Technical Note

Subscapularis Management With Biologic Augmentation in Anatomic Total Shoulder Arthroplasty

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Abstract: Subscapularis insufficiency continues to be a source of morbidity after anatomic total shoulder arthroplasty (TSA). Biologic augmentation following rotator cuff repair has shown promising results. Here we show the technique for performing subscapularis repair after anatomic TSA using a "peel-tenotomy" and bone marrow aspirate concentrate (BMAC). A standard deltopectoral approach is performed. The peel-tenotomy is performed by leaving 0 to 10 mm of subscapularis attached to the lesser tuberosity and peeling off the remainder of the tendon. A trocar is used to aspirate bone marrow from the humeral head, which is then processed. Prior to placing the humeral stem, drill holes are placed at the bicipital groove and lesser tuberosity. Sutures are placed through each drill hole. After impacting the humeral stem, suture is passed through the subscapularis to perform a secure double row repair. Prior to tying the sutures, BMAC is applied along the margins of the subscapularis repair. After securing the sutures, additional BMAC can be applied to the subscapularis repair. It is hypothesized that this technique could provide a more robust subscapularis repair and decrease the rate of subscapularis insufficiency after TSA without any known risk or morbidity to the patient, although further research is needed to show this.

The preservation of subscapularis function following anatomic total shoulder arthroplasty (TSA) is critical for implant stability and function.[1] Postoperative subscapularis dysfunction can lead to weakness, functional limitation, instability, and decreased long-term survival. Various techniques for the management of the subscapularis have been described, including subscapularis peel (SP), subscapularis tenotomy, lesser tuberosity osteotomy (LTO), and subscapularis sparing. However, the optimal method for managing the subscapularis is still not established, with no single technique resulting in superior long-term outcomes.[1,2]

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Biologic augmentation following rotator cuff repair (RCR) is an emerging trend with promising results. Specifically, augmentation with bone marrow aspirate concentrate (BMAC) has been shown to improve healing rates while decreasing rates of revision rotator cuff surgery.[3-5] The mechanism underlying BMAC is that the harvested aspirate contains mesenchymal stem cells (MSCs) capable of promoting the production of type I collagen.[3] Several in vitro studies have shown the molecular pathways through which these MSCs promote improved mechanical tendon strength and tissue regeneration at the bone−tendon interface. Furthermore, because BMAC is an autologous biologic, the risk profile is extremely low.[3,4] Based on this evidence, the addition of BMAC to a subscapularis repair following TSA may serve to promote improved healing. Here we present our approach for the augmentation of subscapularis repair using BMAC following a combined "peel-tenotomy" in the setting of anatomic TSA.

Surgical Technique

The patient is positioned in the beach chair position, and a standard deltopectoral approach is used. The biceps sheath is released proximally through the rotator interval to the level of the glenoid. The biceps tendon is tenotomized and tagged for later tenodesis. Needle tip cautery is used to release the subscapularis using a combined peel-tenotomy technique. This technique involves leaving a 0- to 10-mm cuff of lateral tendon attached to the lesser tuberosity while the remainder of the subscapularis is peeled off its attachment (Video 1).

Following adequate exposure of the bicipital groove, a sharp bone marrow aspiration trocar is placed into the groove, aiming toward the center of the humeral head (Fig 1A). A syringe containing anticoagulant is attached, and approximately 50 mL of BMAC is obtained (Fig 1B). The trocar can be repositioned to obtain more aspirate as needed (Table 1). Once completed, the syringe is passed off the surgical field for filtration and centrifuge processing using the Magellan MAR0Max autologous concentration system (Isto Biologics). Typically, 8 to 12 mL of BMAC is produced. Calcium is also added to the BMAC for processing (Video 1).

The glenoid and humerus are prepared in a standard fashion for anatomic TSA. Prior to final humeral stem placement, 4 drill holes are placed at the bicipital groove and the lesser tuberosity using a 2-mm drill bit. Four looped #2 high-tensile sutures are placed with the loops facing into the humeral canal (Fig 2). The humeral stem is then placed through the 4 suture loops and impacted into position (Video 1).

The subscapularis peel-tenotomy is repaired in a near-anatomic fashion but can be modified as required based on rotational stiffness and range of motion. Four sets of horizontal mattress sutures are passed through the subscapularis medially using the previously passed high-strength suture. Prior to tying the medial row of sutures, the first application of BMAC is placed along the margins of the subscapularis repair (Fig 3A). The medial repair sutures are then tied, and a second application of BMAC is applied to the subscapularis repair (Fig 3B). Tendon-to-tendon repair is then performed with an additional 5 side-to-side nonabsorbable #1 or #2 permanent sutures, and 2 to 3 figure-of-eight sutures are placed in the lateral rotator interval. A routine surgical closure is used for the deltopectoral interval, subcutaneous tissues, and skin (Video 1).

Rehabilitation

Postoperatively, a sling is prescribed for 3 weeks, allowing for elbow, wrist, and hand range of motion. Patients are permitted to eat and use a computer after the second week. Physical therapy is initiated at 4 weeks postoperatively for mobilization, with external rotation restricted to 30° for approximately 6 weeks postoperatively. Patients proceed with range of motion and strengthening per the anatomic TSA protocol.

Discussion

Advances in the design of anatomic TSA have resulted in considerable improvements in functional outcomes and implant survival.[1] However, postoperative subscapularis dysfunction is a significant concern, with resultant poor outcomes and weakness being a source of morbidity for patients undergoing TSA.[1,2]

Although adequate repair of the subscapularis is critical for implant stability and postoperative function, the optimal method of mobilization and repair is still unknown.[1,2] A recent meta-analysis by Del Core et al.[1] found that LTO resulted in significantly lower rates of positive lift-off tests postoperatively. However, the authors noted that the reliability of subscapularis-specific physical exam findings is low because of possible confounding by other functional muscles, such as the pectoralis major and latissimus dorsi. Furthermore, these physical exam findings correlate poorly with ultrasound findings of tendon integrity.[5] In an effort to use more objective measures, handheld dynamometry has been employed to assess subscapularis strength following TSA. A multicenter randomized controlled

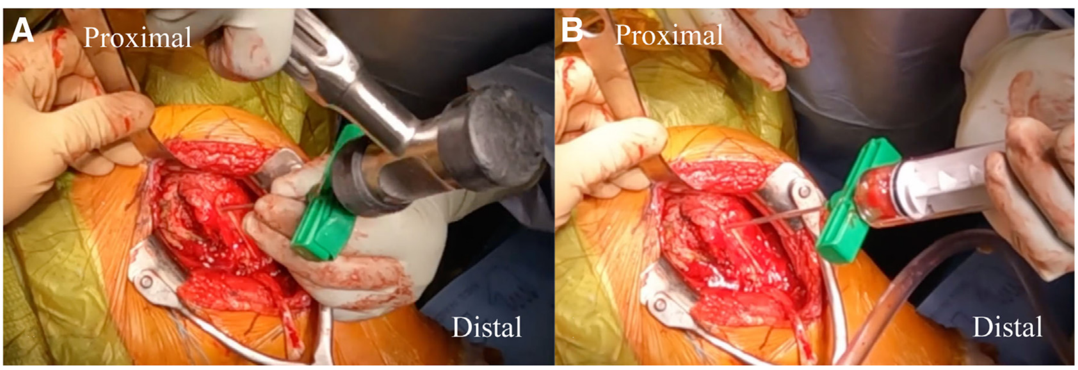

Fig 1. (A) View of a left shoulder in the beach chair position. For collection of the bone marrow aspirate, the trocar is placed in the bicipital groove so that it aims toward the center of the humeral head. (B) A total of 50 mL of bone marrow aspirate is collected in a syringe filled with anticoagulant. This will undergo processing off the field to be used later for repair of the subscapularis tendon.

Table 1. Pearls and Pitfalls of Biologic Augmentation for Subscapularis Repair in Anatomic TSA

Pearls	Pitfalls
- To facilitate easier harvest and trocar placement, make the deltopectoral incision more proximal. - If you need to change the direction of the trocar when aspirating bone marrow, make sure to change the trajectory of the needle tip by 90° to ensure collection from a new donor bed. - If more aspirate is desired, the distal clavicle can be used as a secondary harvest site.	- To ensure you are in the center of the humeral head, do not penetrate too deep with the trocar when harvesting bone marrow. - Avoid placing the trocar too close to the footprint of the subscapularis, as it can compromise the strength of the humeral cortical bone and ultimately the integrity of the subscapularis repair. - Obtain at least 30 mL of bone marrow aspirate before proceeding to centrifugation.

TSA, total shoulder arthroplasty.

trial comparing LTO with SP revealed no significant differences in subscapularis strength assessed by electronic dynamometry.[1] However, following a meta-analysis of dynamometer data, SP was found to result in significantly greater internal rotation strength compared with subscapularis tenotomy, whereas LTO did not.[1] Several studies have also shown that LTO is associated with significantly increased healing rates on ultrasound. Despite these results, nonunion following LTO remains a concern. Ultimately, the current literature fails to show the superiority of any method of subscapularis management in minimizing postoperative weakness. Furthermore, no investigations to date have shown significant differences in postoperative range of motion, with all 3 methods being associated with similarly high patient-reported outcomes and low pain scores.[1,2] Thus, the authors have opted to use a technique that involves a combination of a peel and tenotomy because of ease of repair and surgeon preference while also trying to avoid the risk of nonunion.

The method of subscapularis management is not correlated with the development of postoperative insufficiency. Therefore, methods to optimize tendon healing need to be explored. BMAC has been employed as a biologic agent to augment RCR.[3-5] The underlying principle is that bone marrow contains multipotent MSCs capable of differentiating into tissue of the same germ line, specifically tendon.[3] Using rabbit models, it has been shown that the addition of BMAC to simulated rotator cuff tears results in larger amounts of type I collagen along with the presence of organized fibrocartilage layers and Sharpey fibers at the tendon insertion site.[3,6] Furthermore, biomechanical testing of harvested tissue following the addition of BMAC showed increased tensile strength versus controls. Preliminary clinical studies examining the addition of BMAC to RCR have also shown promising results in terms of functional outcomes and tendon healing.[3-5] Ellera Gomes et al.[7] published a case series of 14 patients with complete rotator cuff tears undergoing mini-open repair and augmentation with BMAC. In their investigation, the mean University of California-Los Angeles scores increased from 12 ± 3 to 31 ± 3.2 at 12 months, with all participants showing tendon integrity on magnetic resonance imaging (MRI). A case−control study conducted by Hernigou et al.[8] showed significantly improved rates of rotator cuff healing following BMAC augmentation at both short- and long-term follow-up ($P < .05$). At 6 months, the BMAC cohort showed 100% healing on ultrasound and MRI compared with only 67% in the standard repair group. When patients were examined at 10-year follow-up, 87% of the BMAC group had intact rotator cuffs compared with only 44% of controls. Of those treated with BMAC who sustained a retear, the amount of MSCs per milliliter was significantly lower ($P < .01$), highlighting a possible dose-dependent relationship. In a recently published randomized controlled trial by Cole et al.,[4] patients receiving iliac crest-derived BMAC at the time of RCR showed significantly lower retear rates at 1 year postoperatively compared with controls, who underwent sham iliac crest harvest. Specifically, 18% of patients undergoing RCR with BMAC had Sugaya scores of 4 (small full-thickness tears) or greater on MRI compared with 57% of those in the control group. The results of these investigations show the

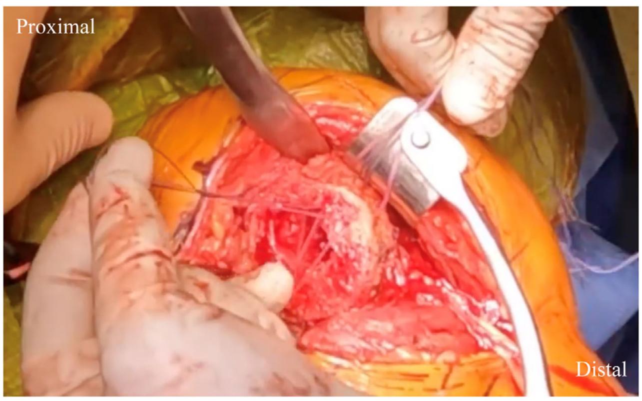

Fig 2. View of a left shoulder in the beach chair position. After drilling holes in the bicipital groove and the lesser tuberosity, 4 looped #2 high-tensile sutures are placed with the loops facing into the humeral canal. These will be used to repair the subscapularis tendon after the implants are placed.

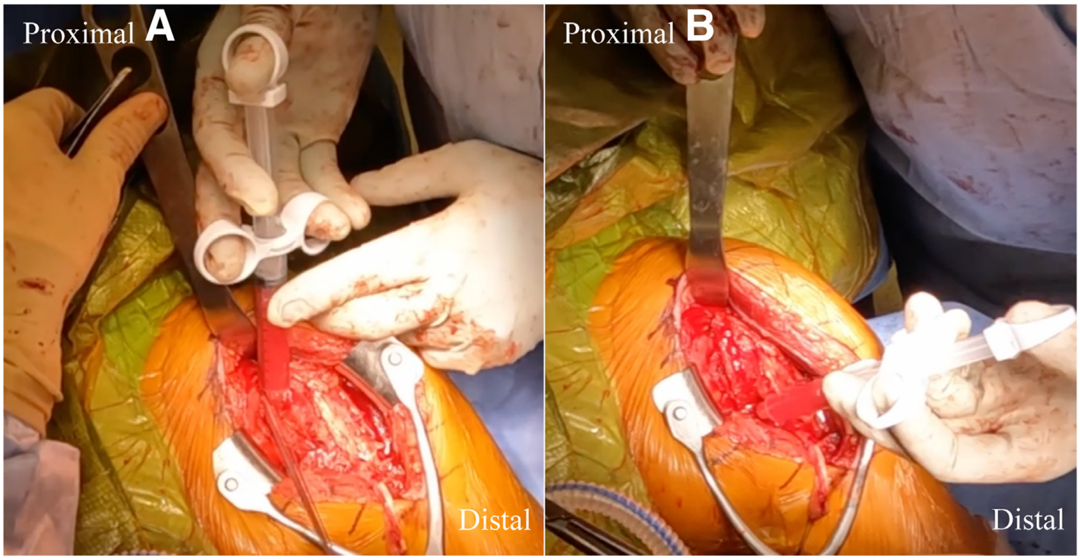

Fig 3. (A) View of a left shoulder in the beach chair position. BMAC is first applied to the margin of the subscapularis repair prior to tying the medial row of sutures. (B) The second application of BMAC to the subscapularis occurs after tying the medial row of sutures. (BMAC, bone marrow aspirate concentrate.)

potential for BMAC to improve tendon healing and decrease retear when used as an adjunct to RCR. The association between higher concentration of MSCs and healing rates also supports the results of in vitro studies examining BMAC's proposed mechanism of action.

Based on the data from RCR literature, it is possible that biologic augmentation may help mitigate the development of subscapularis insufficiency postoperatively. In this technique article, we describe the preferred technique for adding locally derived humeral head BMAC following subscapularis peel-tenotomy in the setting of anatomic TSA. Marrow aspirate from the humeral head was chosen, as it has been shown to provide adequate yield of MSCs while also avoiding the need for and morbidity associated with a secondary harvest site.[3,9] Harvesting from the surgical site results in time savings while also avoiding secondary donor site morbidity. Although the technique employed uses a combined subscapularis peel-tenotomy, this technique can easily be adapted to the surgeon's preferred technique. In our series of patients, no adverse events have been encountered. Future high-quality studies are needed to evaluate the clinical benefit of adding BMAC to subscapularis repair during anatomic TSA while also assessing for any potential risks associated with this therapeutic adjunct.

Disclosures

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