The Tripod-Pulley Technique for Arthroscopic Remplissage in Engaging Hill-Sachs Lesions

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Abstract: Arthroscopic Bankart repair is now a well-established technique for the treatment of shoulder instability. However, failure rates are considerable when significant bony defects are not addressed. Hill-Sachs lesions, present in the vast majority of those with recurrent anterior instability, when of significant dimension and location, may account for some of these failures. The remplissage procedure involves capsulotenodesis of the posterior capsule and the infraspinatus tendon to fill the Hill-Sachs lesion. "Double-pulley" remplissage is a transtendinous technique that has been described elsewhere and that may simplify the procedure. We present a modification of this technique, the "tripod-pulley" technique, which we feel may potentiate healing of the Hills-Sachs lesions of the capsule and infraspinatus by increasing the surface contact area. At the same time, this technique minimizes the risk of potential damage to the infraspinatus as it uses 2.3-mm "all-suture" anchors.

Treatment of shoulder instability has changed and evolved during the last 20 years. However, the dislocation recurrence rate is still high in anterior shoulder instability. The reported rate of recurrence ranges from 19% to 88% in patients treated conservatively[1] and improves to a range between 3.4% and 35% at 10 years of follow-up.[2,3]

Many investigators attempt to explain the reason for the high failure rate. The concepts of an "engaging" Hill-Sachs (HS) lesion and an "inverted pear" aspect of the glenoid were introduced by Burkhart and De Beer.[4] in 2000. Di Giacomo, Itoi, and Burkhart[5] consequently described the concept of "on-track/off-track" lesions in 2014. If the combination of the bipolar lesion leads to an off-track lesion, the recurrence rate is higher and the lesion cannot be addressed with a soft-tissue repair only.[6]

Open surgery (Latarjet procedure, iliac crest, or allograft bone graft procedures) is an option in anteroinferior glenoid bone loss of 25% or more and in "off-track" lesions.[7,8] However, this is not always necessary.[9] Researchers have studied techniques to reinforce an arthroscopic Bankart repair in order to perform an arthroscopic soft-tissue procedure also in shoulders with significant bone loss.

The remplissage technique (RT), described by Wolf et al. in 2004,[10] has shown good results, with a success rate between 85%[11] and 93%.[12,13]

The RT involves a capsulodesis and a tenodesis of the infraspinatus to fill the HS defect, which is converted to extracapsular and prevents engagement through a soft-tissue bumper effect (Fig 1).[14,15]

Different techniques have been published in the literature (Table 1).

Surgical Technique

The procedure is performed under general anaesthesia combined with interscalene nerve block with the

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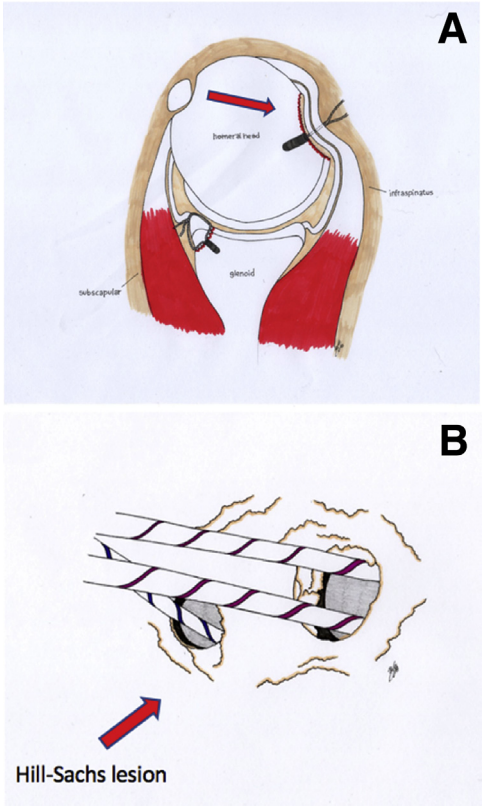

Fig 1. (A) Standard remplissage technique as described by Wolf et al. (B) View of the anchors inserted in the Hill-Sachs lesion. Two 5.5-mm anchors are inserted in the humeral head, and the sutures are passed through the infraspinatus tendon using suture passer instruments. (Arthroscope is in the anterolateral portal of the right 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.)

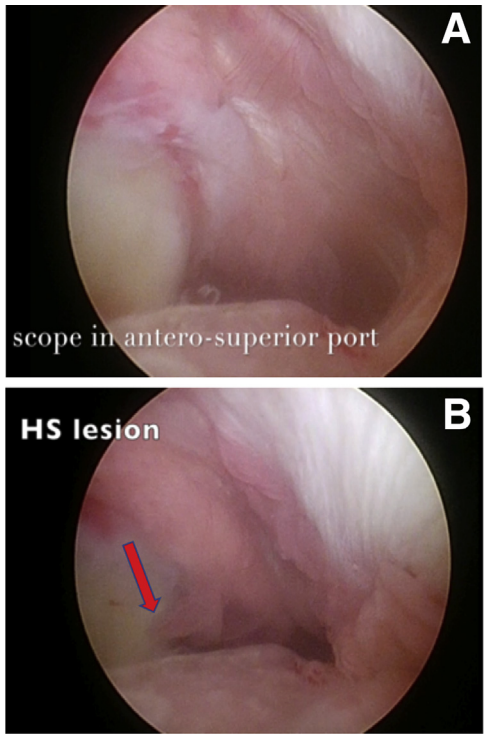

Fig 2. (A, B) Visualization of the Hill-Sachs (HS) lesion from the anterolateral portal. Once the diagnostic arthroscopy is complete, an 8.5-mm cannula (Stryker Dri-Lok disposable cannula) is placed in the rotator interval through the anterolateral portal. The posterior aspect of the shoulder and the HS lesion are assessed. (Arthroscope is in the anterolateral portal of the right 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.)

patient in the lateral position and longitudinal traction (8-10 pounds).

Camera in the Posterolateral Portal

The camera is initially inserted in the standard posterolateral portal, and a diagnostic arthroscopy is performed. The position and the features of the anterior labral lesion are observed as well as the depth, the position, and the size of the HS lesion. An 8.5-mm cannula (Dri-Lok disposable cannula; Stryker, San Jose, CA) is inserted in the rotator interval space, and it will be used to perform the anterior labral repair.

Camera in the Anterolateral Portal

The camera is now switched to anterolateral portal to have a better view of the HS lesion (through the cannula; Stryker Dri-Lok disposable cannula; Fig 2).

If the lesion was confirmed to be an "off-track"[7,8] lesion by the radiologist who has reported the computed tomography scan, a tripod-pulley RT is performed (Table 2).

Three 2.3-mm double-strand all-suture anchors (Stryker Iconix 2.3 mm) are used to perform this technique (Fig 3). Any anchor can be used, but the advantage of all-suture anchors is the small size both in relation to

Table 1. Remplissage Techniques (RTs)

RT	Authors
RT, double anchors	Wolf et al. 2004[10]
	Boileau et al. 2012[16]
RT, single anchor	Camp et al. 2015[17]
Double-barrel RT	Bhatia 2015[18]
Arthroscopic transtendinous double-pulley RT	Parnes et al. 2015[19]

Table 2. Knot Tying

Anchors			Technique
Anteromedial	Posteromedial		Pulley
	Posteromedial	Lateral	Pulley
Anteromedial		Lateral	Arthroscopic knot
Anteromedial	Posteromedial		Pulley
	Posteromedial	Lateral	Pulley
Anteromedial		Lateral	Arthroscopic knot

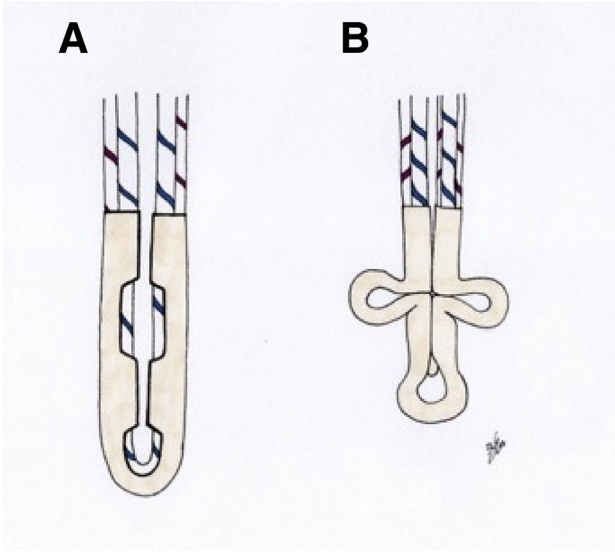

Fig 3. All-suture anchors (A) closed and (B) opened. Three 2.3-mm double-strand all-suture anchors (Stryker Iconix 2.3 mm) are used in this procedure.

the bone and the tendon, which is not damaged more than necessary. A 5-mm cannula (Stryker Dri-Lok disposable cannula) is positioned in the posterolateral portal through the deltoid muscle fibers without violating the integrity of the infraspinatus tendon (Fig 4). A 4-mm shaver (Dyonics Helicut burr 4.5-mm; Smith & Nephew, London, UK) can be used to freshen the bone to enhance the tendon healing (Table 3). The shaver can be easily inserted through the hole in the capsule left by the trocar used at the beginning of the procedure when the camera

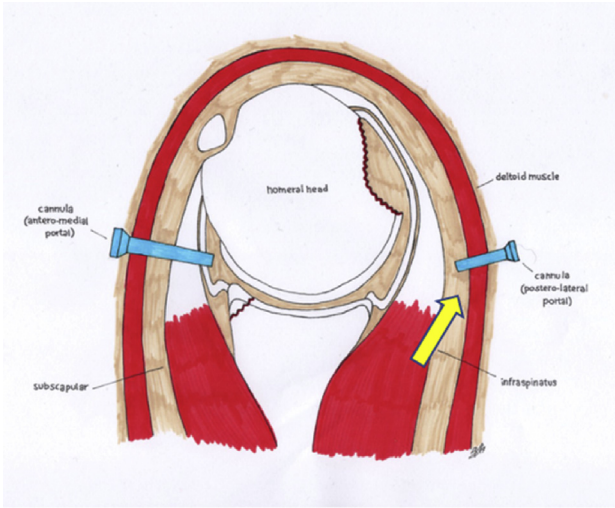

Fig 4. Cannula positioning. A 5-mm cannula (Stryker Dri-Lok disposable cannula) is positioned in the posterolateral portal through the deltoid muscle into the subacromial space. (Arthroscope is in the anterolateral portal of the right shoulder with the patient in the lateral position, but the arthroscope is rotated so the images appear as though the patient is in the beach chair position.)

Table 3. Surgical Steps Involved in the Tripod-Pulley Technique

Camera in the posterolateral portal
Diagnostic glenohumeral joint arthroscopy.
8.5-mm cannula inserted in the anterolateral portal.
Camera in the anterolateral portal
Arthroscope introduced in the anterolateral portal through the cannula.
5-mm cannula introduced in the posterolateral portal through the deltoid only into the subacromial space.
Hill-Sachs (HS) lesion refreshed with bone shaver.
3 all-suture double-strand anchors are inserted in the HS defect in a triangle configuration.
Medioposterior anchor first through a new hole in the tendon/capsule.
A marker clip is put at the end of the suture strands to recognize them and keep them separate from the suture of the other anchors that will follow.
Medioanterior anchor is positioned and passed through the hole already made in the capsule by the trocar when inserted in the posterolateral portal at the beginning of the procedure.
The suture ends are marked differently.
Lateral anchor is inserted. A more lateral hole in the tendon/capsule complex is made.
The suture ends are marker differently and kept separate from the others.
Camera in the posterolateral portal
A standard Bankart repair is performed.
Camera in the anterolateral portal
The first 2 knots are tied outside the shoulder. One suture from each anchor is used to be tied with another anchor suture. Two ends of 2 different sutures (A-B) of 2 different anchors are sutured outside the shoulder, and the final ends are cut. The other ends of each suture are then pulled to slide the knot down into the subacromial space. The same procedure is repeated with a suture end (C) of the third anchor. At this point suture B is knotted with suture A and suture C. Suture A and suture C have one end each free that needs to be knotted together (A + C). Refer to Table 2 for the sequence.
Using a pulley technique, the knots can slide into the shoulder, and direct visualization of the tenodesis effect can be observed with the camera pointing at the HS lesion.
The remaining sutures are tied together in an arthroscopic fashion with a knot pusher to close the triangle.
The same process is repeated with the other 3 strands, one for each anchor. Refer to Table 2 for the sequence.

was inserted in the posterolateral portal. This minimizes the damage to the infraspinatus tendon and capsule complex.

The guide for the all-suture anchor (Stryker Iconix 2.3 mm) is inserted through the cannula (Stryker Dri-Lok disposable cannula) in the subacromial space, and the correct position for the posteromedial anchor is found by applying pressure with the smooth tip of the guide on the infraspinatus tendon without the need to violate its integrity (Video 1). This anchor is the first inserted because it is the furthest away from the camera and positioning of the other 2 anchors before this can reduce our view due to the suture strands. The anteromedial anchor can usually be inserted through the same hole in the capsule mentioned above. This anchor instead needs to go through the infraspinatus tendon

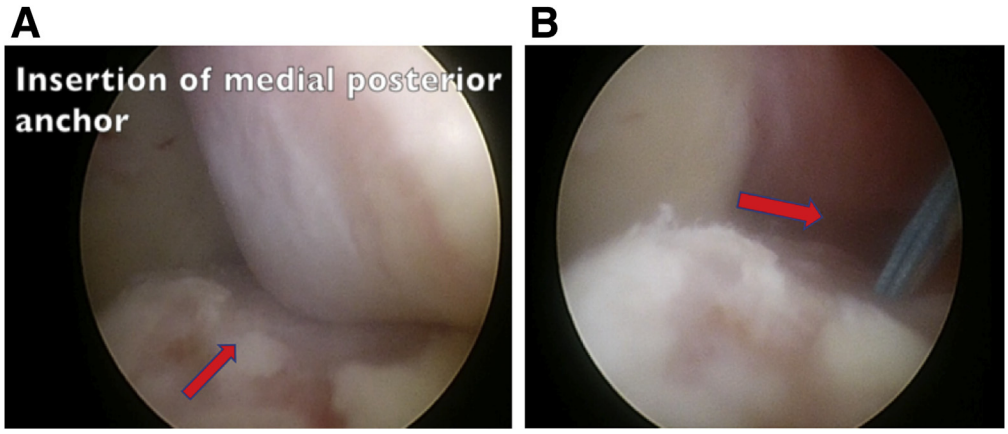

Fig 5. (A) The medial-posterior anchor is inserted through a blind technique to minimize the damage to the infraspinatus tendon. With the camera anterior, the first anchor is inserted medially and posteriorly through the infraspinatus and in the posteromedial area of the Hill-Sachs lesion. (B) A new hole in the tendon is performed to have a bridge of tendon tissue between the anchors. Once the anchor is placed, the sutures need to be marked to keep them divided from the others. (Arthroscope is in the anterolateral portal of the right 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.)

and the capsule in a different position to have a bridge left between the 2 medial anchors. Once the surgeon is happy with the position and the angle of the guide, a drill is used to weaken the bone and a 2.3-mm anchor is inserted. It is important to keep the position of the guide to find the drilled hole where the anchor needs to be inserted (Fig 5).

The procedure is repeated for the anteromedial anchor (Stryker Iconix 2.3 mm) even if, as mentioned above, the surgeon can use the hole already made in the capsule by the trocar at the beginning of the procedure. The guide is inserted through the cannula, and the correct position is searched on the anteromedial border of the HS lesion. When a good position is achieved, the bone is drilled and another 2.3-mm all-suture anchor (Stryker Iconix 2.3 mm) is inserted (Fig 6). It is important to put clips at the end of the sutures of each anchor to recognize them at the end of the procedure when the surgeon will need to tie knots.

The same procedure is repeated for the lateral anchor (Stryker Iconix 2.3 mm; Fig 7). A new hole is made in the infraspinatus tendon and in the capsule by the drill tip to create a bridge between the lateral and the medial anchors. This will allow the surgeon to complete the procedure using the pulley technique. Once again, it is crucial to mark the end of the medial anchor with a different clip or marker to avoid confusion when tying the knots.

Four sutures for each anchor are now coming out from the cannula positioned initially in the

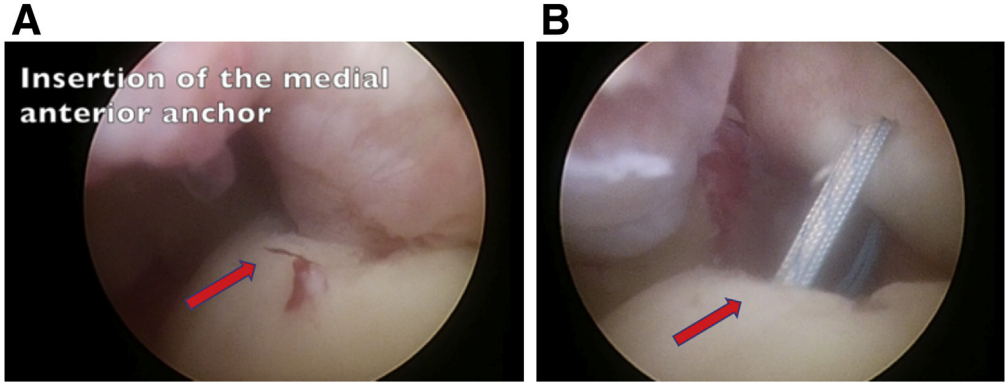

Fig 6. (A, B) The medial-anterior anchor is inserted with the same blind technique to minimize the damage to the infraspinatus tendon. This anchor can be inserted through the original hole in the tendon/capsule corresponding to the posterolateral portal. This will allow a tissue bridge between the 2 anchors to be inserted. (Arthroscope is in the anterolateral portal of the right 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.)

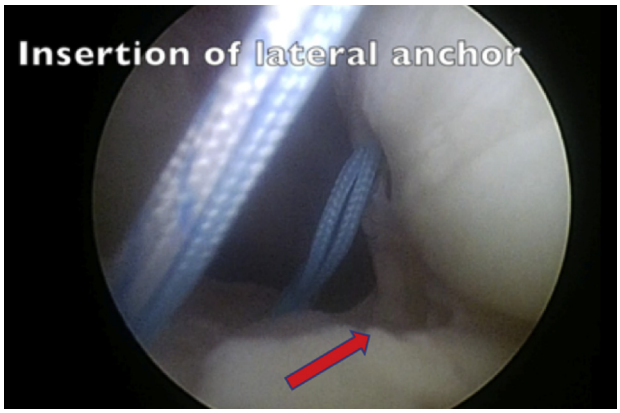

Fig 7. The lateral anchor is inserted. This anchor is inserted more laterally in the tendon/capsule in relation to the posterolateral portal. A more lateral hole in the tendon/capsule is performed to have a tissue bridge between the new hole and the 2 medial holes/anchors. The anchor is secured in the lateral area of the Hill-Sachs lesion. (Arthroscope is in the anterolateral portal of the right 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.)

posterolateral portal (Fig 8). Each anchor (Stryker Iconix 2.3 mm) is recognized by a different marker positioned at the end of the suture strands.

The first part of the procedure is completed.

Camera in the Posterolateral Portal

At this stage, the camera is switched back to the posterolateral portal and the anterior labral repair is performed. The surgeon can use the technique he or she prefers to repair the anterior labrum. This will not affect the RT procedure.

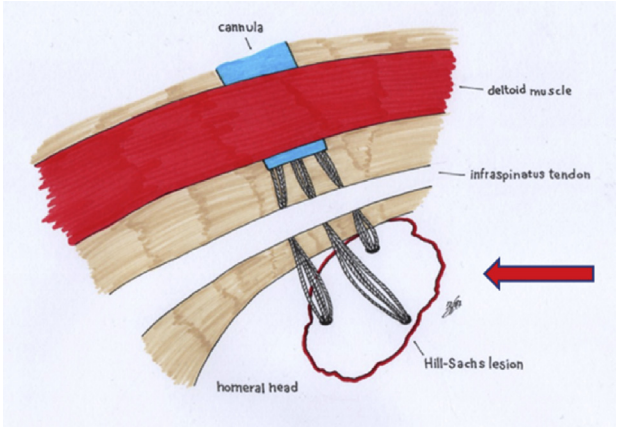

Fig 8. Anchor positioning. Triangular shape of the footprint with 2 anchors medial and one lateral into the Hill-Sachs lesion. The sutures pass through the capsule/tendon complex and then through the cannula positioned in the subacromial space.

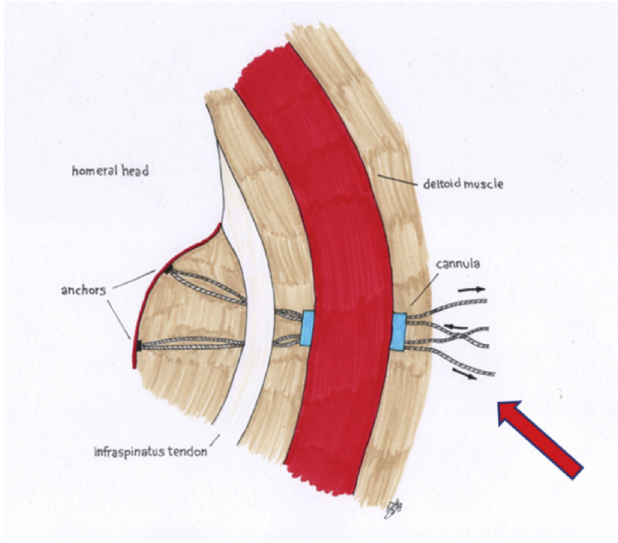

Fig 9. Pulley system. Two ends of 2 different sutures (A-B) of 2 different anchors are sutured outside the shoulder, and the final ends are cut. The other ends of each suture are then pulled to slide the knot down into the subacromial space. The same procedure is repeated with a suture end (C) of the third anchor. At this point the suture B has been knotted with suture A and suture C and pulled into the subacromial space with the pulley technique. Suture A and suture C have one end each free that needs to be knotted together (A + C). This knot will be tied in an arthroscopic fashion with a knot pusher. The same procedure is performed with the other sutures as all the anchors are double loaded. Suture A1 is tied outside the shoulder with suture B1 and suture B1 with suture C1. The ends of the suture are cut, and suture A1 and C1 pulled so that the knots are slided in the subacromial space. At the end, the suture end of A1 is tied with suture end of C1 in an arthroscopic fashion with a knot pusher.

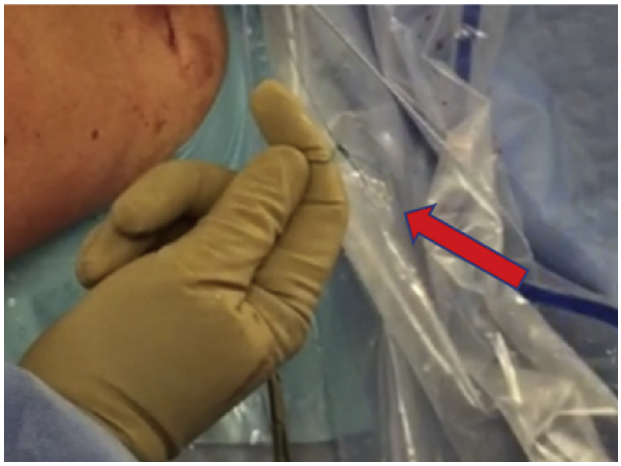

Fig 10. The first 2 knots (the end of suture A knotted with the end of suture B and the end of suture B knotted with the end of suture C) are tied outside the shoulder and advanced down into the subacromial space with a pulley system.

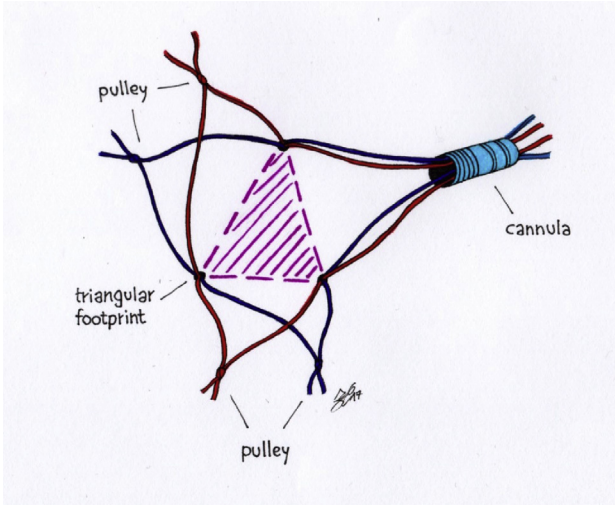

Fig 11. Pulley system and triangular shape of the footprint. After the pulley system is used to slide the knots in the subacromial space, 4 ends, 2 from 2 different anchors, are left and need to be knotted. Suture A and suture C have one end each free that needs to be knotted together (A + C). This knot will be tied in an arthroscopic fashion with a knot pusher. The same procedure is performed with the other sutures as all the anchors are double loaded. Suture A1 is tied outside the shoulder with suture B1 and suture B1 with suture C1. The ends of the suture are cut, and suture A1 and C1 pulled so that the knots slide into the subacromial space. At the end, suture end of A1 is tied with suture end of C1 in an arthroscopic fashion with a knot pusher.

Camera in the Anterolateral Portal

The camera is now in the anterolateral portal again, and the RT needs to be completed. One at a time, the surgeon ties knots between the ends of the sutures (suture A + B and B + C) and cuts them outside the shoulder. The remaining sutures (the free end of A and C) are pulled to slide the knots into the subacromial space (Figs 9 and 10). The same procedure is performed for the other 3 sutures (one for each anchor). Therefore, knots are first tied outside the shoulder (sutures A1 + B1 and B1 + C1) and the suture ends are cut (Fig 11). The remaining sutures (the free end of A1 and C1) are pulled to slide the knots into the subacromial space (Fig 9). At this point the free suture ends (A and C) are tied together in an arthroscopic fashion with a knot pusher. The same is done for the other 2 free suture ends (A1 and C1). The ends are tied together (Fig 12) in an arthroscopic fashion with a knot pusher (Table 2).

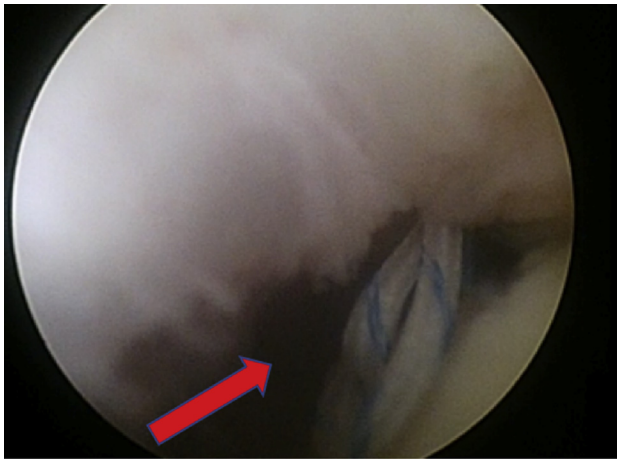

Fig 12. The third knot is tied in an arthroscopic fashion, and the procedure is repeated with the other 2 suture ends. Arthroscopic view of the tenodesis effect. (Arthroscope is in the anterolateral portal of the right shoulder with the patient in the lateral position, but the arthroscope is rotated so the images appear as though the patient is in the beach chair position.)

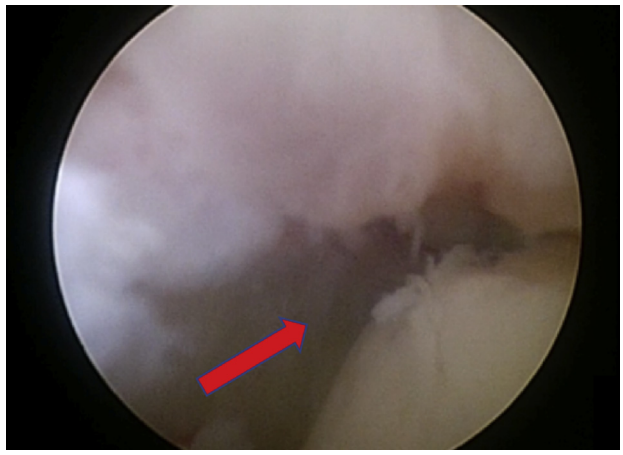

Fig 13. Final result. A secure tenodesis is performed. The surgeon can check under direct visualization the result of the tenodesis effect. (Arthroscope is in the anterolateral portal of the right shoulder with the patient in the lateral position, but the arthroscope is rotated so the images appear as though the patient is in the beach chair position.)

Direct successful tenodesis is confirmed by direct visualization of the tenodesis (reduced distance between the bone and the tendon) through the camera looking at the HS lesion/infraspinatus tendon (Table 3).

The procedure is repeated for the other strands, and the last 2 + 2 ends are tied together (Fig 11) in an arthroscopic fashion with direct visualization of the result of the tenodesis of the infraspinatus (Fig 12).

Table 4. Key Points

Remplissage technique is a reliable technique to address engaging Hill-Sachs lesions.
It can be technically challenging.
Secure tendon-bone surface contact is mandatory to achieve good results.
Our technique minimizes the risk of technical errors, is minimally invasive, and increases the tendon-bone surface contact.

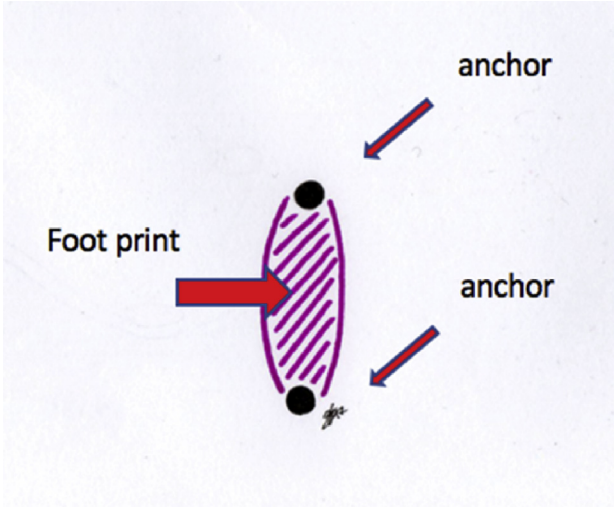

Fig 14. Traditional footprint following remplissage with 2 anchors. With the transtendinous double construct, the contract area between the tendon and the bone is in the shape of a line (it has one dimension).

At this stage the suture ends are cut and assessment of the repair is performed (Fig 13).

Discussion

Arthroscopic Bankart repair is now a well-established technique for addressing shoulder instability with very good outcomes.[20] However, the dislocation recurrence rate is still high in anterior shoulder instability if bony defects are not addressed.[2] These bony lesions may occur both at the glenoid or the humeral head HS lesion. It is accepted that an anteroinferior glenoid bone loss of 25% or more needs to be addressed with a bone block procedure (Latarjet procedure, iliac crest, or allograft) to restore the anterior edge of the glenoid. Options for addressing HS lesions include glenoid bone block procedures such as Laterjet, iliac crest, or allograft bone grafting, reducing external rotation with either anterior soft-tissue shortening or rotational osteotomy of the humerus and filling the HS defect with soft tissue, bone graft, arthroplasty, or transhumeral headplasty.[7,8] The remplissage procedure, first described by Wolf et al.,[10] is an arthroscopic technique that involves filling the HS defect with soft tissue by capsulotenodesis of the posterior capsule and the infraspinatus tendon into the defect to prevent the engagement of the lesion. It is indicated in combination with Bankart repair in those patients with an "engaging" HS lesion or "off-track" lesion in the absence of significant glenoid bone defect.

Reported results of arthroscopic remplissage have so far been promising with good functional outcomes and low recurrent instability rates when used for correct indications.[16] Wolf et al.[10] reported a recurrent instability rate of 4.4% with an average follow-up of 58 months. Similarly, Zhu et al.[14] found a failure rate of 8.2% (4 out of 49) with a mean follow-up of 29 months, whereas Boileau et al.[16] reported recurrence instability only in one of the series of 47 patients. Additionally, there is biomechanical evidence that remplissage and Laterjet have similar instability recurrence rates in a 25% HS defect model.[4]

There are a number of concerns with the procedure, including risk of possible damage to the infraspinatus, loss of external rotation, and healing rates. There are a number of studies that report no loss of external rotation, whereas there are others that indicate a loss of external rotation in the region of 7° to 8°.[16]

Most of the RT previously described involve inserting one or 2 standard anchors into the HS lesion through the infraspinatus and then perforating the infraspinatus with a "clever hook" equivalent suture passer to retrieve the anchor suture limbs.[9,16] Our concern with this technique is the damage sustained to the infraspinatus when inserting 2 standard anchors through the infraspinatus (as a result of the holes made in the tendon). There are a number of investigators who have advocated use of a single-anchor technique with the potential advantage of less damage to the infraspinatus.[17] However, the issue here is whether remplissage with one anchor provides the optimal surface contact area between the bone and infraspinatus as well as adequate construct strength.

The transtendinous double-pulley technique for remplissage described by Parnes et al.[19] is a simplified reproducible technique that involves the use of

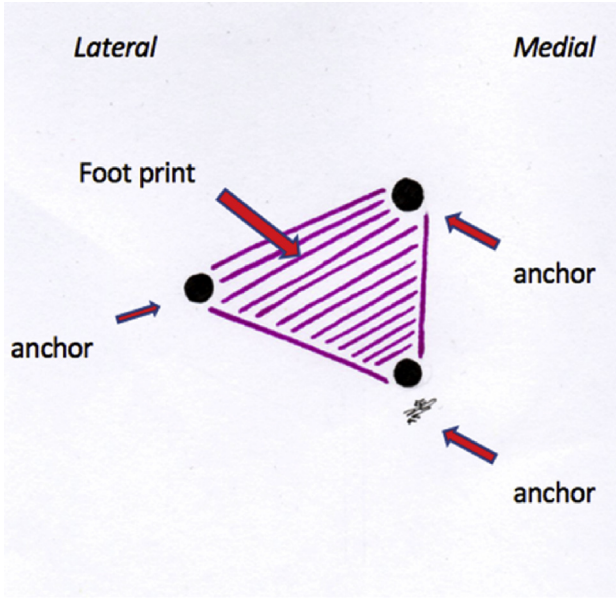

Fig 15. Tripod shape of the footprint. The tripod-pulley technique guarantees a larger contact surface area for healing as the construct is in the shape of a triangle (2 dimensions).

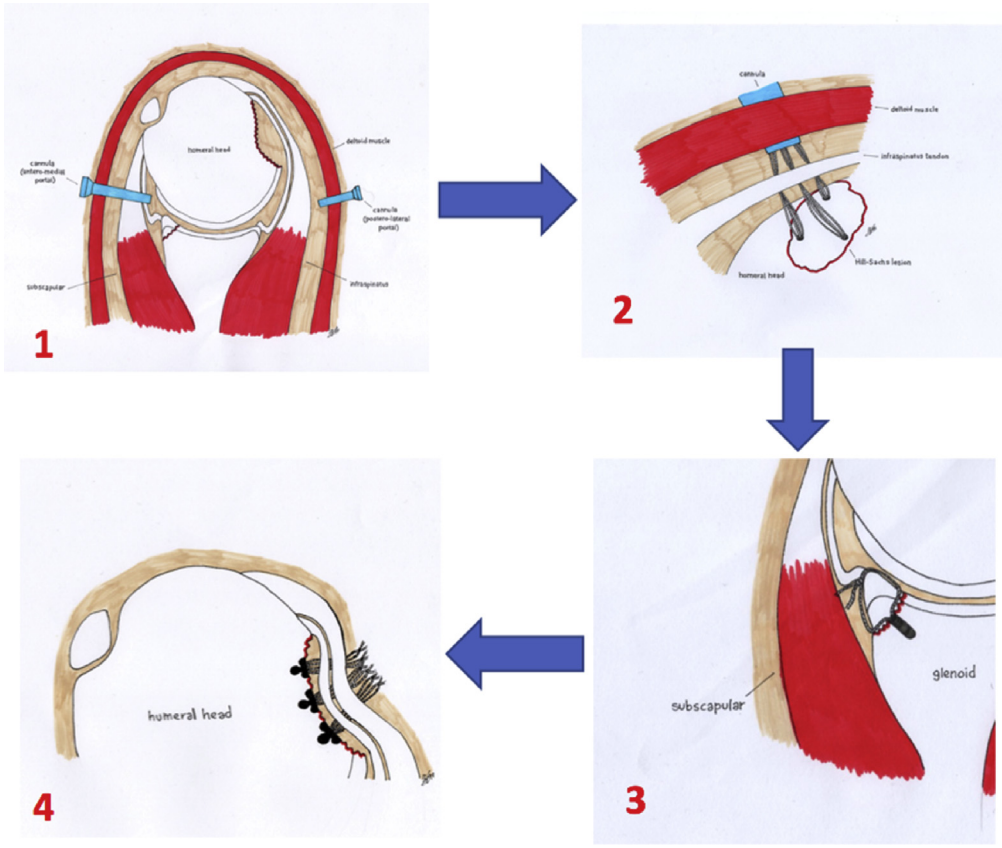

Fig 16. Phases of the technique. One important point to underline in this technique is the staging of the procedures performed. The first step is to address the damage of the anterior labrum and capsule-ligaments complex anteriorly and the Hill-Sachs (HS) lesion extension posteriorly. In this phase, the 2 cannulas (Stryker Dri-Lok disposable cannula) are positioned. The anterior cannula (8.5-mm Stryker Dri-Lok disposable cannula) is positioned in the rotator interval through the capsule into the glenohumeral joint, and the posterior cannula (5-mm Stryker Dri-Lok disposable cannula) is positioned in the subacromial space through the deltoid muscle. The second step is to insert the anchors (Stryker Iconix 2.3 mm) in the HS lesion. Two anchors (Stryker Iconix 2.3 mm) are placed medially and one laterally into the HS defect. At this stage, the knots are not tied. The following step is the anterior labral and capsule-ligaments complex repair. The advantage of performing this procedure before the remplissage technique (RT) procedure is related to the better view and freedom of movements that result in not tying the RT knots. The last step is to complete the RT, tying the knots of the sutures coming from the 3 anchors inserted in the HS defect.

2 standard anchors in an innovative method. Our concern with this technique, however, is the limited contact surface area between the infraspinatus and the bone and the possible consequence that this may have on the healing rate. Furthermore, this technique involves passage of a cannula through the infraspinatus and the insertion of 2 standard anchors through the tendon, therefore raising the possibility of infraspinatus tendon damage.

The tripod-pulley technique described in this paper uses the transtendinous pulley principles but has a number of further advantages over the previously

Table 5. Pearls and Pitfalls

Pearls	Pitfalls
Minimally invasive technique: tendon and bone preservation.	Blind positioning of the anchors can be difficult for not experienced surgeons. All-suture anchors may pull out in very weak bone.
Secure fixation: a larger footprint allows better tendon-bone healing. Three-anchor tenodesis allows a quicker recovery.	Good positioning of the anchors is needed, and good triangulation skills are expected.
Alternative progression (posterior/anterior) allows the surgeon to work in the best conditions with more space and better view.	Working with the camera from anterior can be difficult at the beginning.
The pulley technique can be performed very quickly and reduces the surgical time.	Sutures management can be fiddly if maximal care is not kept throughout all the procedure.
No need to violate the subacromial space using a cannula in the posterolateral portal.	A certain amount of experience is required to tie knots blind without looking for the sutures in the subacromial space.

Table 6. Advantages and Disadvantages

Advantages	Disadvantages
Bone-preserving technique. Leaves the possibility for further surgery in the future if needed (rotator cuff repair).	The surgeon needs to use all-suture anchors for the benefit of bone preservation.
Minimally invasive: preserves the infraspinatus tendon integrity.	Pull-out risk when using all-suture anchors needs to be considered in weak bone.
Secure: 3-anchor fixation.	Relative encumbrance expected in the humeral head using standard 5.5-mm anchors.
Biologic advantage: better and larger bone-tendon contact area.	Blind insertion of the anchors can lead to errors.
The lack of the need to violate the subacromial space saves time and leaves the subacromial space untouched.	Blind knot tying can lead to errors and loose tenodesis.
There is no need to pass the sutures through the tendon once the anchors are placed.	

describe RT (Table 4). First, it maximizes the contact surface area between the tendon and bone with the aim of optimizing healing. With the transtendinous double construct, the contact area between the tendon and the bone is in the shape of a line (it has one dimension; Fig 14). In contrast, with the tripod-pulley technique, the contact surface area of the construct is in the shape of a triangle (2 dimensions) and therefore offers a much larger surface contact area for healing (Fig 15). Second, with this technique we use all-suture 2.3-mm anchors without passing any cannulas through the infraspinatus. The reason for this is to minimize the damage to the infraspinatus by avoiding making comparatively large holes in the tendon. Third, we feel that having smaller holes in the bone, as with 2.3-mm all-suture anchors in comparison with the holes necessary with 5.5-mm or 4.5-mm standard anchors, preserves more bone surface for tendon to bone healing. Fourth, we feel that using all-suture anchors simplifies those techniques that use the pulley principle. Last, the order of steps in this technique makes the procedure easier (Fig 16). Initially we release the anterior labrum but we do not repair the labrum at this stage in order not to tighten the space available for insertion of the HS anchors in the appropriate location. This is followed by insertion of the all-suture into the HS lesion, but again we do not tie the suture anchor limbs at this stage to avoid tightening the space available for anterior labrum repair, which is performed next. The HS anchor suture limbs are then tied following the labrum repair.

There are a number of possible concerns with the tripod-pulley technique. Some investigators may argue that with the small holes made in the infraspinatus it may not be possible to freshen the HS surface with shaver. We found this not to be the case. Although it may be slightly more challenging to pass a standard shaver through the small holes in the infraspinatus, one may usea small shaver or use the drill guide for the all-suture anchor to freshen the HS bone surface. As with all RT, there is a worry with external rotation deficit. So far with our small series with this technique, we have not detected a significant loss of external rotation. Additionally, there may be a concern with the pull-out strength of the all-suture anchors. There is now evidence that modern all-suture anchors have comparable pull-out strengths to standard anchors.[21] All-suture anchors are certainly gaining popularity at a fast rate for labrum and rotator cuff repairs. It also important to emphasize that in the presence of significant glenoid bone loss, we favor the use of a glenoid bone block procedure rather than remplissage and Bankart repair.

In summary, the tripod-pulley technique described here offers the simplicity of the transtendinous double-pulley system in addition to optimizing the healing area by maximizing the surface contact area between the tendon and bone. Furthermore, it minimizes the risk of infraspinatus damage as it uses 2.3-mm all-suture anchors without a standard cannula going through the tendon. We feel that it is a very reproducible technique (Tables 5 and 6).

References

1. Wasserstein DN, Sheth U, Colbenson K, et al. The true recurrence rate and factors predicting recurrent instability after nonsurgical management of traumatic primary anterior shoulder dislocation: a systematic review. *Arthroscopy* 2016;32:2616-2625.
2. Randelli P, Ragone V, Carminati S, Cabitza P. Risk factors for recurrence after Bankart repair: a systematic review. *Knee Surg Sports Traumatol Arthrosc* 2012;20:2129-2138.
3. Boileau P, Villalba M, Héry JY, Balg F, Ahrens P, Neyton L. Risk factors for recurrence of shoulder instability after arthroscopic Bankart repair. *J Bone Joint Surg Am* 2006;88:1755-1763.
4. Burkhart SS, Danaceau SM. Articular arc length mismatch as a cause of failed Bankart repair. *Arthroscopy* 2000;16:740-744.
5. Di Giacomo G, Itoi E, Burkhart SS. Evolving concept of bipolar bone loss and the Hill-Sachs lesion: from "engaging/non-engaging" lesion to "on-track/off-track" lesion. *Arthroscopy* 2014;30:90-98.
6. Locher J, Wilken F, Beitzel K, et al. Hill-Sachs off-track lesions as risk factor for recurrence of instability after arthroscopic Bankart repair. *Arthroscopy* 2016;32:1993-1999.
7. Gerber C, Nyffeler RW. Classification of glenohumeral joint instability. *Clin Orthop Relat Res* 2002;400:65-76.
8. Di Giacomo G, Pouliart N, Costantini A, De Vita A. *Atlas of functional shoulder anatomy*. New York: Springer, 2008.
9. Hartzler RU, Bui CN, Jeong WK, et al. Remplissage of an off-track Hill-Sachs lesion is necessary to restore

biomechanical glenohumeral joint stability in a bipolar bone loss model. *Arthroscopy* 2016;32:2466-2476.
10. Wolf EM, Pollack M. Hill-Sachs "Remplissage": an arthroscopic solution for the engaging Hill-Sachs lesion. *Arthroscopy* 2004;20:e14-e15.
11. Park MJ, Tjoumakaris FP, Garcia G, Patel A, Kelly JD. Arthroscopic remplissage with Bankart repair for the treatment of glenohumeral instability with Hill-Sachs defects. *Arthroscopy* 2011;27:1187-1194.
12. Purchase RJ, Wolf EM, Hobgood ER, Pollock ME, Smalley CC. Hill-Sachs "remplissage": an arthroscopic solution for the engaging Hill-Sachs lesion. *Arthroscopy* 2008;24:723-726.
13. Ko SH, Cha JR, Lee CC, Hwang IY, Choe CG, Kim MS. The influence of arthroscopic remplissage for engaging Hill-Sachs lesions combined with Bankart repair on redislocation and shoulder function compared with Bankart repair alone. *Clin Orthop Surg* 2016;8:428-436.
14. Zhu Y, Lu Y, Zhang J, Shen JW, Jiang CY. Arthroscopic Bankart repair combined with remplissage technique for the treatment of anterior shoulder instability with engaging Hill-Sachs lesion: a report of 49 cases with a minimum 2-year follow-up. *Am J Sports Med* 2011;39:1640.
15. Degen RM, Giles JW, Johnson JA, Athwal JS. Remplissage versus Latarjet for engaging Hill-Sachs defects without substantial glenoid bone loss. A biomechanical comparison. *Clin Orthop Relat Res* 2014;472:2363-2371.
16. Boileau P, O'Shea K, Vargas P, Pinedo M, Old J, Zumstein M. Anatomical and functional results after arthroscopic Hill-Sachs remplissage. *J Bone Joint Surg Am* 2012;94:618-626.
17. Camp CL, Dahm DL, Krych AJ. Arthroscopic remplissage for engaging Hill-Sachs lesions in patients with anterior shoulder instability. *Arthrosc Techn* 2015;4:499-502.
18. Bhatia DN. Double-barrel remplissage: an arthroscopic all-intra-articular technique using the double-barrel knot for anterior shoulder instability. *Arthrosc Techn* 2015;4:65-70.
19. Parnes N, Carey PA, Schumacher C, Price MD. Arthroscopic transtendinous double-pulley remplissage technique in the beach-chair position for large Hill-Sachs lesions. *Arthrosc Techn* 2015;4:305-309.
20. Harris JD, Gupta AK, Mall NA, et al. Long-term outcomes after Bankart shoulder stabilization. *Arthroscopy* 2013;29:920-933.
21. Galland A, Airaudi S, Gravier R, Le Cann S, Chabrand P, Argenson JN. Pullout strength of all suture anchors in the repair of rotator cuff tears: a biomechanical study. *Int Orthop* 2013;37:2017-2023.