



Triple-Row Modification of the Suture-Bridge Technique for Arthroscopic Rotator Cuff Repair

Roger V. Ostrander III, M.D., Jarrod Smith, M.D., and Michael Saper, D.O.

Abstract: Recent advances to improve outcomes in rotator cuff repair include using arthroscopic double-row suture-bridge techniques in an effort to reconstruct the rotator cuff footprint and improve fixation. However, when using this technique for larger tears, it can be difficult to get the lateral portion of the rotator cuff into an anatomic position. This report describes a triple-row modification of the suture-bridge technique that results in significantly more footprint contact area and contact pressure compared with the double-row and standard suture-bridge techniques. Maximizing the rotator cuff footprint contact area exposes more of the tendon to bone and may improve the healing potential.

Recent advances to improve outcomes in rotator cuff repair include using arthroscopic double-row suture-bridge techniques in an effort to reconstruct the rotator cuff footprint and improve fixation.¹⁻⁶ Yet, although studies have shown biomechanical advantages with the use of double-row repairs compared with single-row repairs, there is no definitive difference in clinical outcomes between the 2 repair constructs.⁵⁻⁷ Furthermore, retear rates of 10% to 30% have been found in double-row techniques with higher rates (40% to 64%) in those patients with large-to-massive tears (≥ 3 cm).^{3,4,6,8-11} When using this technique for larger tears, it can be difficult to get the lateral portion of the rotator cuff into an anatomic position. There is concern that this results in limited rotator cuff footprint contact area. Maximizing the footprint contact area exposes more of the tendon to bone and may improve the healing potential.

With high retear rates after arthroscopic rotator cuff repair despite the use of a double-row construct, there is a need for more effective repair strategies. The purpose of this report was to describe, in detail, the

triple-row modification of the suture-bridge technique for arthroscopic rotator cuff repair. This technique has been shown to result in significantly more footprint contact area and contact pressure compared with the double-row and standard suture-bridge techniques.¹²

Surgical Procedure

A demonstration of the repair technique in a right shoulder is provided in [Video 1](#). The indication, advantages, and pearls of the procedure are presented in [Table 1](#). The contraindications, limitations, and pitfalls are summarized in [Table 2](#).

Patient Positioning and Preparation

Preoperatively, the patient receives an interscalene nerve block with indwelling catheter. After the induction of general anesthesia, an examination under anesthesia is performed to assess range of motion and stability. Next, the patient is placed in the lateral decubitus position on a beanbag with an axillary roll in place. The patient's hips and knees are flexed slightly with all lower extremity bony prominences padded to prevent nerve compression on the downside leg. Bilateral lower extremity sequential compression devices are used in all cases. The operative extremity is placed in balanced suspension at approximately 60° of abduction using 10 to 15 lbs of axial traction. The patient's skin is cleaned with a chlorhexidine solution and sterile drapes are applied. Bony landmarks including the acromion, clavicle, acromioclavicular joint, and coracoid process are outlined with a marking pen. An arthroscopic pump is used with pressures around 40 mm Hg with hypotensive general anesthesia.

From the Andrews Institute for Orthopaedics and Sports Medicine, Gulf Breeze, Florida, U.S.A.

The authors report the following potential conflicts of interests or sources of funding: R.V.O. receives support from IFlow, Arthrex, Breg, and ArthroSurface.

Received March 14, 2016; accepted May 9, 2016.

Address correspondence to Roger V. Ostrander III, M.D., Andrews Institute for Orthopaedics and Sports Medicine, 1040 Gulf Breeze Pkwy, Gulf Breeze, FL 32561, U.S.A. E-mail: rostrander@andrewsortho.com

© 2016 by the Arthroscopy Association of North America. Open access

under CC BY-NC-ND license.

2212-6287/16225

<http://dx.doi.org/10.1016/j.eats.2016.05.004>

Table 1. Indication, Advantages, and Pearls for the Triple-Row Rotator Cuff Repair

Indication	Any repairable full-thickness rotator cuff tear in a patient who has failed conservative treatment
Advantages	Anatomic reduction of the rotator cuff back to the greater tuberosity Decreased dog-ear formation resulting in greater contact area Greater contact pressures when compared with standard suture bridge More points of fixation Improved visualization when tying medial-row knots
Pearls	If biceps tenodesis is being performed, it should be performed before rotator cuff repair Pass sutures anterior to posterior. Tie knots posterior to anterior The middle-row anchor should anatomically reduce the rotator cuff Anterior lateral-row anchor should be placed just posterior to the bicipital groove Posterior lateral-row anchor should be placed anterior to the vessels overlying the posterior rotator cuff

Portal Placement and Diagnostic Arthroscopy

The posterior portal is established 2 cm distal and 1 cm medial to the posterolateral corner of the acromion, and a 30° arthroscope (Arthrex, Naples, FL) is inserted. The anterior portal is then established under direct visualization with an outside-in technique by use of an 18-gauge spinal needle. Its position can be variable, depending on concomitant pathology. Systematic diagnostic arthroscopy is performed and any intra-articular pathology is addressed. Rotator cuff tear morphology is evaluated from the intra-articular position.

Rotator Cuff Repair Technique

The arthroscope is withdrawn from the glenohumeral joint and introduced into the subacromial space. A lateral portal is established approximately 4 cm lateral to the lateral edge of the acromion at the junction of the anterior and middle 1/3 of the acromion. A thorough bursectomy is performed with a 4.5-mm arthroscopic shaver blade (Smith & Nephew, Andover, MA) and a VAPR radiofrequency device (DePuy Mitek, Raynham, MA), and the bursal surface of the rotator cuff tear is visualized. The undersurface of the acromion is exposed with the VAPR device. Standard anterior acromioplasty is then performed using a cutting block technique with a 5.5-mm arthroscopic burr (Smith & Nephew). It should be noted that the coracoacromial ligament is preserved in cases of potentially irreparable rotator cuff tears.

A grasper is introduced through the lateral portal and tear morphology and mobility are further assessed while viewing from the posterior portal. The potential for tension-free repair is confirmed by tendon

mobilization with the grasper to the native footprint. Tear morphology should also be assessed while viewing from the lateral portal to obtain a better understanding of tear characteristics (Fig 1). Soft tissue releases are performed if necessary to mobilize the tear. The greater tuberosity is then cleared of all soft tissues using the VAPR device, and the burr is used to prepare the greater tuberosity to bleeding bone. When preparing the greater tuberosity, it is important not to breach the cortical bone, which could compromise anchor purchase.

An accessory lateral portal is established just lateral to the lateral border of the acromion. This portal is established after localization with an 18-gauge spinal needle. Proper placement of this portal is paramount, as it should allow for anchor insertion at the midpoint of the tear footprint on the greater tuberosity while maintaining the deadman's angle. An anterior subacromial portal is established through the same skin incision as the anterior glenohumeral portal. A 6-mm PassPort cannula (Arthrex) is placed in the anterior portal. One 8-mm PassPort cannula is placed in the lateral portal, and another is placed in the accessory lateral portal. The length is determined based on the size of the patient and tissue depth. If the tear is a U-shaped, L-shaped, or reverse L-shaped tear, margin convergence sutures are placed. This is not necessary for crescent-shaped tears.

Through the accessory lateral portal, a 5.5-mm Bio-Composite Corkscrew FT anchor (Arthrex) is placed just lateral to the articular margin at the deadman's angle (Fig 2A). For a standard repair, 2 medial-row anchors are utilized, and the anterior anchor is placed first (Fig 2B). It should be noted that smaller tears may only require 1 medial-row anchor, whereas massive tears may necessitate 3 to 4 anchors. Sutures from the

Table 2. Contraindications, Limitations, and Pitfalls of the Triple-Row Rotator Cuff Repair

Contraindications	Irreparable rotator cuff tears Significant glenohumeral arthropathy
Limitations	Increased cost compared with the standard suture-bridge technique Increased operative time. This is minimized as the surgeon becomes familiar with the procedure.
Pitfalls	Anchor location is critical to ensure that the anchors do not interfere with each other and to ensure that the articular surface is not violated. The tear pattern must be correctly identified so that the middle-row anchor is placed in a position that allows for anatomic reduction. Failure to do so will result in the formation of a dog-ear deformity. Tight, secure knots should be tied. Failure to do so will result in poor contact at the articular margin and decreased overall construct stiffness.

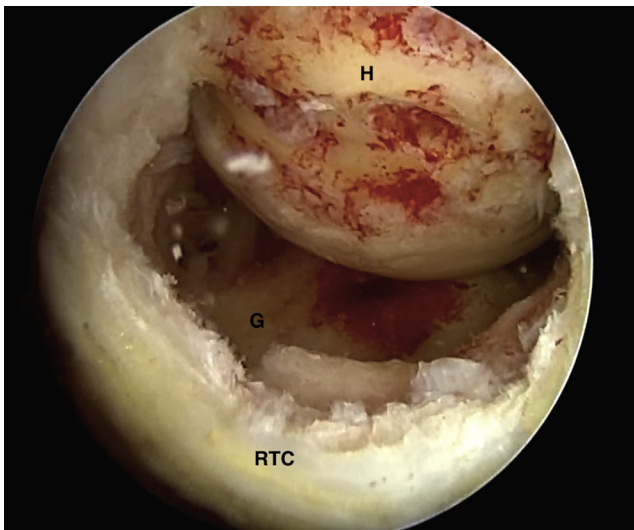


Fig 1. Right shoulder (lateral decubitus position) viewed from the lateral viewing portal with a 30° arthroscope. The large crescent full-thickness rotator cuff tear is clearly visualized. (G, glenoid; H, humeral head; RTC, rotator cuff.)

medial-row anchors are passed through the torn rotator cuff tendon in a horizontal mattress fashion with an Expressw suture-passing device (DePuy Synthes, Warsaw, IN). As each suture limb is passed, it is retrieved using a grasper through the anterior portal.

One end of a free TigerTape (Arthrex) is passed approximately 5 mm lateral to the leading edge of the torn rotator cuff with an Expressw suture passer from the articular side to the bursal side (Fig 3A). This limb is retrieved through the anterior portal with a grasper. The other end of the TigerTape is passed through the torn rotator cuff approximately 5 mm posterior to the other limb, and it is retrieved through the accessory lateral portal with grasper. This results in an inverted horizontal mattress stitch that will be used to reduce the rotator cuff back to its anatomic position on the tuberosity. After both limbs of the TigerTape are retrieved through the lateral portal, the rotator cuff tendon is mobilized to the lateral margin of the rotator cuff

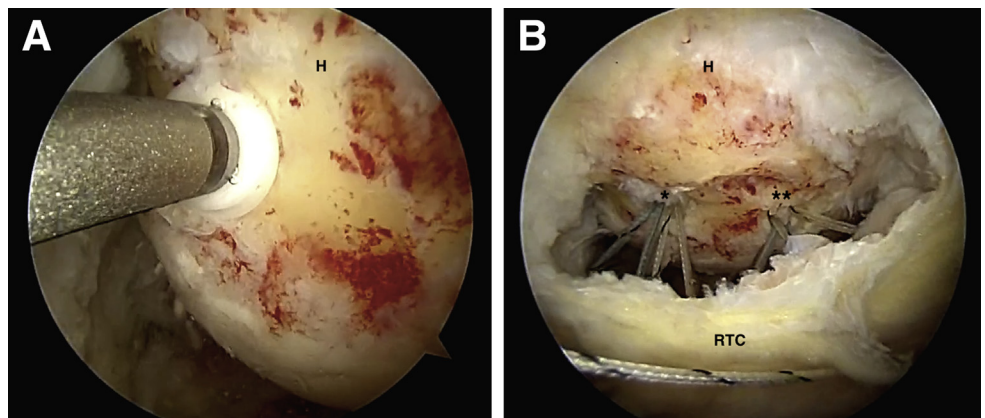
footprint using a looped suture grasper to assess the placement of the middle-row anchor (Fig 3B). The position of the middle-row anchor is marked with the VAPR device (Fig 3C). The 2 TigerTape limbs are placed through the eyelet of a 4.75-mm PEEK (polyether ether ketone) SwiveLock C anchor (Arthrex). The anchor is then inserted through the lateral portal at the lateral margin of the rotator cuff footprint in a position that will anatomically reduce the rotator cuff (Fig 3D). It is important to place appropriate tension on the TigerTape limbs as the anchor is inserted. The inverted horizontal mattress suture helps prevent dog-ear formation by approximating the free edge of the rotator cuff to its anatomic position on the greater tuberosity. Sutures from the medial-row anchors are then retrieved and tied through the accessory lateral portal, thus re-establishing the rotator cuff footprint.

One suture tail from each medial-row anchor is retrieved through the lateral portal using a loop grasper (Fig 4A). The retrieved tails are placed through the eyelet of a 4.75-mm PEEK SwiveLock C anchor. Through the lateral portal, the anchor is inserted approximately 10 mm distal to the lateral edge of the greater tuberosity, just posterior to the bicipital groove. The remaining suture tails from the medial row are retrieved through the lateral portal and placed through the eyelet of another 4.75-mm PEEK SwiveLock C anchor (Fig 4B). This final anchor is inserted posterior to the previous anchor, thus completing the suture-bridge configuration (Fig 5).

Postoperative Rehabilitation

The skin portals are closed with No. 3-0 Ethilon (Ethicon, Somerville, NJ), a sterile dressing is applied, and the patient is placed in an abduction sling. Postoperatively, rehabilitation consists of passive range of motion exercises started in 2 to 3 days after surgery. Active range of motion and strengthening exercises can be initiated at 6 weeks postoperatively. A review of the postoperative rehabilitation protocol is presented in Table 3.

Fig 2. Right shoulder (lateral decubitus position) viewed with a 30° arthroscope. (A) After preparation of the greater tuberosity, the medial-row anchors are placed just lateral to the articular margin through the accessory lateral portal (posterior viewing portal). (B) Final position of anterior (*) and posterior (**) suture anchors (lateral viewing portal). (H, humeral head; RTC, rotator cuff.)



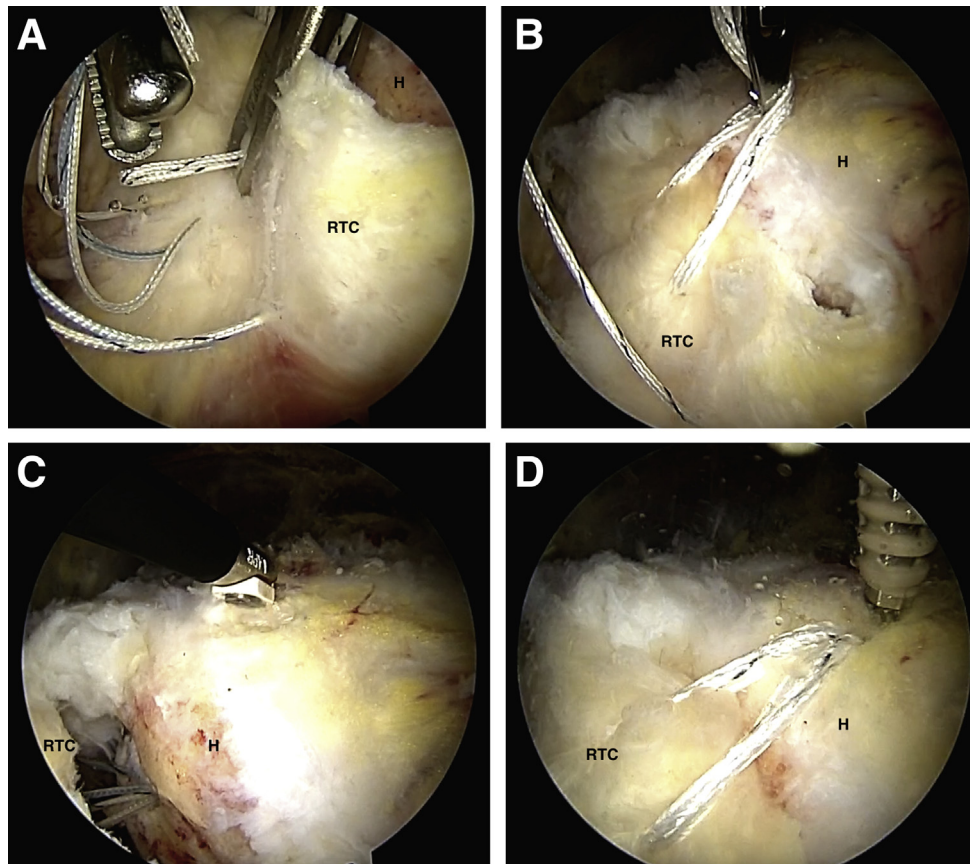


Fig 3. Right shoulder (lateral decubitus position) viewed from the posterior viewing portal with a 30° arthroscope. (A) Through the lateral portal, one end of a free No. 2 TigerTape suture is passed antegrade through the RTC tendon and pulled out through the accessory lateral portal. The other end of the suture is passed through the tendon in a similar fashion creating an inverted horizontal mattress. (B) After both limbs are retrieved through the lateral portal, the RTC tendon is mobilized to the lateral margin of the RTC footprint using a looped suture grasper to assess the placement of the middle-row anchor. (C) The position of the middle-row anchor is marked with an electrocautery device. (D) The RTC is reduced, appropriate tension is placed on the sutures, and the 4.75-mm PEEK (polyether ether ketone) SwiveLock C anchor is secured into the greater tuberosity. (H, humeral head; RTC, rotator cuff.)

Discussion

An arthroscopic approach to rotator cuff repair has become standard practice for many surgeons.¹³ The advantages of arthroscopic repair include excellent visualization of the tear anatomy, less morbidity, and less postoperative pain.¹⁴ However, studies have reported retears after single-row repair despite documented patient satisfaction. In fact, imaging studies examining the structural integrity after single-row repair have found recurrence rates ranging from 19% to 94%.⁵ Millet et al.⁶ in their meta-analysis of Level I randomized controlled trials comparing single-row with double-row repairs showed an overall re-tear rate of 25.9% in the single-row group compared with 14.2% in the double-row group. The authors also found a statistically significant increased risk of sustaining an imaging-proven re-tear of any type in the single-row

repair group, with partial-thickness retears accounting for the majority of the difference.

Factors thought to improve the healing potential for rotator cuff repair include more secure fixation as well as increased contact area and pressure of the rotator cuff tendon and underlying tuberosity. Double-row fixation techniques, such as the suture bridge construct, were developed to help address these factors in effort to improve repair rates.^{1,15,16} Nevertheless, there are shortcomings associated with these standard double-row techniques. The success rate of any repair is influenced by tear size. When used for larger tears, it can be difficult to reconstruct the cuff anatomically. The rotator cuff can be quite displaced from its anatomic location and is often pulled in a medial and posterior direction. As the medial-row anchors are tied, the cuff is pulled and bunched medially. There is a concern that

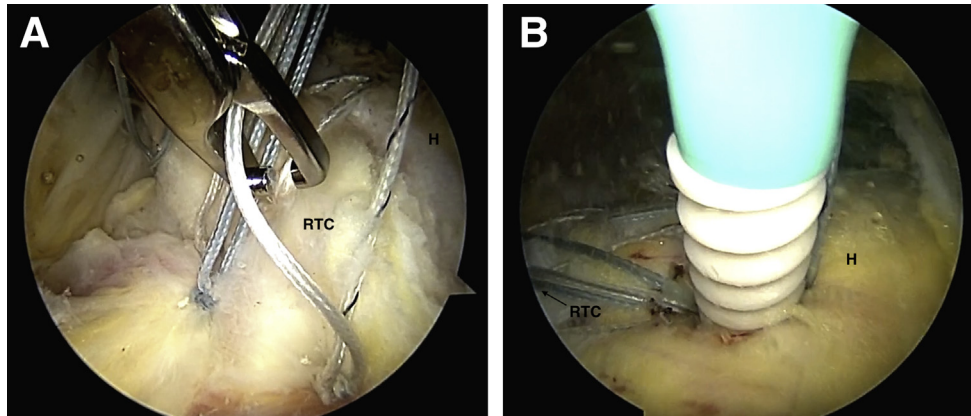


Fig 4. Right shoulder (lateral decubitus position) viewed from the posterior viewing portal with a 30° arthroscope. (A) With the RTC fixed laterally, the sutures from the medial-row anchors are tied. One limb from each knot is retrieved out the lateral portal for lateral-row anchor placement in a suture-bridge fashion. (B) 4.75-mm PEEK (polyether ether ketone) SwiveLock C anchors are placed laterally, directly in line with the medial anchors and ≥ 10 mm distal to the lateral edge of the greater tuberosity. The more posterior anchor is placed last. (H, humeral head; RTC, rotator cuff.)

this results in limited rotator cuff footprint contact area. Retear rates of 10% to 30% have been found in double-row techniques with higher rates (40% to 64%) in those patients with large-to-massive tears.^{3,4,6,8-11}

The triple-row modification of the suture bridge construct, using a third row of fixation placed between the typical medial and lateral rows, was developed to help improve the rotator cuff footprint contact area and pressure by anatomic positioning of the cuff before tying the medial anchors. Medial-row anchors are placed in a standard fashion and the sutures are passed through the cuff medially but are not tied. The goal of the middle-row anchor is to reduce the cuff back into its anatomic position. A suture tape is passed through the leading edge of the rotator cuff, in an inverted horizontal mattress fashion, and is then used to maneuver the cuff and reduce it to its anatomic position. The limbs of the tape are then placed

through the eyelet of an anchor. The anchor is placed at the site that restores anatomy, in a position midway between the medial and anticipated lateral-row anchors. As the cuff is reduced, the inverted mattress tucks the free edge of the cuff down to bone. The sutures from the medial anchors are then tied. Tying these medial anchors is technically easier now that the rotator cuff is reduced and out of the way. As these are tied down, the rotator cuff footprint is re-established. Then, using standard suture-bridge technique, 1 suture limb from each of the medial anchors is then secured with 2 lateral-row anchors placed in line with the medial anchors.¹

Technically, this triple-row modification has been shown to significantly improve footprint contact area and contact pressure when compared with the standard suture bridge.¹² As discussed, it enables the surgeon to reconstruct the footprint anatomicly, increasing the

Fig 5. Arthroscopic images of the completed triple-row repair in a right shoulder viewed with a 30° arthroscope from the (A) posterior and (B) lateral portals and the patient in the lateral decubitus position. There are 3 rows of anchors—medial footprint, lateral footprint, and lateral to the greater tuberosity. (H, humeral head; RTC, rotator cuff.)

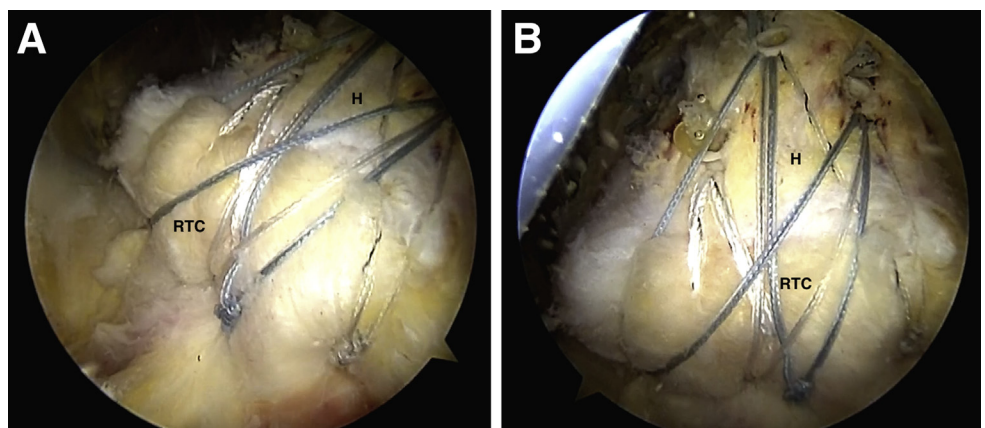


Table 3. Postoperative Rehabilitation After Triple-Row Rotator Cuff Repair

Phase	Goals	Exercises/Precautions	Precautions
Phase I—immediate postsurgical phase d 1-10	<ol style="list-style-type: none"> 1. Maintain integrity of the repair 2. Gradually increase passive range of motion 3. Diminish pain and inflammation 4. Prevent muscular inhibition 	<ul style="list-style-type: none"> • Pendulum exercises • Passive ROM • Active assisted ROM • Elbow/wrist/hand ROM and strengthening • Initiate submaximal isometric rotator cuff exercises at d 4-5 	<ul style="list-style-type: none"> • No lifting • No excessive shoulder extension
Phase II—protection phase d 15-wk 6	<ol style="list-style-type: none"> 1. Allow healing of soft tissue 2. Do not overstress healing tissue 3. Gradually restore full passive ROM 4. Re-establish dynamic shoulder stability 5. Decrease pain and inflammation 	<ul style="list-style-type: none"> • Continue above exercises • Initiate dynamic stabilization • Initiate scapular isometric exercises (wk 4) • Initiate isotonic elbow extension (wk 4) • Initiate active ROM (wk 5) 	<ul style="list-style-type: none"> • No heavy lifting • No behind the back motion
Phase III—intermediate phase wk 7-14	<ol style="list-style-type: none"> 1. Full active ROM 2. Maintain full passive ROM 3. Dynamic shoulder stability 4. Gradual restoration of shoulder strength 5. Gradual return to functional activities 	<ul style="list-style-type: none"> • Continue above exercises • Progress strengthening program • Light functional activities (wk 8) • Initiate isotonic shoulder flexion and abduction with 1 lb weight (wk 10), and increase 1 lb every 10 d 	<ul style="list-style-type: none"> • No heavy lifting • Limit extremes of motion
Phase IV—advanced strengthening phase wk 15-22	<ol style="list-style-type: none"> 1. Maintain full nonpainful ROM 2. Enhance functional use of UE 3. Improve muscular strength and power 4. Gradual return to functional activities 	<ul style="list-style-type: none"> • Continue above exercises • Progress strengthening exercises per above • Initiate self-capsular stretches 	<ul style="list-style-type: none"> • No heavy lifting
Phase V—return-to-activity phase wk 23-36	<ol style="list-style-type: none"> 1. Gradual return to work activities 2. Gradual return to sport activities 	<ul style="list-style-type: none"> • Continue strengthening • Continue stretching • Progress to full sport participation 	<ul style="list-style-type: none"> • No painful activity

ROM, range of motion; UE, upper extremity.

contact area of the tendon to the tuberosity. This is difficult to achieve with the standard suture-bridge technique, especially for larger tears that are often retracted. After the middle-row anchor is placed, the medial-row anchors are tied against this fixed lateral position, generating some initial compression of the entire rotator cuff to the tuberosity. The sutures placed through the lateral-row anchors supply the final compression against the rotator cuff, which is anatomically splayed out against the tuberosity. In contrast, with the suture bridge technique, the medial-row anchors are tied without a fixed lateral position causing the rotator cuff to bunch up medially, thus limiting the amount of contact area and pressure generated.

This modified technique has other technical advantages. Once the cuff is reduced to the tuberosity by our reducing middle-row anchor, visualization is

better and tying the important medial anchors is made easier. The inverted mattress stitch used for the middle-row anchor also tucks the leading edge of the cuff to the bone making dog-ear deformities less of a problem. Furthermore, this repair adds another point of fixation, possibly resulting in a stronger repair with less concern for early postoperative mobilization of the shoulder.¹⁷ There are some potential disadvantages to this technique. There is increased cost with the use of an additional anchor and suture. Also, there will be some increase in the surgical time as well, although this is minimized as the surgeon gains more experience.

Acknowledgment

The authors acknowledge Jim Sims for his assistance with the video production.

References

1. Park MC, Elattrache NS, Ahmad CS, Tibone JE. "Transosseous-equivalent" rotator cuff repair technique. *Arthroscopy* 2006;22:1360.e1-1360.e5.
2. Anderson K, Boothby M, Aschenbrenner D, van Holsbeeck M. Outcome and structural integrity after arthroscopic rotator cuff repair using 2 rows of fixation: Minimum 2-year follow-up. *Am J Sports Med* 2006;34:1899-1905.
3. Huijsmans PE, Pritchard MP, Berghs BM, van Rooyen KS, Wallace AL, de Beer JF. Arthroscopic rotator cuff repair with double-row fixation. *J Bone Joint Surg Am* 2007;89:1248-1257.
4. Sugaya H, Maeda K, Matsuki K, Moriishi J. Repair integrity and functional outcome after arthroscopic double-row rotator cuff repair. A prospective outcome study. *J Bone Joint Surg Am* 2007;89:953-960.
5. Chen M, Xu W, Dong Q, Huang Q, Xie Z, Mao Y. Outcomes of single-row versus double-row arthroscopic rotator cuff repair: A systematic review and meta-analysis of current evidence. *Arthroscopy* 2013;29:1437-1449.
6. Millett PJ, Warth RJ, Dornan GJ, Lee JT, Spiegl UJ. Clinical and structural outcomes after arthroscopic single-row versus double-row rotator cuff repair: A systematic review and meta-analysis of level I randomized clinical trials. *J Shoulder Elbow Surg* 2014;23:586-597.
7. Ying Z, Lin T, Yan S. Arthroscopic single-row versus double-row technique for repairing rotator cuff tears: A systematic review and meta-analysis. *Orthop Surg* 2014;6:300-312.
8. Tudisco C, Bisicchia S, Savarese E, et al. Single-row vs. double-row arthroscopic rotator cuff repair: Clinical and 3 Tesla MR arthrography results. *BMC Musculoskelet Disord* 2013;14:43.
9. Burks RT, Crim J, Brown N, Fink B, Greis PE. A prospective randomized clinical trial comparing arthroscopic single- and double-row rotator cuff repair: Magnetic resonance imaging and early clinical evaluation. *Am J Sports Med* 2009;37:674-682.
10. Koh KH, Kang KC, Lim TK, Shon MS, Yoo JC. Prospective randomized clinical trial of single- versus double-row suture anchor repair in 2- to 4-cm rotator cuff tears: Clinical and magnetic resonance imaging results. *Arthroscopy* 2011;27:453-462.
11. DeHaan AM, Axelrad TW, Kaye E, Silvestri L, Puskas B, Foster TE. Does double-row rotator cuff repair improve functional outcome of patients compared with single-row technique? A systematic review. *Am J Sports Med* 2012;40:1176-1185.
12. Ostrander RV, McKinney BI. Evaluation of footprint contact area and pressure using a triple-row modification of the suture-bridge technique for rotator cuff repair. *J Shoulder Elbow Surg* 2012;21:1406-1412.
13. Colvin AC, Egorova N, Harrison AK, Moskowitz A, Flatow EL. National trends in rotator cuff repair. *J Bone Joint Surg Am* 2012;94:227-233.
14. Yamaguchi K, Levine WN, Marra G, Galatz LM, Klepps S, Flatow EL. Transitioning to arthroscopic rotator cuff repair: The pros and cons. *Instr Course Lect* 2003;52:81-92.
15. Park MC, ElAttrache NS, Tibone JE, Ahmad CS, Jun B-J, Lee TQ. Part I: Footprint contact characteristics for a transosseous-equivalent rotator cuff repair technique compared with a double-row repair technique. *J Shoulder Elbow Surg* 2007;16:461-468.
16. Park MC, Tibone JE, ElAttrache NS, Ahmad CS, Jun B-J, Lee TQ. Part II: Biomechanical assessment for a footprint-restoring transosseous-equivalent rotator cuff repair technique compared with a double-row repair technique. *J Shoulder Elbow Surg* 2007;16:469-476.
17. Cummins CA, Appleyard RC, Strickland S, Haen PS, Chen S, Murrell GA. Rotator cuff repair: An ex vivo analysis of suture anchor repair techniques on initial load to failure. *Arthroscopy* 2005;21:1236-1241.