Technical Note

Arthroscopic V-Shaped Double-Pulley Suture-Bridge Repair of Massive Rotator Cuff Tear

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Abstract: At present, suture bridge is a feasible choice in the treatment of massive rotator cuff tears (MRCTs). However, high tension on the repair site and medial tension during suture tightening and after medial knotting are unavoidable problems in MRCT repair with a suture bridge. Arthroscopic V-shaped double-pulley suture-bridge repair is a pragmatic surgical technique for the repair of MRCTs. The unique parallel design of medial- and lateral-row anchors can minimize tendon tension on the apex portion; 6 sets of double-pulley suture bridges can not only provide sufficient tendon-bone contact area but also reduce the tendon retear rate. Moreover, medial knotless techniques can reduce tendon tension.

Massive rotator cuff tears (MRCTs) cause severe shoulder pain and dysfunction. Given the high retear rate,[1] the optimal ways to treat MRCTs continue to be a debatable topic.[2] High cost, a protracted recovery time, and a relatively high complication risk are related to the new-ways such as superior capsule reconstruction, patch augmentation, and tendon transfer.[3]

Tendon repair is a feasible choice in the treatment of MRCTs. The retear rate of MRCTs with single-row repair has been emphasized, with reported rates of up to 94%.[4] MRCTs that underwent suture-bridge repair have shown satisfactory clinical outcomes.[5] However, high tension on the repair site of MRCTs caused by tendon retraction is a challenging problem.[6] Medial-row tension is further increased during suture tightening and medial knotting during the suture-bridge procedure.[7,8]

Arthroscopic V-shaped double-pulley suture bridge (DPSB) is a pragmatic surgical technique for the repair of MRCTs. The unique parallel design of medial- and lateral-row anchors can minimize tendon tension on the apex portion; 6 sets of DPSBs can not only provide sufficient tendon-bone contact area but also reduce the tendon retear rate. Moreover, medial knotless techniques can reduce tendon tension.

Surgical Technique

Preparation

The patient is administered general anesthesia and placed in the lateral decubitus position with the arm in 20° of flexion and 30° of abduction (Video 1). Pearls and pitfalls of the surgical technique are described in Table 1, and advantages and disadvantages are listed in Table 2. This research was approved by the ethical department in our hospital, and all patients gave informed consent.

Diagnosis and Evaluation

Arthroscopic diagnostic assessment is performed through the posterior portal. The tear shape and size, as well as the amount of tendon retraction, are evaluated. Concomitant pathologies of the long head of the biceps tendon are treated with either tenodesis or tenotomy.

The scope is shifted into the subacromial space, and thorough subacromial bursectomy is applied. When a spur is present at the acromial undersurface, subacromial decompression is adopted. The tear shape and size and the amount of tendon retraction are also evaluated (Fig 1).

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Table 1. Surgical Pearls and Pitfalls

Surgical indications
Patients with severe tendon retraction and high tendon tension are not on the application list; superior capsule reconstruction or tendon transfer is a better choice.
Anchor implantation
Two double-loaded suture anchors—as medial-row anchors—are implanted anteriorly and posteriorly into the debrided humeral head.
The asymmetric anchor layout with 2 medial-row anchors and 1 lateral-row anchor is the surgical requirement.
Suture layout
A total of 6 strands are planned to pass through the tendon evenly, including 3 strands from the posterior-medial anchor and 3 strands from the anterior-medial anchor.
DPSB layout
Two white strands from the posterior-medial anchor and 2 blue strands from the lateral anchor create the first and second sets of DPSBs. Two blue strands from the anterior-medial anchor and 2 white strands from the lateral anchor create the third and fourth sets of DPSBs. One blue strand from the posterior-medial anchor and 1 white strand from the anterior-medial anchor create the fifth set of DPSBs. One white strand from the anterior-medial anchor and 1 blue strand from the anterior-medial anchor create the sixth set of DPSBs.

DPSB, double-pulley suture bridge.

Table 2. Advantages and Disadvantages

Advantages
The middle 2 sets of DPSBs are created with the anchors that were implanted in the debrided humeral head, which not only achieves suture-bridge repair of the tear apex but also minimizes tendon tension by the unique parallel design of medial- and lateral-row anchors.
DPSB repair can obtain the heighten footprint contact, with higher loads to failure and a lower retear rate.
Six sets of DPSBs that compress the tendon against the footprint can provide sufficient tendon-bone contact area in the process of MRCT repair.
Medial knotless techniques can reduce tendon tension at the muscle-tendon junction.
Disadvantages
Patients with severe tendon retraction and high tendon tension are not on the application list; superior capsule reconstruction or tendon transfer is a better choice.
Overmuch suture knots may yield some negative effects, such as subacromial erosion.
The strength of suture compressing the tendon down onto the footprint is weaker than that of conventional SB repair.
Breakage of the DPSB due to knot slipping during the suture-pulling process is disastrous.

DPSB, double-pulley suture bridge; MRCT, massive rotator cuff tear; SB, suture bridge.

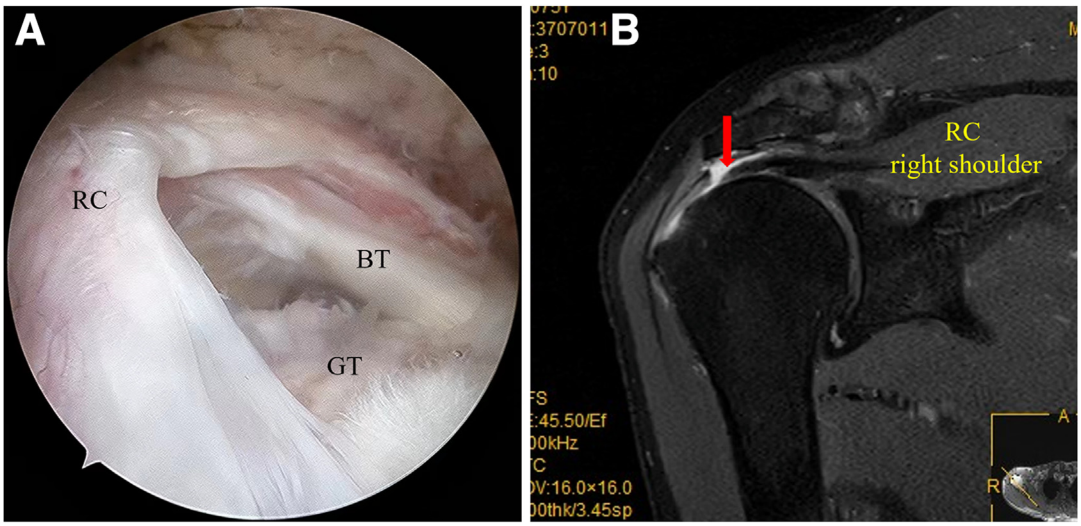

Fig 1. (A) Arthroscopic image of right shoulder (lateral decubitus position) viewed through subacromial lateral portal showing evaluation of tear shape and size, as well as amount of tendon retraction. (BT, biceps tendon; GT, greater tuberosity; RC, rotator cuff.) (B) Coronal T2 fat suppression image of right shoulder preoperatively (magnetic resonance arthrogram). The arrow indicates tendon retraction of the rotator cuff (RC).

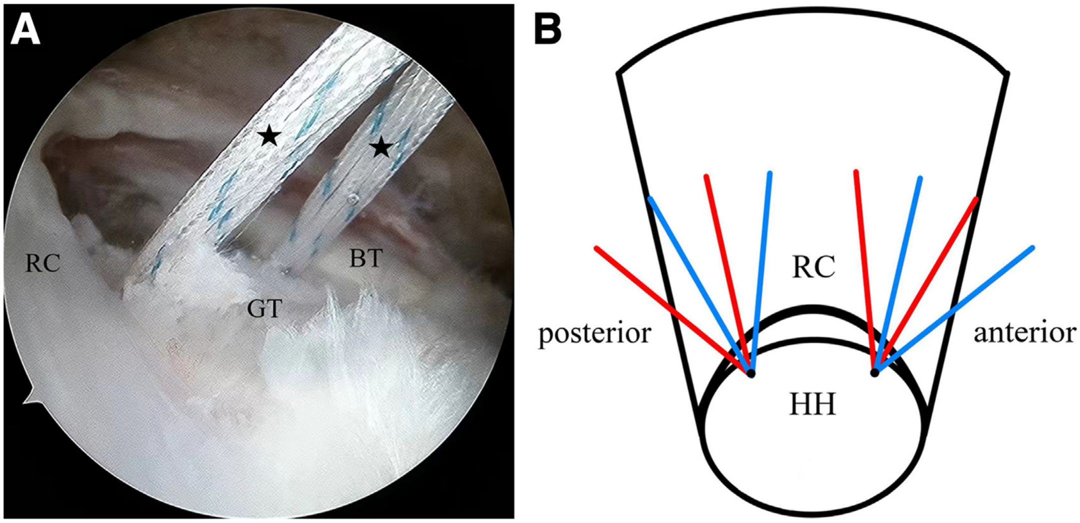

Fig 2. (A) Arthroscopic image of right shoulder (with patient in lateral decubitus position) viewed through subacromial lateral portal: Two double-loaded suture anchors with blue and white strands—as medial-row anchors—are implanted anteriorly and posteriorly into the debrided humeral head. The stars indicate the strands of the medial-row anchors. (BT, biceps tendon; GT, greater tuberosity; RC, rotator cuff.) (B) Schema showing 2 double-loaded suture anchors with blue and white strands—as medial-row anchors—being implanted anteriorly and posteriorly into debrided humeral head (HH). (RC, rotator cuff.)

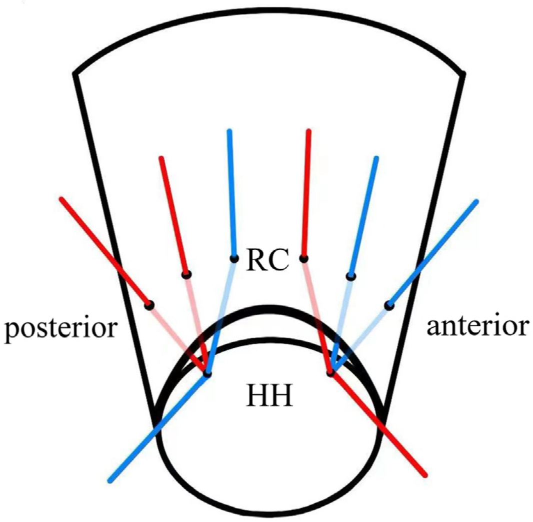

Fig 3. Schema showing total of 6 strands from medial-row anchors being passed through tendon evenly. (HH, humeral head; RC, rotator cuff.)

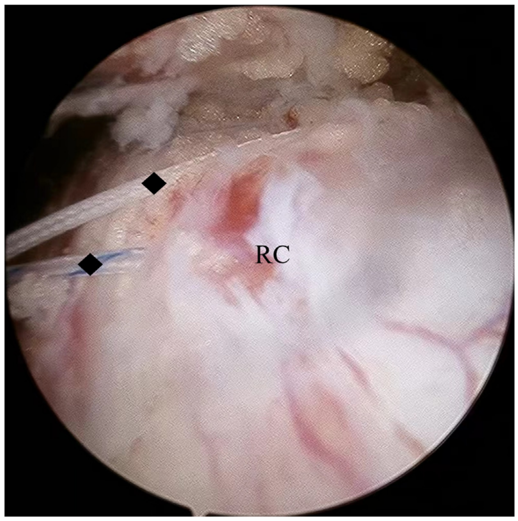

Fig 4. Arthroscopic image of right shoulder (with patient in lateral decubitus position) viewed through subacromial lateral portal: One blue strand (diamond) on the posterior-medial anchor and 1 white strand (diamond) on the anterior-medial anchor are considered the middle 2 sutures (of the 6 sutures) and are passed through the apex part of the tendon. (RC, rotator cuff.)

Tendon Mobilization

A shaver and radiofrequency ablation are used for release of adhesions in the joint and subacromial space to achieve more tendon mobilization. Tendon reduction is evaluated for mobility with a grasper. When the tendon can be easily mobilized and tension-free repair is obtained, the repair process is initiated.

Medial-Row Anchor Insertion

For footprint medialization, 8 mm of articular cartilage of the humeral head is debrided, which can usefully decrease repaired tendon tension. Two double-loaded 5.0-mm suture anchors (TWINFIX; Smith & Nephew, Andover, MA) with blue and white strands—as medial-row anchors—are implanted anteriorly and posteriorly into the debrided humeral head; the bone bridge between the anchors should measure at least 10 mm (Fig 2).

Strand Passage Through Tendon

A total of 6 strands are planned to pass through the tendon evenly (Fig 3). The white strands on the

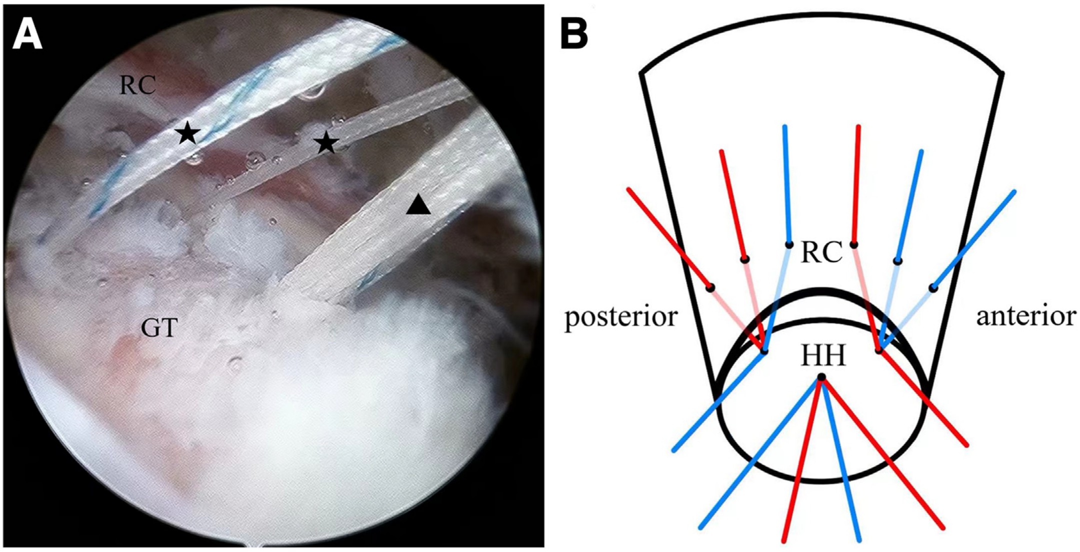

Fig 5. (A) Arthroscopic image of right shoulder (with patient in lateral decubitus position) viewed through subacromial lateral portal: One double-loaded 5.0-mm suture anchor with blue and white strands—as the lateral-row anchor—is implanted into the middle part of the greater tuberosity (GT). The stars indicate the strands of the medial-row anchors that do not pass through the tendon, and the triangle indicates the sutures of the lateral-row anchor. (RC, rotator cuff.) (B) Schema showing 1 double-loaded 5.0-mm suture anchor with blue and white strands—as the lateral-row anchor—being implanted into middle part of greater tuberosity. (HH, humeral head; RC, rotator cuff.)

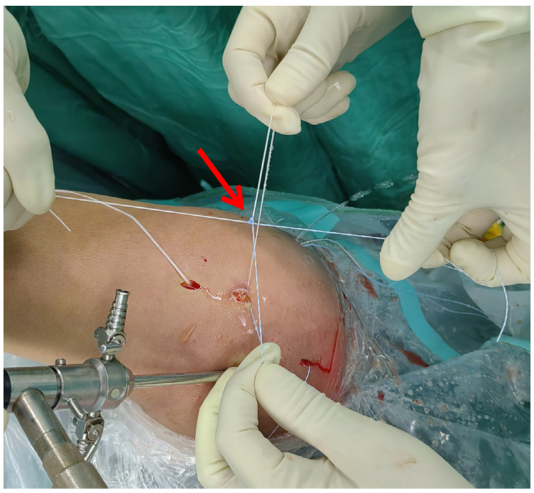

Fig 6. In an extracorporeal manner, the 2 strands are knotted firmly over a Kirschner wire and linked into a blue-white suture. The arrow indicates the knot of the blue-white suture.

Fig 7. As a result of double-pulley technology, the blue-white suture along with the knot will be drawn in a stepwise manner onto the bursal layer of the tendon (red arrow) by pulling on the other side of the 2 strands that exit through the percutaneous portals (blue arrow).

posterior-medial anchor are considered the posterior 2 strands (of the 6 strands) and are passed through the posterior part of the tendon. The blue strands on the anterior-medial anchor are considered the anterior 2 strands (of the 6 strands) and are passed through the anterior part of the tendon. One blue strand on the posterior-medial anchor and one white strand on the anterior-medial anchor are considered the middle 2 sutures (of the 6 sutures) and are passed through the apex part of the tendon (Fig 4).

Lateral-Row Anchor Insertion

One double-loaded 5.0-mm suture anchor (TWIN-FIX) with blue and white strands—as the lateral-row anchor—is implanted into the middle part of the greater tuberosity (Fig 5).

Suture-Relay Procedure

One white strand from the posterior-medial anchor, which has been passed through the posterior tendon, and one blue strand from the lateral anchor are

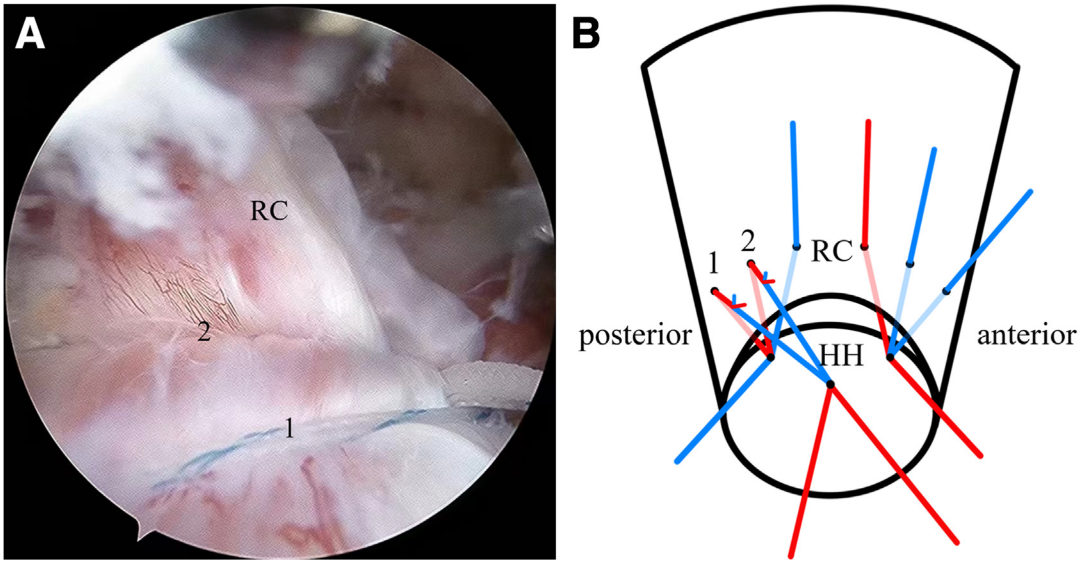

Fig 8. (A) Arthroscopic image of right shoulder (with patient in lateral decubitus position) viewed through subacromial lateral portal: The first set (1) and second set (2) of double-pulley suture bridges (DPSBs) powerfully compress the tendon down onto the footprint. (RC, rotator cuff.) (B) Schema showing first set (1) and second set (2) of DPSBs powerfully compressing tendon down onto footprint. (HH, humeral head; RC, rotator cuff.)

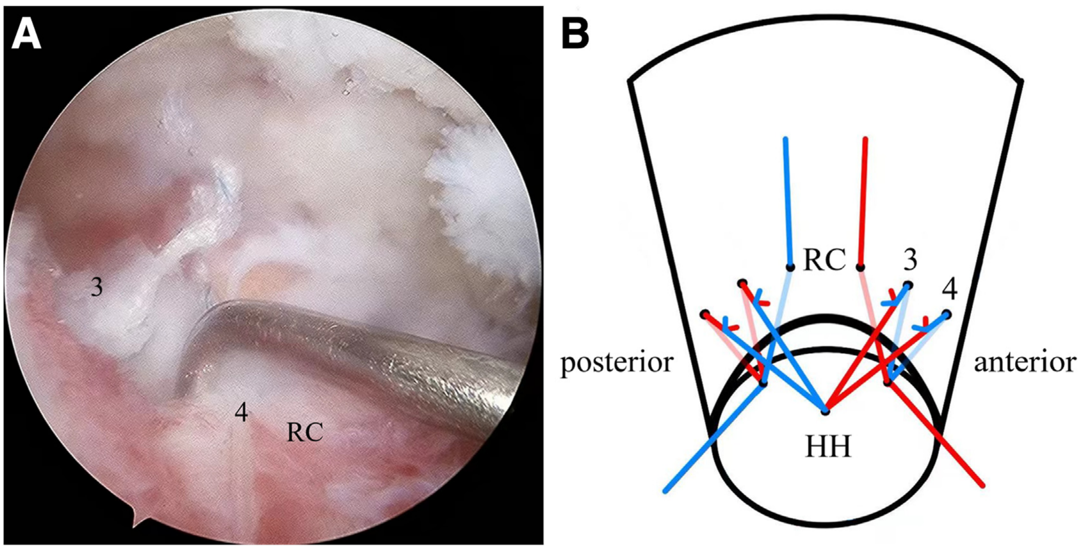

Fig 9. (A) Arthroscopic image of right shoulder (with patient in lateral decubitus position) viewed through subacromial lateral portal: The third set (3) and fourth set (4) of double-pulley suture bridges (DPSBs) powerfully compress the tendon down onto the footprint. (RC, rotator cuff.) (B) Schema showing third set (3) and fourth set (4) of DPSBs powerfully compressing tendon down onto footprint. (HH, humeral head; RC, rotator cuff.)

retrieved out of the body using a grasper. In an extracorporeal manner, the 2 strands are knotted firmly over a Kirschner wire (Fig 6) and linked into a blue-white suture.

As a result of double-pulley technology, the blue-white suture along with the knot will be drawn in a stepwise manner onto the bursal layer of the tendon by pulling on the other side of the 2 strands that exit through the percutaneous portals (Fig 7), and the extra strands are cut. The blue-white suture is the first set of DPSBs and powerfully compresses the tendon down onto the footprint. The expected tension of the tendon will be gained when the opposite strands are repeatedly pulled.

The other-side strands of blue and white sutures, which will create the second set of DPSBs and powerfully compress the tendon down onto the footprint, are knotted firmly with a knot pusher in the subacromial space; the extra strands are also cut (Fig 8). Two blue strands from the anterior-medial anchor, which have

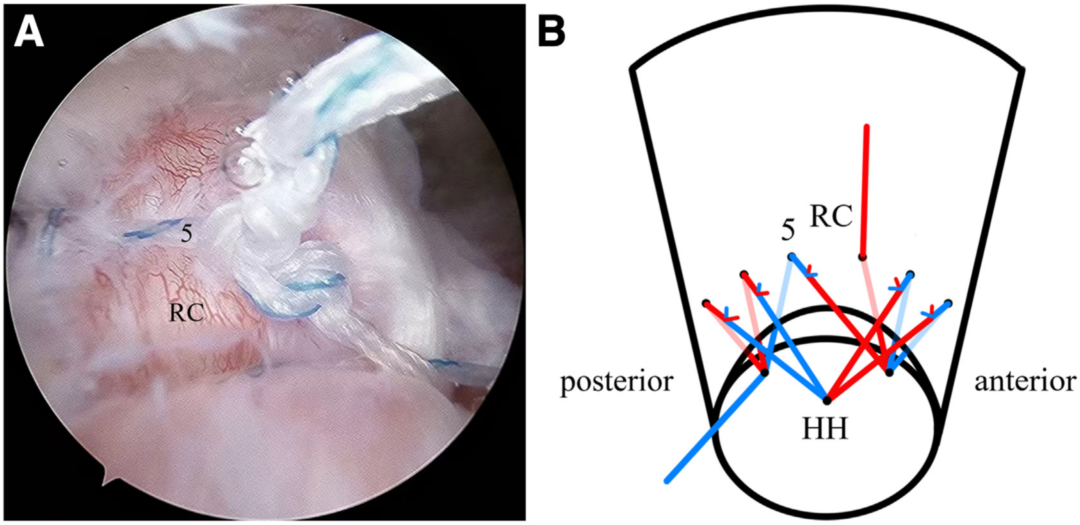

Fig 10. (A) Arthroscopic image of right shoulder (with patient in lateral decubitus position) viewed through subacromial lateral portal: The fifth set (5) of double-pulley suture bridges (DPSB) powerfully compresses the apex part of the tendon. (RC, rotator cuff.) (B) Schema showing fifth set (5) of DPSBs powerfully compressing apex part of tendon. (HH, humeral head; RC, rotator cuff.)

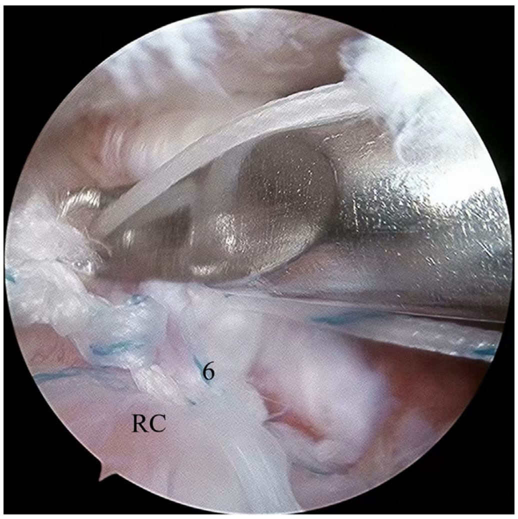

Fig 11. Arthroscopic image of right shoulder (with patient in lateral decubitus position) viewed through subacromial lateral portal: One white strand from the anterior-medial anchor, which has been passed through the apex part of the tendon, and 1 blue strand from the anterior-medial anchor create the sixth set (6) of double-pulley suture bridges (DPSB) with a knot pusher. (RC, rotator cuff.)

been passed through the anterior tendon, and 2 white strands from the lateral anchor create the third and fourth sets of DPSBs (Fig 9).

One blue strand from the posterior-medial anchor, which has been passed through the apex part of the tendon, and 1 white strand from the anterior-medial anchor create the fifth set of DPSBs (Fig 10). One white strand from the anterior-medial anchor, which has been passed through the apex part of the tendon, and 1 blue strand from the anterior-medial anchor create the sixth set of DPSBs (Fig 11). In this procedure, the 2 anchors mutually undertake the work of medial- and lateral-row anchors, forming the unique parallel design of medial- and lateral-row anchors.

Reattachment Confirmation

The reattached tendon containing 6 sets of DPSBs shows the suture layout with parachute effect that powerfully compresses the tendon against the footprint with low tendon tension (Fig 12). The scope is shifted into the joint, and the reattached tendon is evaluated.

Discussion

Tendon tension is the foremost element for the structural integrity of repaired tendon.[9] Obtaining as much footprint coverage as possible without undue tension is the ideal pattern.[10] Nevertheless, tendon retraction due to tendon stump shortening and loss of tissue elasticity is a common symptom accompanying MRCT.[11-13] Performing mobilization of the scarred retracted tendon while realizing a tension-free process represents a great challenge for surgeons.[14] High tension has been confirmed to place the reattached tendon at severe retear risk.[15,16] The most common approach to increase tendon excursion is release of adhesions. However, Kim et al.[17] reported that excessive release of adhesions harmfully affected tendon-bone healing owing to tendon devascularization.

Suture-bridge repair possesses obvious superiority over single-row repair in terms of retear rate reduction after MRCT repair,[18] but the high retear rate cannot be ignored and is still a difficulty to be solved. Trantalis et al.[7] proposed overmuch medial tension during the suture-bridge procedure of suture tightening as the

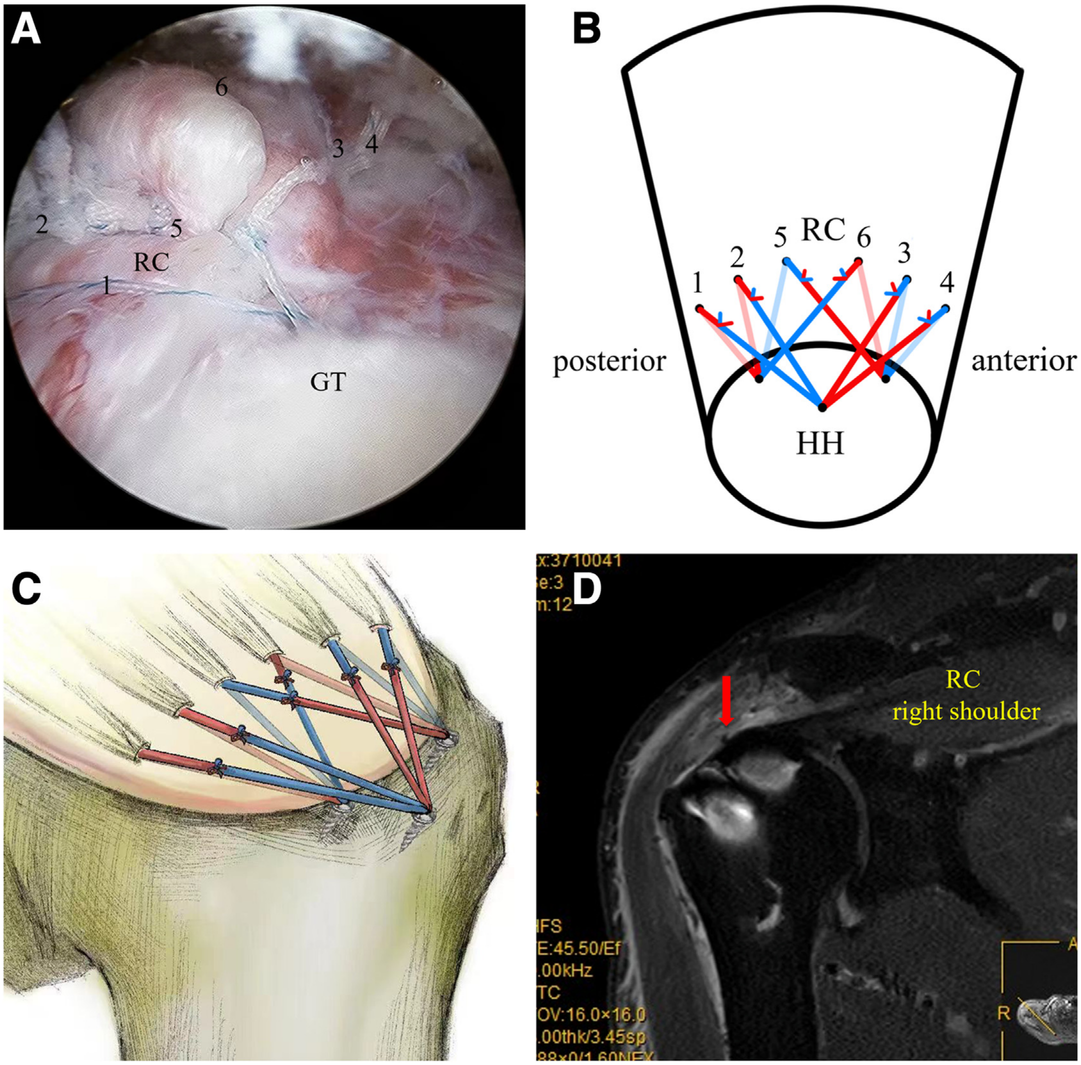

Fig 12. (A) Arthroscopic image of right shoulder (with patient in lateral decubitus position) viewed through subacromial lateral portal: The reattached tendon containing 6 sets of double-pulley suture bridges (DPSBs) shows the suture layout with parachute effect that powerfully compresses the tendon against the footprint with low tendon tension. (GT, greater tuberosity; RC, rotator cuff; 1, first set; 2, second set; 3, third set; 4, fourth set; 5, fifth set; 6, sixth set.) (B, C) Schema of reattached tendon containing 6 sets of DPSBs showing suture layout with parachute effect powerfully compressing tendon against footprint with low tendon tension. (HH, humeral head; RC, rotator cuff; 1, first set; 2, second set; 3, third set; 4, fourth set; 5, fifth set; 6, sixth set.) (D) Coronal T2 fat suppression image of right shoulder postoperatively (magnetic resonance arthrogram). The arrow indicates the reattached rotator cuff (RC) tendon.

primary factor of tendon retear. Over-tension and strangulation at the muscle-tendon junction caused by medial tying are also factors of tendon retear.[6,8,19] Kim et al.[20] postulated that the blood supply interruption from the muscle-tendon junction to the tear area was aggravated by suture-bridge repair.

Most MRCTs are U-shaped tears with a long distance from the tuberosity to the tear apex. Given the remarkable increase in tension at the tendon-to-bone interface on the tear apex, the conventional suture bridge applied to MRCT repair will result in a high retear rate.[21,22] The middle 2 sets of DPSBs in this study are created with the anchors that were implanted in the debrided humeral head, which not only achieves suture-bridge repair of the tear apex but also minimizes tendon tension by the unique parallel design of medial- and lateral-row anchors.

We believe that the V-shaped DPSB technique possesses other superiorities in the repair of MRCTs. First, DPSB repair can obtain the heighten footprint contact, with higher loads to failure and a lower retear rate.[23] Second, 6 sets of DPSBs that compress the tendon against the footprint can provide sufficient tendon-bone contact area in the process of MRCT repair. Third, medial knotless techniques can reduce tendon tension at the muscle-tendon junction.

Nevertheless, the arthroscopic V-shaped DPSB technique for MRCT repair possesses some shortcomings:

First, patients with severe tendon retraction and high tendon tension are not on the application list; superior capsule reconstruction or tendon transfer is a better choice. Second, overmuch suture knots may yield some negative effects, such as subacromial erosion.[24] Third, the strength of suture compressing the tendon down onto the footprint is weaker than that of a conventional suture bridge.[25] Fourth, breakage of the DPSB due to knot slippage during the suture-pulling process is disastrous.

Disclosures

All authors (P.H., X.W., Y.F., X.T., Z.X., Z.L., B.P., M.H., C.H.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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