The "Pull-Over" Technique for All Arthroscopic Rotator Cuff Repair With Extracellular Matrix Augmentation

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Abstract: Despite the vast improvement in techniques for arthroscopic rotator cuff surgery, repairs of massive and large tears remain an issue as they are associated with significantly high failure rates, particularly in the elderly population. As a result, there has been a focus of attention to improve rotator cuff repair healing rates. One of the strategies is augmentation of the repair with a patch. Arthroscopic augmentation is, however, technically demanding with challenges in introduction and stabilization of the patch. The purpose of this Technical Note is to describe a technique for arthroscopic rotator cuff repair with augmentation, which offers additional advantages over previous techniques because it facilitates the passage of the patch as well as providing a more robust medial stabilization of the augment and therefore possibly a stronger construct.

In spite of the tremendous progress and innovations in arthroscopic rotator cuff techniques and instrumentation, failure rates may be in excess of 60% in elderly population with large and massive tears.[1] These high failure rates have led to the focus of attention on strategies that could potentially optimize tendon-bone healing by providing a favorable biological environment with minimum tension at the repair site. One of the strategies is augmentation of the repair with a patch.[2] Arthroscopic augmentation is, however, technically demanding with challenges in introduction and stabilization of the patch. The troublesome steps that are critical include maneuvering of the patch in the intended orientation to the correct location without it bunching and folding up or suture limbs becoming tangled and intertwisted, and the robust securing of the augment.

We have previously described a technique for this procedure, which addressed some of the challenges involved ("owl" technique).[3] In addition, we have also previously reported a technique for arthroscopic superior capsular reconstruction, which again in our opinion simplified the procedure ("pull-over" technique for superior capsular reconstruction).[4] The purpose of this Technical Note is to describe a technique for arthroscopic rotator cuff repair with augmentation, which involves a combination of steps in both the "owl" technique for augmentation and the "pull-over" technique for superior capsular reconstruction. We feel that this technique for arthroscopic augmentation may offer additional advantages because it facilitates the passage of the patch into the bursa as well as providing a more robust medial stabilization of the augment that

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Table 1. Key Points

(1) Extracellular matrix augmentation of large and massive rotator cuff tears may decrease repair failure rates
(2) Arthroscopic augmentation is technically challenging
(3) Our technique offers additional advantages over the previously described techniques by facilitating the passage of the patch into the bursa as well as providing a more robust medial stabilization of the augment and therefore possibly a stronger construct

may lead to a biomechanically stronger construct (Table 1).

Surgical Technique

The procedure is performed with the patient under general anesthesia combined with interscalene block with the patient positioned in either a beach chair or lateral decubitus (Table 2).

Standard Repair of the Cuff Tear

This step is the same as that of the "owl technique" with a critical difference that, in addition, a free suture is also passed through the tendon (Fig 1, Video 1, Table 3).[3] The owl technique for arthroscopic rotator cuff repair with augmentation involves performing a standard medial row repair and then shaping the augment ("owl shaped") in a way that minimizes risks of the patch folding up. The patch is then stabilized laterally by inserting 2 lateral row anchors, but there is no medial stabilization of the augment.[3]

A standard medial row repair of the tendon tear is performed using either 1 or 2 medial row anchors with steps that include mobilization of the tendon, preparation of the foot print area on the greater tuberosity, insertion of the medial row anchors (Healicoil Peek, Smith and Nephews, Andover, MA), and passage of the anchor suture limbs through the tendon using a standard suture passer device (we have used the Scorpion device, Arthrex, Naples, FL). In addition, a free suture (FiberWire Number 2, Arthrex) is also passed through the tendon and brought out through the Neviaser port (Fig 1, Video 1). The free suture is used later to "pull over" the augment into the bursa and to secure the augment medially (see below).

Once all the anchor suture limbs have been passed through the cuff, they are tied together using standard arthroscopic knot tying techniques. It is, however, critical not to tie any knots in the free FiberWire suture. If only 1 medial row anchor is used, then one is left with 2 sets of tied anchor suture limbs (1 anterior and 1 posterior). If 2 medial row anchors are used, then 4 sets of tied anchor suture limbs would be present (1 anterior, 1 posterior, and 2 in the middle in which case the 2 middle suture limb sets need to be cut just distal to the knots). The distance between the anterior and posterior knots is then measured (distance *c*) using an arthroscopic hook or special arthroscopic measuring devices (Arthrex) (Fig 2, Video 1, Table 3).

Preparation of the Augment Outside the Patient

Preparation of the augment (Arthrex Dx Reinforcement Matrix, Arthrex) initially involves making 2 holes through the augment using an 18G spinal needle (labeled *k*) (Fig 2). The gap between the 2 holes must be the same as distance *c* (see above) (Fig 2). These holes must be at least 1 cm from the top edge (medial border) of the augment (distance *b*).

In addition, a third hole (labeled *d*) is made approximately 5 mm from the medial edge of the augment between the other 2 holes (Fig 2). The length of the patch (distance between the anterior and posterior edge of the augment [labeled ***l***]) is dependent on the size of the tear, but the holes must be at least 5 mm from these edges (distance ***a***). Similarly, the width (distance between the medial and lateral edge of the augment [labeled ***w***]) of the augments is dependent on the tear size, but it must be at least 2 cm and the holes must be at least 1 cm from the top edge (medial border) of the augment (distance *b*).

In a similar manner to the "owl" technique, the corners of the rectangular patch are cut so one is left with an octagon (Fig 2).[3]

Suture Management

Initially a polydioxanone (PDS) suture (used as the "shuttle suture") is tied to one limb of the free suture limb (previously brought out through the Neviaser portal) (Fig 3).

All 4 anchor suture limbs plus the "free suture" limb, which is tied to the PDS suture, are then brought out through the lateral cannula (Passport, Arthrex) in a standard lateral port while holding on to the one end of the PDS suture outside the Neviaser port (Fig 4).

The PDS suture is then untied from the free suture limb outside the lateral port. The free suture limb is then passed through hole "*d*" of the augment (Fig 5). The PDS end outside the lateral port is then tied to the free suture limbs again and then pulled to bring out the free suture limb through the Neviaser port (Fig 5, Table 3).

The 2 suture limbs of the anterior knot are passed through the anterior "*k*" hole and the 2 suture limbs of the posterior knot through the posterior "*k*" hole (Fig 6).

Insertion of the Augment

The patch is then rolled over itself to pass it inside. After this the free suture limbs outside the Neviaser port are all pulled, therefore pulling over (hence the name "pull-over" technique) the matrix into the bursa (Video 1).

Table 2. Indications and Contraindications

Indications	Contraindications
Repairable rotator cuff tears	Irrepairable rotator cuff tears Rotator cuff arthropathy Active infection or history of shoulder infection

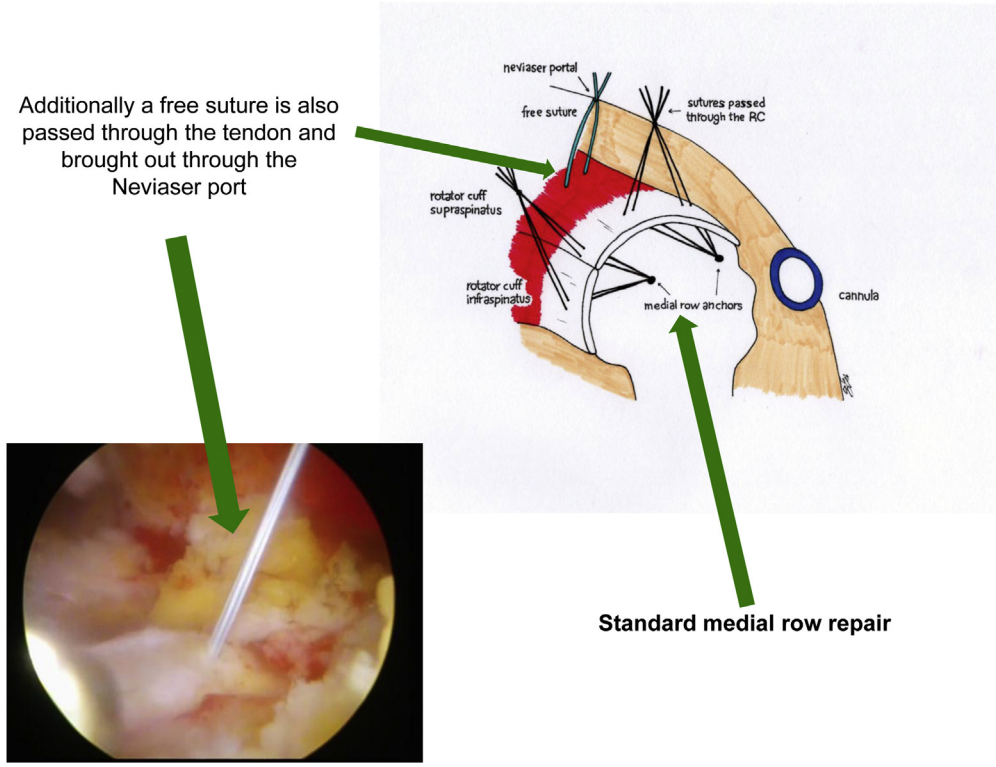


Fig 1. Standard medial row repair with an additional step of passing a free suture through the tendon. The arthroscope is in the standard posterior port of the left shoulder with the patient in the lateral position, but the arthroscope is rotated so the images appear as though the patient is in the beach chair position.

Table 3. Surgical Steps Involved With "Pull-Over" Technique

(1) Diagnostic glenohumeral joint arthoscopy
(2) Arthroscope is introduced into the bursa
(3) Bursectomy
(4) Acromioplasty
(5) Acromioclavicular excision if there is ACJ tenderness
(6) Mobilization of the rotator cuff tear
(7) Preparation of the greater tuberosity
(8) Insertion of 1 or 2 medial row anchors depending on the anatomy of the tear
(9) Passage of anchor sutures through the torn rotator cuff tendon (4 passes with 1 anchor, 8 passes with 2 anchors)
(10) In addition, a free suture is also passed through the tendon and brought out through the Neviaser port
(11) Once all the anchor suture limbs have been passed through the cuff, they are tied together using standard arthroscopic knot tying techniques
(12) It is, however, critical not to tie any knots in the free FiberWire suture
(13) The distance between the anterior and posterior knots is then measured (distance *c*) using an arthroscopic hook or special arthroscopic measuring devices
(14) Augment is prepared
(15) Initially a PDS suture (used as "shuttle suture") is tied to one limb of the free suture limb (previously brought out through the Neviaser port)
(16) All 4 anchor suture limbs plus the "free suture" limb, which is tied to the PDS suture, are then brought out through the lateral cannula
(17) The PDS suture is then untied from the free suture limb outside the lateral port and then passed through hole "*d*" of the augment
(18) The PDS suture end outside the lateral port is then tied to the free suture limbs again and then pulled to bring out the free suture limb through the Neviaser port
(19) Similarly, the 2 suture limbs of the anterior knot are passed through the anterior "*k*" hole and the 2 suture limbs of the posterior knot through the posterior "*k*" hole of the augment
(20) The patch is then rolled over itself to pass it inside
(21) After this the free suture limbs outside the Neviaser port are all pulled, therefore pulling over (hence the name "pull-over" technique) the matrix into the bursa
(22) At the same time, the rolled matrix is pushed through the lateral port into the subacromial space using an artery clip to aid the "pull-over" maneuver
(23) Once the patch is inside the subacromial space, it is laid open flat using a blunt obturator
(24) Medial stabilization of the augment is then performed by tying arthroscopic knots with the 2 free suture limbs through the Neviaser port
(25) Lateral stabilization is subsequently achieved by insertion of 2 lateral row anchors

ACJ, acromio-clavicular joint; PDS, polydioxanone.

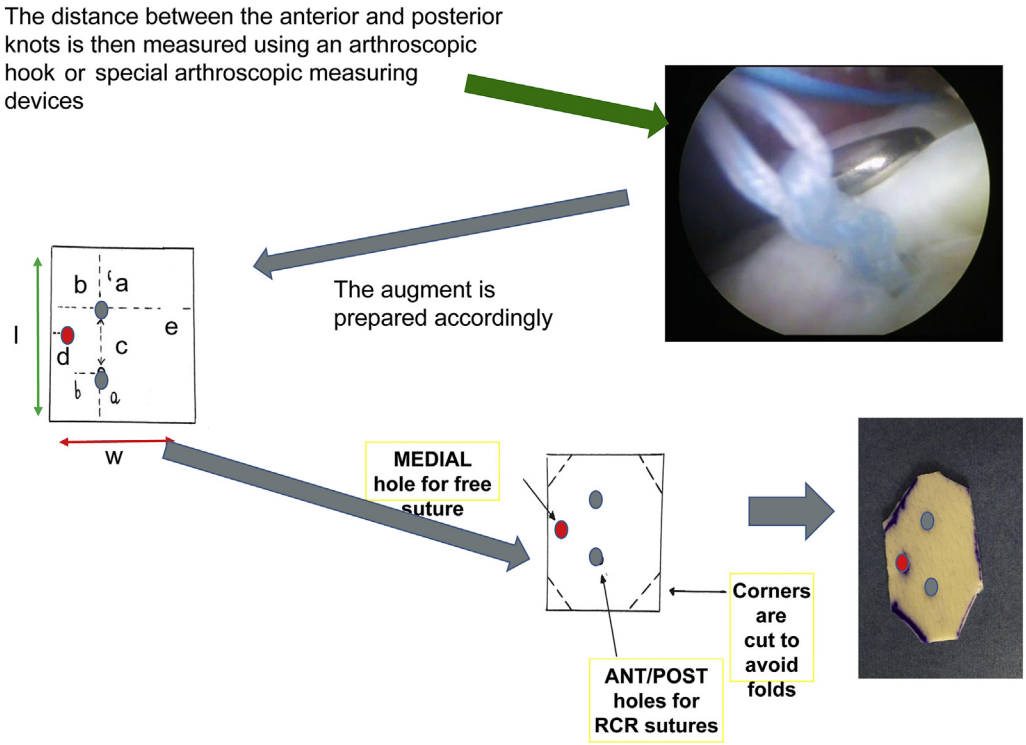


Fig 2. Preparation of the extracellular matrix outside the patient. a = distance between the ANT/POST holes and the ANT/POST edges; b = distance between the ANT/POST holes and the medial edge; c = distance between the 2 holes; d = distance between the medial hole and the medial edge; e = distance between the ANT/POST holes and the lateral edge; l = distance between the anterior and posterior edges (length); w = distance between the medial and lateral edges (width). (ANT, anterior; POST, posterior; RCR, rotator cuff repair.)

At the same time, the rolled matrix is pushed through the lateral port into the subacromial space using an artery clip to aid the "pull-over" maneuver. Once the patch is inside the subacromial space, it is laid open flat using a blunt obturator (Fig 7, Video 1, Table 3).

Augment Stabilization

Once the augment is inside and laid flat, it needs to be stabilized both medially and laterally. Medial stabilization is performed by tying arthroscopic knots with the 2 free suture limbs through the Neviaser port

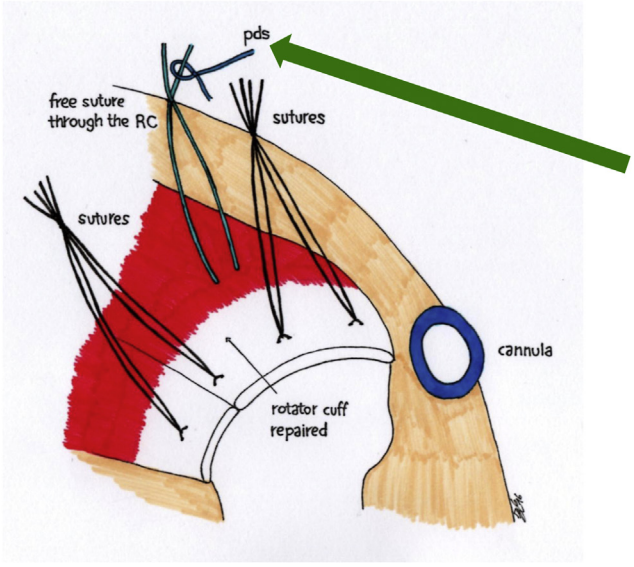
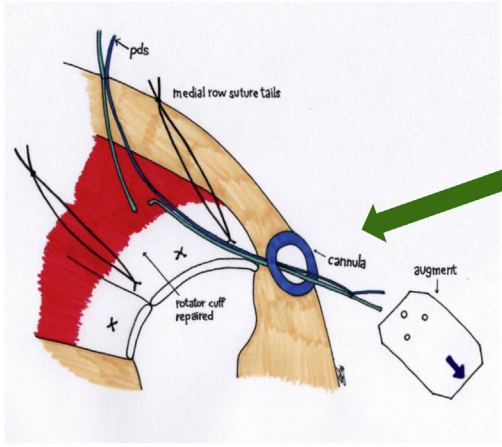


Fig 3. PDS suture (used as the shuttle suture) is tied to one suture limb of the free suture outside the Neviaser port. (PDS, polydioxanone.)



All four anchor suture limbs plus the "free suture" limb that is tied to PDS suture, are then brought out through the lateral cannula in a standard lateral port while holding on to the one end of each PDS suture outside the Neviaser port.

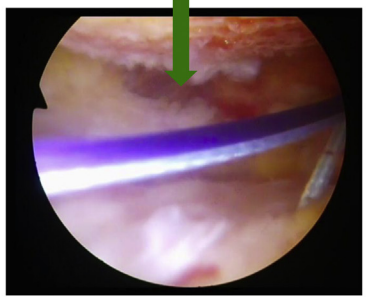
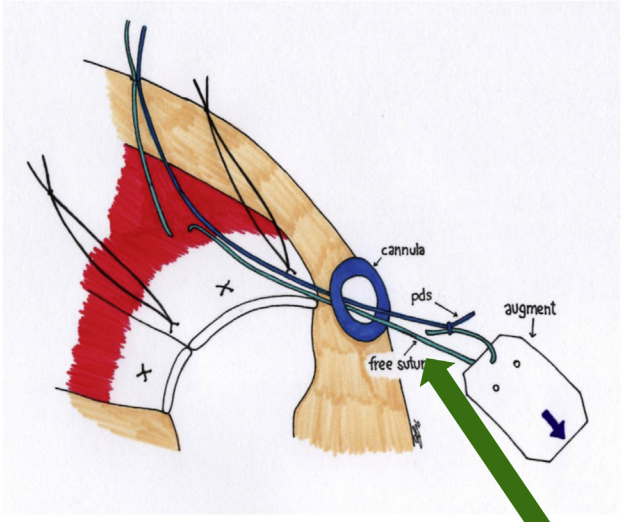


Fig 4. Suture limbs of both anchors and "free suture" limb, which is tied to the PDS shuttle suture, are then brought out through the lateral cannula while holding on to the one end of each PDS suture outside the Neviaser port. The arthroscope is in the standard posterior port of the left shoulder with the patient in the lateral position, but the arthroscope is rotated so the images appear as though the patient is in the beach chair position. (PDS, polydioxanone.)



PDS suture is untied from the free suture limb outside the lateral port. The free suture limb is then passed through hole *"d"* of the augment. The PDS end outside the lateral port is then tied to the free suture limbs again and then pulled to bring out the free suture limb of the through the Neviaser port .

Fig 5. The PDS suture is untied from the anchor suture limbs outside the lateral port. The free suture limb is then passed through hole *"d"* of the augment. The PDS end outside the lateral port is then tied to the free suture limbs again and then pulled to bring out the free suture limb through the Neviaser port. (PDS, polydioxanone.)

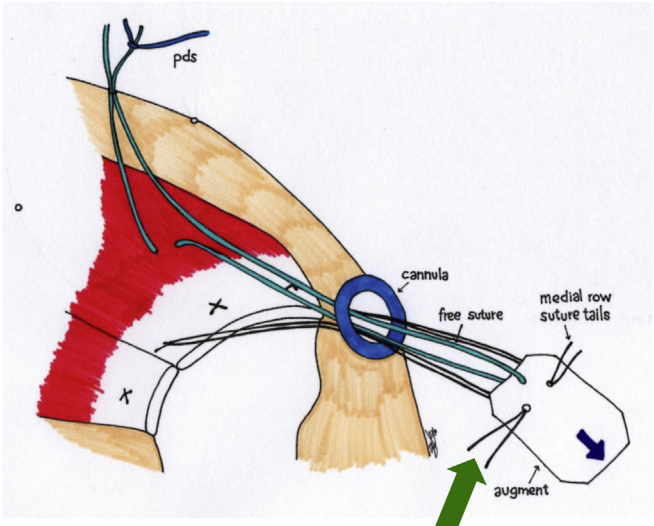


Fig 6. The suture limbs of the anterior anchor are passed through the anterior hole of the patch and those of the posterior anchor through the posterior hole. (PDS, polydioxanone.)

The two suture limbs of the anterior knot are passed through the anterior *"k"* hole and the two suture limbs of the posterior knot through the posterior *"k"* hole .

(Fig 8, Video 1). Lateral stabilization is subsequently achieved by insertion of 2 lateral row anchors (second row anchors) (we use Swivelock 5.5 SP, Arthrex). One of these 2 lateral row anchors is going to be inserted anteriorly and the other one posteriorly. A transosseous equivalent suture bridge technique is used to insert the lateral row anchors incorporating the augment into the construct. This involves passing the medial row

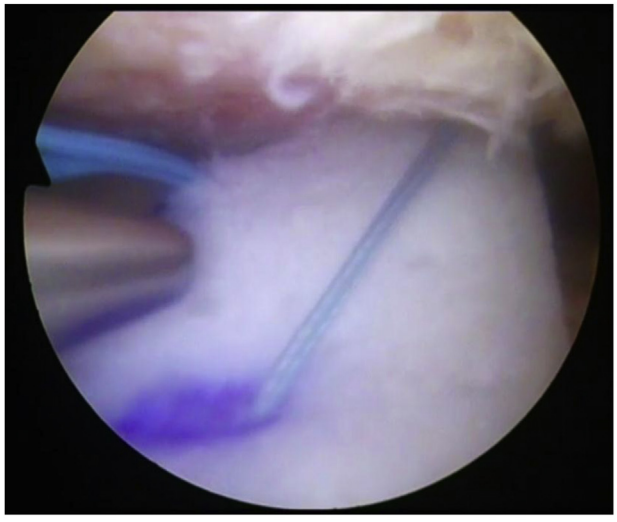


Fig 7. Insertion of the augment. The anchor suture limb outside the Neviaser port is pulled, therefore pulling over ("pull-over" technique) the matrix into the bursa. The arthroscope is in the standard posterior port of the left shoulder with the patient in the lateral position, but the arthroscope is rotated so the images appear as though the patient is in the beach chair position.

During augment insertion,the free suture limb outside the Neviaser port are all pulled, therefore pulling over (hence the name "pull-over" technique") the matrix into the bursa. At the same time the rolled matrix is pushed through the lateral port into the subacromial space using an artery clip to aid the "pull-over" maneuver. Once the patch is inside the subacromial space, it is laid open flat using a blunt obturator .

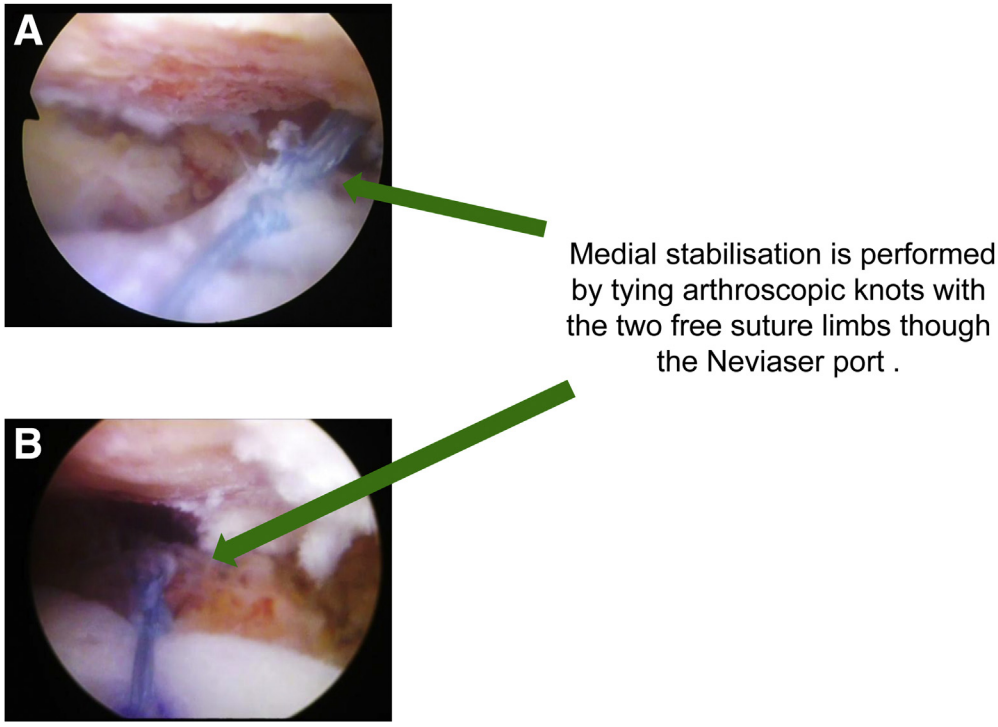


Fig 8. Stabilization of the medial end of the augment to the cuff. (A) The arthroscope is in the standard posterior port of the left shoulder with the patient in the lateral position, but the arthroscope is rotated so the images appear as though the patient is in the beach chair position. (B) The arthroscope is in the lateral port of the left shoulder with the patient in the lateral position, but the arthroscope is rotated so the images appear as though the patient is in the beach chair position.

anchor's suture ends over the laid flat augment and then through the 2 lateral row anchors that are in turn inserted into the distal part of the greater tuberosity. With this technique, the augments are secured as the medial row anchor suture ends are tensioned during the lateral row anchor insertion. The tensioned sutures on top of the augment help to secure it (Fig 9, Video 1, Table 3).

Discussion

The degree of advances in arthroscopic rotator cuff technology over the last 20 years matches that of any

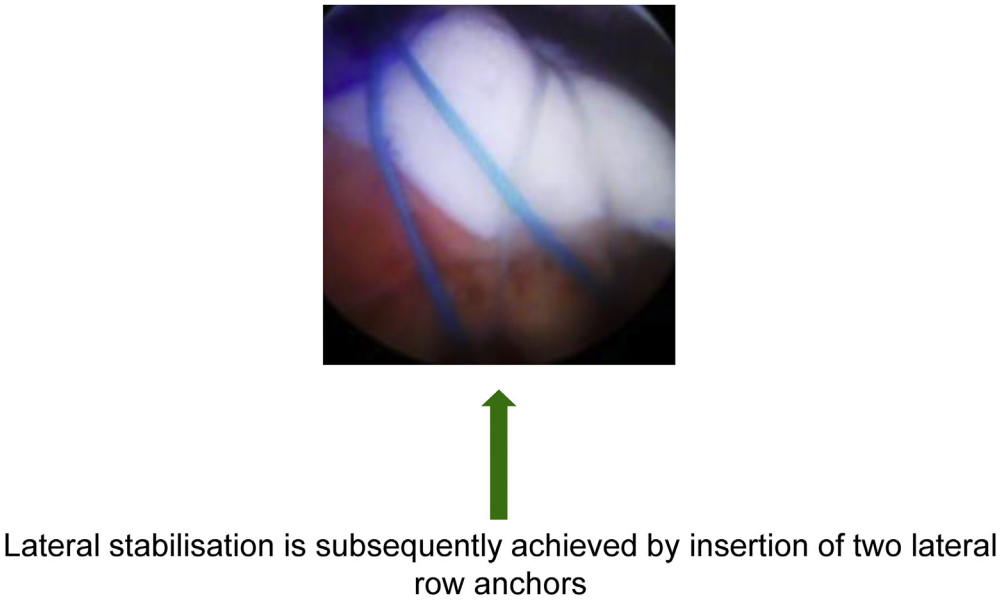


Fig 9. Lateral stabilization of the augment and the final construct. The arthroscope is in the lateral port of the left shoulder with the patient in the lateral position, but the arthroscope is rotated so the images appear as though the patient is in the beach chair position.

Table 4. Advantages and Risk

Advantages	Risks
(1) Involves relatively few suture limbs	(1) Those related to the standard arthroscopic shoulder procedure
(2) Reduced risk of suture ends becoming tangled together	(2) Inflammatory response to the matrix
(3) Introduction of the augment is much easier as the augment is also "pulled over"	(3) Infection
(4) With this technique the medial border of the augment is additionally fixed to the cuff therefor providing a more robust medial stabilization of the augment and possibly a stronger construct	

other surgical field. Despite this progress, failure rates may be in excess of 60% for elderly patients who undergo large or massive rotator cuff repair.[1] As a result, over the last few years, attention has been focused on a number of strategies to improve this healing rate. These include use of patch augmentation and administration of platelet-rich plasma and bone marrow aspirate concentration to the repaired construct.[2] Augmentation of the repair with the extracellular matrix or synthetic patch has regained popularity in recent years as a result of improved arthroscopic instrumentation and techniques as well as advances in processing techniques that significantly enhance removal of antigenic material form the extracellular matrix, therefore minimizing risks of immune and inflammatory response and adhesions.[5] There has also been a number of biomechanical, histological, clinical, and radiological reports that have suggested enhanced construct strength as well as good function and healing with the use of augmentation with rotator cuff tears.[6-10]

Arthroscopic augmentation techniques, however, are technically challenging, difficult to reproduce consistently, and time consuming. We have previously described a technique for this procedure, which addressed some of the challenges involved ("owl" technique) including maneuvering of the patch in the intended orientation to the correct location without it bunching and folding up or suture limbs becoming tangled and intertwisted.[3] In addition, we have also previously reported a technique for arthroscopic superior capsular reconstruction, which again in our opinion simplified the procedure ("pull-over technique for superior capsular reconstruction").[4] In this Technical Note, we have described a further technique for arthroscopic rotator cuff augmentation, "pull-over technique for rotator cuff repair with augmentation," which is the combination of both the "owl technique" and the "pull-over technique" for superior capsular reconstruction.

We feel that the "pull-over technique for rotator cuff repair with augmentation" has additional advantages over previously described techniques. First, with this technique there is a "free suture" inserted medially through the cuff and brought out through the Neviaser port. Furthermore, a PDS suture is attached to one limb of this free suture. This PDS suture is used to shuttle the one limb of the free suture through augment and then back out again through the Neviaser port as described above. This facilitates the insertion of the matrix allowing it to be pulled through to the correct location in the subacromial space with relative ease (Table 4).

Secondly, this free suture allows a more robust stabilization of the medial border of the augment once it is

Table 5. Pearls and Pitfalls

Pearls	Pitfalls
(1) Adequate bursectomy must be performed	(1) In the absence of inadequate bursectomy, visualization becomes difficult and the augment will not lay open flat
(2) Neviaser port must be used	(2) Without the Neviaser port, one would not be able to "pull over" the augment as described in this technique
(3) Free suture must be passed through the rotator cuff as described above	(3) Without the free suture and the PDS shuttle suture, the "pulling" of the augment over with this technique and medial stabilization of the augment as described above is not possible
(4) Using the PDS to shuttle free suture limbs is essential for this technique	
(5) Bringing out the free suture limb through the Neviaser port (using the PDS as the shuttle suture) and pulling it (once they are passed through the matrix) pulls over the matrix to the desired position in the subacromial space	

PDS, polydioxanone.

laid flat inside the subacromial bursa. With this technique the medial border of the augment is fixed to the cuff by tying the 2 free suture limbs together using standard arthroscopic knot tying techniques through the Neviaser port as described above. We feel that this may result in a stronger construct with a greater maximum load to failure as a recent study has suggested that when performing rotator cuff repair with augmentation, stabilization of both medial and lateral borders of the augment may lead to raised maximum load to failure values (Tables 4 and 5).[7]

As with other techniques that utilize the extracellular matrix, possible risks of the procedure include inflammatory response, stiffness, and infection (Table 4). As mentioned above, with the modern extracellular matrix, advances in processing techniques significantly enhance removal of antigenic material. These processes are reported to exhibit more than 94% removal of DNA, therefore minimizing risks of immune and inflammatory response and adhesions.[5] We did not have any cases of infection or excessive inflammatory response. We do, however, recommend that augmentation should not be performed in the presence of any active infection or previous shoulder joint infection. Similarly, the technique should not be used to bridge the gap in the presence of an irrepairable tear. It should only be used to augment a tear that is repairable.

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