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Irreparable Massive Rotator Cuff Tears: Subacromial Balloon Surgical Technique

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Massive irreparable rotator cuff tears pose a significant challenge for both the treating orthopedic surgeon and patient. Surgical treatment options for massive rotator cuff tears include arthroscopic debridement, biceps tenotomy or tenodesis, arthroscopic rotator cuff repair, partial rotator cuff repair, cuff augmentation, tendon transfers, superior capsular reconstruction, subacromial balloon spacer, and ultimately reverse shoulder arthroplasty. The present study will provide a brief overview of these treatment options along with a description of the surgical technique for subacromial balloon spacer placement.

Introduction

Massive irreparable rotator cuff tears pose a significant challenge for both the treating orthopedic surgeon and patient.¹ Massive rotator cuff tears account for ~10-40% of all rotator cuff tears and not infrequently can be considered irreparable.²⁻⁴ Massive tears are defined by number of tendons involved⁵ or simply by size,⁶ whereas irreparable tears are based on

degree of retraction, amount of fatty infiltration, and muscle atrophy.⁷ Further complicating treatment, massive tears have shown to have higher recurrent tear rates, failure of healing after repair, and potential for irreparability.^{8,9} A tear in the rotator cuff can disrupt axial forces, leading to superior subluxation of the humeral head and, consequently, shoulder dysfunction.¹⁰ Often, propagation of rotator cuff tears occurs as torn tendons cannot participate in load sharing, thus resulting in an increased amount of tensile load being placed on the remaining fibers, further damaging the shoulder joint.³

Surgical treatment options for massive rotator cuff tears include arthroscopic debridement, biceps tenotomy or tenodesis, arthroscopic rotator cuff repair, partial rotator cuff repair, cuff augmentation, tendon transfers, superior capsular reconstruction (SCR), subacromial balloon spacer, and ultimately reverse shoulder arthroplasty (RSA).¹¹⁻¹⁷ Comparative efficacy of each of these treatments remains unclear and to achieve the best possible outcome for the patient, surgeons should have a strong understanding of the indications and clinical results for each of these treatments. The present study will provide a brief overview of the aforementioned treatment options along with a description of the surgical technique for subacromial balloon spacer placement.

Treatment Options for Massive Rotator Cuff Tears

Debridement and Tenotomy of the Biceps Tendon

Debridement with biceps tenotomy can be a viable option for the elderly patient with low physical demands. Studies have shown pain significantly

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decreased, while range of motion and the ability to perform activities of daily living significantly increased with improvement in American Shoulder and Elbow Surgeons (ASES) scores.^{18,19} Arthroscopic biceps tenotomy in patients with full-thickness rotator cuff tears was found to decrease the acromiohumeral space by a mean of 1.3 mm, yield good objective improvement, and a high degree of patient satisfaction (87%) at a mean of 57 months' follow-up.²⁰ However, one drawback remains significantly decreased arm elevation strength.¹⁸ Furthermore, poor preoperative forward elevation has been shown to be a predictor of negative outcome.²¹

Rotator Cuff Repair

The ideal rotator cuff repair restores normal biomechanics and function, while decreasing pain; however, the outcomes of massive cuff repairs are less predictable. Surgery to repair a torn rotator cuff involves reattaching the damaged tendon back onto the humeral head. Functional outcomes are satisfactory; however, proper tendon healing is inconsistently achieved. Proper tendon healing correlates with better postoperative outcomes. Factors associated with better healing include age less than 65, no smoking history, minimal fatty degeneration, and acromiohumeral distance greater than 6 mm.²² Chet et al. found that patients with lower preoperative ASES scores and elevated visual analog scale (VAS) pain scores had better improvement in ASES scores at 2-year follow-up following partial repair.²³ The long recovery time is a common complaint of patients, as recovery takes several months to regain full range of motion and function. Furthermore, a systematic review reported postoperative retear rates of 48.8%, further complicating the long-term benefits of repair for massive rotator cuffs.²⁴

Cuff Augmentation

In cuff augmentation, the rotator cuff is repaired and subsequently augmented with a graft over the tendon to cover the remainder of the rotator cuff footprint with the goal to improve stability and healing. This technique bridges the gap between a massive rotator cuff tear medially and the tuberosity laterally and represents an alternative to tendon transfer (discussed below). Multiple studies have shown favorable outcomes for augmentation repair using a variety of patch materials emphasizing that the type of patch may influence the outcome.^{22,25-33} Kim et al. reported a mean ASES score improvement from 50 preoperatively to 83 ($P < .001$) at 3 years follow-up.³⁴ However, long-term outcomes of interposition grafts are limited.

Cuff augmentation is performed for two primary reasons: 1) to provide structural support or 2) improve biological environment to augment healing. With



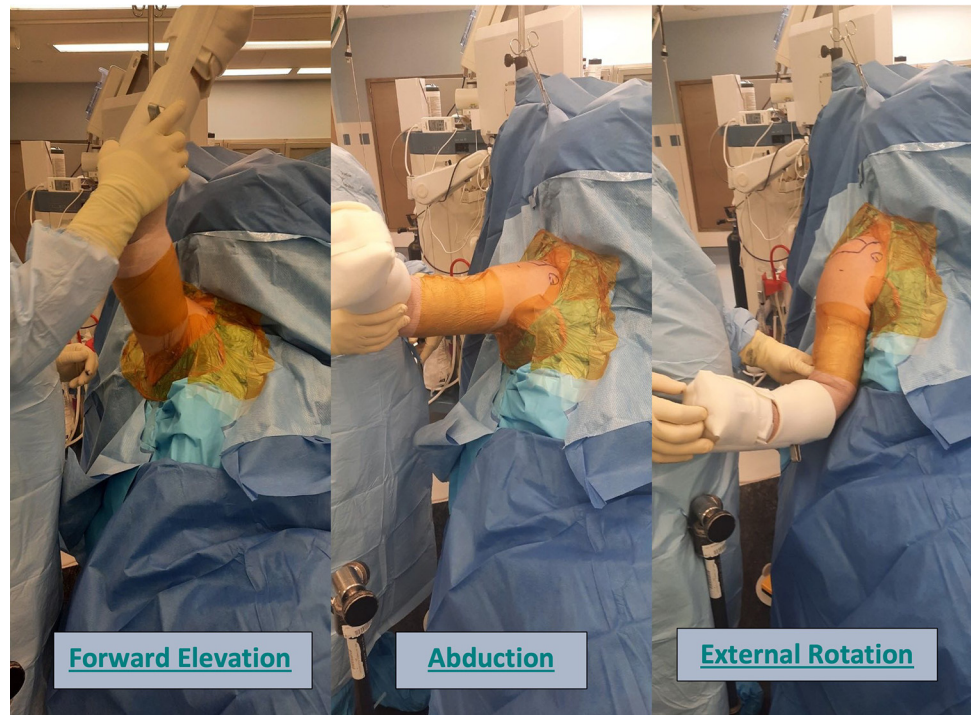
Fig 1. Patient positioning in standard beach chair at 90° with articulating arm holder on operative side.

progressing massive cuff tears that display muscle atrophy and degenerative changes, a patch augmentation can help bridge the gap between the muscle tendon and tuberosity. Biologic augmentation technique captures the subacromial bursal tissue, which is a reservoir of mesenchymal stem cells, and reimplants the tissue on the rotator cuff tendon following patch augmentation to promote biological healing.³⁵

Tendon Transfers

For the young active patient with an irreparable rotator cuff tear, tendon transfers have emerged as favorable option, given concerns for potential complications and longevity of RSA. Goals of tendon transfer for irreparable tears are to restore force couples across the glenohumeral joint, while providing pain relief. For anterosuperior rotator cuff tears, pectoralis major is the most common option, while the latissimus dorsi and lower trapezius are reserved for tendon transfers for

Fig 2. Exam under anesthesia tests passive range of motion in forward elevation, external rotation, and abduction.



posterior superior cuff tears.³⁶ Lower trapezius tendon transfers have demonstrated favorable short-term outcomes.³⁷ One systematic review determined latissimus tendon transfers to have greatest improvement in active shoulder range of motion (forward flexion, external rotation, and abduction).³⁸ In addition to being technically demanding, indications for tendon transfers are strict, as the procedure is most appropriate for younger, active patients with minimal glenohumeral arthritis, and no severe functional limitations.

Superior Capsular Reconstruction

SCR was first popularized in Japan as an alternative to RSA for treatment for the irreparable massive rotator cuff tear.³⁹ Grafts used are often region dependent, as SCR are described as using fascia lata autograft¹⁵ versus

bovine dermal allograft.⁴⁰ The SCR graft is anchored medially at the superior glenoid and laterally over the greater tuberosity. Short- and mid-term data have demonstrated sustained improvements in ASES scores, maintenance of acromiohumeral interval, return to work, and graft maintenance, proving SCR a viable surgical option for massive tears.^{15,39,41,42} However, it must be noted patients with graft failure did go on to develop rotator cuff arthropathy.³⁹ Despite promising results, SCR is a technically demanding procedure, necessitating surgeon expertise, and places the burden of intense postoperative rehabilitation on patients.

Reverse Shoulder Arthroplasty

For the elderly patients with lower baseline activity demands, RSA is a well-established treatment for

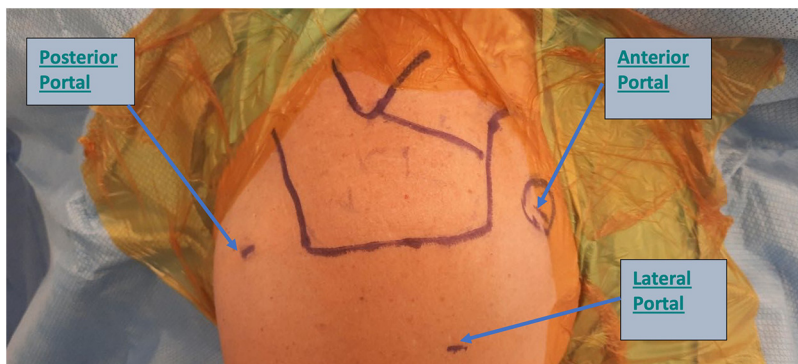


Fig 3. Anatomic shoulder landmarks are outlined: posterior scapular spine, lateral border of acromion, clavicle, acromioclavicular joint, coracoid, and portals (posterior, lateral and subacromial).

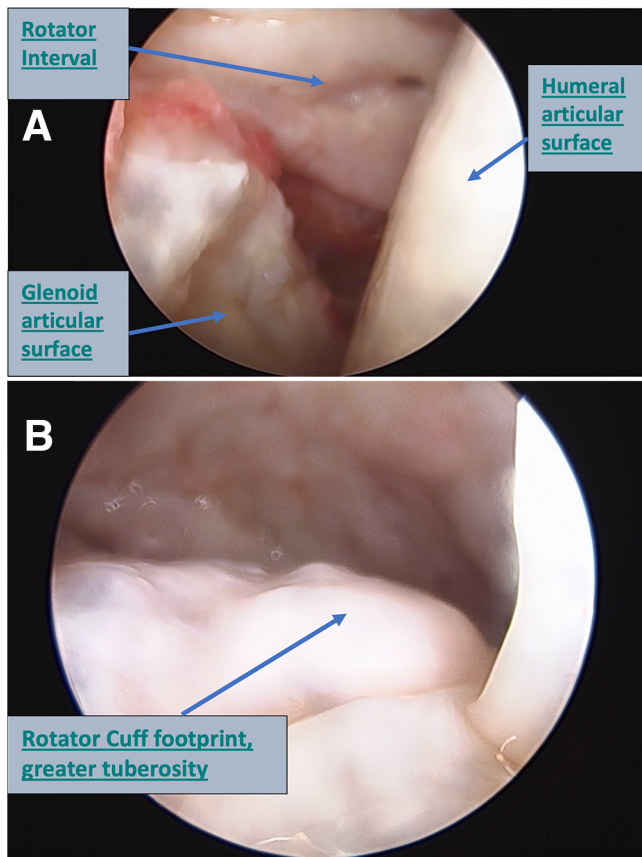


Fig 4. Diagnostic arthroscopy is performed in the following order: the rotator interval, subscapularis, extra-articular biceps tendon, superior labrum, anchor for long head of the biceps tendon, glenoid surface, humeral head and rotator cuff insertions, axillary recess, and subscapular space. Viewing portal: posterior.

massive irreparable cuff tears. Often, RSA can serve as salvage procedure for more severe pathologies and injuries previously untreatable; however, appropriate use and indications remain critical. Studies have reported both improvement in ASES and pian scores.^{16,43} Disadvantages are more apparent when applied to the younger patient (<60 years old) and those with higher preoperative function and internal rotation, as these are risk factors for poorer outcomes.⁴³ Ma et al. showed that RSA had lower complication rates when compared to anatomic shoulder arthroplasty for patients older than 50; however, no difference was observed for patients younger than 50.⁴⁴ RSA is an excellent choice for the indicated patients; however, it is not for all.

Surgical Technique

Equipment

As seen in [Video 1](#), the following equipment is needed:

- Standard beach chair — Tenet T-Max Shoulder Positioner (Smith & Nephew, Inc; Andover, MA)

- Articulating arm holder — McConnell Positioning System (McConnell Orthopedic Manufacturing; Greenville, TX)
- 4.0-mm 30° arthroscope and camera — Stryker 4.0-mm Precision Ideal Eyes HD Autoclave Arthroscope, C-Mount, Speed-Lock (Stryker Corporation; Kalamazoo, MI)
- 5.4-mm arthroscopic probe — Arthrex AR-10000 Probe, Hook 5.4 mm, Tip w/ 5 mm Markings. (Arthrex; Naples, FL)
- Arthroscopic shaver with 3.5-mm shaver — Stryker Formula Arthroscopic Shaver Handpiece, TPS Small Joint Cutters Stryker 3.5-mm Shaver (Stryker Corporation; Kalamazoo, MI)
- 18 gauge spinal needle
- 50 cc syringe
- Saline
- Implants

○ InSPACE Balloon (Stryker Corporation; Kalamazoo, MI)

Positioning, Prepping, and Draping

- The patient is positioned in standard beach chair fashion at 90° with articulating arm holder on operative side. All bony prominences are padded ([Fig 1](#)).
- Prior to draping, a physical exam under anesthesia is performed testing patient passive range of motion in forward elevation, external rotation, and abduction ([Fig 2](#)).
- The limb is prepped and draped in standard sterile fashion.
- The following anatomic shoulder landmarks are outlined: posterior scapular spine, lateral border of acromion, clavicle, acromioclavicular joint, coracoid, and portals.
- The following portals are utilized: posterior portal (2 cm inferior and 1 cm medial to the posterolateral

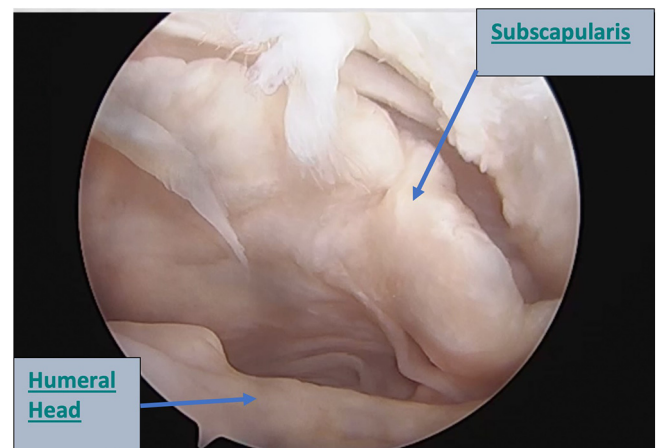


Fig 5. Assessment of the quality of subscapularis. Viewing portal: posterior.

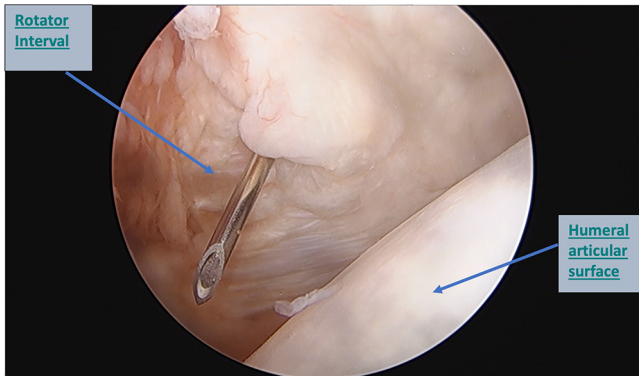


Fig 6. Establishment of anterior working portal in inside-out fashion utilizing 18-G spinal needle through rotator interval. Viewing portal: posterior. Working portal: anterior.

acromion, in line with the axillary fold) and a lateral subacromial portal (2 finger breadths below lateral acromial border and 2 cm posterior to anterolateral corner of acromion) (Fig 3).

Diagnostic Arthroscopy and Subacromial Preparation

Once the patient is positioned, a diagnostic arthroscopy and subacromial preparation is performed.

- Posterior portal is established in line with axillary fold serving as the standard viewing portal.
- A diagnostic arthroscopy is performed in the following order: the rotator interval, subscapularis, extra-articular biceps tendon, superior labrum, anchor for long head of the biceps tendon, glenoid surface, humeral head and rotator cuff insertions, axillary recess, and subscapular space (Fig 4).
- During diagnostic arthroscopy, attention is paid to the quality of subscapularis, the integrity of glenoid and humeral cartilage, and irreparability of the rotator cuff are assessed (Fig 5).

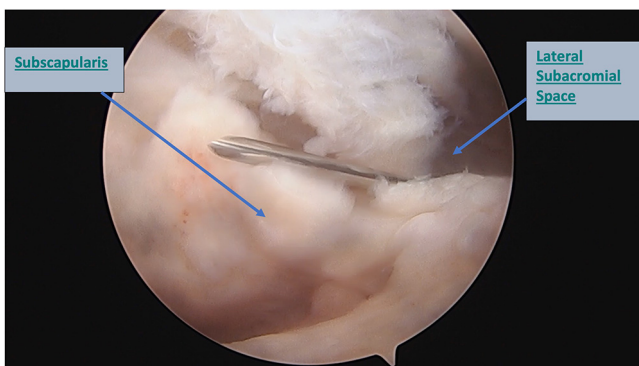


Fig 7. Alternatively, establishment of lateral subacromial portal in inside-out fashion using 18-G spinal needle. Viewing portal: posterior. Working portal: lateral.

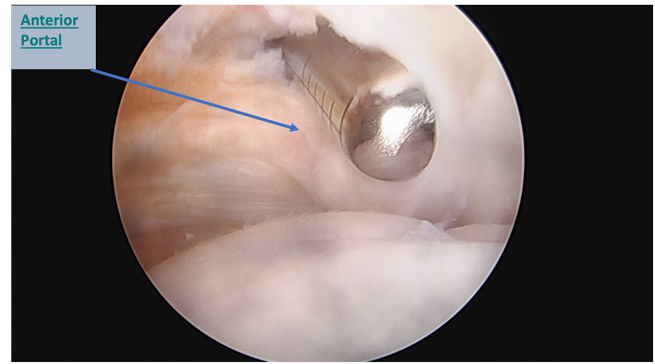


Fig 8. Intra-articular debridement of labrum, capsule, and rotator cuff is performed with arthroscopic shaver as needed through the anterolateral portal. Viewing portal: posterior. Working portal: anterior.

- The anterior working portal is established in inside-out fashion utilizing 18 g spinal needle through rotator interval for localization (Fig 6). Alternatively, a lateral sub-acromial border is utilized. The lateral subacromial portal is established in inside-out fashion utilizing 18-G spinal needle (Fig 7).
- Intra-articular debridement of labrum, capsule, and rotator cuff is performed with arthroscopic shaver, as needed, through the anterolateral portal (Fig 8).
- Light subacromial debridement is performed through the lateral portal. Debridement should be minimal, so as to allow sufficient visualization of subacromial space, but as to not provide room for spacer to shift.

Spacer Sizing, Selection, and Placement

- Using 5-mm arthroscopic probe, subacromial space is measured. First anterior to posterior dimensions under the acromion followed by 1 cm medial to superior glenoid rim to greater tuberosity laterally (Fig 9).

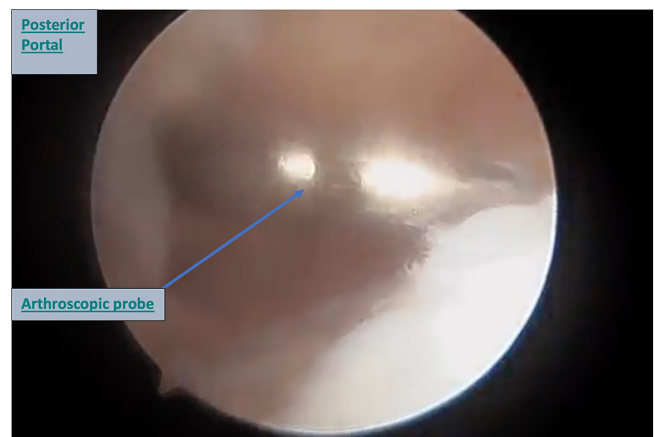


Fig 9. Subacromial space is measured using a 5-mm arthroscopic probe. Viewing portal: posterior. Working portal: lateral.

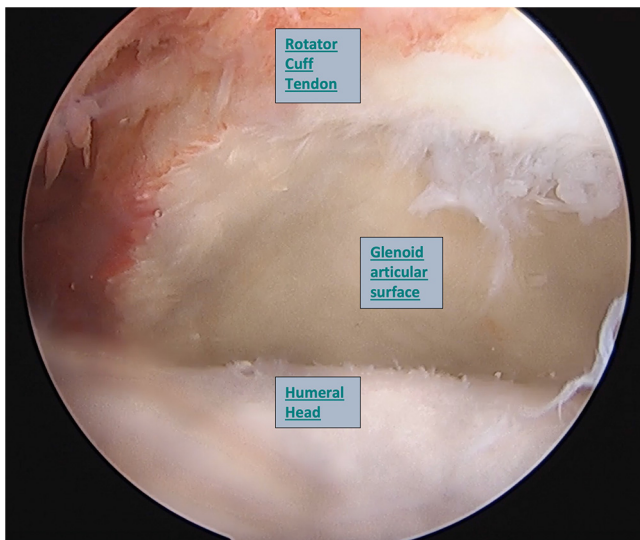


Fig 10. Arthroscopic camera is switched from the posterior to the lateral viewing portal using a switching stick. Viewing portal: lateral. Working portal: posterior.

- Arthroscopic camera is then switched from the posterolateral viewing portal using switching stick (Fig 10).
- Posterior portal is expanded to accommodate the delivery system (Fig 11).
- Spacer balloon is available in three sizes (small, medium, and large). Once appropriate size is selected, attention is turned to preparing the inflating system.
- A 50-cc syringe is filled with heated saline with care to ensure any residual air bubbles are removed.

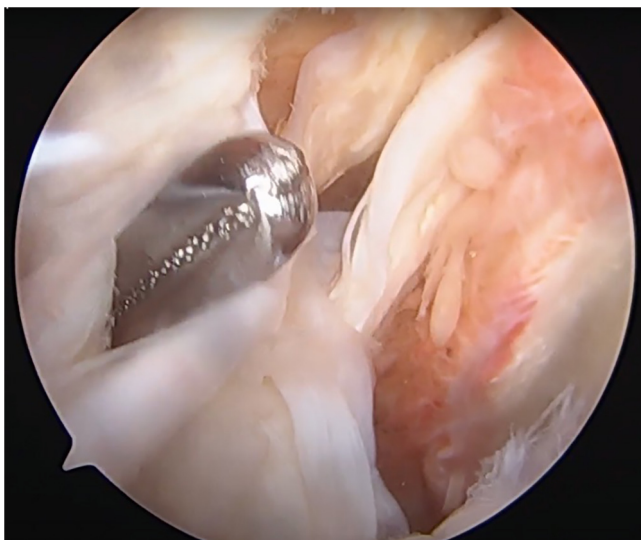


Fig 11. Posterior portal is expanded to accommodate the delivery system. Viewing portal: lateral. Working portal: posterior.

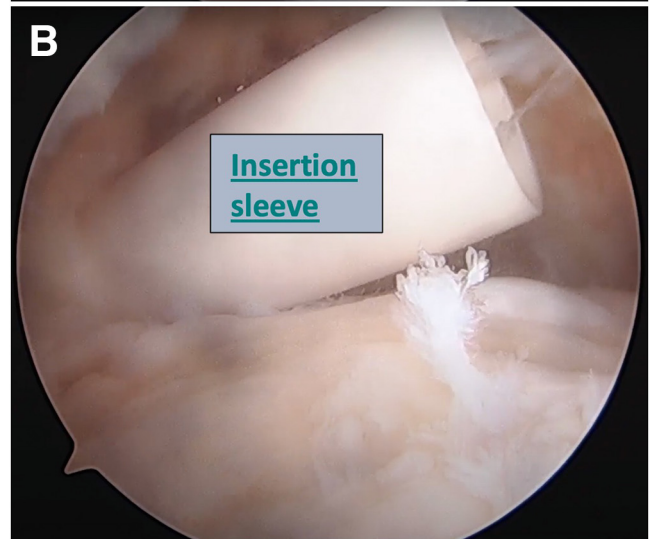
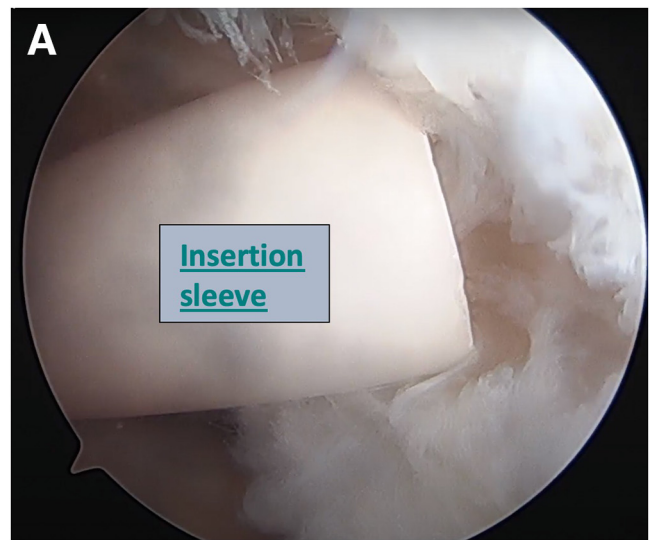


Fig 12. Delivery system is introduced through posterior portal and placed 2 cm medial to the glenoid rim overlying the rotator cuff tendon stump. Viewing portal: lateral. Working portal: posterior.

- Through the posterior portal, the delivery system is introduced and placed 2 cm medial to glenoid rim overlying the rotator cuff tendon stump (Fig 12, Table 1).
- Once in the appropriate position, gently pull back, protecting the sheet to expose the balloon. It is essential to not adjust delivery system position during this stage (Fig 13).
- Connect the extension tube to the delivery system, attaching the 50-cc syringe and then fully inflate balloon. Maintain the valve open to allow saline to flow back into the syringe once the balloon is inflated within acceptable limits (Fig 14).
- Once appropriate volume has been achieved, the delivery system is ready to be removed. First, push

Table 1. Pearls and Pitfalls

Pearls	Pitfalls
<ul style="list-style-type: none"> Minimal intra-articular and subacromial debridement required to minimize balloon migration Insertion of balloon can be performed through posterior portal or lateral portal. Author preferred technique through posterior portal 	<ul style="list-style-type: none"> Lack of long-term data on influence of biodegradation of balloon implant Possible migration of balloon implant Equivocal data on superiority to debridement

the red safety button on the delivery device forward and then turn the green knob. At this point, the delivery device can be detached.

- Removed delivery system.
- Take operative limb through the full range of motion in forward elevation, external rotation, and abduction. Verify balloon stability and position during and following functional range of motion testing.

Closure and Postoperative Protocol

- Portals are closed in the standard fashion; sterile dressing is applied.
- Sling
- Postoperative protocol: A sling is used for 4-6 weeks postoperatively followed by formal outpatient physical therapy.

Discussion

First described in 2012 by Savarese and Romeo, the subacromial balloon spacer represents a potential solution for treatment of the massive irreparable tears

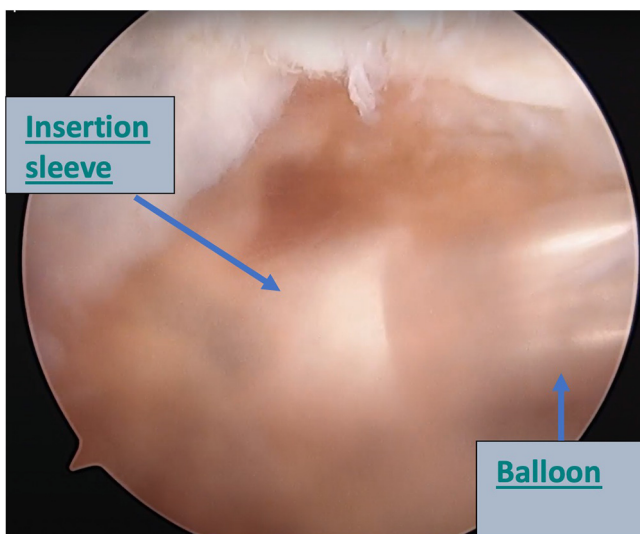


Fig 13. Protection sleeve is pulled back to expose balloon. Viewing portal: lateral. Working portal: posterior.

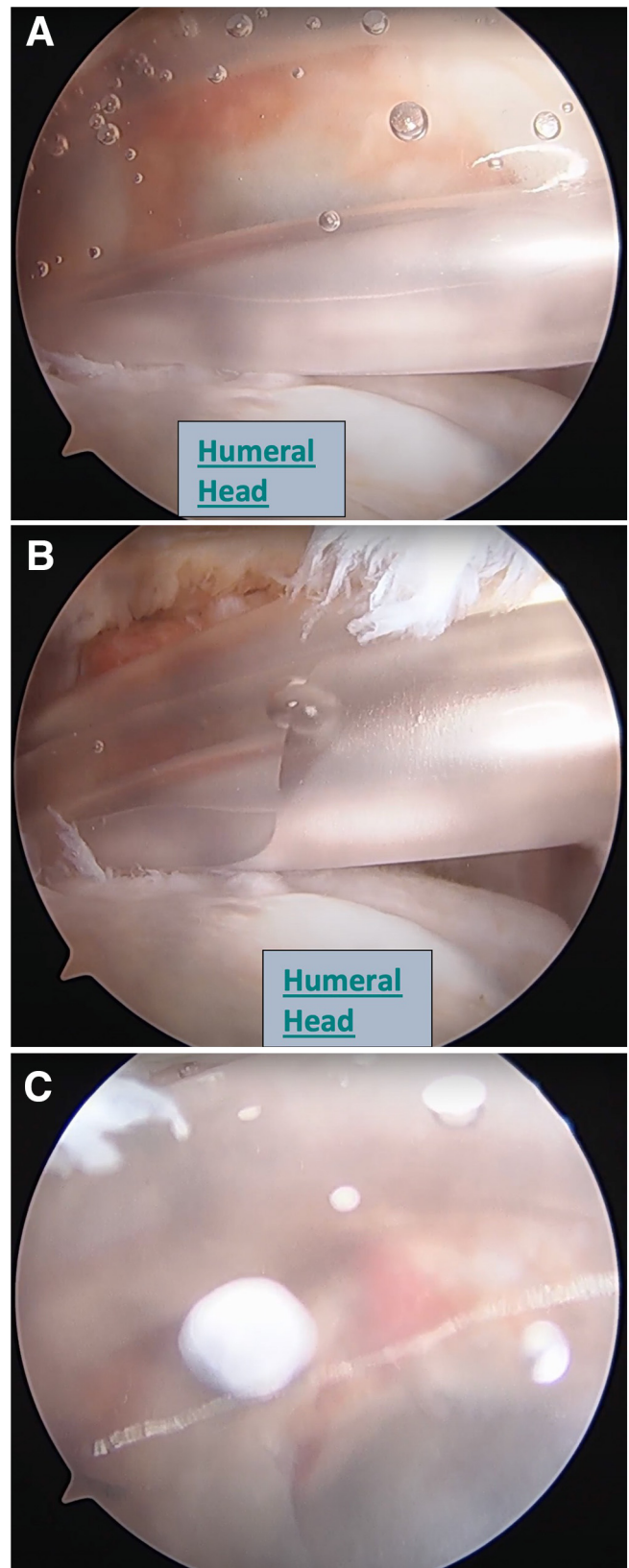


Fig 14. (A-C) Connect the extension tube to the delivery system, attaching the 50 cc syringe and then fully inflate the balloon. Progression of balloon inflation. Viewing portal: lateral. Working portal: posterior.

with the advantages of a smaller surgical footprint, a quicker recovery, and a less technically demanding procedure.⁴⁵ The purpose of the implantable biodegradable balloon is to restore the biomechanical integrity of the glenohumeral joint by depressing the humeral head, reducing subacromial friction during shoulder abduction, allowing for the restoration of force couples, and prevention of tear propagation.⁴⁵

An initial study of a cadaveric model has supported the balloon ability to do this.⁴⁰ A recent multicenter randomized controlled trial comparing partial rotator cuff repair with balloon spacer found 82% of balloon spacer patients compared to 81% in a partial repair group achieved the ASES minimally clinically important difference threshold.³² However, not all studies have proven the balloon spacer to be a superior treatment, Metcalfe et al. found superior functional outcomes for arthroscopic debridement compared to both debridement and the InSpace balloon device for irreparable tears.⁴⁶

For the elderly patient with more complex medical comorbidities, the balloon spacer is an attractive option. Furthermore, concerns for poor tendon healing capability or anchor use in osteopenic bone are mitigated with use of the minimally invasive balloon. Another postulated benefit is the decreased rigorous post-operative rehabilitation required; however, further study in this area is required to prove this claim. Short-term data have been favorable as Piekhaar et al. demonstrated both improvement in pain and functional scores along with a high satisfaction rate.⁴⁷ Range of motion and improvement of forward shoulder elevation by an average of 58° have also been reported.⁴⁸ With promising short-term results, long-term data are required to fully understand the effectiveness of the balloon spacer, along with implications of balloon resorption after 12 months.

Strict indications for the subacromial balloon spacer are key. Indications for the device are as follows: preserved passive motion, preserved active elevation of the arm up to 90°, an intact subscapularis, an intact teres minor, a massive irreparable rotator cuff tear, and no

shoulder osteoarthritis.^{46,49-54} Additionally, patients must have failed a trial of conservative management prior to subacromial balloon spacer placement. It is important to note on-label use for this device is intended for patients over the age of 65; however, shared decision making between surgeon and patient may be appropriate on an individual basis.

This technique does have limitations. First, the biodegradation of the implant raises concerns for local tissue reaction with the material in addition to the possibility of recurrent symptoms once reabsorbed. Second, cost of the implant is prohibitive and contradicts with the direction of medicine toward value-based care; however, there is potential uncaptured value given shorter operative times required. Fourth, a recent study demonstrated equivalent or superior results with arthroscopic debridement, raising additional concerns over the utility of the implant; however, balloon placement does provide possible advantage of preventing rapid progression of rotator cuff arthropathy. Longer-term data are required for a better understanding of the benefits and limitations of the subacromial balloon implantation (Table 2).

Conclusion

There has been a myriad of proposed treatment options for the management of massive irreparable rotator cuff tears. For indicated patients, the surgical technique for placement of subacromial balloon spacer implant described provides a minimally invasive solution to this difficult challenge, while still preserving treatment options if revision is required.

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Table 2. Advantage and Disadvantages

Advantages	Disadvantages
<ul style="list-style-type: none">• Minimally invasive, lower risk procedure• Shorter operative time• Early functional recovery and pain relief post procedure• Preservation of surgical treatment options in event of treatment failure• Minimal intraoperative complications	<ul style="list-style-type: none">• Potential temporary solution given balloon degradation• Does not permanently restore “normal” shoulder anatomy• Contraindicated in patients with allergy to implant material• Contraindicated in those with an active infection at or around implant site• Only three predetermined size options (small, medium, and large)

- associated with improved functional outcomes, low revisions, and complications rate at minimum one year follow-up. *Int Orthop* 2022;46:573-579.
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Time	Slide	Description	Note
0:00 to 0:09	Title Slide		
0:10 to 0:15	Author Disclosures	Author disclosures	
0:16 to 0:31	Equipment	List of equipment for subacromial balloon spacer placement. Prior to draping, perform a physical exam under anesthesia, testing patient's passive range of motion in forward elevation, external rotation, and abduction.	Exam under anesthesia can also be performed prior to diagnostic arthroscopy
0:32 to 0:39	Steps	Overview of surgical steps	
0:40 to 1:00	1. Diagnostic arthroscopy	A diagnostic arthroscopy is performed visualizing the rotator interval, superior labrum, glenoid surface, humeral head, rotator cuff insertion, axillary recess, and subscapular space. Viewing portal: posterior	
1:01 to 1:17	2. Assess subscapularis	Attention is paid to the quality of subscapularis, integrity of glenoid and humeral cartilage, as well as the irreparability of the rotator cuff. Viewing portal: posterior	In this case, the upper border of the subscapularis demonstrated a tear, and repair was performed.
1:18 to 1:29	3. Establish anterior portal	The anterior working portal is established in inside-out fashion utilizing 18-G spinal needle through rotator interval for localization. Viewing portal: posterior Working portal: anterior	Alternatively, a lateral subacromial portal can be used.
1:30 to 1:41	4. Debridement with shaver	Intra-articular debridement of labrum, capsule, and rotator cuff is performed with arthroscopic shaver, as needed, through the anterior/or alternative lateral portal. Viewing portal: posterior Working portal: anterior/lateral	Anterior or lateral portals can be used for debridement.
1:42 to 1:55	5. Establish lateral portal, minimal debridement	A lateral portal is established, and a light subacromial debridement is performed. Viewing portal: posterior Working portal: lateral	Debridement should be minimal as to allow sufficient visualization of subacromial space but as to not provide room for spacer to shift.
1:56 to 2:10	6. Switch camera to lateral portal, assess rotator cuff excursion.	Arthroscope is switched to lateral portal. From the posterior portal, rotator cuff excursion is assessed. Viewing portal: lateral Working portal: posterior	Use a switching stick.
2:11 to 2:19	7. Dilate posterior portal	Posterior portal is dilated to accommodate balloon sleeve insertion. Viewing portal: lateral Working portal: posterior	A mosquito hemostat is the author-preferred device for dilation.
2:20 to 2:36	8. Insert sleeve	Through the posterior portal the delivery system is introduced and placed 2 cm medial to glenoid rim overlying the rotator cuff tendon stump. Viewing portal: lateral Working portal: posterior	This is a variation from the standard insertion through the lateral portal, as we prefer to insert the balloon through a posterior portal. Balloon sizing was performed using a standard measuring technique.
2:37 to 2:48	9. Retract sleeve	Once in the appropriate position, gently pull back the protecting sleeve to expose the balloon. Next, the extension tube is connected to the delivery system. Viewing portal: lateral Working portal: posterior	It is essential to not adjust the delivery system position during retraction of the sleeve.

(continued)

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Time	Slide	Description	Note
2:49 to 3:08	10. Inflate balloon	The 50-cc syringe is attached, and the balloon is fully inflated with care to maintain the valve open, allowing for free flow of saline back into syringe, once the balloon is inflated within acceptable limits.	Once appropriate volume has been achieved, the delivery system can be removed, and the operative limb is taken through the full range of motion to verify balloon stability and position.
3:09 to 3:25	11. Closure and postoperative protocol	Viewing portal: lateral Working portal: posterior Portals closed in a standard fashion; a sterile dressing is applied. Sling Postoperative protocol: A sling is used for 4-6 weeks postoperatively followed by formal outpatient physical therapy.	