Technical Note

Double Attack Repair for Massive Rotator Cuff Tears: Superior Capsular Reconstruction Using the Long Head of Biceps Tendon Plus Margin Convergence Repair

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Abstract: Arthroscopic repair of massive retracted rotator cuff tears is very challenging with a high incidence of retears. Many techniques have been described to improve the outcomes of arthroscopic repair. In this technique, a superior capsular reconstruction using the long head of the biceps is combined with margin convergence repair aimed at improving the mechanical strength of the repair. The long head of the biceps is used as a superior capsular reconstruction to stabilize the humeral head and prevent proximal migration. Moreover, margin convergence provides an efficient gap filling between remnants of the supraspinatus and infraspinatus tendons to restore an efficient rotator repair in anatomical, biological, and tension-free fashion.

Massive chronic retracted rotator cuff tears are a real challenge for shoulder arthroscopic surgeons. They are associated with tendon retraction and severe muscle atrophy. Arthroscopic repair of these tears is troublesome, with a high incidence of retears. Many strategies have been postulated to try to improve repair outcomes. The 2 most commonly used strategies are superior capsular reconstruction (SCR) and margin convergence repairs (MC).[1,2]

Recently, many techniques have been described for the use of the long head of the biceps tendon (LHB) for SCR: the Hamburger technique, the biceps loop technique, the cuff plus technique, the biceps-cuff-bursa composite technique, the box technique, the L-shape shifting technique, and others. Some authors use LHB alone or in combination with fascia lata, whereas others add extracellular matrix. However, none of them reported its use with margin convergence repair for massive tears.[3-9]

The BicepsLink technique presented in this Technical Note provides a unique solution for massive delaminated tears. It merges the merits of margin convergence repair and superior capsular reconstruction. The long head can independently link the north with the south, reproducing a superior tent to stabilize the humeral head and prevent proximal migration. Moreover, margin convergence links the east with the west, reproducing an efficient gap filling between remnants of the supraspinatus and the infraspinatus to restore an efficient rotator cable in an anatomical, biological, tension-free fashion. This scissoring construct renders the BicepsLink technique a more consistent, powerful solution for massively retracted rotator cuff tears.

Surgical Technique

The advantages and disadvantages of the technique are presented in Table 1. The pearls and pitfalls are shown in Table 2. The procedure steps are presented in Video 1.

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Table 1. Advantages and Disadvantages of BicepsLink Procedure

Advantages
The BicepsLink combines the merits of margin convergence repair with the SCR techniques
Synergistic repair with better stability and survival with the least risk for retear than SCR using LHB alone
Building the construct using patients' native local graft in an intersected style connecting east and west and in the same time connecting north to south, gives the construct a superior mechanical stiffness and biological durability that can tolerate an early postoperative rehabilitation program with low incidence of retears
Disadvantages
Steep learning curve
Too many sutures that may entangle during the repair
Biceps tenotomy after using the biceps inside the construct may lead to biceps pain and cramps due to traction on musculocutaneous nerve

LHB, long head of the biceps tendon; SCR, superior capsular reconstruction.

Table 2. The Pearls and Pitfalls of the BicepsLink Procedure

Step	Pearls	Pitfalls
Biceps loading with 2 free cinch sutures	Use 2 cinch sutures of different colors on either side of the biceps tendon	Using the same colors of sutures may lead to suture entanglement.
Inserting the 2 medial anchors	Keep 2 anchors 1 cm apart with proper bone bridge in between to avoid tunnels convergence.	Poor tissue holding in delaminated retracted tears may lead to failure of the repair. It is better to apply double layer mattress sutures or modified lasso sutures for better tissue holding.
East to west with 2 margin convergence sutures	Two different colors side to side sutures should be used to avoid suture entanglement. Side-to-side sutures are repaired first with biceps smothered in between to close the cuff defect.	Incorporating the biceps inside the side-to-side sutures may lead to fraying of the biceps tendon, which is usually of low quality in these types of tears. Care should be taken to avoid tangling of multiple suture strands used in this technique.
Connect the BicepsBridge with suture bridge	A cannula should be used for better suture management. To avoid suture entanglement, it is better to combine the sutures tails of the same color together.	Avoid inserting the 2 lateral anchors near to each other with a small bone bridge in between. This may lead to greater tuberosity blowout.

Preoperative Assessment

Patients are assessed before surgery for supraspinatus and infraspinatus weakness. Patients' preoperative range of motion is determined both active and passive. Magnetic resonance imaging is done to evaluate the degree of tendon retraction and fatty infiltration. Patients with irreparable rotator cuff tears, fatty infiltration more than Goutallier grade III, rotator cuff arthropathy, and stiff shoulders should not undergo this repair.

Patient Positioning and Setup

The procedure is performed with the patient under general anesthesia with ultrasound-guided regional interscalene nerve block. The patient is positioned in a modified beach chair position (semi-setting). A team-based approach is used to ensure that the patient is in the appropriate position. Care should be taken to maintain the head and neck of the patient in neutral position. Examination of the operated shoulder is performed to confirm the free passive range of motion and stability of the shoulder. The patient's skin is disinfected with povidone iodine, and sterile drapes are applied. An arthroscopic pump is used starting with pressures around 40 mm Hg with hypotensive general anesthesia.

Portal Placement and Diagnostic Arthroscopy

A posterior portal is established 2 cm distal and 1 cm medial to the posterolateral corner of the acromion, and a 30° arthroscope (Stryker Endoscopy, San Jose, CA) is introduced. Systematic diagnostic shoulder arthroscopy is performed, and any intra-articular pathology is addressed.

With the arthroscope in the posterior portal, cuff inspection is performed intra-articularly. A lateral portal is created using an outside-in technique with an 18-gauge spinal needle under direct visualization toward the center of the tear. A 4.5-mm shaver blade (Stryker Endoscopy) is used to debride tissues, adhesions, tendon edges, and footprint. A radiofrequency ablation device (VAPR; DePuy Mitek, Raynham, MA) is introduced through the lateral portal to clear the footprint over the greater tuberosity from all soft tissues. An arthroscopic 5-mm burr (Stryker Endoscopy) is then introduced through the lateral portal to debride the footprint until bleeding bone surface is reached. It is important not to breach the cortical bone with the burr, because it may compromise anchor purchase.

Intra- and extra-articular mobilization of the retracted and scarred tendon are then followed using a soft-tissue liberator, arthroscopic shaver, or radiofrequency

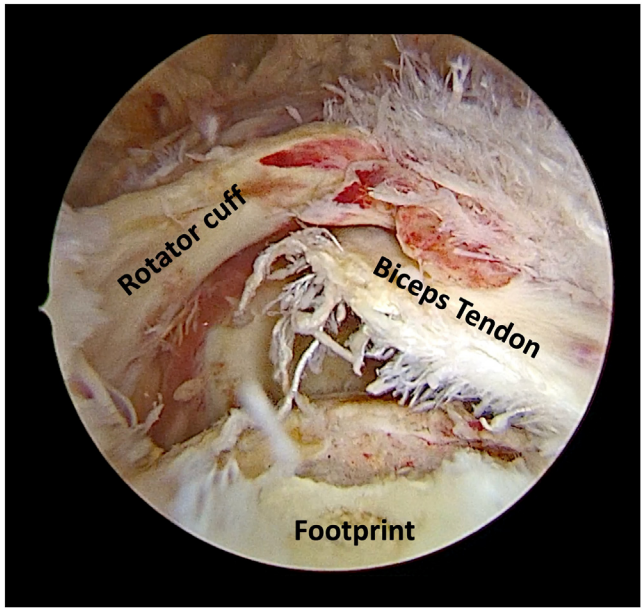

Fig 1. Arthroscopic view from the lateral portal of the right shoulder in a modified beach chair position showing a massive retracted delaminated rotator cuff tear with a frayed biceps tendon.

ablation device. Tendon reduction is checked using a grasper or ring forceps.

The scope is then shifted to the subacromial space in which the bursal side of the rotator cuff is inspected, and the tear morphology is determined. Arthroscopic subacromial decompression is performed using a radiofrequency ablation device and a 5.5-mm motorized burr if there is a spur at the undersurface of the acromion. The scope is then shifted to the lateral portal to have an en-face view of the rear. The motorized shaver is introduced through the posterior portal to complete the subacromial bursectomy.

From the lateral view, cuff retraction and delamination can be assessed (Fig 1). A tissue grasper is used to assess tendon mobilization. A soft tissue liberator is used to dissect the retracted tendons from the underlying glenoid and overlying scapular spine. A radiofrequency ablation device (VAPR) is introduced from anterolateral or posterolateral to ablate adhesions between the tendons and scapular spine posteriorly and the coracoid anteriorly.

Step 1: Biceps Loading With 2 Free Cinch Sutures

A suture passer (DePuy Mitek) is then used through the anterolateral portal to pierce the biceps tendon, and 2 cinch sutures are made on both sides of the tendon. The tendon is tenotomized at the point of entrance into the bicipital groove to keep the origin of the LHB at the glenoid intact. The tenotomized proximal end is now suspended by 2 locking cinch sutures of different colors. In this manner, the tenotomised end can hang freely, with these 2 sutures to be used later at the stage of BicepsBridge (Figs 2-5).

Step 2: Inserting the 2 Medial Anchors

The second step of the procedure is passing the sutures of the 2 medial anchors. Two titanium double-loaded V-Lox 5.5 mm anchors (Parcus Medical, Sarasota, FL) are placed just lateral to the articular cartilage 1 to 2 cm apart through separate portals that are established under direct visualization using an 18-gauge spinal needle. The anteromedial anchor is placed first then the posteromedial anchor (Figs 6, 7).

Thereafter, a suture passer is used to pass the strands of both medial anchors independently through the cuff as mattress or modified lasso sutures for better tissue holding of the retracted delaminated tendon. The long head of the biceps is not included in the repair of the medial row (Fig 8).

Step 3: Paving a Central Path for the Biceps

An arthroscopic 5-mm burr (Stryker Endoscopy) can be used through the anterolateral portal to pave a groove for the biceps tendon in the middle of the foot print. This lane improves biceps tendon stability inside the repair and helps healing of the tendon to the cancellous bleeding surface of the footprint.

Step 4: East to West With 2 Margin Convergence Sutures

A suture passer loaded with high-strength suture strand is then introduced from the posterior portal

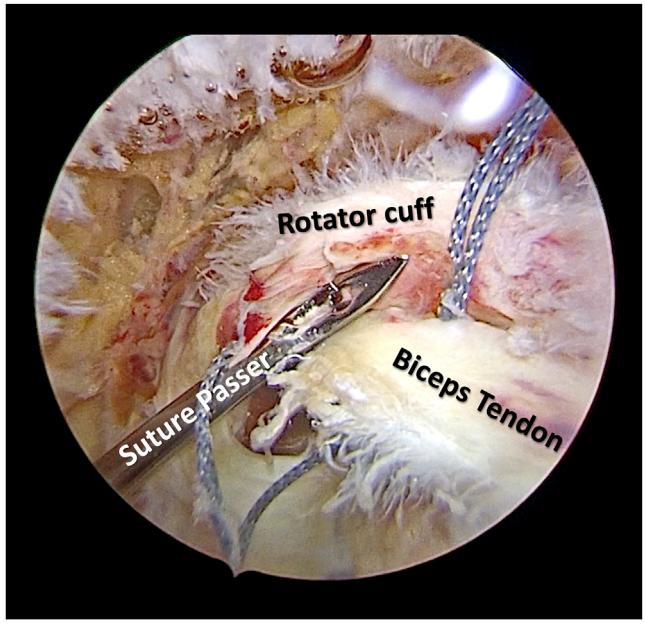

Fig 2. Arthroscopic view from the lateral portal of the right shoulder in a modified beach chair position showing a suture passer used to make the first cinch suture in the long head of the biceps tendon.

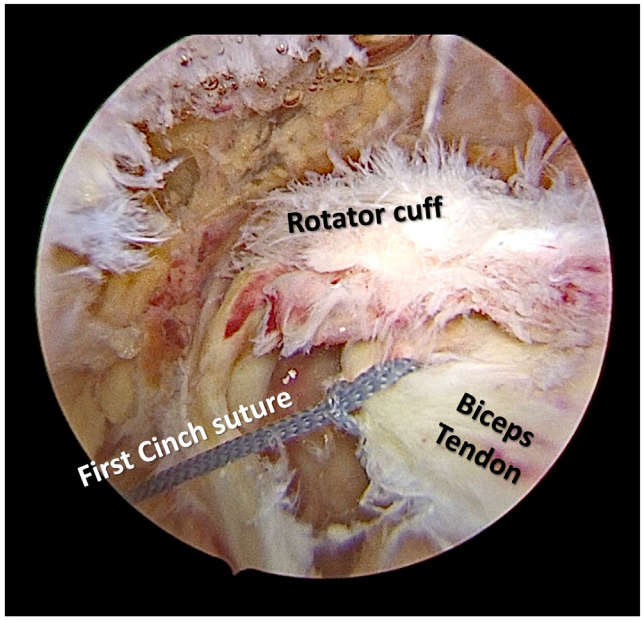

Fig 3. Arthroscopic view from the lateral portal of the right shoulder in a modified beach chair position showing the first cinch suture through the long head of biceps.

through the cuff tissue posteriorly to make first side-to-side suture above the biceps tendon. A second suture passer from the opposite angle is used from the anterior portal to grasp the same suture through the anterior cuff. The same step is repeated with a different suture color but below the biceps tendon. These 2 side-to-side sutures are tightened first to close the cuff defect in a

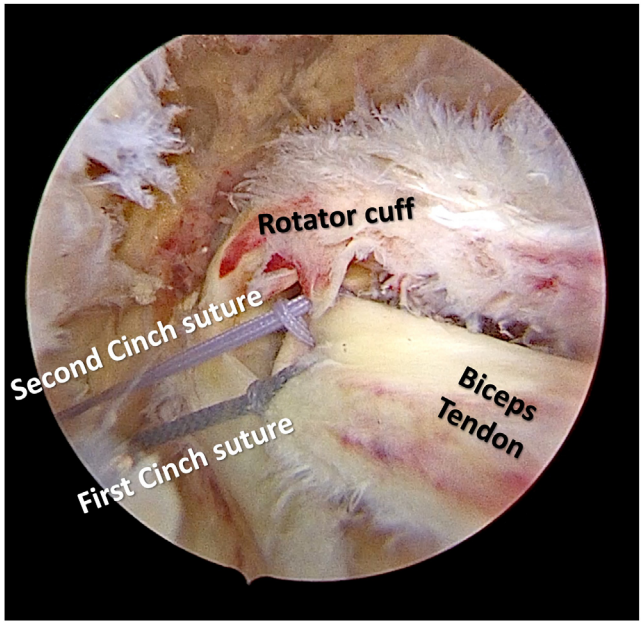

Fig 4. Arthroscopic view from the lateral portal of the right shoulder in a modified beach chair position showing the two cinch sutures on each side of the long head of biceps.

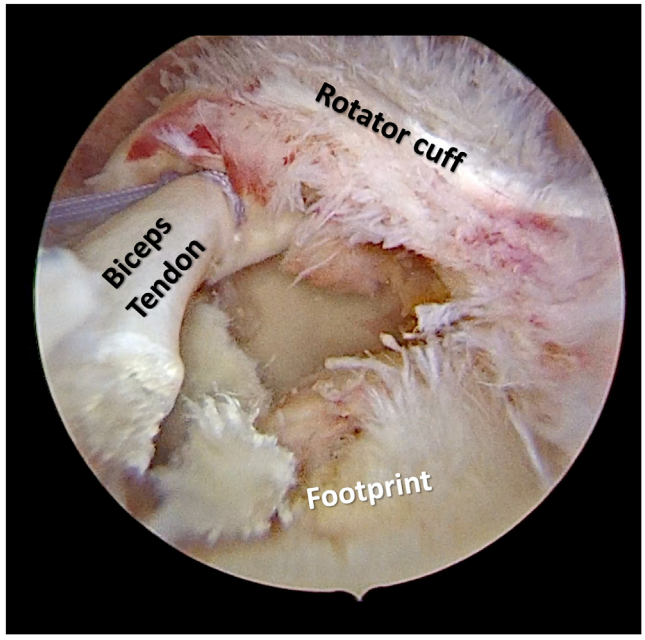

Fig 5. Arthroscopic view from the lateral portal of the right shoulder in a modified beach chair position showing the free hanging of the tenotomized long head of the biceps that is suspended by the 2 cinch sutures.

margin convergence fashion with the biceps tendon smothered in between (Figs 9, 10).

Step 5: Tying the Medial Anchors

The medial row mattress sutures of the 2 medial anchors are then tied, which will result in 4 mattress sutures at the medial row. Care should be taken to avoid tangling the multiple suture strands used in this technique.

Step 6: Connect the Bridges (2 Bridges: Biceps Bridge and Suture Bridge)

The lateral wall of the greater tuberosity is then prepared using a shaver blade and a radiofrequency device. A PassPort Cannula (Arthrex Inc, Naples, FL) is then inserted for better suture management. Afterward, 2 knotless anchors (VersaLoc 5.5 mm; DePuy Mitek) are placed lateral to the greater tuberosity 1 cm apart as a lateral row. Each knotless lateral anchor is loaded with 1 cinch suture of the biceps and suture strands from the anteromedial and posteromedial anchors through the VersaLoc Quick Load Threader tab, with the Peel Quick Load tab removed from the VersaLoc shaft, and straight down to load sutures through the anchor pin. Insert an anchor into the bone by malletting the anchor to the distal edge of the laser line right before the insertion collar. Then use the VersaLoc gun with the tension wheel to tension the sutures until an audible "click" is heard to confirm that sutures are locked in place. Once adequate tension of the rotator cuff is achieved by tensioning the suture limbs manually or with the

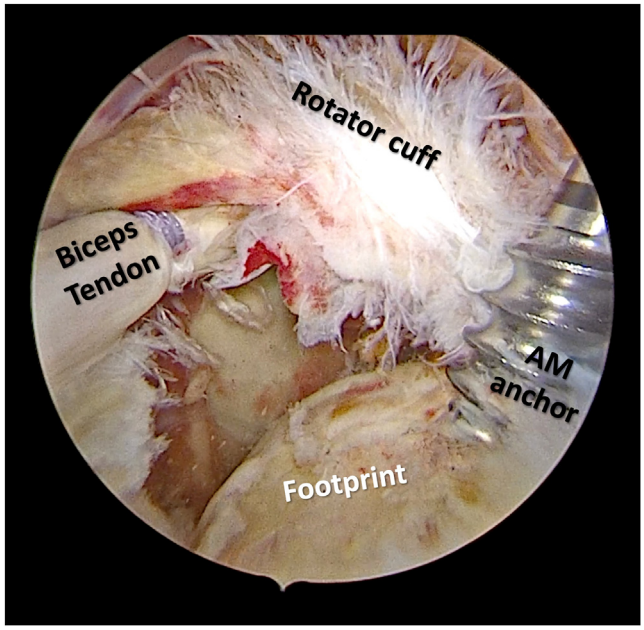

Fig 6. Arthroscopic view from the lateral portal of the right shoulder in a modified beach chair position showing insertion of the anteromedial titanium anchor just behind the articular cartilage.

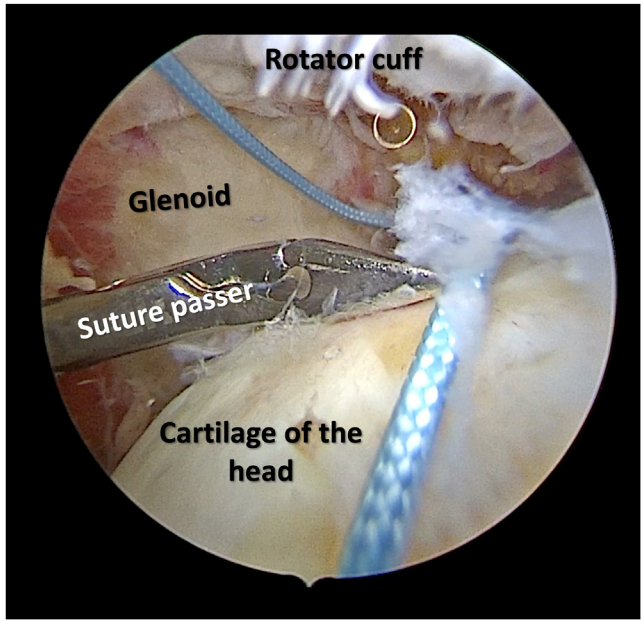

Fig 8. Arthroscopic view from the lateral portal of the right shoulder in a modified beach chair position showing a suture passer inserted though the posterior cuff for fastening the cuff.

tension wheel, pull the trigger completely to lock the anchor and sutures in place. Release the trigger fully, unlock the switch, remove the gun, and cut the sutures to complete the repair. To avoid suture entanglement, it is better to combine the sutures tails of the same color together.

This final BicepsLink pavilion is a combination of SutureBridge and BicepsBridge techniques. The sutures of the medial row are loaded to the lateral anchor independently from the biceps sutures. The LHB is tensioned tightly on the 2 lateral anchors, with each biceps cinch suture loaded on a single knotless anchor independent from the cuff sutures. Similar to the

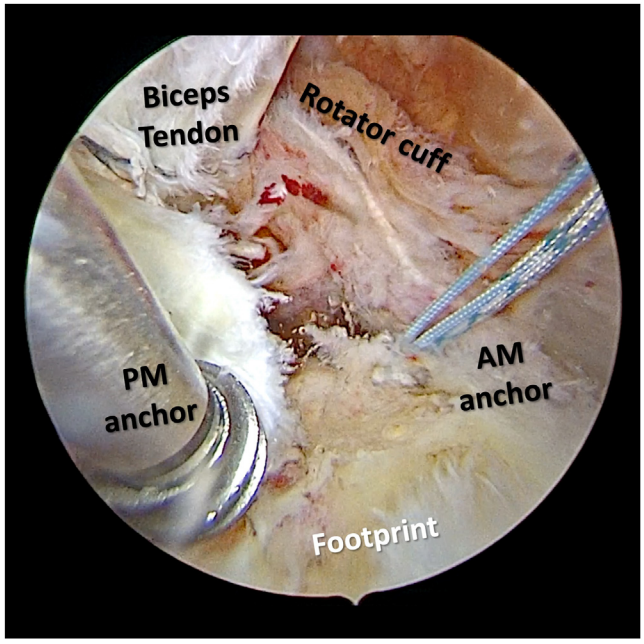

Fig 7. Arthroscopic view from the lateral portal of the right shoulder in a modified beach chair position showing insertion of the posteromedial titanium anchor just behind the articular cartilage. AM, anteromedial; PM, posteromedial.

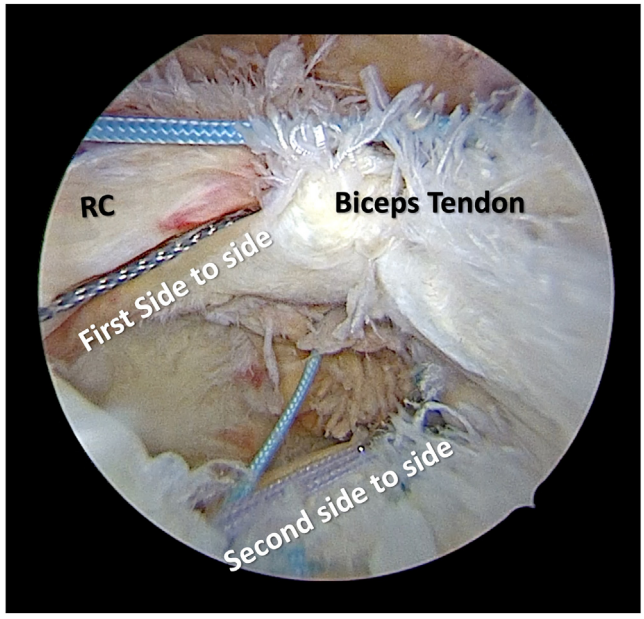

Fig 9. Arthroscopic view from the lateral portal of the right shoulder in a modified beach chair position showing the 2 side-to-side sutures, one above and the other below the biceps tendon. RC, rotator cuff.

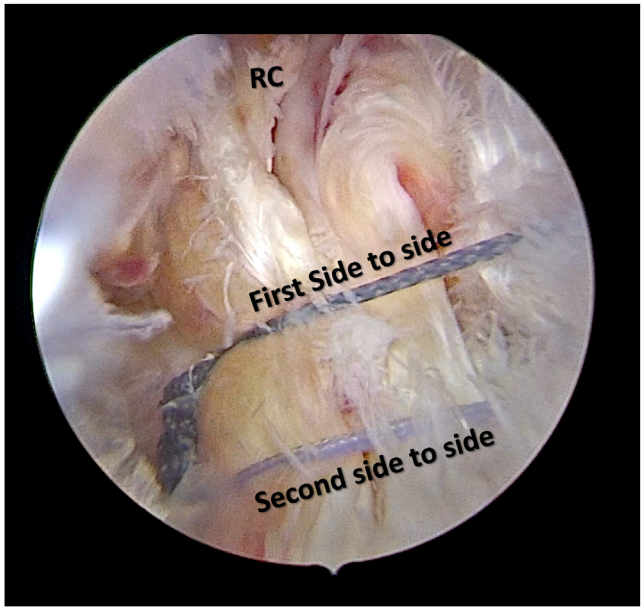

Fig 10. Arthroscopic view from the lateral portal of the right shoulder in a modified beach chair position showing the margin convergence of 2 side-to-side sutures with the biceps tendon smothered inside. RC, rotator cuff.

originally described SCR, the LHB is tensioned at 30° glenohumeral abduction in the scapular plane (correlating to 45° of shoulder abduction) to keep the stabilizing effect of the long head of the biceps to the humeral head (Fig 11).

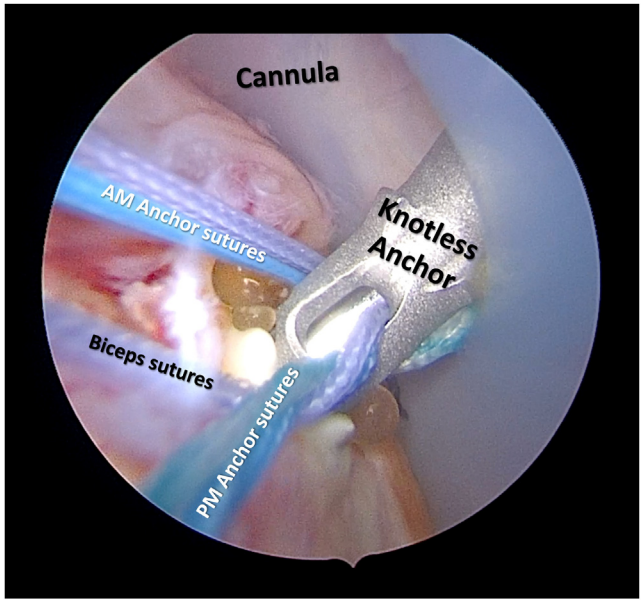

Fig 11. Arthroscopic view of the right shoulder subacromial space through the posterior portal in a modified beach chair position. The knotless lateral anchor is inserted holding cinch biceps sutures (2 violet sutures), anteromedial (AM) anchor sutures (blue sutures), and posteromedial (PM) anchor sutures (Tiger sutures).

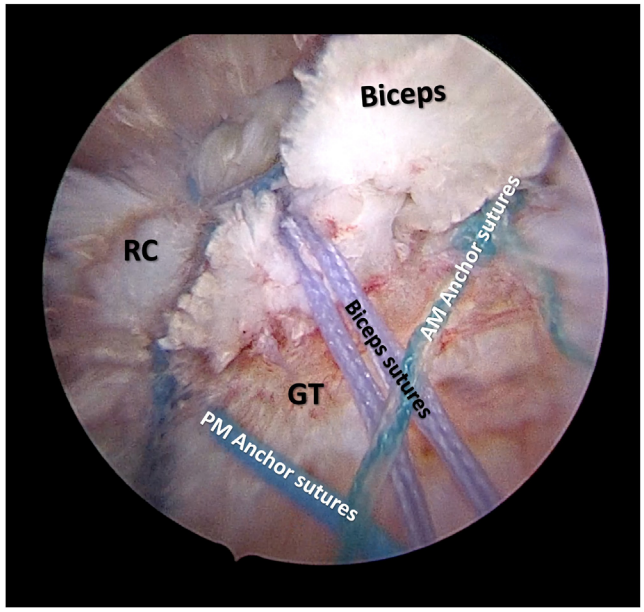

Fig 12. Arthroscopic view of the right shoulder subacromial space through the lateral portal in a modified beach chair position. Linking of the medial row anchor sutures with biceps sutures to the 2 lateral row knotless anchors. BicepsLink pavilion is a combination of SutureBridge and BicepsBridge techniques. RC, rotator cuff.; GT, greater tuberosity.

Finally, the arthroscope is shifted to the lateral portal to assess the adequacy of cuff compression without any dogear formation. Then the scope is switched intra-articularly through the posterior portal to evaluate the competency of the repair from inside the joint (Figs 12, 13). A summary of the technique is illustrated in Figure 14.

Discussion

Massive cuff tears can be challenging to repair because of the retraction, the fatty infiltration, and the defect size. It can be defined as 2- or 3-tendon tears of the cuff that are retracted and cannot be mobilized back to their original footprint. Results of arthroscopic repair of massive cuff tears cannot be deliberately ignored. Despite the technical improvement of the arthroscopic procedure of rotator cuff repair, the data are alarming, with the reported successful healing rates range from 27% to 74% and the incidence of retears or incomplete healing ranging from 40% to 60%. This is because those tears are associated with advanced fatty infiltration, supraspinatus and infraspinatus muscle atrophy, and high grades of tendon retraction. Better outcomes are associated with successful restoration of the rotator cuff integrity compared with vulnerable or deficient cuff repairs.[10]

Several techniques have been proposed to improve the outcome of arthroscopic massive cuff repairs, such as the double-row, suture bridge, triple row, superior

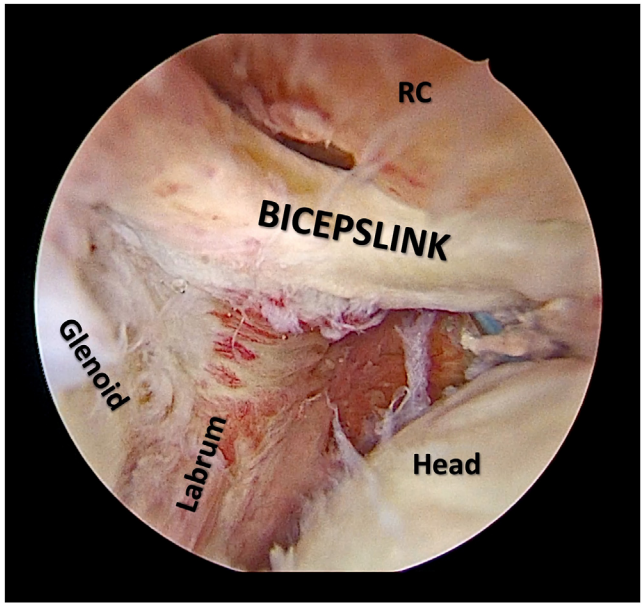

Fig 13. Intra-articular arthroscopic view of the right shoulder through the posterior portal in a modified beach chair position. The tear is sealed completely and anatomically reduced back to its footprint. The rotator cable is restored with the BicepsLink loaded inside the repair. RC, rotator cuff.

capsular reconstruction, scaffolds, biceps augmentation, margin convergence and muscle transfers. A muscle transfer such as latissimus dorsi or trapezius transfer can be an option, although the results are unpredictable, and a more anatomic repair is usually preferred. Moreover, biological enhancements were described such as bone morphogenetic proteins, bursal tissue, and platelet-rich plasma to decrease the rate of retears in such massive tears.[2,8,10]

Burkhart promoted the "margin convergence" (MC) in the 1990s, which demonstrated an effective biomechanical behavior to overcome the high strain of reducing massive U-shaped tears in many cadaveric studies.[2] Hatta et al.[11] recommended use of multiple MC sutures for repair of massive tears. Mazzocca et al.[12] found that there was a significant decline in rotator cuff strain and gap size after margin convergence repair for a massive retracted tear. Clinically, margin convergence repair has demonstrated improved postoperative outcomes using the patient's native tissue without artificial scaffolds.[13,14]

More recently, Mihata et al.[15] introduced the SCR technique using fascia lata autograft or a dermal allograft for the management of massive rotator cuff tears.

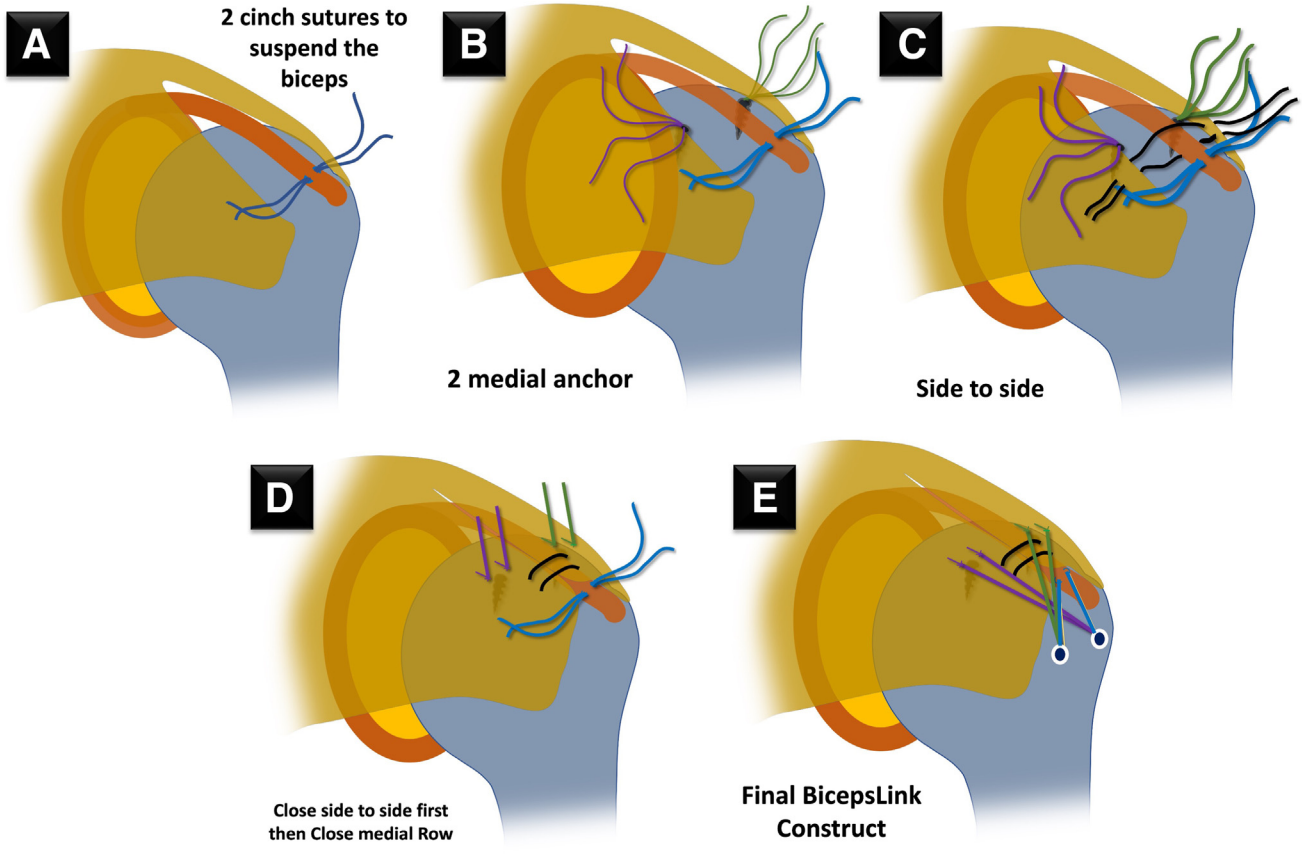

Fig 14. Summary of technique. (A) Two cinch sutures are applied to suspend the tenotomized biceps tendon. (B) Application of the 2 medial anchors. (C) Passing side-to-side sutures. (D) Closing the defect by tying the margin convergence sutures first then tying the 2 medial anchors. (E) Loading the sutures over knotless anchors.

SCR aims to normalize superior translation and to increase acromiohumeral distance, which improves glenohumeral kinematics, allowing the deltoid and the remaining cuff to function more effectively.[15] Altintas et al.[16] reported that SCR showed good to excellent short-term clinical outcomes with adequate pain relief and functional improvement.

The problem of massive, retracted tears has 2 main roots (biological and mechanical) that can advocate failure and retears. The use of the intra-articular portion of the biceps tendon for arthroscopic augmentation of massive tears repairs has been gaining popularity in recent years because it solves both the mechanical problem and the biological problem: It is available for most patients; there are no immune reactions because it is an autograft; it is relatively easy to harvest during the same arthroscopic procedure; and it is rich in tenocytes and fibroblasts. Moreover, the biceps autograft technique uses no artificial augmentation, so it is comparatively less costly than other techniques. There are many techniques reported for biceps augmentation, with some studies leaving the proximal portion (SCR) or distal portion intact (Biceps augmentation), whereas others used it as a free graft.[10,17] Berthold et al.[1] performed a biomechanical study to evaluate the LHB as an SCR. They found that using the LHB for reconstruction of the superior capsule improved shoulder function by preventing superior humeral migration, decreasing deltoid forces and subacromial peak contact pressure; hence, the development of rotator cuff tear arthropathy in patients with irreparable posterosuperior rotator cuff tears.[1]

Ciccotti et al.[18] compared results of the 2 main strategies used for the repair of massive tears, the MC repair, and the SCR. They found that both MC and SCR provided similar improvement in outcomes; however, SCR resulted in a significantly lower survivorship rate at 2 years after surgery. These results evoke the idea of integrating both strategies in a double attack repair incorporating SCR with MC repair together based on a biceps tendon core. The real advantage of the BicepsLink technique is that it combines the merits of both techniques. This synergistic repair may have better repair stability and survival with the least risk for retear than SCR using LHB alone. Furthermore, building the pavilion using patients' native tissues in an interlaced fashion gives the construct a superior mechanical stiffness and biological durability that can tolerate an early postoperative rehabilitation program with a low incidence of retears.

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