Technical Note

Arthroscopic Modified Double-Pulley Suture-Bridge Repair of Medium-Sized Supraspinatus Tendon Tears

Peiguan Huang, M.Med., Xiaoxu Wang, M.Med., Chunrong He, M.D., and Bin Peng, M.D.

Abstract: At present, the repair patterns for medium-sized supraspinatus tendon tears are double- and single-row repairs. However, the limitations of double-row repair include excessive anchor implantation and incremental surgical cost and time, whereas a deficient tendon-bone contact area exists with single-row repair. The modified double-pulley suture-bridge repair presented in this study is an arthroscopic technique using 3 double-loaded suture anchors combined with a double-pulley technique to form a hybrid repair pattern with a double row as the mainstay and a single row as the supplement. In the treatment of medium-sized tendon tears, the modified double-pulley suture-bridge repair can not only maximize the tendon-bone contact area but also lower the surgical cost and shorten the operative time. The surgical technique is described, including pearls and pitfalls, as well as advantages and disadvantages.

Medium-sized supraspinatus tendon tear repair presents the non-negligible concern of a high retear rate.[1] Compared with single-row repair, double-row repair has been shown to yield better clinical outcomes in patients with supraspinatus tendon tear widths greater than 3 cm.[2-4] Double-row repair presents a better pressurized contact area, improved initial strength, and decreased gap formation and re-creates the crude footprint more closely.[5,6]

However, double-row repair of medium-sized tendon tears possesses certain limitations: Excessive anchor implantation reduces the tendon-bone contact area, and the process of lateral-row anchor implantation, as well as additional suture management, increases the surgical cost and time. A deficient tendon-bone contact area exists with single-row repair; fortunately, less anchor demand, lower surgical cost, and simple suture management are closely related to single-row procedures.[7]

Scholars are keen to compare double- and single-row repairs as rivals,[2,4-6] and the literature on hybrid repairs combining double- and single-row repairs is rare. Therefore, we have designed an arthroscopic technique of modified double-pulley suture-bridge (DPSB) repair using 3 double-loaded suture anchors combined with a double-pulley technique to form a hybrid repair pattern with a double row as the mainstay and a single row as the supplement. In the treatment of medium-sized tendon tears, the modified DPSB repair can not only maximize the tendon-bone contact area but also lower the surgical cost and shorten the operative time.

Surgical Procedure

Preparation

The patient is operated on while under general anesthesia in the lateral decubitus position; the joint space is gently opened up by upper-limb traction with 4 kg (Video 1). The surgical technique, including pearls and pitfalls, is described in Table 1, and advantages and disadvantages are listed in Table 2. This research was approved by the ethical department of our hospital, and all patients gave informed consent.

Diagnosis and Evaluation

The posterior portal is executed for the joint examination. Either tenotomy or tenodesis is performed to address biceps tendon tears or SLAP lesions. Acromioplasty is performed for a curved or hook-type acromion. The cuff margin is debrided back to tissue of satisfactory quality. Evaluation of tear width and

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

Received November 25, 2023; accepted February 3, 2024.

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

2212-6287/231696
https://doi.org/10.1016/j.eats.2024.102975

Table 1. Surgical Pearls and Pitfalls

Anchor implantation considerations
Anterior and posterior lateral-row anchors are placed on the anterior and posterior sides of the broken end of the supraspinatus tendon, respectively.
If all suture procedures of the first lateral-row anchor are completed and then the second lateral-row anchor is implanted, this technique will be simplified.
Suture procedure considerations
The double-pulley suture bridge must consist of sutures of different colors.
The sutures on the medial-row anchor must be passed through the supraspinatus tendon in blue and white way.
The suture of the medial-row anchor that is passing through the posterior portion of the supraspinatus tendon needs to create a double-pulley suture bridge with the suture of the anterior lateral-row anchor, and vice versa.
The double-pulley suture bridge needs to be pulled with the desired quantity of tension to ensure that the supraspinatus tendon can be powerfully compressed against the footprint.
If the knotted blue-white suture bridge is suddenly locked during the process of pulling on the opposite strands of 2 sutures that exit through percutaneous portals, cutting off the knot and then linking the 2 strands with the Sixth Finger knot pusher in the subacromial space can solve this intractable problem.
Single-row fixation is performed after the completion of the double-pulley suture bridge.

shape, as well as tendon movability, is performed (Fig 1). A supraspinatus tendon with a tear width of 2 to 4 cm is the applicative indication for the modified DPSB repair.

Suture Anchor Insertion

A burr is used to perform decortication to obtain a bleeding footprint. A double-loaded suture anchor (Corkscrew; Arthrex, Naples, FL) with No. 2 nonabsorbable polyester strands (blue and white), as a medial-row anchor, is implanted into the articular border of the greater tuberosity (Fig 2). A total of 6 sutures are planned to pass through the supraspinatus tendon evenly. The suture strands on medial-row anchor pass through the supraspinatus tendon with alternating blue and white (Fig 3). Two identical double-loaded suture anchors (Corkscrew) with No. 2 nonabsorbable polyester strands (blue and white), as lateral-row anchors, are implanted into the lateral border of the greater tuberosity; anterior and posterior lateral-row anchors are placed on the anterior and posterior sides of the broken end of the supraspinatus tendon, respectively (Fig 4).

Suture-Relay Procedure

One white suture strand of the medial-row anchor that is passing through the posterior portion of the supraspinatus tendon, as well as one blue strand of the anterior lateral-row anchor, is retrieved through the lateral portal (Fig 5). In an extracorporeal manner, the 2 strands are firmly tied with a static knot over an instrument (Fig 6); the suture strands are cut above the knot. Owing to the knot, the independent blue and white strands are linked into a continuous blue-white suture bridge.

As a result of double-pulley technology, the blue-white suture bridge along with the knot is delivered into the subacromial space in a stepwise manner by

Table 2. Advantages and Disadvantages

Advantages
The 4 sets of double-pulley suture bridges can powerfully compress a major part of the supraspinatus tendon against the footprint; single-row repair of lateral row anchor can also be applied to fix the supraspinatus tendon that has not been repaired by DPSB (such as the middle part of the tendon), rather than having to repair the anterior and posterior part of the tendon.
Three suture anchors is the minimum number of suture anchors used in the treatment of medium-sized tendon tears; increased tendon-bone contact area and better tendon healing will be the harvest from this unique anchor structure.
The double-loaded suture anchor as a lateral-row anchor can significantly reduce the surgical cost; the use of 1 medial-row anchor further reduces the cost.
Single-row repair, as an inherent component of the technique, can reduce the overall operative time.
Disadvantages
The surgical time may be increased owing to cumbersome and complicated suture management during the operation.
Subacromial impingement and bursitis may be caused by the 6 sets of knots from the double-pulley suture-bridge and single-row fixation.
The strength of the reattached tendon after the single-row process is inadequate, resulting in the overall suture strength being inferior to that of traditional double-row repair.
The use of 3 suture anchors will limit the coverage area of the suture configuration; a supraspinatus tendon tear width >4 cm cannot be fully covered.
Once the suture is locked or suture-bridge is broken due to knot slipping, the operation will fail.

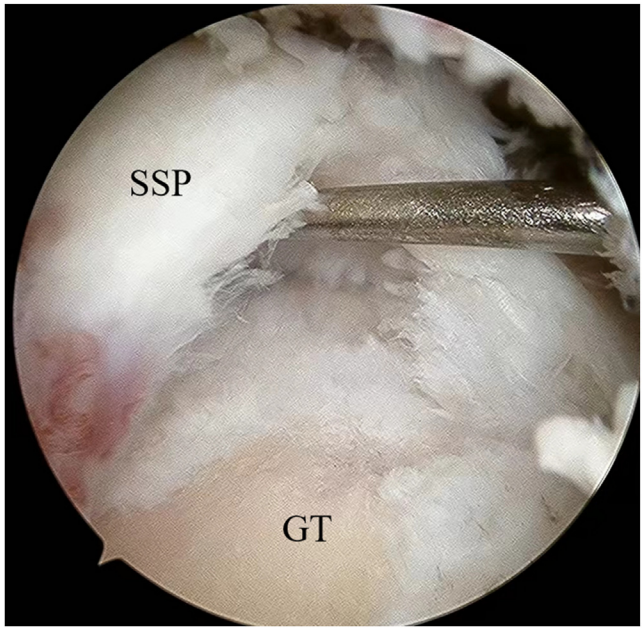

Fig 1. Arthroscopic image of right shoulder (lateral decubitus position) viewed through the subacromial lateral portal showing the evaluation of tear width and shape, as well as tendon movability. (GT, greater tuberosity; SSP, supraspinatus tendon.)

pulling on the opposite strands of 2 sutures that exit through percutaneous portals (Fig 7) and is seated onto the supraspinatus tendon (Fig 8); the suture strands are cut above the knot. This artificial blue-white suture bridge is actually regarded as the first set of DPSBs (Fig 9). The opposite strands of blue and white suture need to be pulled with the desired quantity of tension to ensure that the supraspinatus tendon can be powerfully compressed against the footprint.

The opposite blue and white suture strands are retrieved through the lateral portal, a static knot is firmly tied with the Sixth Finger knot pusher (Smith & Nephew, Andover, MA) in the subacromial space (Fig 10), and the independent blue and white strands are linked into a continuous blue-white suture bridge; in addition, the suture strands are cut above the knot. This artificial blue-white suture bridge is regarded as the second set of DPSBs (Fig 11). The 2 sets of DPSBs between the medial-row and anterior lateral-row anchors are now finished. The blue suture of the medial-row anchor and the white suture of the posterior lateral-row anchor are then used to create the other 2 sets of DPSBs; the procedure is the same as that described earlier. The 4 sets of DPSBs can powerfully compress a major part of the supraspinatus tendon against the footprint (Fig 12).

One white strand of the anterior lateral-row anchor (Fig 13), which is regarded as the foremost strand among the 6 aforementioned sutures, is passed through the anterior portion of the supraspinatus tendon (Fig 14) and fixes the tendon via a single row (Fig 15). One blue strand of the posterior lateral-row anchor, which is regarded as the backmost strand among the 6 aforementioned sutures, is passed through the posterior portion of the supraspinatus tendon and fixes the tendon via a single row.

Reattachment Confirmation

With the completion of the modified DPSB repair, 4 sets of DPSBs and 2 sets of single rows are seated on the supraspinatus tendon and powerfully compress the whole tendon against the footprint (Fig 16). The scope is placed in the joint, and the reattached tendon is examined eventually. The surgical technique is described in Video 1, Table 1 (pearls, pitfalls), and Table 2 (advantages, disadvantages).

Discussion

Tendon-bone healing after supraspinatus tendon repair has come under high scrutiny.[8] A greater tendon-bone contact area will lead to a higher possibility of tendon healing.[9,10] However, the tendon-bone contact area will be decreased after anchor implantation. Grasso et al.[11] noted that the probable number of suture anchors for a double-row procedure is 2 to 7 suture anchors.

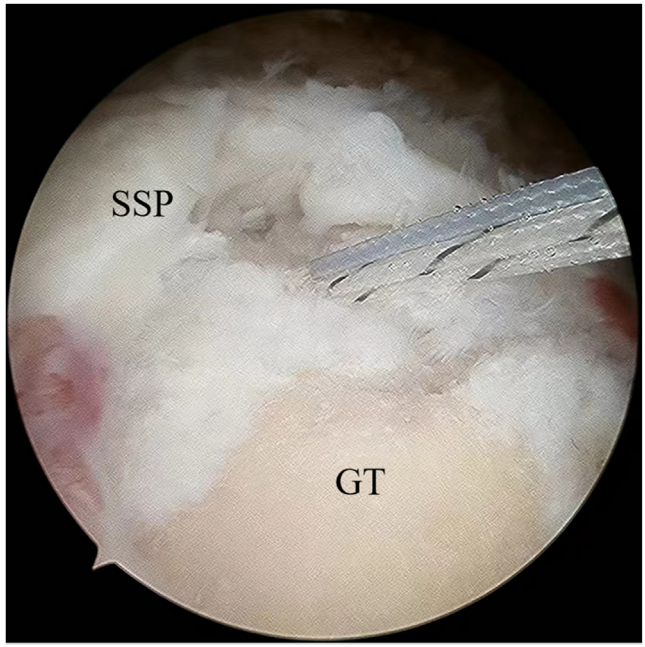

Fig 2. Arthroscopic image of right shoulder (lateral decubitus position) viewed through the subacromial lateral portal showing a double-loaded suture anchor, as a medial-row anchor, is implanted into the articular border of the greater tuberosity. (GT, greater tuberosity; SSP, supraspinatus tendon.)

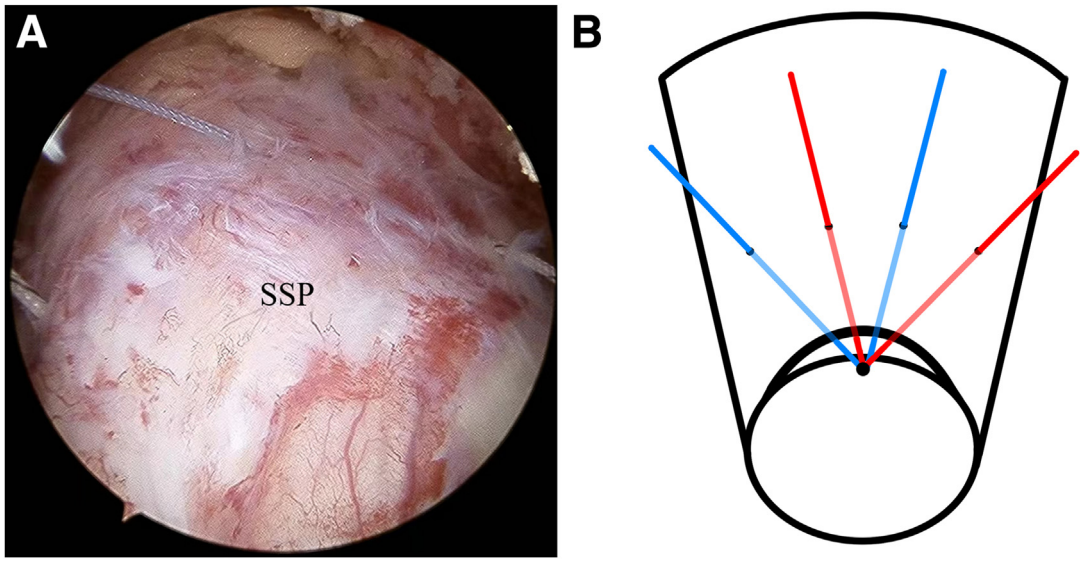

Fig 3. (A, B) Arthroscopic image of right shoulder (lateral decubitus position) viewed through the subacromial lateral portal showing the sutures on the medial-row anchor will be passed through the supraspinatus tendon (SSP) in blue and white way (blue line, blue strand; red line, white strand, black dot, suture anchor).

Hypothetically, a technique that can provide equivalent reattached footprint coverage with fewer suture anchors will be much more helpful for cuff repair.[12] A construct using 3 suture anchors in a double-row procedure is a potential means to maximize the tendon-bone contact area.[13]

The number of suture anchors used and the surgical time are the important determining factors for treatment cost.[14] Given that lateral-row anchor application will increase the overall number of anchors used, double-row repair requires more surgical costs.[15,16] The process of lateral-row anchor implantation and additional suture management will require more surgical time than single-row treatment.[16-18] Franceschi et al.[18] reported that the mean surgical time for single-row repair was 42 ± 18.9 minutes whereas that for double-row repair was 65 ± 23.4 minutes. The practical surgical cost will be increased in association with the incremental surgical time.[16]

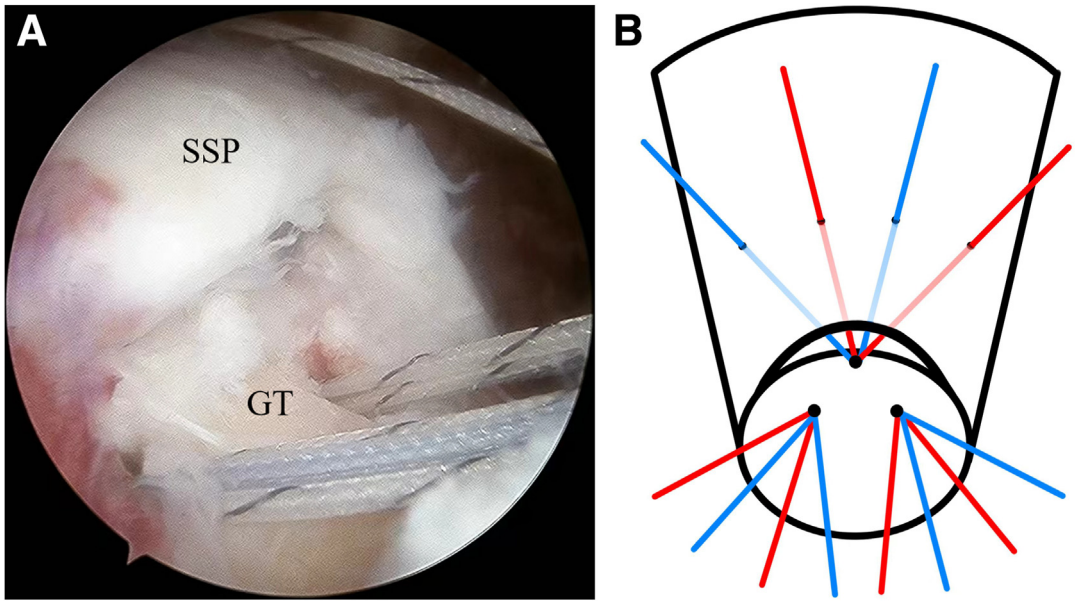

Fig 4. (A, B) Arthroscopic image of right shoulder (lateral decubitus position) viewed through the subacromial lateral portal showing two double-loaded suture anchors, as lateral-row anchors, are implanted into the lateral border of the greater tuberosity (GT) (blue line, blue strand; red line, white strand, black dot, suture anchor). (SSP, supraspinatus tendon.)

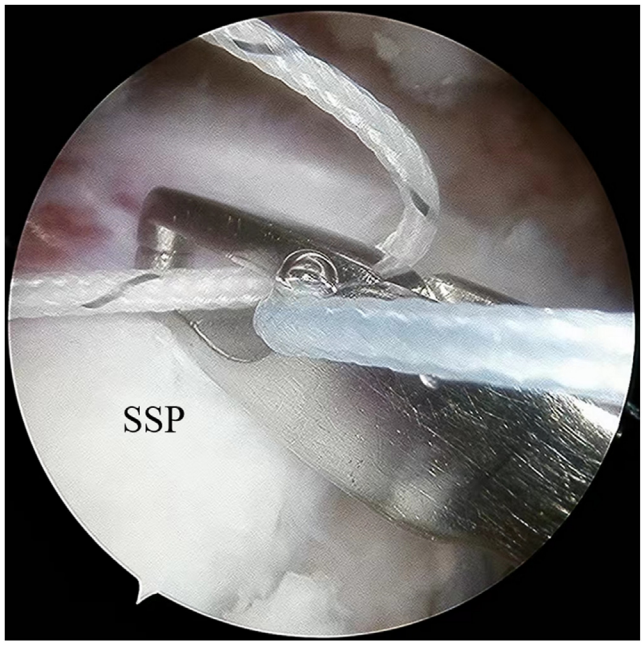

Fig 5. Arthroscopic image of right shoulder (lateral decubitus position) viewed through the subacromial lateral portal showing one white suture strand of the medial-row anchor that is passing through the posterior portion of the supraspinatus tendon (SSP), as well as one blue strand of the anterior lateral-row anchor, is retrieved through the lateral portal.

The suture configuration is a decisive factor in the success or failure of tendon repair.[17] Hybrid repair is an option to change the suture layout configuration. Chu et al.[19] reported a hybrid repair that combined knotless and suture-tying designs. Chauhan et al.[20] described a hybrid technique combining a modified SpeedBridge (Gemini Cannula; Arthrex) technique and double-pulley technique. Jeong et al.[21] reported a hybrid repair using a double row of infraspinatus tendon and a single row of supraspinatus tendon to achieve medialization of the supraspinatus tendon footprint and transosseous-equivalent augmentation.

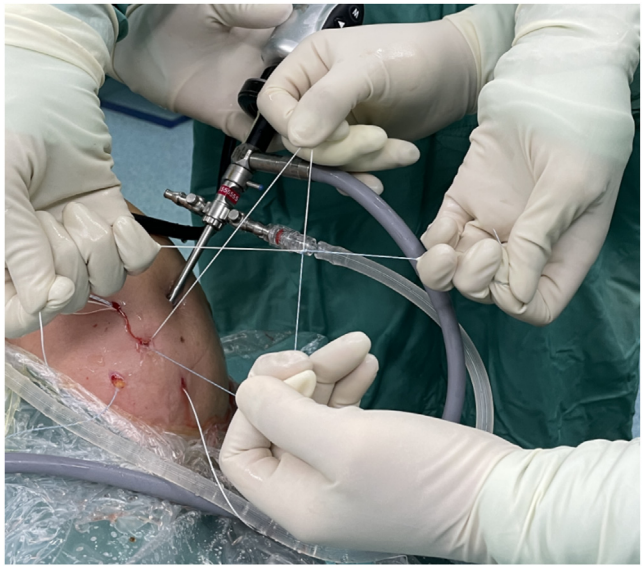

Fig 6. In an extracorporeal manner, the 2 strands are firmly tied with a static knot over an instrument.

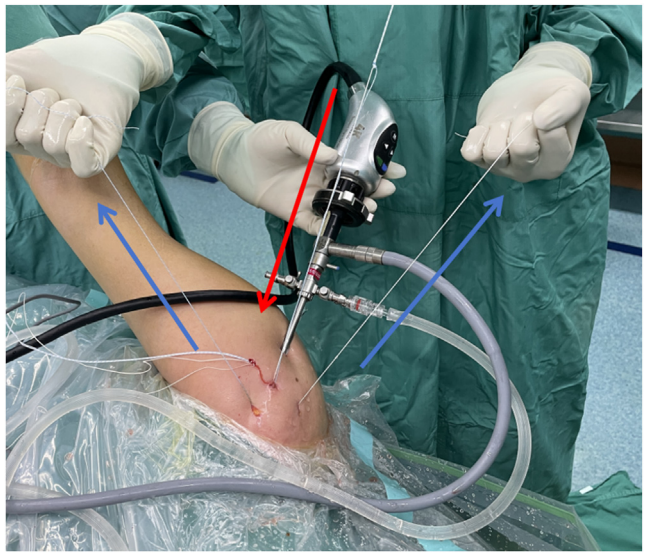

Fig 7. The blue-white suture bridge along with the knot is delivered in a stepwise manner into the subacromial space by pulling on the opposite strands of 2 sutures that exit through percutaneous portals.

The arthroscopic technique of modified DPSB repair uses 3 double-loaded suture anchors combined

Fig 8. Arthroscopic image of right shoulder (lateral decubitus position) viewed through the subacromial lateral portal showing the blue-white suture bridge with the knot is seated onto the supraspinatus tendon (SSP).

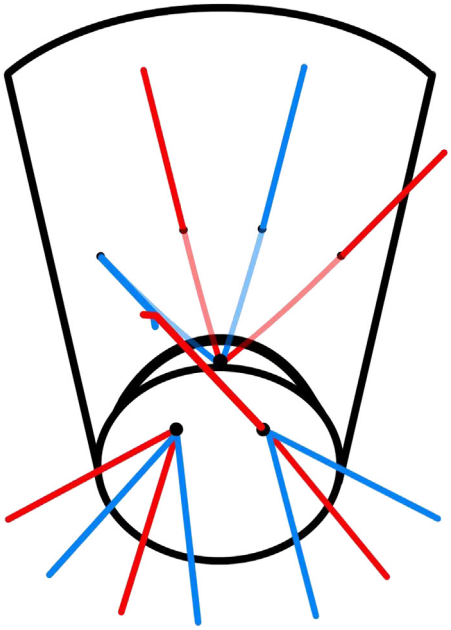

Fig 9. The blue-white suture bridge is considered the first set of double-pulley suture bridges.

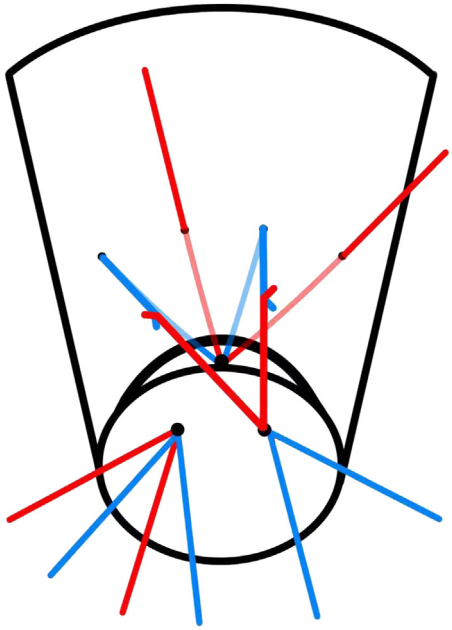

Fig 11. The blue-white suture bridge is considered the second set of double-pulley suture bridges (blue line, blue strand; red line, white strand, black dot, suture anchor).

with a double-pulley technique to form a hybrid repair pattern with a double row as the mainstay and a single row as the supplement. In the treatment of medium-sized tendon tears, the modified DPSB repair can not only maximize the tendon-bone contact area but also lower the surgical cost and shorten the operative time. From our viewpoint, the advantages are as follows: First, the 4 sets of DPSBs can powerfully compress a major part of the supraspinatus tendon against the footprint; single-row

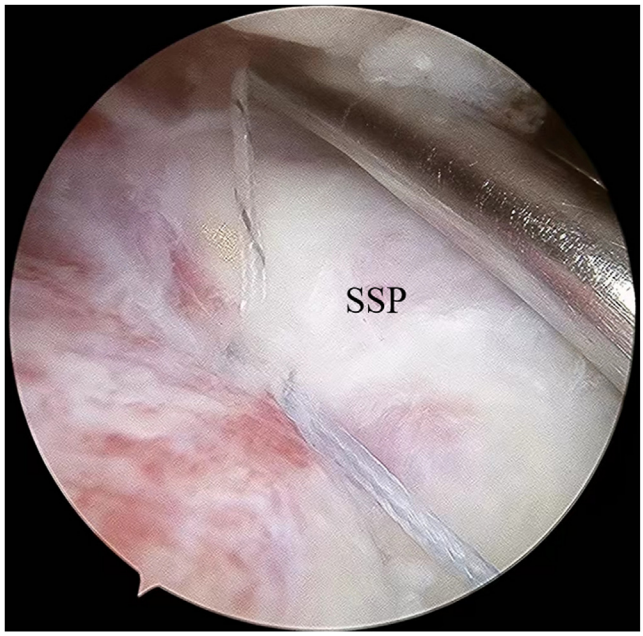

Fig 10. Arthroscopic image of right shoulder (lateral decubitus position) viewed through the subacromial lateral portal showing the static knot is firmly tied with the Sixth Finger knot pusher in the subacromial space. (SSP, supraspinatus tendon.)

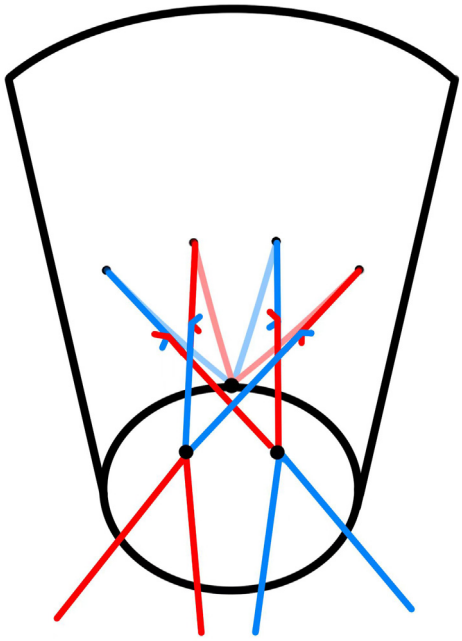

Fig 12. The 4 sets of double-pulley suture bridges are created (blue line, blue strand; red line, white strand, black dot, suture anchor).

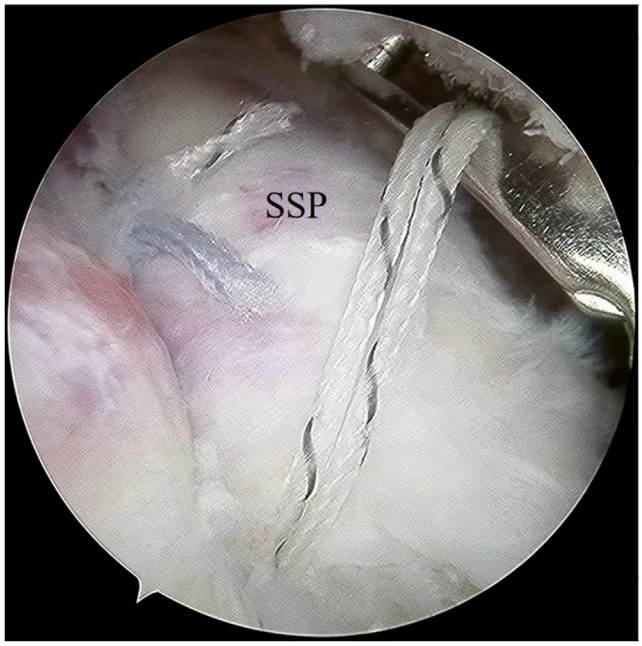

Fig 13. Arthroscopic image of right shoulder (lateral decubitus position) viewed through the subacromial lateral portal showing the white suture from the anterior lateral-row anchor will be used to fix the anterior portion of the supraspinatus tendon (SSP) in a single-row manner.

repair repairs can fix the tendon that cannot be compressed by the double-pulley suture-bridge. Second, 3 suture anchors is the minimum number of

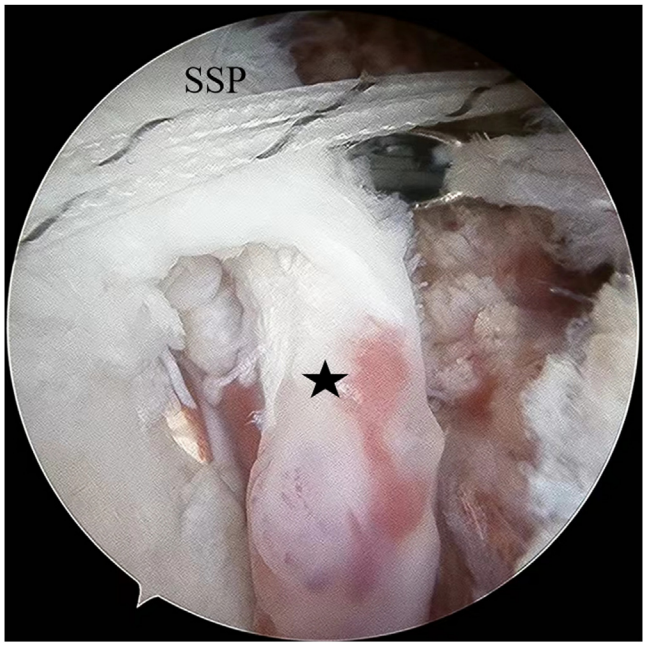

Fig 14. Arthroscopic image of right shoulder (lateral decubitus position) viewed through the subacromial lateral portal showing the anterior portion of the supraspinatus tendon (SSP) will be passed through with a suture hook (star, the anterior portion of the supraspinatus tendon).

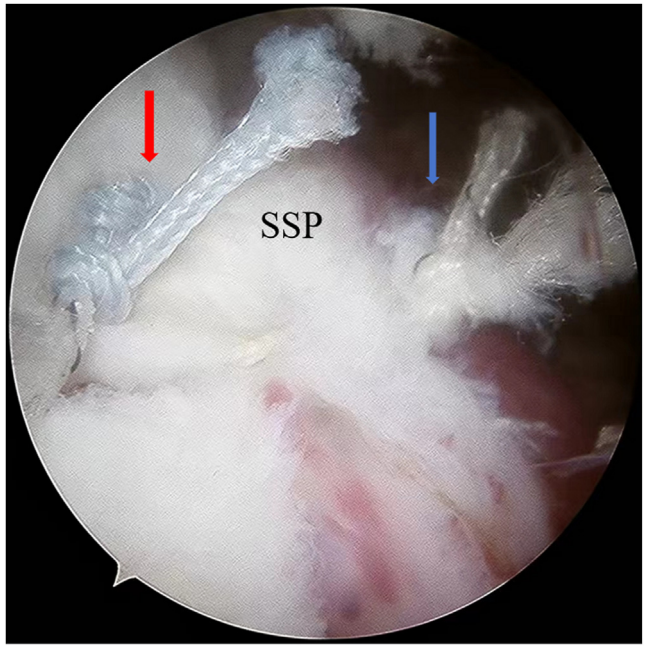

Fig 15. Arthroscopic image of right shoulder (lateral decubitus position) viewed through the subacromial lateral portal showing a single row and double-pulley suture bridge are created. (SSP, supraspinatus tendon; red arrow, the knot of single; blue arrow, the knot of double-pulley suture bridge.)

suture anchors used in the treatment of medium-sized tendon tears; increased tendon-bone contact area and better tendon healing will be the harvest from this unique anchor structure. Third, the design of the double-loaded suture anchor as a lateral-row anchor not only is a revolutionary surgical innovation but also can significantly reduce the surgical cost; the use of 1 medial-row anchor further reduces the cost. Fourth, although the DPSB procedure does not contribute to a reduction in the operative time, the single-row repair—as an inherent component of this technique—can reduce the overall operative time. Fifth, the modified DPSB repair is suitable for various forms of medium-sized tendon tears, including crescent, L-shaped, U-shaped, and longitudinal tears.

Nevertheless, the modified DPSB repair has some shortcomings: First, the surgical time may be increased owing to cumbersome and complicated suture management during the operation. Second, subacromial impingement[22] and bursitis may be caused by the 6 sets of knots from the DPSB and single-row fixation. Third, the strength of reattached tendon after the single-row process is inadequate, resulting in the overall suture strength being inferior to that of traditional double-row repair. Fourth, the use of 3 suture anchors will limit the coverage area of the suture configuration; a supraspinatus tendon tear width greater than 4 cm cannot be fully covered. Fifth, once the suture is locked or suture-

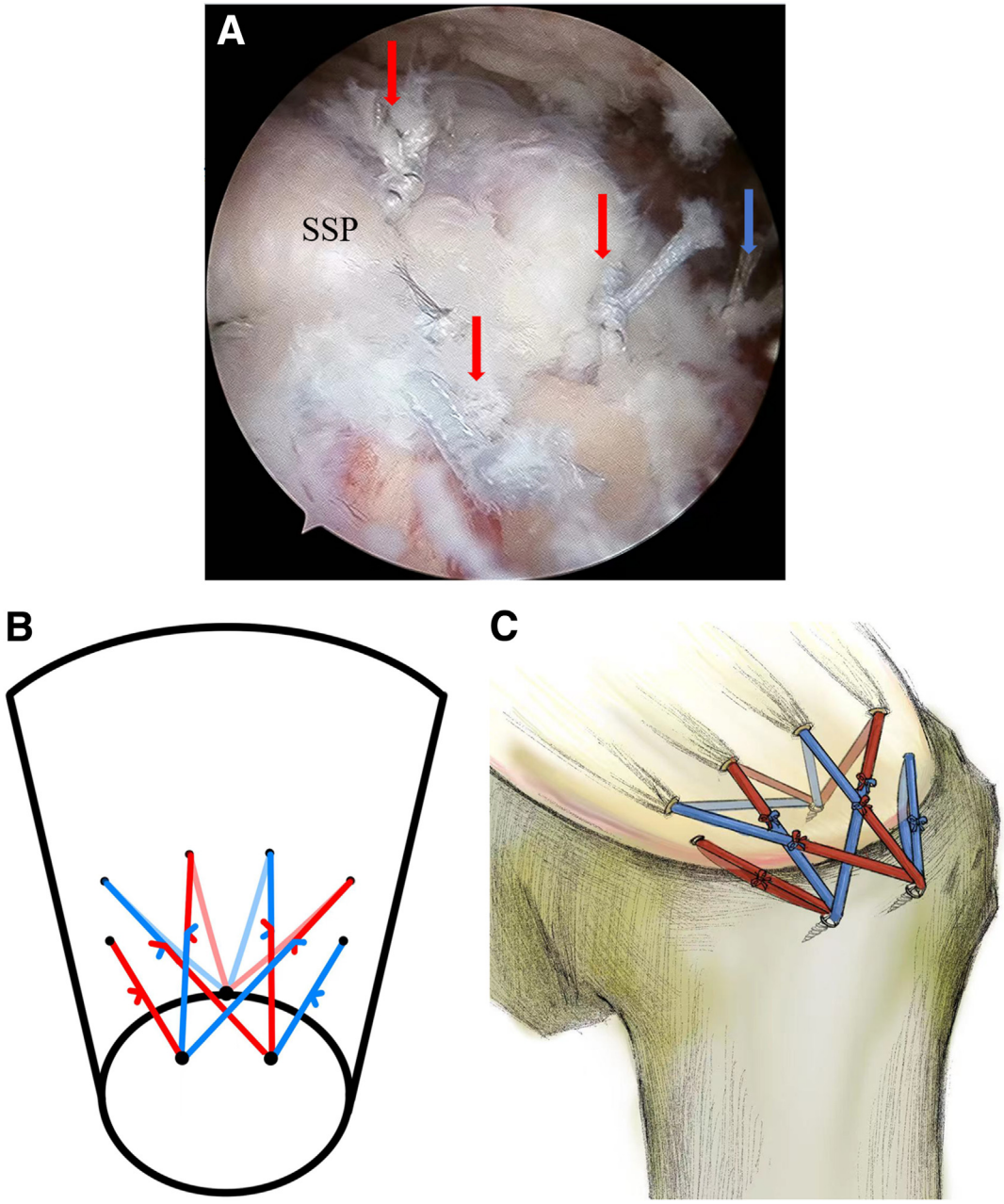

Fig 16. (A-C) Arthroscopic image of right shoulder (lateral decubitus position) viewed through the subacromial lateral portal showing four sets of double-pulley suture bridges and 2 sets of single rows are seated on the supraspinatus tendon (SSP) and powerfully compress the whole tendon against the footprint. The blue arrow indicates the single-row knot, and the red arrows indicate the double-pulley suture-bridge knots. (SSP, supraspinatus tendon; red arrow, the knot of single; blue arrow, the knot of double-pulley suture bridge.)

bridge is broken due to knot slipping, the operation will fail.

Disclosures

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

References

1. Chalmers PN, Granger E, Nelson R, Yoo M, Tashjian RZ. Factors affecting cost, outcomes, and tendon healing after arthroscopic rotator cuff repair. *Arthroscopy* 2018;34:1393-1400.
2. Imam M, Sallam A, Ernstbrunner L, et al. Three-year functional outcome of transosseous-equivalent double-row vs. single-row repair of small and large rotator cuff tears: A double-blinded randomized controlled trial. *J Shoulder Elbow Surg* 2020;29:2015-2026.

3. Li C, Zhang H, Bo X, et al. Arthroscopic release combined with single-row fixation or double-row suture bridge fixation in patients with traumatic supraspinatus tear and adhesive capsulitis non-responsive to conservative management: A prospective randomized trial. *Orthop Traumatol Surg Res* 2021;107:102828.
4. Carbonel I, Martinez AA, Calvo A, Ripalda J, Herrera A. Single-row versus double-row arthroscopic repair in the treatment of rotator cuff tears: A prospective randomized clinical study. *Int Orthop* 2012;36:1877-1883.
5. Hein J, Reilly JM, Chae J, Maerz T, Anderson K. Retear rates after arthroscopic single-row, double-row, and suture bridge rotator cuff repair at a minimum of 1 year of imaging follow-up: A systematic review. *Arthroscopy* 2015;31:2274-2281.
6. Hohmann E, König A, Kat CJ, Glatt V, Tetsworth K, Keough N. Single- versus double-row repair for full-thickness rotator cuff tears using suture anchors. A systematic review and meta-analysis of basic biomechanical studies. *Eur J Orthop Surg Traumatol* 2018;28:859-868.
7. Savage AJ, Spruiell MD, Schwertz JM, McGwin G, Eberhardt A, Ponce BA. The effect of sliding knots on the suture-tendon interface strength: A biomechanical analysis comparing sliding and static arthroscopic knots. *Am J Sports Med* 2013;41:296-301.
8. Apreleva M, Ozbaydar M, Fitzgibbons PG, Warner JJ. Rotator cuff tears: The effect of the reconstruction method on three-dimensional repair site area. *Arthroscopy* 2002;18:519-526.
9. Lee KW, Yang DS, Lee GS, Ma CH, Choy WS. Clinical outcomes and repair integrity after arthroscopic full-thickness rotator cuff repair: Suture-bridge versus double-row modified Mason-Allen technique. *J Shoulder Elbow Surg* 2018;27:1953-1959.
10. Park MC, Cadet ER, Levine WN, LU Bigliani, Ahmad CS. Tendon-to-bone pressure distributions at a repaired rotator cuff footprint using transosseous suture and suture anchor fixation techniques. *Am J Sports Med* 2005;33:1154-1159.
11. Grasso A, Milano G, Salvatore M, Falcone G, Deriu L, Fabbriciani C. Single-row versus double-row arthroscopic rotator cuff repair: A prospective randomized clinical study. *Arthroscopy* 2009;25:4-12.
12. Salata MJ, Sherman SL, Lin EC, et al. Biomechanical evaluation of transosseous rotator cuff repair: Do anchors really matter? *Am J Sports Med* 2013;41:283-290.
13. Ng SHA, Tan CHJ. Double-row repair of rotator cuff tears: Comparing tendon contact area between techniques. *World J Orthop* 2020;11:10-17.
14. Huang AL, Thavorn K, van Katwyk S, MacDonald P, Lapner P. Double-row arthroscopic rotator cuff repair is more cost-effective than single-row repair. *J Bone Joint Surg Am* 2017;99:1730-1736.
15. Mather RC III, Koenig L, Acevedo D, et al. The societal and economic value of rotator cuff repair. *J Bone Joint Surg Am* 2013;95:1993-2000.
16. Genuario JW, Donegan RP, Hamman D, et al. The cost-effectiveness of single-row compared with double-row arthroscopic rotator cuff repair. *J Bone Joint Surg Am* 2012;94:1369-1377.
17. Cummins CA, Murrell GA. Mode of failure for rotator cuff repair with suture anchors identified at revision surgery. *J Shoulder Elbow Surg* 2003;12:128-133.
18. Franceschi F, Ruzzini L, Longo UG, et al. Equivalent clinical results of arthroscopic single-row and double-row suture anchor repair for rotator cuff tears: A randomized controlled trial. *Am J Sports Med* 2007;35:1254-1260.
19. Chu T, McDonald E, Tufaga M, Kandemir U, Buckley J, Ma CB. Comparison of completely knotless and hybrid double-row fixation systems: A biomechanical study. *Arthroscopy* 2011;27:479-485.
20. Chauhan A, Regal S, Frank DA. Hybrid repair of large crescent rotator cuff tears using a modified SpeedBridge and double-pulley technique. *Arthrosc Tech* 2014;3:e409-e412.
21. Jeong JY, Yoon YC, Lee SM, Yoo JC. Arthroscopic incomplete repair using a "hybrid technique" for large to massive rotator cuff tears: Clinical results and structural integrity. *Arthroscopy* 2018;34:2063-2073.
22. Kim SH, Kim J, Choi YE, Lee HR. Healing disturbance with suture bridge configuration repair in rabbit rotator cuff tear. *J Shoulder Elbow Surg* 2016;25:478-486.