Long Head of the Biceps as a Suitable Available Local Tissue Autograft for Superior Capsular Reconstruction: “The Chinese Way”

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Abstract: Massive irreparable rotator cuff tears remain a challenging condition during daily clinical practice. Irreversible fatty infiltration of muscles and excessive chronic retraction of tendons predispose to high failure rates of their surgical treatment. Superior capsular reconstruction with either fascia lata autograft or a dermal allograft patch is a newly described solution that could prevent superior humeral head migration and restore the anteroposterior shoulder muscle force couples. The purpose of this article is to propose a technical modification of superior capsular reconstruction using long head of the biceps tendon autograft. The tendon’s insertion into the glenoid is left intact, whereas laterally, it is tenotomized, transferred, and sutured with anchors onto the footprint of the supraspinatus tendon acting as a superior static stabilizer of the shoulder joint. Although this surgical modification has theoretical biological advantages, could be performed with the least technical demands, and simplifies the original demanding procedure, further prospective studies with large cohort populations and long-term follow-up are necessary to establish its effectiveness.
Surgical Technique

Preoperative Evaluation and Indications

All patients undergo careful clinical and appropriate radiologic examination of the RC including radiographs, magnetic resonance imaging, or arthro–computed tomography scanning. Possible indications for performing SCR by use of the LHBT are irreparable posterosuperior massive RC tears with Hamada stage 2 or 3 and Goutallier stage 3 or 4 muscle fatty infiltration. The supraspinatus tendon is mainly retracted and degenerated and is intraoperatively irreducible (Patte stage III) (Fig 1A). Partially or fully reparable infraspinatus and subscapularis tendon tears may also exist. The shape of the lesion is usually a retracted L or reverse L (Fig 1C). Preoperative recovery of passive range of motion of the shoulder joint is advised, and an existing LHBT with no excessive tendinitis or partial tears should be confirmed intraoperatively.

Patient Position, Arthroscopic Portals, and Initial Joint Exploration

Under general anesthesia and additional interscalene nerve block, the patient is placed in the beach-chair position. Usually, the following 6 standard arthroscopic portals are necessary: posterior, posterolateral, lateral, anterolateral, anterior, and Nevisier portals (Fig 1B). A standard posterior portal 2 cm medial and inferior to the posterolateral corner of the acromion is created, and a 30° arthroscope is introduced into the glenohumeral joint. A careful evaluation confirming the massive RC lesion, the glenohumeral cartilage condition, and the LHBT quality is obtained. Thereafter, 1 anterior arthroscopic portal through the rotator interval and 1 lateral portal (at the level of the lateral projection of the clavicle) about 1 cm below the lateral acromion are created. The latter is ideally placed under arthroscopic control by using a spinal needle inserted through the tear just above the greater tuberosity.

Subscapularis Tendon Tear Repair

According to our preferences in cases in which a reparable subscapularis lesion exists, it is initially addressed (“inside-the-box” repair).10 To restore the stabilizing force couple in the transverse plane, the surgeon should always attempt to repair the subscapularis tendon by also preserving the portion of the superior glenohumeral–coracohumeral ligament complex (“comma sign”). The arthroscope is kept...
intra-articularly from the posterior portal, and by use of the already established anterior and lateral portals, any adhesions are released and the lesser tuberosity is prepared. However, an additional anterosuperolateral portal may also be necessary during subscapularis tear repair. In the case of no retracted lesion (absence of comma sign) and tears involving less than the upper two-thirds of the tendon insertion, 1 suture tape (FiberTape; Arthrex, Naples, FL) is passed through the subscapularis tendon by use of a needle suture passer (NeedlePunch; Arthrex) or a lasso-loop device (Banana Lasso; Arthrex). The surgeon repairs the tendon onto the lesser tuberosity with one 4.75-mm Bio-Composite SwiveLock anchor (Arthrex), performing a SpeedFix technique (Arthrex). By use of the remaining traction suture of the anchor as well, the previous repair can be reinforced (Fig 1 C1-C3). In retracted lesions with a comma sign present, a double-row repair is preferred.

Exploration of Subacromial Space

The arthroscope is introduced into the subacromial space (Fig 2A). An additional posterolateral portal, 1 cm lateral and inferior to the posterior corner of the acromion, is established. With a motorized shaver and a radiofrequency electrocautery device (Super TurboVac 90; ArthroCare, Austin, TX), extensive bursectomy and release of the RC tendons adhesions are performed. With a tendon grasper, an evaluation of RC retraction and degeneration is also performed.

Once the irreparability of the massive posterosuperior cuff tear is confirmed, the greater tuberosity is prepared with a 5.5-mm motorized burr to enhance tendon-to-bone healing, and a concomitant acromioplasty, emphasizing the lateral aspect of the acromion and removal of anterior osteophytes, is performed. The coracoacromial ligament is preserved, preventing superior migration of the humeral head.

SCR With LHBT

By keeping the arthroscope in the posterolateral portal, a 10-mm flexible PassPort cannula (Arthrex) is placed in the lateral portal to aid future suture management. Through the lateral portal, a 5.5-mm triple-loaded Bio-Corkscrew FT Suture Anchor (Arthrex) is inserted approximately in the middle of the greater tuberosity (just behind the bicipital groove) (Fig 2B1). Sequentially, using the NeedlePunch suture passer, the surgeon passes all the sutures through the intact LHBT, performing a “lasso-loop” configuration (Fig 2 B2 and C). The sutures are retrieved from the anterior or posterior working portal. With the aid of the radiofrequency cautery device, the biceps tendon is dissected and tenotomized approximately at the middle of the bicipital groove. No tenodesis is performed regarding the distal part of the LHBT. Thereafter, the sutures of the anchor are sequentially retrieved and tied through the PassPort cannula. In this manner, the LHBT is transferred and securely fixed onto the footprint of the supraspinatus tendon on the greater tuberosity. Therefore, the biceps tendon, which is natively fixed on the glenoid, acts as the autograft for SCR (Fig 2 D and E). The free ends of the tied sutures...
are not cut but are retrieved through the anterior working portal.

Repair of Posterior RC Tendons

Depending on the retraction and inelasticity of the remaining infraspinatus tendon, its partial repair is attempted. Depending on the tear size, a SpeedFix technique (for small lesions) or transosseous-equivalent configuration (SpeedBridge [Arthrex], for larger lesions) with the use of FiberTape and 4.75-mm BioComposite SwiveLock anchors is performed. Although the surgeon can always change the arthroscope placement to evaluate the progression of the repair, the posterolateral portal is the main viewing portal during this step of the procedure. In cases in which a needle suture passer (NeedlePunch) is used, the anterolateral portal with the flexible PassPort cannula is the main working portal for passing the suture tapes. Thereafter, they are mainly retrieved posteriorly. However, when a suture lasso device (Banana Lasso) is preferred, the infraspinatus tendon is penetrated and the sutures are directly retrieved from the posterior portal (Fig 3A). In addition, when a SpeedFix repair is performed, 1 suture tape and 1 knotless anchor are sufficient. In cases of a transosseous-equivalent configuration (SpeedBridge), 2 medial suture-loaded and 2 lateral knotless anchors are necessary (Figs 3C and 4).

Final Construct

The No. 2 FiberWire sutures (Arthrex) that were used for LHB T fixation are retrieved sequentially from the anterior to the lateral portal. By use of the NeedlePunch suture passer or a suture lasso device (Banana Lasso), they are passed through the infraspinatus and the retracted supraspinatus posteriorly and/or the rotator interval—“comma sign” anteriorly, providing an additional side-to-side, “tension-free” marginal repair of the RC with the LHB T (Fig 3 B1-B3, C1, and C2). In this manner, any RC tendon defect can be covered by the LHB T. Moreover, side-to-side fixation of the infraspinatus with the LHB T is expected to prevent any later posterior retraction of the tendon. Final construct evaluation with both subacromial and intra-articular views is performed (Figs 3 C1-C3, Video 1, Table 1).

Postoperative Rehabilitation

Postoperatively, the patient follows a massive RC repair rehabilitation protocol. The arm is placed in an abduction pillow at 60°, which is generally maintained for 6 weeks. However, active hand, wrist, and elbow
Exercises are allowed from the first day, and progressive passive shoulder mobilization is commenced under observation 15 days postoperatively. Active-assisted physiotherapy, hydrotherapy, and progressive withdrawal of the abduction pillow are advised 6 weeks postoperatively, focusing on full passive and active shoulder range-of-motion gains and performance of common daily activities without difficulties. No strengthening or resistance exercises are allowed before 6 months.

**Discussion**

With this technical note, we propose a modification of the originally described SCR using the LHBT as an autograft. Compared with the method described by Mihata et al., the main principles remain the same. The LHBT’s insertion onto the glenoid is carefully preserved, and its distal part into the bicipital groove is tenotomized, transferred, and fixed onto the middle part of the greater tuberosity. In addition, we attempt to restore the anterior and posterior shoulder force couples by repairing the subcapsularis and infraspinatus tendons, respectively, and by performing a side-to-side marginal repair with the LHBT.

In comparison with the original technique of Mihata et al., some authors proposed replacing the fascia lata autograft with a human acellular dermal patch allograft in an effort to avoid any additional skin incisions and any donor-site morbidity. They proposed modified double-row fixation of the allograft onto the glenoid and distally transosseous-equivalent techniques for the repair onto the greater tuberosity. All of them supported the marginal repair with the remaining RC tissue anteriorly and posteriorly. The thickness of the allograft provided is 3.5 mm and the dimensions measure 4 × 7 cm, which can be adapted according to the lesion’s size and the glenohumeral anatomy. In addition, to obtain an appropriate graft, Mihata et al. harvested a section of fascia lata 2 to 3 times the size of the superior capsular defect that they further folded twice or thrice. In this way, they accomplished obtaining an autograft of 6 to 8 mm thick and with 6.1 × 3–cm mediolateral and anteroposterior dimensions.

We prefer to use the existing LHBT, the diameter of which, at the humeral head articular margin, is approximately 6.6 mm. This value is close to the 8-mm graft thickness most recently proposed by Mihata et al. Furthermore, according to published data, the mechanical properties may also be sufficient, given that the ultimate strength of the LHBT measures 32.5 ± 5.3 MPa whereas the value for the supraspinatus tendon is only 16.5 ± 7.1 MPa.

Similar to several other authors, we believe that the static superior capsule is important in maintaining humeral head depression and its effect is possibly higher than the dynamic effect of the RC muscles. This possible kinematic restoration is the reason SCR techniques resulted in significant pain relief. The purpose of the aforementioned technique is to transform the LHBT into an efficient superior static stabilizer, without applying any materials on the glenoid and without any additional incisions for tendon harvesting. Furthermore, because of the control of superior head subluxation in cases with large or massive tears, SCR could protect the repaired tendons in favor of their healing process. Finally, another possible advantage is the biological aspect of using a local autograft, attached on the superior glenoid, such that its vascularization might be preserved (Table 2).

However, it should be noted that our technique has several limitations. The principal condition is the presence of an LHBT with relatively good quality, not excessively degenerated or partially torn. This may not always be possible in cases of chronic massive irreparable RC tears. In addition, the LHBT is reported to be a pain generator in patients with RC tears, and tenotomy
Table 1. Surgical Steps, Tips and Pearls, and Pitfalls of Technique

| Surgical Steps                                      | Tips and Pearls                                                                 | Pitfalls                                                                                       |
|-----------------------------------------------------|---------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|
| 1. Intra-articular diagnostic arthroscopy—evaluation of lesion | - The necessary arthroscopic portals are as follows: posterior, anterior, lateral, and posterolateral. An anterosuperolateral portal may be necessary in cases of subscapularis tears. A Neviser portal also may be used during suture passage to the infraspinatus.  
- Evaluation of the subscapularis tendon, LHB, and posterosuperior rotator cuff tendon is performed from the posterior standard portal.  
- When a subscapularis tendon tear exists, it is initially repaired using the posterior portal as a viewing portal and the anterior, anterosuperolateral, and lateral portals as working portals (inside-the-box repair).  
- The LHBT is excessively degenerated or torn. Thereafter, the SCR procedure with this autograft is not suitable.  | - Excessive burring of the tuberosity or excessive acromioplasty with ablation of the coracoacromial ligament could increase the risk of further superior migration of the humeral head in the case of tendon healing failure.  
- Inadequate debridement of the cuff can result in underestimation of its mobility and of the exact tear pattern.  
- In these massive tears, especially in revision cases, the posterior cuff is sometimes adhered to the posterior acromion and to the subdeltoid fascia. Starting the debridement by using only the posterior viewing portal could be a potential issue. Immediate transfer of the arthroscope to the lateral viewing portal is preferred to correctly address and safely release the cuff.  |
Table 1. Continued

| Surgical Steps                                                                 | Tips and Pearls                                                                                     | Pitfalls                                                                                   |
|------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|
| 4. Partial repair of infraspinatus tendon                                     | • For SpeedFix repair, 1 suture tape and 1 knotless anchor are used.                               | • An inability to recognize delaminated tears is possible. The surgeon should place the arthroscope into the lateral viewing portal and, using a tendon grasper from the anterior or anterosuperolateral portal, pull all the layers of the delaminated posterosuperior cuff. Thereafter, the accurate placement of a lasso-loop device (Banana Lasso) through the Neviaser portal is a valuable method to address these tears. |
| (SpeedFix or SpeedBridge configuration)                                       | • For a transosseous-equivalent configuration (SpeedBridge), 2 medial suture-/tape-loaded and 2 lateral knotless anchors are necessary. | • Again, at this surgical step, one possible pitfall is anchor failure resulting from low bone density in the area. The surgeon should try to position the anchor near the cartilage of the humerus. |
|                                                                              | • The sutures and/or tapes are passed through the infraspinatus by use of either a NeedlePunch suture passer or a suture lasso device (Banana Lasso). | • Care should be taken with suture management. A solution is to keep the sutures of the LHBT at the anterior portal and to retrieve the sutures for the partial repair of the infraspinatus tendon posteriorly. The surgeon must be organized. |
|                                                                              | • The 2 sutures from the LHBT can be passed through the infraspinatus tendon also.                   | • Soft-tissue swelling and difficulties in finalizing the construct may occur. The surgeon should always respect the subdeltoid fascia and preserve low arthroscopic pump tension during the operation. |
|                                                                              | • The surgeon should fix the infraspinatus according to the chosen technique.                      |                                                                                            |
| 5. Final construct                                                            | • The surgeon could pass 1 suture anteriorly through the rotator interval.                         |                                                                                            |
|                                                                              | • The surgeon should secure the sutures of the LHBT anchor by performing a side-to-side, tension-free marginal repair of the RC with the LHBT. |                                                                                            |
|                                                                              | • Finally, a watertight construct may be achieved.                                                 |                                                                                            |

LHBT, long head of biceps tendon; SCR, superior capsular reconstruction.
Table 2. Advantages, Risks, and Limitations of SCR Using LHBT Autograft

| Advantages                                                                 |
|----------------------------------------------------------------------------|
| No additional incisions and donor-site morbidity for graft harvesting      |
| Autograft use and possible preservation of biceps anchor vascularity       |
| No medial preparation of glenoid for SCR and no risk of suprascapular nerve|
| injury or possible fracture of glenoid and cartilage damage                |
| No allograft use, limiting possible inflammatory reactions                 |
| No need for additional materials                                           |
| Lower cost in terms of socioeconomic aspects                               |

| Risks                                                                     |
|----------------------------------------------------------------------------|
| Popeye sign, esthetic discomfort, or muscle cramps of biceps distally     |
| Pain derived from “biceps anchor” (degeneration of proximal biceps)       |
| As in all massive tears, increased risk of postoperative stiffness         |
| (preoperative correction of passive joint range of motion is strongly advised) |

| Limitations                                                               |
|----------------------------------------------------------------------------|
| Excessive degeneration of LHBT                                             |
| Torn LHBT                                                                  |
| Rotator cuff arthropathy, Hamada stage ≥ 4                                 |

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

or tenodesis has been proposed as an effective surgical solution. Theoretically, the use of the LHBT as an autograft for SCR could potentially augment postoperative pain. However, before we decided to report the technique, our short-term follow-up showed no such undesirable effects. The Popeye sign could represent another possible risk, more in terms of cosmesis than functional impairment. Prospective studies with large cohort populations and long-term follow-up are necessary to establish the effectiveness of the technique. With the described technique, SCR could be performed with the least technical demands only by transferring and fixing the distal part of the LHBT onto the greater tuberosity.

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References
1. Kim I-B, Kim M-W. Risk factors for retear after arthroscopic repair of full-thickness rotator cuff tears using the suture bridge technique: Classification system. Arthroscopy 2016;32:2191-2200.
2. Kim S-J, Kim S-H, Lee S-K, Seo J-W, Chun Y-M. Arthroscopic repair of massive contracted rotator cuff tears: Aggressive release with anterior and posterior interval slides do not improve healing and integrity. J Bone Joint Surg Am 2013;95:1482-1488.
3. Shon MS, Koh KH, Lim TK, Kim WJ, Kim KC, Yoo JC. Arthroscopic partial repair of irreparable rotator cuff tears: Preoperative factors associated with outcome deterioration over 2 years. Am J Sports Med 2015;43:1965-1975.
4. Petri M, Warth RJ, Horan MP, Greenspoon JA, Millett PJ. Outcomes after open revision repair of massive rotator cuff tears with biologic patch augmentation. Arthroscopy 2016;32:1752-1760.
5. Steinhaus ME, Makhni EC, Cole BJ, Romeo AA, Verma NN. Outcomes after patch use in rotator cuff repair. Arthroscopy 2016;32:1676-1690.
6. Kanatl U, Özer M, Öztüğlu MB, et al. Arthroscopic-assisted latissimus dorsi tendon transfer for massive irreparable rotator cuff tears: Technique and short-term follow-up of patients with pseudoparalysis. Arthroscopy 2017;33:929-937.
7. Mihata T, Lee TQ, Watanabe C, et al. Clinical results of arthroscopic superior capsule reconstruction for irreparable rotator cuff tears. Arthroscopy 2013;29:459-470.
8. Petri M, Greenspoon JA, Millett PJ. Arthroscopic superior capsule reconstruction for irreparable rotator cuff tears. Arthrosc Tech 2015;4:e751-e755.
9. Hirahara AM, Adams CR. Arthroscopic superior capsular reconstruction for treatment of massive irreparable rotator cuff tears. Arthrosc Tech 2015;4:e637-e641.
10. Burkhart SS, Brady PC. Arthroscopic subscapularis repair: Surgical tips and pearls A to Z. Arthroscopy 2006;22:1014-1027.
11. Mihata T, McGarry MH, Kahn T, Goldberg I, Neo M, Lee TQ. Biomechanical effects of acromioplasty on superior capsule reconstruction for irreparable supraspinatus tendon tears. Am J Sports Med 2016;44:191-197.
12. Adams CR, Denard PJ, Brady PC, Hartzler RU, Burkhart SS. The arthroscopic superior capsular reconstruction. Am J Orthop (Belle Mead NJ) 2016;45:320-324. http://www.mdedge.com/amjorthopedics/article/109992/arthroplasty/joint-replacement/arthroscopic-superior-capsular. Accessed January 24, 2017.
13. Denard PJ, Dai X, Hanypsiak BT, Burkhart SS. Anatomy of the biceps tendon: Implications for restoring physiological length-tension relation during biceps tenodesis with interference screw fixation. Arthroscopy 2012;28:1352-1358.
14. Mihata T, McGarry MH, Kahn T, Goldberg I, Neo M, Lee TQ. Biomechanical effect of thickness and tension of fascia lata graft on glenohumeral stability for superior capsule reconstruction in irreparable supraspinatus tears. Arthroscopy 2016;32:418-426.
15. McGough RL, Debski RE, Taskiran E, Fu FH, Woo SL. Mechanical properties of the long head of the biceps tendon. Knee Surg Sports Traumatol Arthrosc 1996;3:226-229.
16. Verma NN, Lubowitz JH, Brand JC, Provencher MT, Rossi MJ. Could disruption of the shoulder superior capsule be the “essential lesion” of rotator cuff disease? Possibly, but questions remain…. Arthroscopy 2016;32:2421-2423.
17. Mihata T, McGarry MH, Kahn T, Goldberg I, Neo M, Lee TQ. Biomechanical role of capsular continuity in superior capsule reconstruction for irreparable tears of the supraspinatus tendon. Am J Sports Med 2016;44:1423-1430.