



Arthroscopic Rotator Cuff Repair With Allograft Augmentation: Making It Simple

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Abstract: Rotator cuff tears are increasing in frequency in the aging population and are a common issue seen by orthopaedic surgeons. In patients with large, multi-tendon rotator cuff tears or retears, treatment can be challenging. Failure rates of up to 90% have been reported for rotator cuff repair (RCR) of large, multi-tendon tears. Biological augmentation has been an area of interest because of the distinctly different biology of the repaired tendon compared with the native tendon. These biological differences affect the ultimate tensile properties of the repair and may contribute to gap formation and the high failure rate of repairs. RCR with allograft augmentation is a technique that shows potential benefit to healing and preventing retears. Arthroscopic augmentation of RCRs can be challenging. The technique described in this Technical Note illustrates a simple and easily reproducible method for augmenting RCRs with human acellular dermal allograft.

Rotator cuff tears are increasing in frequency in the aging population and are a common issue seen by orthopaedic surgeons.¹ In patients with large, multi-tendon rotator cuff tears or retears, treatment can be challenging. Failure rates of up to 90% have been reported for rotator cuff repair (RCR) of large, multi-tendon tears.² Most larger tears are degenerative, often with an acute trauma precipitating the symptoms of pain and enlarging the tear size. Whether purely degenerative or acute on chronic, there is usually tissue loss, tissue retraction, and a high incidence of gap formation when primary repair is attempted.³ Subsequently, the ability of the tendon to heal properly to

bone after repair is impaired. Age, sex, and fatty atrophy of the rotator cuff, as well as additional conditions, can impair tendon healing.⁴

The tendon-to-bone healing after RCR is very different from the native tendon-to-bone interface.¹ The normal tendinous insertion is made up of predominantly type I collagen fibers, whereas the repaired tendon-to-bone interface is mostly type III collagen.^{5,6} This type III collagen is less organized and has poorer tensile properties than the native tendon insertion.⁶ Owing to high failure rates, increasing interest in the addition of biological augmentation to RCR has emerged.^{7,8}

Augmentation should be considered when repairs are at high risk of re-tear or incomplete healing. Indications for RCR with augmentation are not consistent in the literature but usually include revision RCR; large, multi-tendon repairs; or poor-quality degenerative tendon tissue.⁸⁻¹¹ Augmentation will not compensate for advanced muscle fatty atrophy or neurapraxia. Previously described methods of augmenting an RCR can be extremely technically demanding.¹¹ Our technique aims at creating a simple and reproducible method for rotator cuff augmentation that can be easily adopted by arthroscopic shoulder surgeons.

Surgical Technique

Patient Setup

Our surgical technique is described in detail in [Video](#)

1. The preferred patient position is the lateral

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The authors report the following potential conflicts of interest or sources of funding: J.L. is a consultant for ConMed Linvatec and Smith & Nephew. J.A. is a consultant for ConMed Linvatec, Smith & Nephew, Rotation Medical, Mitek, Cayenne, and Ingen Medical. Full ICMJE author disclosure forms are available for this article online, as [supplementary material](#).

Received November 29, 2018; accepted February 3, 2019.

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2212-6287/181446

<https://doi.org/10.1016/j.eats.2019.02.003>

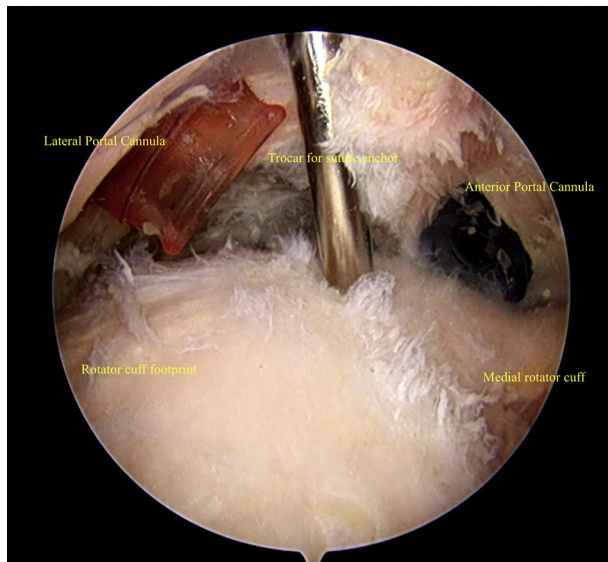


Fig 1. Arthroscopic image of left shoulder in lateral decubitus position from posterior portal. A sharp trocar is placed percutaneously and in a transtendinous manner in the antero-medial position for desired graft placement.

decubitus position but this technique can be used with other standard positions for shoulder arthroscopy such as the beach-chair position. We recommend that all patients agreeable to undergoing preoperative regional anesthesia receive a regional block to help with post-operative pain control. The patient is positioned on the operative table, and general anesthesia is induced. We then position the patient in the lateral decubitus position with the operative extremity up and free. The hand of the operative extremity is placed in an inflatable cuff and fastened to the traction boom. A vacuum beanbag is used to maintain the lateral decubitus position, and an axillary roll is placed under the nonoperative arm to protect the neurovascular structures. The patient is then prepared and draped.

Approach

We use 3 standard portals to access the subacromial space: posterior, lateral, and anterior. The posterior portal is the main viewing portal, whereas the lateral and anterior portals aid in visualization, instrument use, graft placement, and suture management. Subacromial decompression is accomplished with a combination of a Coblation wand (Smith & Nephew, Andover, MA) and a reciprocating shaver (Ultra Dual Purpose, 4.2 mm; ConMed MTF, Largo, FL). Care is taken to fully remove the subacromial bursa and expose the lateral gutter to aid in visualization of the cuff repair, as well as placement of lateral anchors to secure the graft. The rotator cuff tendon is reduced and repaired to the footprint. Numerous techniques have been described to repair the rotator cuff. Each surgeon can use the method best suited to his or her technical skills.

After cuff repair, our technique for augmentation is dependent on good fluid management and appropriate fluid seals at all portals. A 6.5-mm threaded cannula (Clear-Trac Flexible; Smith & Nephew) is placed in the lateral incision, and a 5.5-mm threaded cannula is placed in the anterior portal. With the surgeon viewing through the posterior portal, a 17-gauge spinal needle is inserted just lateral to the anterior third of the acromion. The spinal needle is used to localize the appropriate position for the anchors and graft. Two double-loaded all-suture anchors (Y-Knot percutaneous, 1.8 mm; ConMed Linvatec, Largo, FL) are inserted percutaneously through the deltoid and in a transtendinous manner through the repaired rotator cuff tendon into the greater tuberosity of the humerus (Fig 1). The first all-suture anchor is placed at the anterior-lateral edge of the acromion to obtain a more medial and perpendicular fixation point. The Y-Knot anchor system has a sharp trocar that aids in penetration through the deltoid and rotator cuff tendons. By use of a mallet, the trocar and drill guide are tapped gently into the bone of the tuberosity to seat the drill guide for stability while drilling the hole for anchor placement. The surgeon holds the guide stable while the assistant drills the pilot hole. The drill is removed, and the all-suture anchor is inserted through the guide. Gently engaging the anchor into the predrilled hole is important to ensure that the all-suture anchor is successfully deployed into the bone, which cannot be achieved if the drill guide has moved. When the anchor is seated, gentle taps with the mallet to start and heavier taps to finish will place the anchor into the bone. The sutures are uncled from the anchor insertion handle,

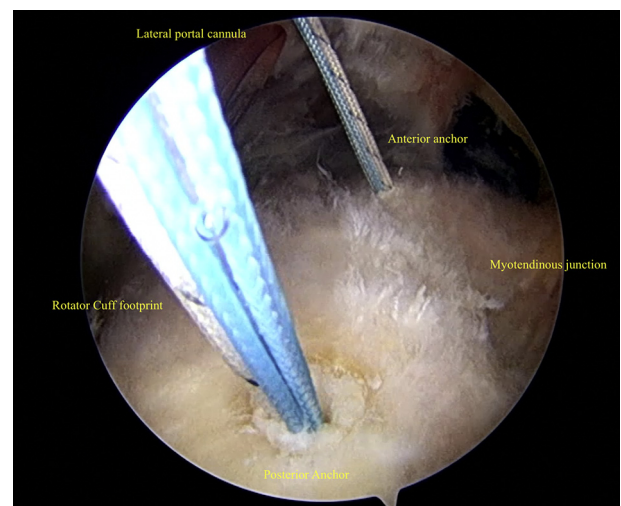


Fig 2. Arthroscopic view of left shoulder in lateral decubitus position from posterior portal. Both the antero-medial and posteromedial anchors are in place through the rotator cuff tendon and are ready to shuttle the graft into the subacromial space.

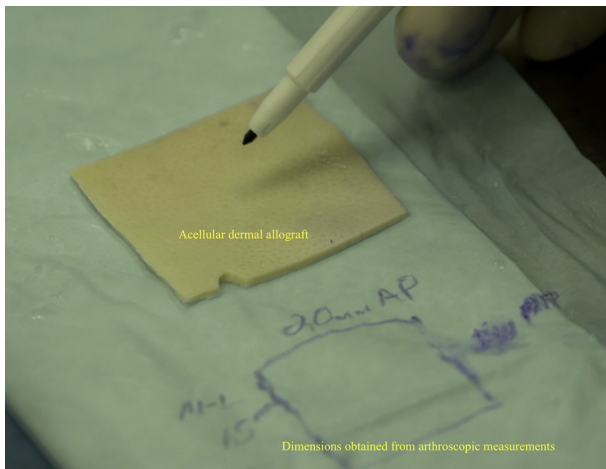


Fig 3. Acellular human dermal allograft with shiny, pigmented, dermal side up, prepared to be marked and cut to fit arthroscopic measurements.

and the inserter is removed. Tension is then applied to the suture, and stable placement is verified through the arthroscope. Generally, the first anchor is placed just anterior to the most anterior cuff repair suture. The posterior anchor is placed just posterior to the most posterior cuff repair suture, so the graft, when deployed, will cover the entirety of the repair site and provide compression of the repair (Fig 2). Anchor placement may appear to be too medial; if this occurs, we recommend that the arthroscope be placed intra-articularly after the guide is seated to ensure there is no damage to the articular cartilage. The steps are repeated for placement of the second anchor on the posterior aspect of the rotator cuff tendon. Alternatively, if ideal positioning of the graft would place the medial anchors intra-articularly, the anterior and posterior anchors can be replaced by 2 free sutures that are passed at the myotendinous junction. These, in turn, are used for passing and securing the graft medially in place of the anterior and posterior anchors. An alternative method preferred by one of the senior authors is to pass 2 free sutures through the medial musculotendinous junction instead of placing the anchors first. These sutures will be used for allograft delivery.

Allograft Preparation, Delivery, and Internal Fixation

An arthroscopic ruler (ConMed Linvatec) is introduced through the anterior cannula and used to measure the anterior-to-posterior distance between the 2 anchors. The ruler is then inserted through the lateral portal, and a measurement from the anterior and posterior anchors to the lateral edge of the footprint is made to give the medial-to-lateral dimensions of the graft. The surgeon may choose to unload the second suture from the anchors or choose to keep it for an extra point of fixation. For reproducibility, the blue

striped suture is retained in the posterior anchor and the black striped suture is left in the anterior anchor. A single limb from each anchor is then retrieved using a ring grasper inserted from the lateral portal. To ensure a tangle-free construct, the surgeon should start with a single limb of the posterior suture. The posterior suture is retrieved first through the lateral cannula and secured to a cleat on the posterior aspect of the lateral cannula. A single limb of the anterior suture can then be retrieved through the lateral cannula. To verify that there is no entanglement, the ring grasper is again placed in the lateral cannula, the anterior black striped suture is encircled, and the ring grasper is pulled out of the cannula. If no entanglement is noted, the tiger suture is secured firmly to an anterior cleat (directly opposite the posterior suture) on the lateral cannula. This step is critical to avoid entanglement of the sutures and the loss of graft control during the shuttle technique.

An assistant should annotate the dimensions of the graft on the back table at the time of arthroscopic measurements (the measurements are used to fashion the graft to the appropriate size). Non-irradiated acellular human dermis graft (Allopatch HD; ConMed Linvatec) is selected based on thickness (Fig 3). The graft must fit in the subacromial space without impingement but also provide sufficient structural properties. The senior author recommends a 2.5- to 3.0-mm-thick allograft. The epidermal side (the more shiny and more pigmented side compared with the opposite dermal side) is placed upward and marked with an arrow pointed medially. This allows the correct dimensions to be oriented appropriately and the dermal side to be positioned against the RCR site. Because there is some elasticity to the allograft, which is important to consider when measuring and cutting the graft to size, we recommend cutting the graft to the exact size and then placing the sutures 3 to 5 mm from

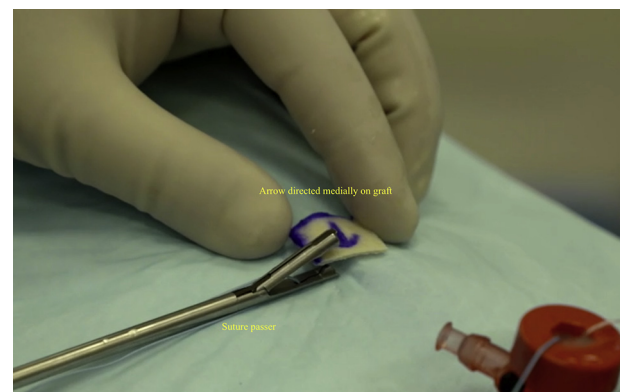


Fig 4. Use of an arthroscopic suture passer to pass the posterior suture limb through the posteromedial corner of the marked allograft.

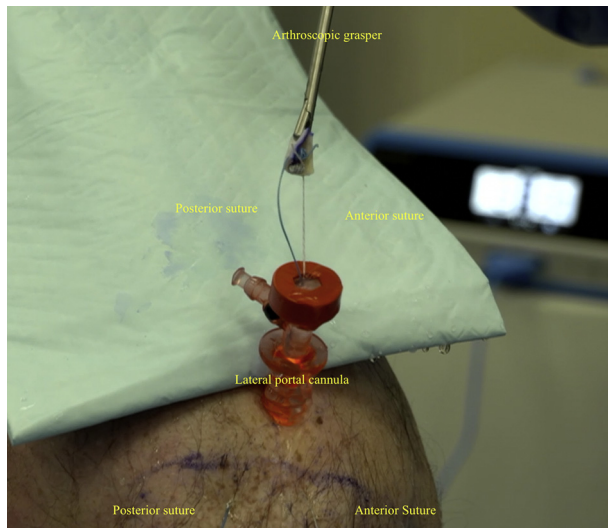


Fig 5. Tensioning of graft-shuttling construct. An arthroscopic grasper is holding the lateral edge of the graft while tension on the anterior and posterior suture limbs advances the graft toward the lateral cannula.

the graft edge. This will create ideal tension on the graft after it is secured in place. A suture-passing device is used to pass the anterior suture limb through the graft on the side that will be medial when shuttled into the subacromial space (Fig 4). A mulberry knot is tied by wrapping the suture around 1 finger and twisting it numerous times, with the free end finally being pulled through the loop to create a large space-occupying knot. Two half-hitches will help secure the mulberry knot. This process is repeated for the posterior suture limb. Excess suture is trimmed near the knots to leave a small wick of suture to be able to grab to retrieve the knot easily. It is important for the assistant to keep the suture limbs separated during the process to avoid entanglement. The anterior and posterior sutures can now be uncled from the lateral trocar, and the slack in the suture pulley can be removed by pulling equal tension on the suture limbs that remain in the percutaneous anchor holes (Fig 5). The graft is advanced to the aperture of the lateral cannula and folded along its longitudinal axis. When the system is tensioned, an arthroscopic grasper is used to grip the lateral edge of the allograft, and the assistant pulls equivalent tension on the free ends of the anterior and posterior sutures. The arthroscopic grasper aids in pushing the graft as it traverses the cannula (Fig 6). Equal tension must remain on the sutures throughout positioning to keep the shuttle sutures from entanglement. Viewing the subacromial space from the posterior portal, we can ensure the graft unfurls and is correctly positioned over the repair site. The mulberry knot is retrieved and pulled through the lateral portal with an arthroscopic grasper. This knot is cut, and the suture is tied with an SMC arthroscopic knot slid down into place on the graft

with 2 alternating half-hitches on alternating posts. We repeat these steps for the posterior suture.

Final Graft Fixation

The lateral gutter region of the subacromial space must be well cleared to visualize the location for the 2 lateral anchors. The anchors will be placed to appropriately tension the graft to provide compression over the repaired tendons. A ring grasper, introduced through the lateral portal, is used to grasp the antero-lateral corner of the graft and pull tension on the graft. A 17-gauge spinal needle is inserted through the deltoid to identify the trajectory of the percutaneous drill guide for the anterolateral suture anchor. The spinal needle is removed, a small skin incision is made, the percutaneous guide is introduced, and the process for placing the suture anchor is followed. After the anchor is placed, all but a single suture is unloaded from the anchor and the remaining suture is passed arthroscopically using an antegrade suture passer through the anterior-lateral corner of the graft (Fig 7). This corner of the graft is secured using an SMC knot. The process is repeated for the posterior-lateral corner of the graft.

In a possible variation, if the surgeon has chosen a double-row construct, he or she may leave free sutures in 2 of the lateral anchor eyelets and use those sutures for anterior-lateral and posterior-lateral graft fixation. This will save the additional cost of more anchors and allow the anchors to perform 2 functions: lateral-row fixation of the primary repair and lateral fixation of the graft.

Finally, the graft is inspected for appropriate tension. The transtendinous sutures that secure this graft offer a second row of fixation to the rotator cuff with the addition of the biological properties of the graft overlying the repair site (Fig 8).

If an alternative technique of passing the graft with sutures through the myotendinous junction is used, care must be taken to push the graft into place while

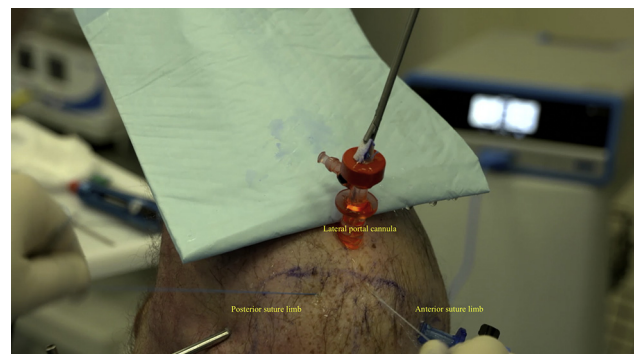


Fig 6. Shuttling of the graft through the lateral portal cannula while equal tension on the anterior and posterior suture limbs is combined with gentle pressure through the arthroscopic grasper on the graft.

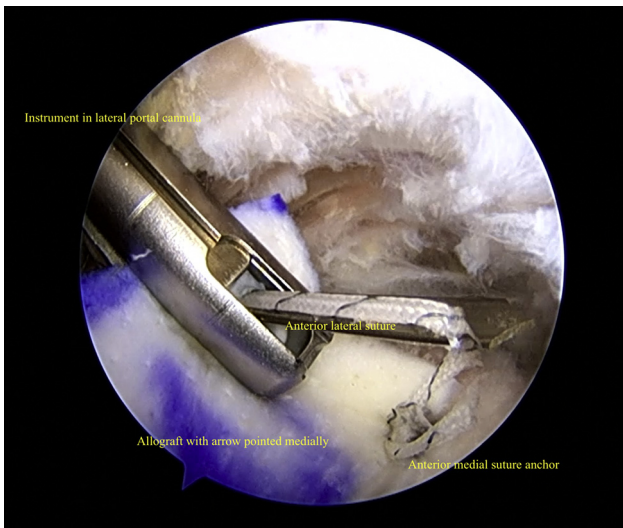


Fig 7. Arthroscopic image of left shoulder in lateral decubitus position from posterior portal. By use of an arthroscopic suture passer, the anterolateral suture is passed through the corresponding anterolateral corner of the graft.

simultaneously taking the slack out of the sutures to guide the graft into place. Once the graft is in the appropriate position, the previously described technique of anchoring each corner of the graft is undertaken. The graft should be taut over the RCR.

Postoperative Rehabilitation

The patient is placed in a sling with an abduction pillow after surgery. The patient is limited to non-weight bearing on the operative extremity, with passive and active range of motion of the elbow and wrist starting immediately postoperatively. Physiotherapy is initiated at postoperative week 6 because the tears tend to be either very large or revisions. We advise caution in starting physiotherapy before the 6-week mark.

Discussion

Rotator cuff disease is common in both men and women and can cause significant pain, dysfunction, and disability.¹² With an aging population, the use of RCR is anticipated to increase over the coming years.¹³ Despite improvements in surgical instrumentation, anchors, sutures, and techniques, retears and loss of fixation remain formidable problems—especially in large to massive tears.¹⁴

Looking specifically at large to massive RCRs, 20% to 90% of patients undergoing primary RCRs have some aspect of repair failure or a retear.¹⁴ The patients most likely to experience retears presented with massive or multi-tendon tears.¹² In an effort to improve the outcomes of repairs of large to massive cuff tears, augmentation with additional tissue has become a topic of much investigation.¹ Many types of reinforcement

have been attempted, including dermal allografts; xenografts; and interposition, augmentation, and synthetic grafts.¹⁴ The addition of allograft reinforcement to an RCR may offer increased structural support along with a tissue scaffold that can allow for ingrowth and neovascularization of the graft.⁹

In a review article on rotator cuff augmentation in the *Journal of the American Academy of Orthopaedic Surgeons*, Gillespie et al.¹⁴ concluded that much of the literature on graft augmentation relies on lower-level case series or cohort studies but further randomized research is necessary. In addition, they stated, “data must be weighed against the associated costs of the graft material, additional surgical time necessary for implantation and risk of inflammation, infection and graft degradation.” The purpose of this technique is to demonstrate a simple and reproducible method for rotator cuff augmentation that can be easily adopted by arthroscopic shoulder surgeons with hopes to decrease surgical time and frustration.

Xenografts for rotator cuff augmentation have yet to show superior results to controls in human subjects; however, a recent case series by Thon et al.¹⁵ showed promising results without an immunogenic reaction at 2 years’ follow-up.¹⁴ Allografts, usually acellular dermis, offer immediate structural strength and avoid associated morbidity at the autograft donor site.

Despite relatively few studies with allografts, the preliminary results are encouraging. In a retrospective case series, Agrawal⁸ performed revision RCR with acellular human dermal allograft augmentation in patients with large to massive rotator cuff tears. After 1 year of follow-up, magnetic resonance imaging (MRI) evaluation revealed that 85% of the rotator cuffs were

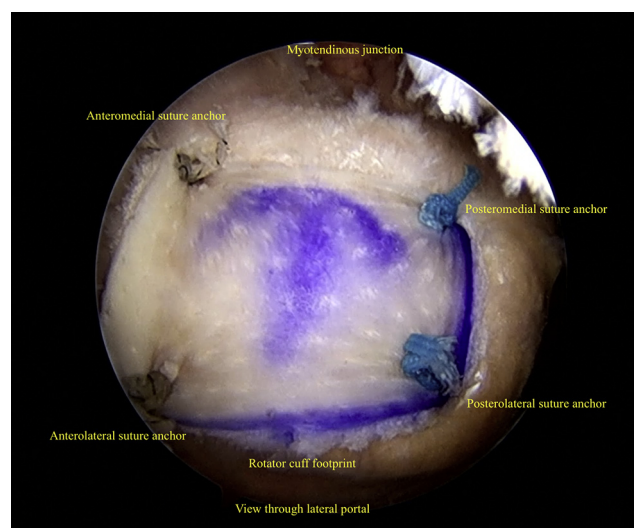


Fig 8. Arthroscopic image of left shoulder in lateral decubitus position from lateral portal. The allograft is tensioned appropriately over the rotator cuff repair site with the arrow pointed medially to the rotator cuff muscle.

Table 1. Pearls and Pitfalls

Pearls	
	Be certain to create good fluid seals and have proper fluid management.
	Thoroughly clear the lateral gutter for adequate visualization.
	Use a ring grasper to ensure that the anterior and posterior sutures of the shuttling construct are not twisted in the lateral cannula.
	Pull equal tension on the suture limbs when passing the graft.
	Use the grasper to push the graft gently through the lateral cannula.
	If the tear extends medially, use the free sutures at the myotendinous junction for medial-row fixation.
Pitfalls	
	The medial-row anchors should not be placed too medially because of potential damage to the articular surface.
	Failure to hold the drill guide in the correct position can make anchor seating difficult or impossible.
	Incorrect measurement of the graft can alter the ability to compress the graft over the footprint.
	Poor suture management can lead to difficulty tying the suture limbs to the graft.

intact, with significant improvements in postoperative Constant scores and pain scores. Objective scapular-plane abduction and strength significantly improved. However, historical data have suggested that all patients receiving rotator cuff surgery have improved outcome scores; thus, without a control group, the true clinical significance is difficult to ascertain.¹⁶ Notably, no reactions to or complications from the allograft tissue were reported.

Barber et al.⁹ reported a prospective, multicenter, randomized controlled trial of 22 patients who underwent single-row repair of large, 2-tendon tears with or without augmentation with acellular non-cross-linked dermal allograft. At a mean follow-up of 2 years, both groups had improved American Shoulder and Elbow Surgeons (ASES), Constant, and University of California, Los Angeles scores; the augmented group showed significantly more improved ASES and Constant scores compared with the non-augmented group. Furthermore, when gadolinium-enhanced MRI scans were performed, 85% of repairs in the augmented group showed intact cuffs compared with only 40% in the non-augmented group.

Regarding reactions to allograft tissue, minute amounts of DNA have been detected on the brand of acellular dermis graft used by Barber et al.⁹ However, to date, there have been no reported immunogenic complications from the graft in this or any other clinical studies using acellular dermis allograft.^{7,16,17}

Steinhaus et al.¹⁸ compiled 24 studies into a meta-analysis and reported improved clinical and functional outcomes with surgical intervention for large to massive rotator cuff tears. They suggested that RCRs augmented with allograft had similar improvements in patient-reported outcomes to RCRs without augmentation. An overall retear rate of 25% for large to massive tears was found, with 15%, 23%, and 44%

retear rates for RCRs augmented with synthetic grafts, allografts, and xenografts, respectively. Care must be taken in interpreting the results because most articles included in the meta-analysis were Level III and IV evidence, with publication dates ranging from 1986 to 2014, and only 15% of included cases were completed arthroscopically.

More recently, Bailey et al.⁷ reviewed 36 studies in a systematic review and performed a meta-analysis of 5 studies with RCR or reconstruction with augmented tissue or matrix. The results showed improved outcome scores in nearly all surgically treated groups but showed significantly greater improvement in ASES scores in the augmented group compared with the non-augmented group. Likewise, the augmented group showed significantly lower retear rates compared with non-augmented repairs. However, it was concluded that randomized and better-powered studies are needed for evidence-based recommendations on the use of augmentation.

Acevedo et al.¹⁹ reviewed the multiple applications of acellular human dermal allograft. Their review of the literature regarding augmenting large and massive RCRs found improved pain and functional outcome measures with minimal complications.

In a prospective case series, Bokor et al.²⁰ evaluated augmenting partial-thickness rotator cuff tears with highly porous collagen implants. Their study showed that augmented tendons increased in thickness. Comparing MRI scans preoperatively and postoperatively at 3, 6, 12, and 24 months, they found that grafts incorporated into tendons and were indistinguishable on imaging. No progression of tearing was noted in their study. They also showed consistent improvement in clinical outcome measures (i.e., Constant and ASES scores).

There are inherent limitations and risks associated with placing 4 additional anchors in a transtendinous manner into the greater tuberosity footprint, including potentially disrupting the RCR, weakening the greater tuberosity footprint, and increasing the likelihood of placing an anchor through the articular cartilage. These risks are minimized by using 1.8-mm all-suture anchors

Table 2. Advantages and Disadvantages

Advantages	
	The technique is simple and reproducible.
	Graft is easily tensioned to be taut over the rotator cuff repair, providing compression of the repair.
	There is potential for superior healing and repair durability.
Disadvantages	
	The use of anchors and graft increases the cost.
	There are possible risks of inflammation, infection, and graft degradation—no documented reaction to date. ¹⁴
	The operating room time is longer.
	Visualization can be difficult because the graft occupies space.

and placing the arthroscope intra-articularly if there is concern that the anchors may cause chondral damage. RCR augmentation increases the operating room time and exposes the patient to increased time under anesthesia. With additional anchors and allograft, costs are increased compared with simple RCR.⁷ Although there are risks associated with the use of cadaveric tissue, as discussed earlier, no immunogenic complications have been reported to date.^{7,16,17} Table 1 lists pearls and pitfalls of the described technique, and Table 2 presents advantages and disadvantages.

The data, although inconclusive thus far, are encouraging that allograft augmentation improves rotator cuff healing and helps prevent retears. This technique provides a simple, reproducible method for cuff augmentation that can be easily adopted by shoulder surgeons.

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