Technical Note

Arthroscopic 4-Anchor Double-Pulley Suture-Bridge Repair of Large Rotator Cuff Tear

Peiguan Huang, M.Med., Xiaoxu Wang, M.Med., Yong Fu, M.D., Xiaojun Tang, M.D., Zhihong Xiao, M.D., Zhengmao Li, M.D., and Chunrong He, M.D.

Abstract: Currently, suture bridge (SB) is a popular way to treat large rotator cuff tears. However, the restricted number of sutures used for tendon fixation, the knotted medial row, and the excessive number of tendon holes created from suture hook piercing are the shortcomings of SB repair. Arthroscopic 4-anchor double-pulley suture-bridge (DPSB) repair is a pragmatic surgical technique and can overcome these shortcomings of SB repair. In the repair of large rotator cuff tears with the 4-anchor DPSB technique, 8 sets of DPSBs can obtain powerful fixation strength on the tendon, and sufficient tendon-to-bone coverage area, a knotless medial row, and only 4 tendon holes created from suture hook piercing can reduce the type 2 retear rate.

Arthroscopic treatment of large rotator cuff tears (LRCTs) has significant challenges, and the controversy on the best way to treat LRCTs continues.[1] Suture-bridge (SB) repair can obtain heightened tendon strength, lessened gap formation, and greater footprint coverage.[2] For patients with a tear size less than 3 cm, SB repair has no remarkable advantage over single-row repair; when the tear size is more than 3 cm, the retear rate after SB repair is prominently reduced.[3] Even so, high retear rates of 40% to 64% have been reported in LRCT patients who underwent double-row repair.[4]

A suture number that matches the tendon tear size is vital to achieve satisfactory clinical outcomes. The use of more sutures in a repair procedure can obtain greater ultimate strength and a lower retear rate.[5,6] Low tension on the tendon is the another important factor for the structural integrity of a reattached repair.[7] High tension on the medial-row tendon will strangulate the tendon and lead to surgical failure.[8] The excessive number of tendon holes created from suture hook piercing may also increase the risk of tendon retear.

Arthroscopic 4-anchor DPSB repair is a pragmatic surgical technique. In LRCT repair with 4-anchor DPSB, 8 sets of DPSBs can obtain powerful fixation strength on the tendon, and sufficient tendon-to-bone coverage area, the knotless medial row, and only 4 tendon holes created from suture hook piercing can reduce the type 2 retear rate.

Surgical Technique

Anesthesia and Patient Positioning

The patient is placed in the lateral decubitus position under general anesthesia; the operative shoulder is exposed by upper-limb traction (Video 1). Pearls and pitfalls of our technique are described in Table 1, and advantages and disadvantages are presented in Table 2. This study was approved by the ethical department of our institution, and the patient signed an informed consent form for participation.

Diagnostic Arthroscopy

Joint examination is performed through the posterior portal. SLAP lesions or biceps tendon tears are addressed with tenodesis or tenotomy. The scope is placed into the subacromial space, and a thorough subacromial bursectomy is performed. Subacromial decompression is applied to a hook-type acromion. The tendon margin is debrided to yield tissue of satisfactory quality. The tear size and shape, as well as retraction of the tendon, are evaluated (Fig 1). A tendon with a tear

From The Second Affiliated Hospital, Department of Joint Surgery, Hengyang Medical School, University of South China, Hengyang, China.

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Address correspondence to Peiguan Huang, M.Med., The Second Affiliated Hospital, Department of Joint Surgery, Hengyang Medical School, University of South China, Hengyang, Hunan, 421001, China. E-mail: 714489037@qq.com

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Table 1. Surgical Pearls and Pitfalls

Surgical indication consideration
A rotator cuff with a tear size of 3-5 cm is the optimal indication for our surgical technique.
Anchor implantation considerations
Two double-loaded suture anchors (TWINFIX) with blue and white strands are inserted into the articular border of the greater tuberosity as medial-row anchors.
Two double-loaded suture anchors (TWINFIX) with blue and white strands are inserted into the lateral border of the greater tuberosity as lateral-row anchors.
Suture layout consideration
A total of 4 tendon holes, which are pierced by a suture hook, are created on the medial tendon. All 8 strands from anchors A and B will be passed through the 4 holes. Four strands from anchors A and B are all passed through the 4 holes with alternating blue and white. Each hole contains 2 different-color strands from anchors A and B.
DPSB layout consideration
One blue suture strand from anchor A that is passing through the posterior portion of the cuff tendon, as well as 1 white strand from anchor D, is retrieved out of the body and created into the first set of DPSBs; the opposite blue strand from anchor A and white strand from anchor D are created into the second set of DPSBs; the white strands from anchor A and blue strands from anchor D will be created into the third and fourth sets of DPSBs; and the strands from anchors B and D will be created into the fifth, sixth, seventh, and eighth sets of DPSBs.

DPSB, double-pulley suture bridge.

Table 2. Advantages and Disadvantages

Advantages
DPSB repair, which is a type of SB technique, can obtain heightened tendon strength, lessened gap formation, and greater footprint contact.
Eight sets of DPSBs maximize the number of sutures crossing the repair site while heightening the ultimate strength of the repaired tendon.
The knotless medial row can lower the tension on the medial-row tendon and reduce the type 2 retear rate.
Four tendon holes is the minimal number for 8 suture strands passing through; compared with 8 tendon holes, the tendon trauma on the medial row is minimal.
Disadvantages
This surgical technique has a tough learning curve given the complicated suture management and tedious surgical procedure.
When all 4 anchors are implanted, the bone mass of the greater tuberosity will incur a certain amount of destruction.
The 8 knots may lead to some problems such as subacromial impingement.
Certain special problems may be encountered during the suture-pulling process, such as suture locking during suture tightening and DPSB breakage owing to knot slippage.

DPSB, double-pulley suture bridge; SB, suture bridge.

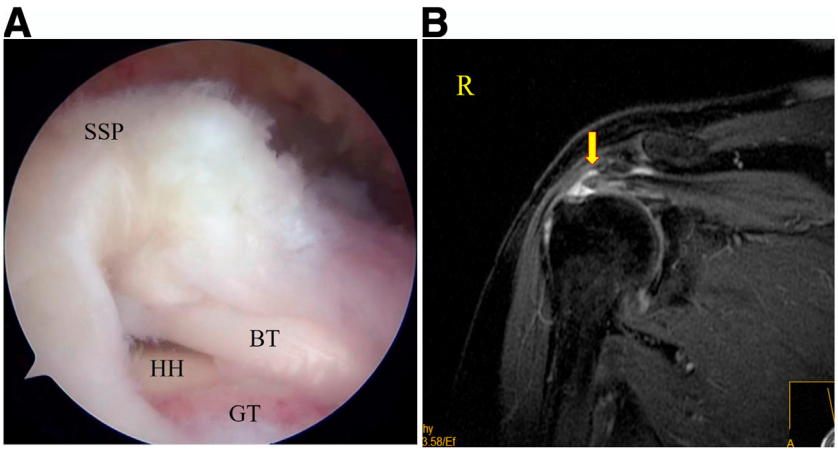

Fig 1. (A) Arthroscopic image of right shoulder (lateral decubitus position), viewed through subacromial lateral portal, showing evaluation of tear size and shape, as well as supraspinatus tendon (SSP) retraction. (BT, biceps tendon; GT, greater tuberosity; HH, humeral head). (B) Magnetic resonance imaging of right shoulder (oblique coronal short tau inversion recovery view) showing rotator cuff tear (arrow). (R, right shoulder.)

size of 3 to 5 cm is the optimal indication for our surgical technique.

Medial- and Lateral-Row Anchor Insertion

Two double-loaded suture anchors (TWINFIX; Smith & Nephew, Andover, MA) with blue and white strands are inserted into the articular border of the greater tuberosity as medial-row anchors; these are called anchors A and B. Two identical double-loaded suture anchors (TWINFIX) are inserted into the lateral border of the greater tuberosity as lateral-row anchors; these are called anchors C and D (Fig 2).

Strand Passage Through Tendon

A total of 4 tendon holes, which are pierced by a suture hook, are created on the medial tendon. All 8 strands from anchors A and B will be passed through the 4 holes. Four strands from anchors A and B are all passed through the 4 holes with alternating blue and white (Fig 3A). Each hole contains 1 blue strand and 1 white strand from anchors A and B (Fig 3B).

Suture-Relay Procedures

One blue suture strand from anchor A that is passing through the posterior portion of the cuff tendon, as well as one white strand from anchor D (Fig 4), is retrieved through the lateral portal. In an extracorporeal manner, the 2 strands are firmly tied and created into a blue-white suture. This blue-white suture is the first set of DPSBs (Fig 5).

As the result of the double-pulley technique, the first set of DPSBs is delivered into the subacromial space in a stepwise manner and seated onto the tendon by pulling on the opposite 2 strands from anchors A and D (Fig 6); the strands are cut above the knot. The opposite 2 strands are pulled with the desired quantity of tension to ensure that the tendon can be powerfully compressed against the footprint by the first set of DPSBs (Fig 7).

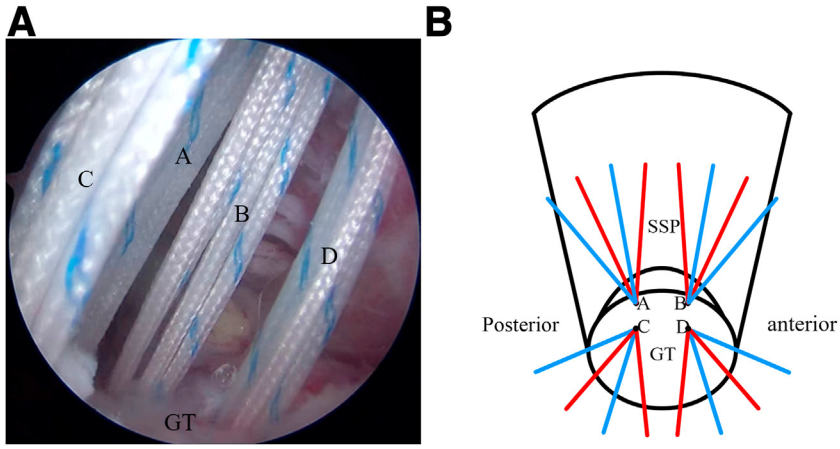

Fig 2. (A) Arthroscopic image of right shoulder (lateral decubitus position), viewed through subacromial lateral portal, showing insertion of 4 double-loaded suture anchors with blue and white strands, as medial- and lateral-row anchors, into greater tuberosity (GT). (A, 4 strands from anchor A; B, 4 strands from anchor B; C, 4 strands from anchor C; D, 4 strands from anchor D.) (B) In a right shoulder, 4 double-loaded suture anchors with blue strands (blue lines) and white strands (red lines), as medial- and lateral-row anchors, are inserted into the greater tuberosity (GT). (A, anchor A; B, anchor B; C, anchor C; D, anchor D; SSP, supraspinatus tendon.)

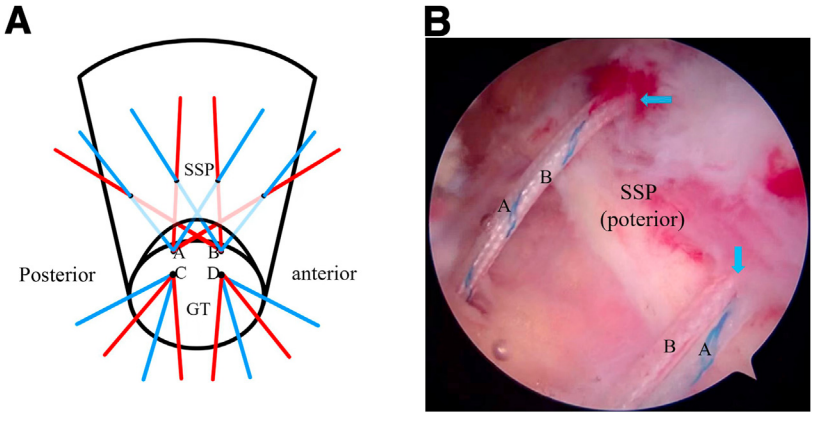

Fig 3. (A) All 8 strands from anchors A and B are passed through 4 tendon holes; 4 strands from anchors A and B are all passed through the 4 holes with alternating blue and white. The blue lines indicate the blue strands, and the red lines indicated the white strands. (A, anchor A; B, anchor B; C, anchor C; D, anchor D; GT, greater tuberosity; SSP, supraspinatus tendon.) (B) Arthroscopic image of right shoulder (lateral decubitus position), viewed through subacromial lateral portal, showing that each tendon hole (arrows) contains 1 blue strand and 1 white strand from anchors A and B. (A, strands from anchor A; B, strands from anchor B; SSP, supraspinatus tendon.)

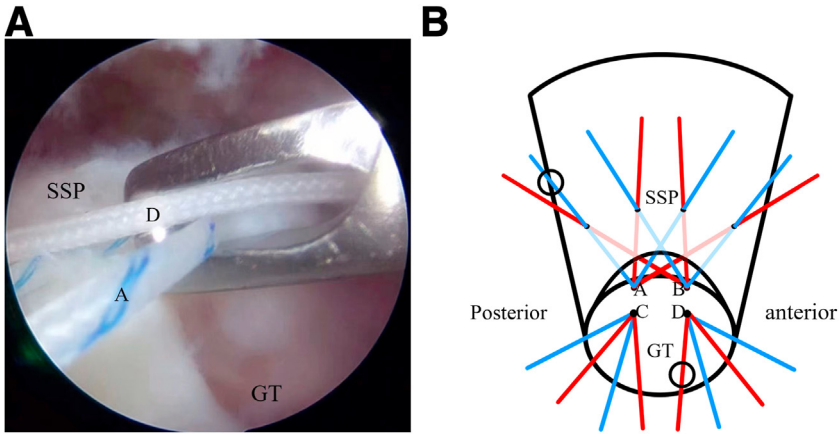

Fig 4. (A) Arthroscopic image of right shoulder (lateral decubitus position), viewed through subacromial lateral portal, showing 1 blue suture strand from anchor A that is passing through posterior portion of cuff tendon (A), as well as 1 white strand from anchor D (D), being grabbed by grasper. (GT, greater tuberosity; SSP, supraspinatus tendon.) (B) In a right shoulder, 1 blue suture strand from anchor A that is passing through the posterior portion of the cuff tendon, as well as 1 white strand from anchor D, will be retrieved through the lateral portal. The black circles indicate the strands that will be created into the first set of double-pulley suture bridges; blue lines, blue strands; and red lines, white strands. (A, anchor A; B, anchor B; C, anchor C; D, anchor D; GT, greater tuberosity; SSP, supraspinatus tendon.)

The opposite blue strand from anchor A that is passing through the anterior portion of the cuff tendon, as well as the opposite white strand from anchor D (Fig 8A), is firmly tied with a knot pusher in the subacromial space and created into the second set of DPSBs (Fig 8 B and C); again, the strands are cut above the knot.

The white strands from anchor A and blue strands from anchor D are created into the third and fourth sets of DPSBs and powerfully compress the tendon against the footprint; the procedure is the same as that described earlier. At this point, the 4 strands from anchor A and the 4 strands from anchor D are all used to create 4 sets of DPSBs (Fig 9).

Then, all the strands from anchors B and D are created into the fifth, sixth, seventh, and eighth set of DPSBs (Fig 10). A total of 8 sets of DPSBs are created to compress the tendon against the footprint.

Discussion

The maximization of ultimate strength at the tendon-to-bone interface is important for tendon healing. The number of sutures crossing the repair site is the primary element affecting the ultimate strength

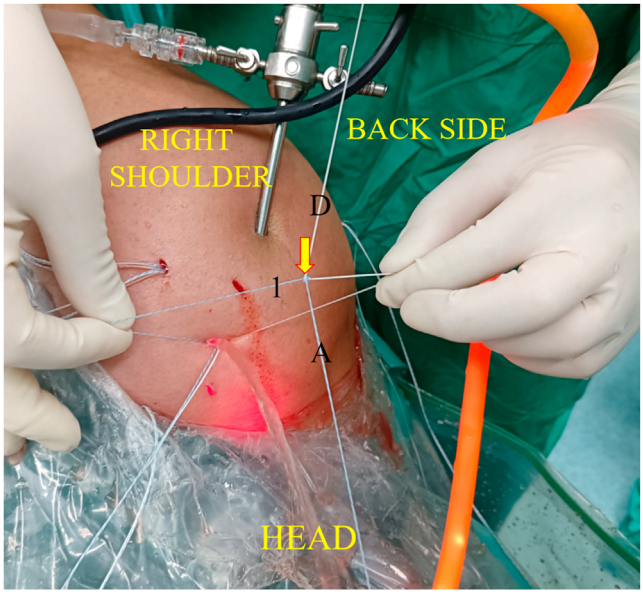

Fig 5. In an extracorporeal manner, the strands from anchor A (A) and anchor D (D) are firmly tied and created into the first set of double-pulley suture bridges (1). The arrow indicates the knot.

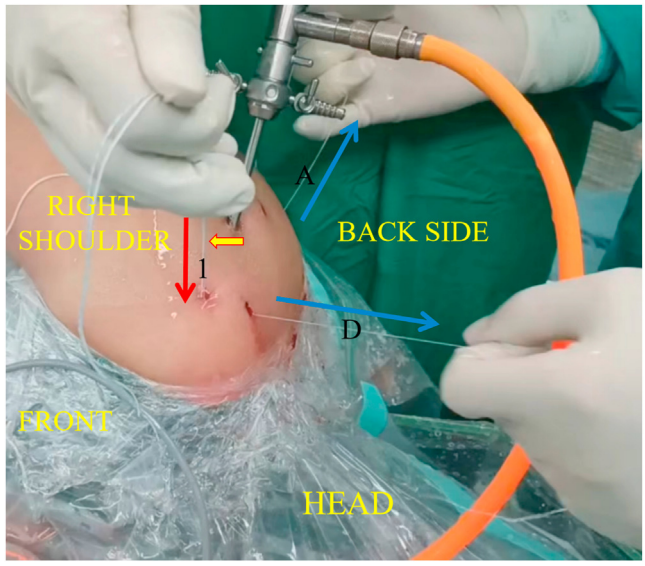

Fig 6. As the result of the double-pulley technique, the first set of double-pulley suture bridges (1) is delivered into the subacromial space in a stepwise manner by pulling on the opposite 2 strands from anchor A (A) and anchor D (D). The yellow arrow indicates the knot; blue arrows, the directions in which the strands are pulled out; and red arrow, the direction in which the first set of double-pulley suture bridges is drawn into the body.

of the repaired tendon.[9] The ultimate strength of the tendon increases as the number of sutures crossing the repair site increases.[10] A study using an ovine model found that the ultimate strength of the tendon after the application of 2, 4, and 6 strands was positively associated with the incremental suture number.[11] Another ovine experiment verified that increasing the number of sutures used per anchor can prominently increase the ultimate strength of the tendon.[12] A study of distal-extremity tendon repair of the human hand showed that the ultimate force of the overall repair site can be improved with an increasing number of sutures passing through the tendon.[13] In double-row repair, the better biomechanics is relevant to the increased suture number rather than the additional lateral-row anchors.[14] Jost et al.[15] reported that once the suture number was equivalent, the surgical results of single- and double-row repairs were the same.

The standard SB repair possesses a knotted medial row.[8] Knotted suture constructs may restrict vascular inflow on the proximal tendon.[16] A type 2 retear, described as a medial tendon tear, is caused by the knotted medial row.[17] Trantalis et al.[18] supposed that massive tension performed on the medial row during suture tightening was an important cause of type 2

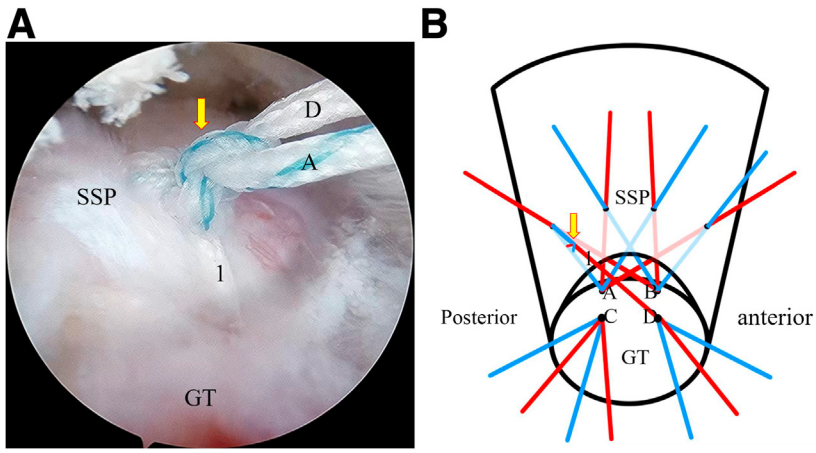

Fig 7. (A) Arthroscopic image of right shoulder (lateral decubitus position), viewed through subacromial lateral portal, showing first set of double-pulley suture bridges (1) powerfully compressing supraspinatus tendon (SSP) against footprint (yellow arrow indicates the knot of the first set of DPSB). (A, strands from anchor A; D, strands from anchor D; GT, greater tuberosity.) (B) In a right shoulder, the first set of double-pulley suture bridges (1) powerfully compresses the supraspinatus tendon (SSP) against the footprint. The yellow arrow indicates the knot; blue lines, blue strands; and red lines, white strands. (A, anchor A; B, anchor B; C, anchor C; D, anchor D; GT, greater tuberosity.)

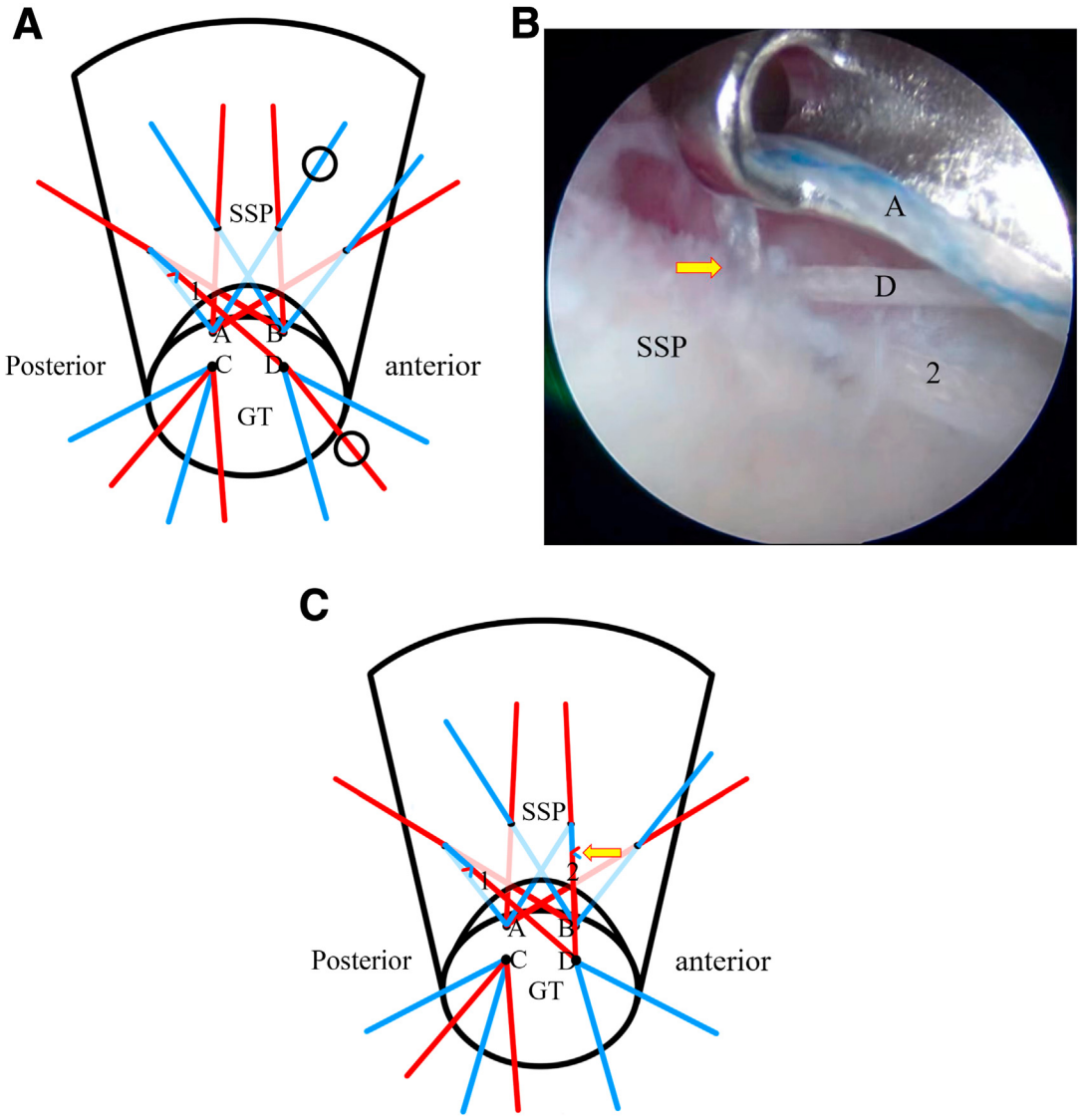

Fig 8. (A) In a right shoulder, the opposite blue strand from anchor A and white strand from anchor D will be created into the second set of double-pulley suture bridges (DPSBs). The blue lines indicate the blue strands; red line, white strands; and black circles, strands that will be created into second set of DPSBs. (A, anchor A; B, anchor B; C, anchor C; D, anchor D; GT, greater tuberosity; SSP, supraspinatus tendon; 1, first set of DPSBs.) (B) Arthroscopic image of right shoulder (lateral decubitus position), viewed through subacromial lateral portal, showing opposite blue strand from anchor A (A) and white strand from anchor D (D) being firmly tied with Sixth Finger knot pusher (Smith & Nephew, Andover, MA) in subacromial space and created into second set of DPSBs (2) (yellow arrow indicates the knot of the second set of DPSB.). (SSP, supraspinatus tendon.) (C) In a right shoulder, the opposite blue strand from anchor A and white strand from anchor D are created into the second set of DPSBs (2). The blue lines indicate the blue strands; red lines, white strands; and yellow arrow, knot. (A, anchor A; B, anchor B; C, anchor C; D, anchor D; GT, greater tuberosity; SSP, supraspinatus tendon; 1, first set of DPSBs.)

retears. The potential tendon strangulation from the knotted medial row may affect tendon healing.[19] Knotless SB repair can reduce tension overload on the medial row and lower the possibility of tendon strangulation.[20] Knotless SB repair can also improve the compression at the bone-to-tendon interface without compromising tendon strength.[21,22]

Each tendon hole created from suture hook piercing will cause tissue trauma, although the extent of this trauma is minimal. As the number of tendon holes increases, trauma on the medial-row tendon cannot be neglected. An excessive number of tendon holes on the cuff tendon may be a secluded factor means a risk of tendon retear for type 2 tendon retears; even so, this concept is rarely mentioned in the literature.

We believe that the 4-anchor DPSB technique possesses 4 advantages in the repair of LRCTs. First, DPSB repair, which is a type of SB technique, can obtain

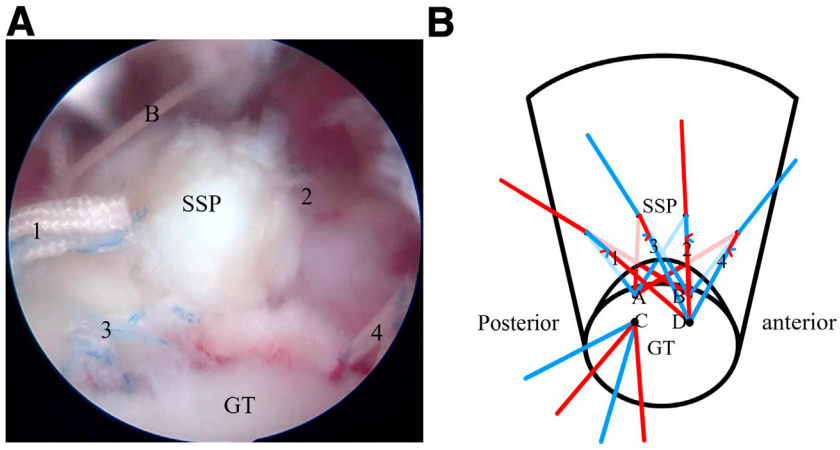

Fig 9. (A) Arthroscopic image of right shoulder (lateral decubitus position), viewed through subacromial lateral portal, showing use of all 4 strands from anchors A and D to create 4 sets of double-pulley suture bridges (DPSBs). (B, strands from anchor B; GT, greater tuberosity; SSP, supraspinatus tendon; 1, first set of DPSBs; 2, second set of DPSBs; 3, third set of DPSBs; 4, fourth set of DPSBs.) (B) In a right shoulder, all 4 strands from anchors A and D are all used to create 4 sets of DPSBs. The blue lines indicate the blue strands, and the red lines indicate the white strands. (A, anchor A; B, anchor B; C, anchor C; D, anchor D; GT, greater tuberosity; SSP, supraspinatus tendon; 1, first set of DPSBs; 2, second set of DPSBs; 3, third set of DPSBs; 4, fourth set of DPSBs.)

heightened tendon strength, lessened gap formation, and greater footprint contact. Second, 8 sets of DPSBs can maximize the number of sutures crossing the repair site while heightening the ultimate strength of the repaired tendon. Third, the knotless medial row can lower the tension on the medial-row tendon and reduce the type 2 retear rate. Fourth, 4 tendon holes is the minimal number for 8 suture strands passing through the tendon; compared with 8 tendon holes, the tendon trauma on the medial row is minimal.

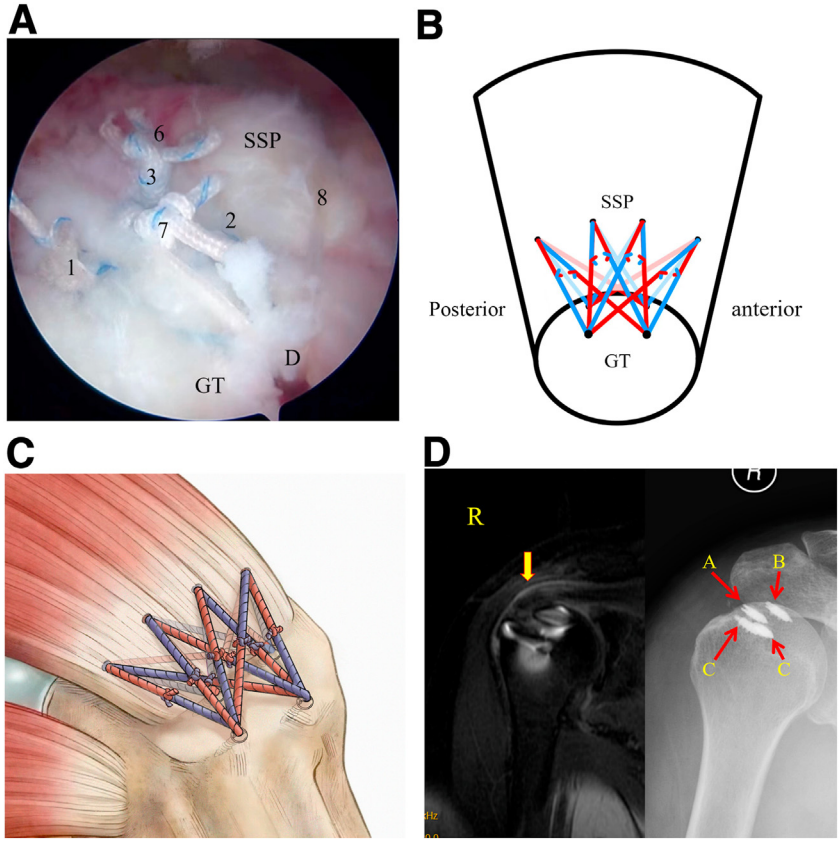

Fig 10. (A) Arthroscopic image of right shoulder (lateral decubitus position), viewed through subacromial lateral portal, showing that a total of 8 sets of double-pulley suture bridges (DPSBs) are created to compress the supraspinatus (SSP) tendon against the footprint. (D, anchor D; GT, greater tuberosity; 1, first set of DPSBs; 2, second set of DPSBs; 3, third set of DPSBs; 6, sixth set of DPSBs; 7, seventh set of DPSBs; 8, eighth set of DPSBs.) (B, C) In a right shoulder, a total of 8 sets of DPSBs are created to compress the supraspinatus (SSP) tendon against the footprint. (GT, greater tuberosity.) (D) Magnetic resonance imaging (oblique coronal short tau inversion recovery view) and anteroposterior radiograph of right shoulder showing repaired supraspinatus tendon (yellow arrow). (A, anchor A; B, anchor B; C, anchor C; D, anchor D; R, right shoulder.)

Nevertheless, arthroscopic 4-anchor DPSB repair of LRCTs still has some shortcomings: First, this surgical technique has a tough learning curve given the complicated suture management and time-consuming surgical procedure. Second, when all 4 anchors are implanted, the bone mass of the greater tuberosity will incur a certain amount of destruction. Third, the 8 knots may lead to some problems such as subacromial impingement. Fourth, certain special problems may be encountered during the suture-pulling process, such as suture locking during suture tightening and DPSB breakage owing to knot slippage.[23]

Disclosures

All authors (P.H., X.W., Y.F., X.T., Z.X., Z.L., 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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