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Subscapularis lengthening in shoulder arthroplasty

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Purpose: To report the technique and outcome of subscapularis (SSC) lengthening in shoulder arthroplasty.

Procedure: When external rotation measures less than 20°, a coronal subscapularis lengthening is performed. This utilizes the interval between the anterior shoulder capsule and subscapularis to titrate the correct amount of anatomic length.

Results: Average preoperative passive ER was -2°. Average postoperative ER was 48°. Belly press was graded as normal in 13 pts, mild in 12 pts, and poor in 2 pts.

Conclusion: Subscapularis tendon lengthening provides a large surface area for tendon healing and allows anatomic length to be restored. Subscapularis lengthening may preserve a better length-tension relationship of the SSC muscle in shoulders with significant IR contracture undergoing shoulder arthroplasty.

Level of evidence: III; Case-control study; Treatment study

Keywords: Subscapularis; Lengthening; Arthroplasty; Shoulder

The deltopectoral interval is the standard approach utilized when performing a shoulder arthroplasty. Paramount to a successful surgical outcome is proper management of the subscapularis (SSC) tendon (Figure 1, *A*, *B*). The SSC is the most powerful of the rotator cuff muscles and plays a major role in optimal shoulder function.[8,14-16,26] The subscapularis can be mobilized and detached in a variety of ways, each with its own specific set of pros and cons.[1,3,4,11,27] No matter the specific technique utilized, shoulder function will not be optimal unless the tendon is firmly reattached with sufficient tension and excursion present to allow for adequate external rotation of the shoulder. This would theoretically place the muscle-tendon unit in the middle of the length-tension curve, and provide the best environment for function. An internal rotation contracture is not uncommon in arthritic conditions of the shoulder, and this can be exacerbated by an improperly performed SSC repair. If the subscapularis tendon is repaired under too much tension, external rotation of the shoulder will be limited significantly and the tendon may avulse from the bone during rehabilitation. If the tendon is repaired with an excessive amount of slack, the length-tension curve of the SSC muscle belly will not be optimal and manifest loss of strength and poor function.[11,18-20]

Because of the diminished clinical results seen with non-anatomic tensioning of subscapularis tendon, we have developed an ''either-or'' approach to subscapularis management. If, after a rotator interval release is performed, the passive external rotation of the shoulder is not at least 20°, then coronal SSC tendon lengthening is performed. If 20° of external rotation is able to be obtained, then the SSC tendon is incised 6-8-mm medial to the lesser tuberosity and repaired in a primary fashion. The reasoning behind the 20° threshold was our extensive clinical experience. We have seen that the subscapularis tendon cannot be lengthened after the fact; meaning that once it is

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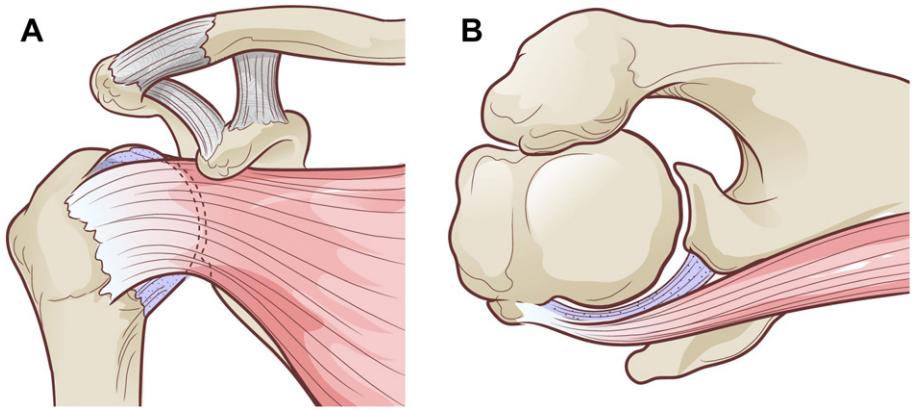

Figure 1 **A**, **B**, Anterior and superior views of a right shoulder. The underlying capsule is light blue with the subscapularis lying anterior to it.

tenotomized off the lesser tuberosity, it is extremely difficult to lengthen. The original description by Neer of subscapularis lengthening does not specifically describe the technique, but in his textbook illustrations show that the subscapularis is lengthened by sewing it end to end to the capsule or dividing the lateral capsule, thus thinning it out and flapping it back on itself and then doing again an end to end repair.[22,23] This Z-plasty technique does create a tenuous repair. A modification of this technique, as described by Green and Norris, reveals that the coronal Z-plasty flap consists of subscapularis muscle and the superficial 50% of the subscapularis tendon.[12] The lateral flap has the deep 50% of the subscapularis tendon and the anterior capsule. This again then shows that the repair is done end-to-end without significant overlap. There have been anecdotal reports in the literature that authors no longer do coronal Z plasty, because it may indeed weaken the repair; yet, there is no clinical series specifically reporting results of subscapularis tendon lengthening.[4] Our technique has been to do a subscapularis tendon lengthening by doing a subscapularis ''slide'', as will be described in this paper. It is not an end-to-end repair.

We developed this because, due to our extensive clinical experience, we have found that after releasing the rotator cuff interval, if we did not have at least 20° of external rotation at the side, at the end of the procedure after an extensive 360° release of the subscapularis, releasing the anterior capsule, the inferior capsule off the inferior border of the subscapularis, osteophyte removal, and adhesions from the subscapularis to the base of the coracoid, that there was a distinct potential to not be able to repair the subscapularis to the lesser tuberosity and achieve 30° of external rotation at the side.

This may indeed be because of chronic contracture of the muscle tendon unit itself, as well as the fact that the lesser tuberosity has been displaced laterally by the recreation of normal humeral offset by placing the glenoid component—and now an anatomical humeral head component—in where before the joint may have been markedly contracted. Furthermore, the ability for the humerus to now externally rotate will move the lesser tuberosity laterally away from the SSC tendon; therefore, the potential for having either a very poor repair or a repair under significant tension is created, thus the ''either or'' approach to subscapularis management and this subscapularis slide/lengthening technique.

The purpose of this study is to describe specifically the technique of SSC tendon lengthening and report the clinical outcomes of this subscapularis management technique in shoulder arthroplasty.

Materials and methods

Criteria for study inclusion consisted of any patients who underwent either a total or hemiarthroplasty of their shoulder with primary subscapularis lengthening. Patients were not excluded based on race, gender, age, or primary diagnosis. During the time period of the study, a total of 133 shoulder arthroplasties were reviewed, with 27 patients (20%) requiring subscapularis lengthening per our protocol. All patients had internal rotation contractures present, with less than 20° of external rotation at the side measured from the frontal plane of the torso. There were 17 males and 10 females, with an average age of 57 years (range, 18-80). The average follow-up was 3.5 years (range, 2-8), with a minimum of 2 years post-surgery. Twenty-two patients (81%) required total shoulder arthroplasties and 5 patients (19%) required hemiarthroplasties. The primary diagnosis was osteoarthritis in 15 patients, post-capsulorrhaphy DJD in 6, prior fracture malunions in 3, and chronically locked posterior dislocations in 3 others. The dominant extremity was operated on in 19 out of 27 patients. Four patients were diabetics and 3 were smokers who did not reduce their nicotine intake during the pre- or postoperative period. No patients in this study had rheumatoid arthritis in their medical history.

All patients had pre- and postoperative range of motion documented by the senior author (GPN). All patients were rated pre- and postoperatively, using the American Shoulder and Elbow Scoring Scale, the Simple Shoulder Test, and the Visual Analog Scoring System. The average passive external rotation with the arm at the side was -2° (range, -25-20). The average ASES, SST, and VAS preoperative outcome scores were 34, 2.6, and 6.1, respectively.

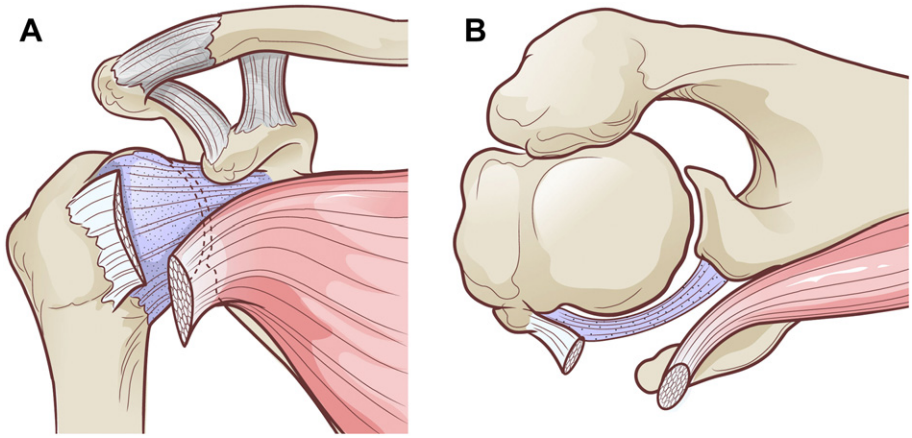

Figure 2 **A**, **B**, Anterior and superior views. The subscapularis tendon is incised approximately 5-8 mm medial to the lesser tuberosity. The tendon is elevated off the underlying intact capsule and reflected medially. The muscle tendon unit is elevated off the glenoid rim to provide access to the capsule medially.

Subscapularis function was documented by the lift-off test and the belly-press or Napoleon test. The lift-off test was utilized as described by Gerber.[10] The belly press test was described by Gerber, and in this study was graded as described by Scheibel: a normal result if the patient can push the hand against the stomach with the wrist straight; an intermediate result if the angle of the wrist allowed the elbow to fall back to the mid-axillary line but the hand was able to stay on the belly; and a positive test for subscapularis dysfunction if the elbow fell back to the posterior axillary line and the wrist flexed more than 60°.[9,25] This was a modification of the belly press test that was described as the Napoleon sign by Burkhart and Tehrany.[5] Burkhart had felt that the Napoleon test was normal if the patient could keep the hand against the stomach with the wrist straight. It was an intermediate test if the wrist flexed 30°-60° but the hand was able to stay on the belly.

Surgical technique

Standard pre-operative radiographs were obtained on all patients, consisting of true anteroposterior, scapular-Y, and axillary-lateral views. If there was ever a concern about the integrity of the rotator cuff, then a pre-operative MRI was ordered. If posterior glenoid bone loss was a concern, then a limited CT scan through the glenohumeral joint was obtained. Twenty of the 27 patients in this study had advanced imaging pre-operatively (15 CT scans, 5 MRIs). The surgical approach for all 27 patients was through a deltopectoral interval. Our technique utilizes needle tip bovie to dissect through the subcutaneous fat and fascia until the deltopectoral interval is identified. The cephalic vein is then identified and mobilized laterally with the deltoid. In order to maximize visualization, approximately 10 mm of the superior portion of the pectoralis major and approximately 5 mm of the anterior edge of the coracoacromial ligament are released. The clavipectoral fascia is released and the gliding plane between the strap muscles and the anterior surface of the subscapularis is bluntly released. The gliding plane in the sub-deltoid space is similarly freed of any adhesions. The rotator interval was then released surgically. This is performed by externally rotating the shoulder and placing the coracohumeral ligament and contents of the rotator interval on stretch. Mayo scissors are used to incise this tissue by releasing it down to the base of the coracoid process. After this release, the patient's external rotation is assessed. Per our protocol, any patient with external rotation less than 20° at this point will undergo lengthening of the subscapularis tendon.

Subscapularis tendon lengthening technique

An overlapping slide, not an end-to-end repair

Coronal lengthening of the subscapularis tendon is performed with needle tip cautery. The subscapularis is incised 5-8 mm from its lateral insertion and carefully reflected off the underlying capsule.The needle cautery is very helpful to preserve tissue and elevate the SSC tendon off the capsule. The tendon is tagged with sutures and mobilized off the intact capsule with blunt dissection and spread technique after the lateral aspect of the tendon has been elevated off the capsule with needle cautery. As the dissection proceeds medially, the muscle-tendon unit is easier to elevate and not as integrated into the underlying capsule. This reflected muscle-tendon unit forms the medial and anterior flap of the final tendon repair (Figure 2, *A*, *B*). This muscle-tendon unit is mobilized off the coracoid and a 360° release of the muscle-tendon unit is performed. The preserved capsule, with the intact lateral stump of subscapularis tendon, is then incised off the glenoid neck as medially far as possible, and then reflected laterally. During mobilization of the medial capsule, tag sutures are placed in the superior and inferior corners of the capsule. This capsular tissue, including the lateral insertion of the subscapularis, forms the lateral and posterior flap of the final tendon repair (Figure 3, *A*, *B*).

A shoulder arthroplasty is then performed in the standard manner. After the proper components are placed and the joint adequately irrigated, the subscapularis lengthening and repair can be performed. The arm is placed in approximately 30° of external rotation and the previously placed tagged sutures are used to ''titrate'' the tension and length of the tendon repair. The subscapularis muscle-tendon unit (anterior flap) is then repaired to the capsular flap (posterior flap) with vertical mattress #2 braided nylon sutures under light tension. The interphase at the tendon edge can be repaired with a running suture if necessary. This provides excellent overlapping surface area for tendon healing to occur (Figure 4, *A*, *B*). It is very important to not neglect the rotator interval. The upper border of the lengthened SSC unit is repaired to the anterior border of the supraspinatus in

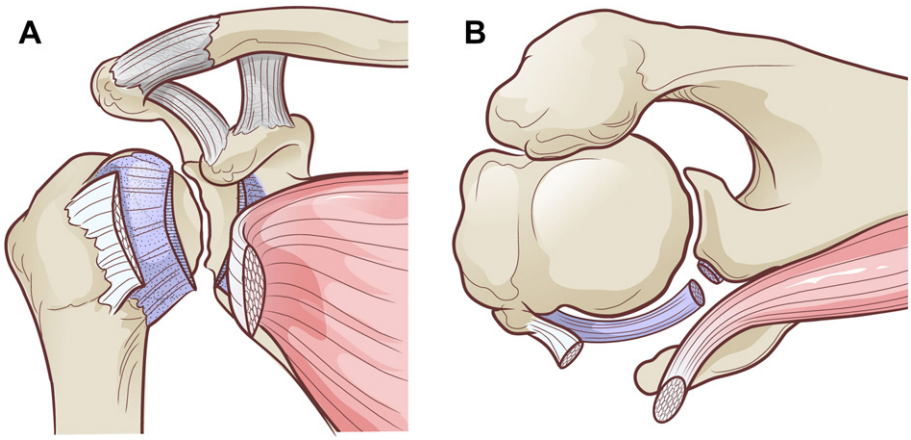

Figure 3 **A**, **B**, The capsule (*light blue*) is now incised off the glenoid as far medially as possible. The capsule is released from the glenoid to form a rectangular shaped laterally based flap. This flap is composed of the subscapularis tendon insertion and anterior capsule.

approximately 20° of external rotation. Upon completion of the repair, the anterior and posterior flaps move as a contiguous unit without significant gapping or undue tension present. On average, 1 cm of additional tendon length translates to approximately 20° of increased external rotation.[24, 17] The remainder of the incision is closed in standard fashion. Postoperatively, patients are placed in a sling and de-rotation wedge that immobilizes the patient's shoulder in neutral position essentially in a ''hand shake'' position of 0° of rotation.

Results

All 27 patients were available for follow-up and willing to participate in this study. All patients were rated pre- and postoperatively, using the American Shoulder and Elbow Scoring Scale, the Simple Shoulder Test, and the Visual Analog Scoring System. There were no cases of instability and no surgical complications that arose from this procedure. No patients required reoperations after their initial shoulder arthroplasty. The ability to perform a lift-off test was present in 22 out of 27 patients (81%). Belly press was normal in 13 patients (48%), intermediate (elbow falls back to mid-axillary line) in 12 (44%), and poor (elbow falls back to posterior axillary line) in 2 (8%); thus 2 patients had a markedly positive belly-press test. Average preoperative passive external rotation with the arm at the side was -2° (range, -25°-20°). Average postoperative active external rotation with the arm at the side was 46° (range, 30°-54°). Average postoperative active forward elevation was 141° (range, 105°-170°) with average postoperative internal rotation to L3. Pre-operative ASES, SST, and VAS scores were 34, 2.6, and 6.1, respectively. Postoperative ASES, SST, and VAS scores were 88, 8.8, and 0.9, with all score increases being statistically significant with a P value $<.05$. When asked about overall satisfaction with their procedure, 19 patients were extremely satisfied, 8 satisfied, and 0 dissatisfied. One-hundred percent of patients polled stated they would undergo this procedure again.

Discussion

Postoperative subscapularis dysfunction can present as a significant problem after total shoulder arthroplasty. These patients can present with decreased motion, strength, and function as a result of an improperly released or tensioned subscapularis tendon. Miller et al found that despite meticulous attention to the subscapularis repair, 67% of patients had abnormal liftoff examination and 66% had abnormal belly press examinations.[20] Armstrong et al found that subscapularis repairs after total shoulder arthroplasty demonstrated a high healing rate by ultrasound.[2] However, the clinical function of that intact subscapularis may still be comprised after total shoulder arthroplasty. The exact reason for this dysfunction is unclear; however, the length of time the patient has had arthritis, the magnitude of the internal rotation contracture, length-tension curve of the repaired subscapularis muscle, and possible denervation by excessive mobilization are all potential reasons.

With significant internal rotation contracture, the ability to gain length in the subscapularis tendon by releases alone has been shown to only gain approximately 1-1.5 cm of length.[4, 7] Approximately 20° gained in external rotation can be obtained by 1 cm of subscapularis tendon length gain.[17] If that length is not gained by the aforementioned releases, the patient now has a subscapularis tendon that cannot reach the lesser tuberosity. Therefore, a subscapularis lengthening cannot be done after subscapularis tenotomy, and the releases that need to be done off the anterior and inferior capsules, the coracoid, and osteophyte removal cannot be done without tenotomizing the subscapularis. As a result, our approach has been to release the coracohumeral ligament and the rotator cuff interval to determine if we were at 20° of external rotation at the side. If this was not reached easily, then a subscapularis lengthening approach was performed, as described in this paper. After that approach, the standard releases of the

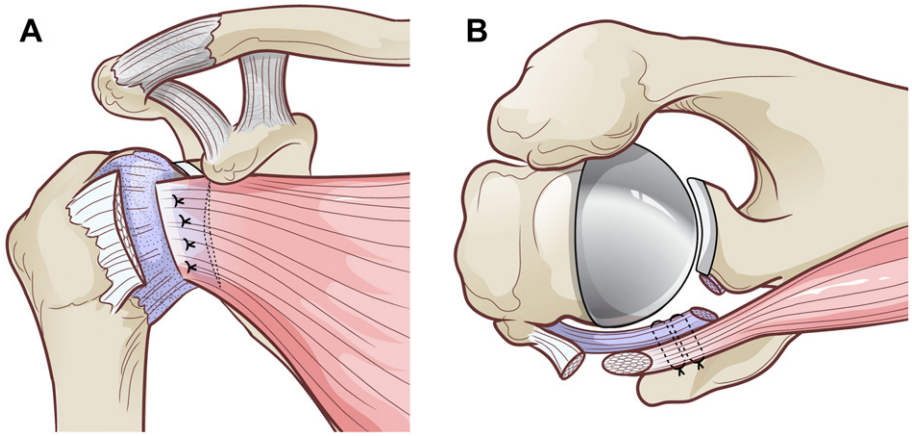

Figure 4 **A**, **B**, After shoulder arthroplasty, the shoulder is rotated to 30° of external rotation. The subscapularis tendon (the anterior flap) is repaired with vertical mattress sutures to the underlying capsule (the posterior flap) under light tension. There is excellent surface area available for repair and healing. This demonstrates the sliding overlap of the flaps to gain length. It is not an end-to-end repair.

subscapularis muscle tendon unit off the coracoid and anterior and inferior capsules are performed. If after that, total shoulder arthroplasty is performed, and the subscapularis can be repaired anatomically, then it is done. If it is not able to be done, then a subscapularis slide lengthening is performed, thus titrating the length with the arm at 30° of external rotation at the side, as described in technique. We believe that this may provide a better tension to the subscapularis muscle tendon unit and a potentially better length-tension curve.

Our technique allows proper tensioning of the subscapularis to occur while external rotation is adequately restored. The function of the subscapularis, as determined by the patient's ability to perform the belly press test in our series, showed that 48% had a normal belly press or Napoleon examination. There was an intermediate result to the midaxillary line in 44%, and only 8% of patients showed a positive belly press sign for subscapularis dysfunction. The lift-off test was possible in 22 of 27 patients (81%). This was comparable and superior to Miller and Flatow's results for primary SSC repair in total shoulder arthroplasty.[20] Most significant was the increase in the patient's external rotation from -2° pre-operatively to 46° postoperatively.

This technique allows a reliable, reproducible, and effective way to gain external rotation without the need for a lesser tuberosity osteotomy to be performed or supplemental tendon grafts to be utilized (Figures 5,6). The lesser tuberosity osteotomy has been described as a way for a more robust fixation of the subscapularis. However, this technique has not been described as a way to obtain subscapularis muscle tendon unit length. It is more for the potential for more robust fixation and potential bone to bone healing. We do not feel that a lesser tuberosity osteotomy offers the ability to lengthen the subscapularis.[21] Simple tenotomy and repair and lesser tuberosity osteotomy have both shown the ability to heal and provide subscapularis functionality.[6,13]

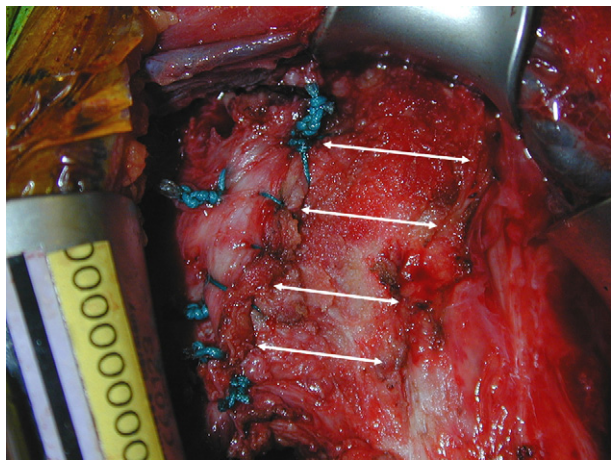

Figure 5 Reflected SSC with intact capsule. A right shoulder with the subscapularis tendon (SSC) reflected off the intact capsule. There are tag sutures in the SSC tendon reflecting it medially. A robust tendon/capsular insertion (white arrows) has been retained laterally.

The released medial capsule and lateral subscapularis tendon allow a large surface area to be primarily repaired while maintaining overall tendon integrity upon completion. As demonstrated by the fact that only 20% of our patients required this procedure, the majority of total shoulder arthroplasty patients can be treated effectively without a subscapularis lengthening being performed; however, this technique is a useful adjunct to have at your disposal when a patient's external rotation is less than 20°. Potential drawbacks to the study include that we did not perform postoperative imaging to evaluate SSC tendon integrity or muscle belly status. We did not have a clinical reason to image these patients and did not have approval or funding for postoperative imaging. Objective strength testing was not done routinely with either dynamometer or spring balance to determine strength in all patients. We utilized the lift-off and belly-press tests, as described in the paper.

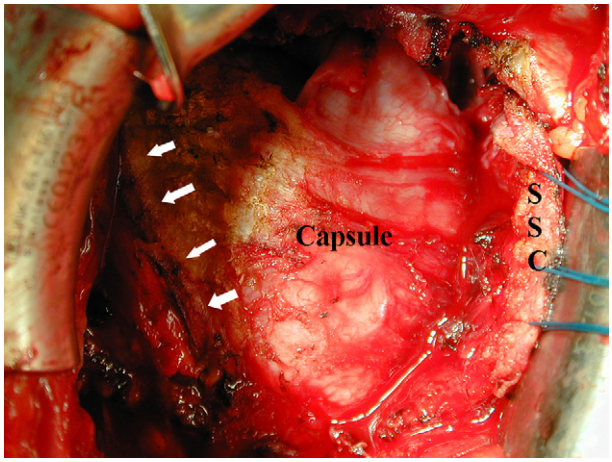

Figure 6 Completed SSC lengthening. An anterior view of a left shoulder after SSC lengthening. The white arrows show the amount of length gained. One centimeter of length should provide about 20 degrees of greater rotation. Note the mattress sutures, and in addition there is a running suture to secure the repair edge.

The use of a sling with an attached external rotation wedge is a crucial postoperative step for these patients to undergo. The wedge automatically places the lengthened subscapularis tendon under gentle tension, and prevents scarring from occurring in the internally rotated position. This also allows the gained external rotation to be maintained and built upon when physical therapy begins. The external rotation wedge is typically discontinued 2-3 weeks postoperatively, with the sling worn for activities of daily living until 4 weeks out.

As with all new surgical techniques, there is a learning curve to be expected. This procedure should be performed by orthopaedic surgeons who are well-versed in total shoulder arthroplasties and the various complications that can arise when taking down the subscapularis tendon.

Conclusion

When performing a total shoulder arthroplasty, postoperative subscapularis dysfunction can present as a significant problem. With significant internal rotation contractures, the ability to gain length in the subscapularis tendon by releases alone has been shown to gain approximately 1-1.5 cm of length. Our subscapularis lengthening technique allows a reliable, reproducible, and effective way to gain external rotation without the need for a lesser tuberosity osteotomy to be performed or supplemental tendon grafts to be utilized. This technique also allows proper tensioning of the subscapularis to occur while external rotation is adequately restored, and can be a useful adjunct to current surgical techniques.

Disclaimer

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