the described procedure are highlighted in Table 1. As part of the LTO, externally rotating and slightly abducting the arm allows for the surgeon to adequately palpate the cleft for the correct site of the osteotomy. The capsular release procedure is most safely performed by releasing down the anatomic neck anteriorly and then along the metaphysis medially with the electrocautery, rather than along the osteophytes, which can lead to inadvertent axillary nerve injury and incomplete capsular release. Repeated palpation of the axillary nerve and placement of blunt retractors for protection are necessary to avoid iatrogenic damage to the axillary nerve. Comparatively, it is imperative that the LTO be appropriately sized as a

Table 2. Advantages and Limitations

Advantages
• LTO allows for more substantial bone-to-bone healing with no violation of the subscapularis tendon
• LTO allows for a repair technique that mimics the native anatomy
• LTO repair can be closely monitored radiographically during the perioperative healing process
• Capsulectomy procedure helps with subscapularis excursion and optimizes soft-tissue balance
• Capsulectomy procedure improves glenoid exposure and allows for easier glenoid component insertion by removing thickened diseased tissue
Limitations
• LTO is associated with a small risk of non-union, resorption of the tuberosity fragment, and intraoperative fracture
• Due to the significant capsular release along the humeral head, the axillary nerve is at risk of injury with extensive dissection

LTO, lesser tuberosity osteotomy.

large osteotomy increases fracture risk and a small osteotomy can inhibit sufficient bone-to-bone healing. In the postoperative period, patients should not begin active internal rotation until the osteotomy has healed at 6 weeks, as this can damage LTO repair and result in subscapularis failure.

The technique described here offers several advantages and limitations for surgeons performing TSA (Table 2). The application of an LTO allows for more predictable bone-to-bone healing with no violation of the subscapularis tendon. In addition, the use of our capsulectomy procedure adequately mobilizes the subscapularis and optimizes soft-tissue balance and glenoid exposure during the procedure. Furthermore, capsulectomy may improve postoperative range of motion by removing the thickened and contracted capsular tissue. Limitations include the possibility of nonunion, resorption of the tuberosity fragment, and intraoperative fracture with LTO. Furthermore, there is a risk of axillary nerve injury if not adequately protected during the entirety of the capsulectomy procedure.

Shoulder arthroplasty continues to be an evolving field with changes in implant technology, patient-specific instrumentation, and understanding of the biomechanics of the glenohumeral joint. Management of the capsule and subscapularis for optimal glenoid exposure and improving patient range of motion postoperatively will continue to be paramount in maximizing patient outcomes after anatomic TSA.

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