

True Transosseous Hybrid Rotator Cuff Repair

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Abstract: Transosseous repair has been used safely and effectively for primary and revision rotator cuff repair for decades; as a result, it is considered by many the historical gold standard of open repair techniques. Transosseous repair offers the advantage of excellent biology, double-row anatomic footprint reconstruction, and the ability to create multiple low-cost fixation points per surface area of tendon with high-strength suture, while avoiding anchor pullout, cyst formation, and imaging artifact. More recently, in arthroscopic applications, transosseous-equivalent anchor-based repairs have been introduced that have shown satisfactory clinical and biomechanical results; however, these attributes have been coupled with increased cost, nonbiologic burden to the healing interface of the tendon, and new catastrophic failure modes including tendon transection, anchor pullout, and bone voids. This article delineates a technique for arthroscopic true transosseous hybrid cuff repair that combines the use of anchors and transosseous techniques to maximize the benefits and minimize the detriments of both techniques. Level 1 (shoulder); level 2 (rotator cuff).

As with many thought paradigms, rotator cuff repair methods exhibit a recursive cyclical pattern beginning with open transosseous, then progressing to mini-open transosseous, arthroscopic anchor-based techniques, and finally a return to arthroscopic transosseous.¹⁻⁴ Fundamentally, the literature has never shown any difference in outcomes between techniques; however, it stands to reason that the arthroscopic ease of use and biomechanical strength of anchors have fostered their adoption, contributing to the use of anchors as the current preferred repair modality.

Initial healing of arthroscopic single-row anchor constructs had high failure rates, but clinical results have now become satisfactory as transosseous equivalent techniques have approached the double-row footprint reconstruction of transosseous techniques. In fact, the term “transosseous equivalent” references the

similarity of the construct geometry to true transosseous repairs, underscoring the desirability of the transosseous cerclage effect, which enables better footprint anatomy and compression, decreased shear force, and increased compression at the repair site and is associated with improved healing rates.^{5,6} Achieving transosseous repair geometry by means of multifocal hardware anchor points has come with biological and financial consequences. A new catastrophic failure mode of tendon transection has been introduced that is difficult to revise¹: bone voids and cysts may be created, and an increasing volume of nonbiologic material is introduced into the healing zone, impairing the revisability of the construct and limiting further technology options because of cost.

With regard to transosseous repairs, early evidence has shown that these repairs save cost and are equivalent regarding operating room (OR) time to anchor-based repairs.^{7,8} There is ample evidence that transosseous repairs are safe and effective,⁹⁻¹³ are likely noninferior to anchor-based repairs in terms of outcome, and have improved cost characteristics, making them ideal for value-based practice. A level 1 study has shown improved pain reduction in transosseous repairs relative to anchor constructs in the early healing phases.⁹

Biomechanically, the most important characteristic of strength is the number of sutures crossing the repair site, not the absolute number of fixation points or the strength of a single point.¹⁴ It therefore may be inferred that increased fixation point density per surface area of the tear should be maximized to allow load sharing,

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The author reports the following potential conflicts of interest or sources of funding: B.S. reports other from Tensor Surgical and has a patent, US 9,839,418 B2. Full ICMJE author disclosure forms are available for this article online, as [supplementary material](#).

Received March 17, 2019; accepted May 11, 2019.

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2212-6287/19373

<https://doi.org/10.1016/j.eats.2019.05.012>

Table 1. Advantages and Disadvantages of True Transosseous Hybrid Repair

Advantages	Disadvantages
Lower cost per fixation point, and no cost ceiling within a case	Requires specific device/capital expenses
Biomechanics likely noninferior to anchors; adds a knotless anchor for cortical augmentation outside healing zone	Requires knot tying
Preserves biologic healing surface with no inert material; high surface area compression and anatomic triple-row geometry	Learning curve for suture management
Easier revision without anchor voids or hardware; tendon transection/disruption is minimized	Still uses an anchor laterally, which could potentially overcompress or strangulate tendon
Synergizes with all existing knotless anchors while decreasing the number required per case	Many third-party payer scenarios do not create incentives to reward the practice of value-based medicine by reducing hardware cost

increase strength, and avoid catastrophic failure at the musculoskeletal junction. Unlimited transosseous fixation points within a case, with no cost ceiling afforded by a reusable device, allows the surgeon to pragmatically achieve this goal. Further, it may be more desirable to match rather than exceed the modulus of composite tissues in a poorly healing rotator cuff.¹⁵ Anchor-based constructs have introduced a new failure mode, causing truncation of the tendon, possibly as a result of modulus mismatch and stress risers at the medial anchor, tissue strangulation, or impaired vascularity. In contradistinction, transosseous repairs tend to respect vascularity in the repaired tendon and leave more tendon remnant available for revision.¹⁻³

The most common concerns regarding arthroscopic transosseous repairs relate to the learning curve, time in the OR, bone quality, tensioning, and knot tying. The technique described herein attempts to address these concerns by using a hybrid technique that allows true transosseous, double-row type, anatomic footprint reconstruction with good shear reduction using geometry similar to the transosseous-equivalent repair, while achieving a 5-fixation-point repair with only 1 anchor. The healing surface is biologically intact, with no inert material present, and the transosseous repair can function as a standalone repair if necessary. If backup fixation is desired because of soft bone or other concern, the addition of 1 anchor allows independent

backup fixation with the cortical strength of commercially available anchors with reduced number and cost. This addition also allows independent additional tensioning of the repair and additional compression sutures over the repair site, using a linked technique with self-reinforcing geometry. The final construct is a triple-row, multipoint construct that maximizes biology, biomechanics, cost reduction, and simplicity.

Technique

Advantages and disadvantages of the technique are listed in [Table 1](#), and pearls and pitfalls in [Table 2](#).

The patient is placed in the beach chair position with a mechanical arm holder or lateral decubitus depending on surgeon preference. The standard arthroscopic posterior portal is created, and diagnostic arthroscopy is performed. The primary working portal for this technique is a low anterolateral portal that allows access to approximately the anterior 60% of the footprint. A relevant pearl with regard to portal placement is to create a slightly lower portal than required for anchor techniques. A spinal needle is placed just across the greater tuberosity, and the anterolateral portal is made ~8 mm inferior from this position. This allows the surgeon to obtain purchase in the stronger bone of the humerus while minimizing the resistance of the deltoid muscle ([Video](#)).

Table 2. Pearls and Pitfalls of True Transosseous Hybrid Repair

Pearls	Pitfalls
Make the anterolateral tunnel portal low, 6 to 8 mm inferior to the greater tuberosity, so that the tunnel gains purchase in the strongest bone of the tuberosity.	A higher, anchor-type portal requires a different trajectory; a high portal will make it difficult to rotate low on the tuberosity for the lateral fixation point.
Use the awl by hand to assess bone quality; if a mallet is required, the bone is deemed satisfactory. If the awl is pushed in by hand, proceed with caution.	Bone cysts or soft bone can compromise fixation of anchors or tunnels.
Use meticulous suture management techniques: static fixation of the inferior limbs and exteriorization of inferior sutures outside of cannula is recommended. Also, use at least 3 different colors to aid in management, and keep an external topographic representation of the internal state of sutures.	Sutures in tunnels behave slightly differently than anchors unless they are secured inferiorly. This could lead to unloading a suture. If a suture unloads, another suture can be used to replace them in the tunnel.
Adopt technique slowly with small tears or simple suture pattern or use around or between anchors until comfortable.	Suture management can be confusing during the learning curve. Be prepared as necessary to convert to technique of choice.

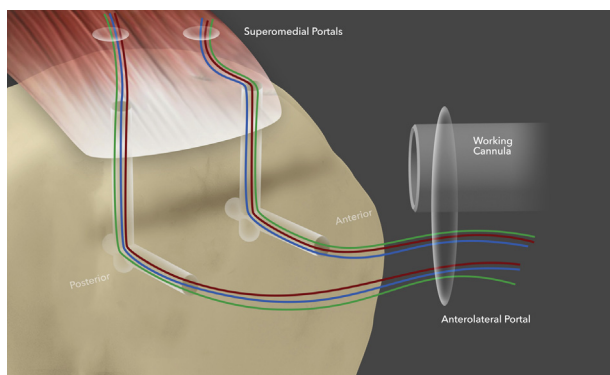


Fig 1. Posterolateral view of right shoulder in schematic showing triplets (3 sutures of different colors) in place in the anterior and posterior tunnel. The superior limbs are passed through the tendon by surgeon preference and managed through the superomedial portals, whereas the inferior limbs are outside the working cannula but inside the anterolateral portal.

After standard cuff mobilization and tear pattern recognition, an appropriate repair construct for the tear pattern is selected, as detailed elsewhere.⁴ Briefly, for small or partial tears, a single tunnel is used with arthroscopic Mason-Allen sutures bounding the anterior and posterior edges. For single tendon supraspinatus tears, a 2-tunnel hybrid is usually selected. For massive tears, a 3-tunnel double box configuration is used, with or without lateral row anchors. Herein the 2-tunnel repair construct is used.

The medial 2.9-mm awl is introduced through the standard superomedial portal in a similar fashion to an anchor awl, creating a medial tunnel just adjacent to the articular margin. If the awl can be pushed into the bone by hand, then augmentation with an anchor or a hybrid technique may be considered. If the awl requires

malleting, a pure transosseous technique may be used. The footprint fixation points may be planned and placed all at 1 time in this step. The TransOs Tunneling device (Tensor Surgical, Chattanooga, TN) is then introduced in an inverted fashion through the portal, piercing the subdeltoid fascia with the tip of the instrument inferiorly, then rotating 180° into the subacromial space to find the previously placed tunnel. The tip is then inferiorly translated into the tunnel, and the handle is inferiorly rotated to achieve low purchase on the humerus and maximize the length of the bone bridge, usually between 15 and 20 mm. The shuttling suture is passed, and a triplet of 3 sutures of different colors are placed in the tunnel. The second tunnel is created in the same fashion, and another triplet is placed. The inferior limbs are secured to the surgical drapes on the arm in static mode to prevent sliding of the suture and maintain an external topographic representation of the internal suture position for meticulous suture management. The sutures are then passed through the tendon in the manner selected by the surgeon to best restore anatomy. These are passed as simple rather than mattress sutures, so this step tends to save time (Fig 1).

To perform the X box repair, I begin with the superior limb of the “box.” Two sutures from different tunnels are selected. My current preference is to use the same-colored suture. These sutures are brought out of the cannula and tied together using multiple surgeon’s knots. The knot is then brought back in the joint by pulling on the inferior limbs. The limbs can be pulled to bring the knot into the desired location to maximize footprint compression (Fig 2). I then select the sutures that will be tied as simple transosseous sutures in each tunnel and tie them by retrieving the inferior and superior limbs out of the cannula, then using a sliding locking knot. This step will usually reduce the cuff anatomically, and the rest of the steps are managing

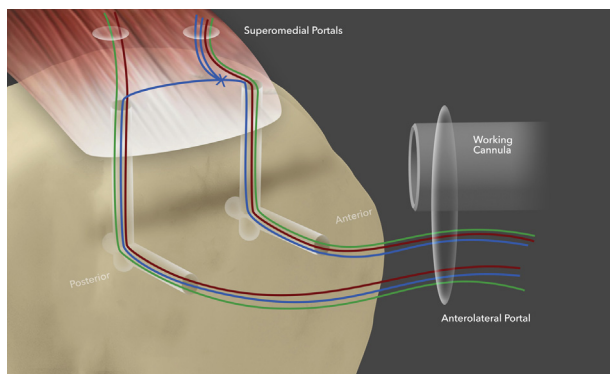


Fig 2. Posterolateral view of right shoulder showing creation of the superior limb of the mattress-suture spanning tunnels. The blue sutures from the anterior and posterior tunnel have been tied together outside the cannula, and the inferior limbs have been pulled to bring the knot into a desirable position on top of the rotator cuff tendon.

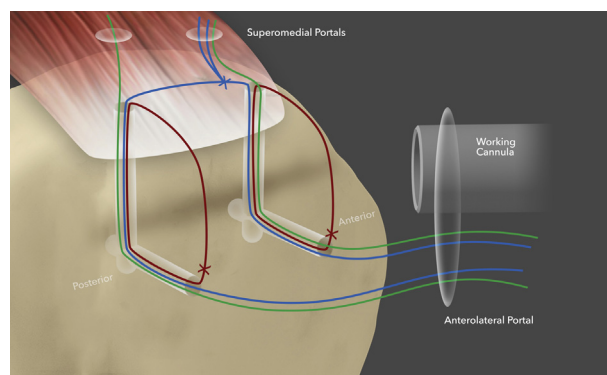


Fig 3. Posterolateral view of right shoulder showing creation of the vertical limbs of the box configuration. The red sutures have been selected to be the vertical limbs. Each red suture is tied as a simple suture, with the post low and lateral using a sliding, locking knot.

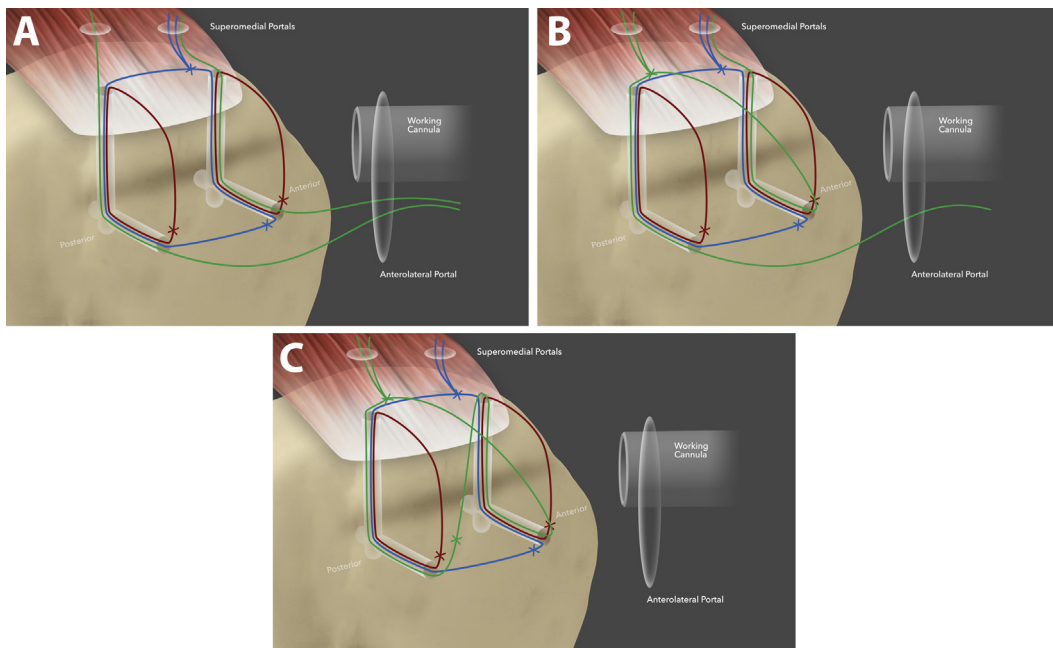


Fig 4. (A) Posterolateral view of right shoulder showing tying of the inferior limb of the blue mattress suture spanning the anterior and posterior tunnel. This is performed with a nonsliding knot. The blue sutures now complete the superior and inferior limbs of the box, whereas the red sutures complete the vertical limbs of the box configuration. (B) Posterolateral view of right shoulder showing the first step in tying the crossing stitch in the X box suture configuration. The green sutures are selected for this limb. The superior posterior-medial green suture is retrieved, with the antero-inferior-lateral green limb outside the cannula, and tied together with a surgeon's knot. The posterior inferior-lateral green limb is then used to pull the knot into a desirable position on top of the rotator cuff tendon. Slack is taken out by pulling gently on the anterior superomedial green limb. (C) Posterolateral view of right shoulder showing the completion of the crossing limb of the X box configuration. The posterior inferolateral suture is retrieved and used as the post. The anterior superomedial green suture is retrieved through the cannula and tied to the post with a nonsliding knot.

sutures to accomplish crossing limbs (Fig 3). For those inexperienced in transosseous repairs, it is beneficial to tie next the inferior limbs of the mattress suture that was previously placed, using a nonsliding knot (Fig 4A).

Now only the crossing stitch remains. The superior suture in the posterior tunnel is retrieved out of the cannula, and the inferior limb of the anterior tunnel is retrieved out of the same cannula. These are secured

together as previously described. The inferior limb of the posterior tunnel is used to bring the knot back into the repair site, and the limbs are then retrieved out of the superomedial portal for storage (Fig 4B). The inferior limb of the posterior tunnel and the superior limb

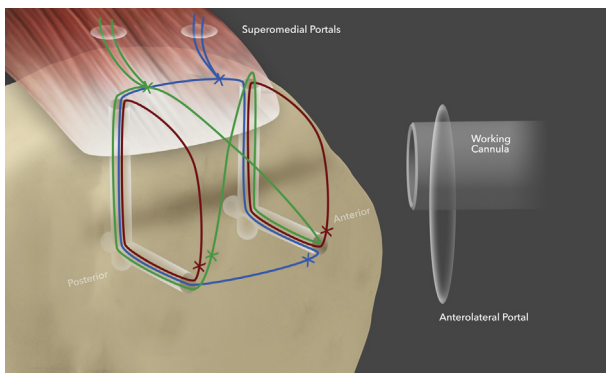


Fig 5. Posterolateral view of right shoulder showing the completion of the X box configuration. The superomedial tails have been left long. This is a stand-alone transosseous repair in an X box suture configuration.

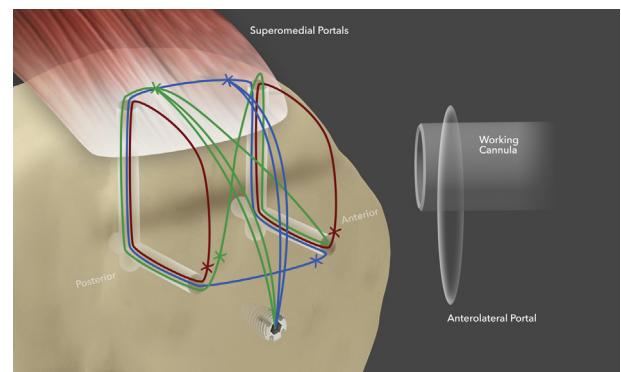


Fig 6. Posterolateral view of right shoulder showing the completion of the true transosseous hybrid repair. The superomedial tails are retrieved and placed laterally below the horizontal limb of the X box using the knotless anchor of choice. This step allows for retensioning of the repair, cortical augmentation of the construct, and a triple-row effect with self-reinforcing properties.

of the anterior tunnel can then be retrieved and tied arthroscopically with a nonsliding knot (Fig 4C).

At this phase, a fully transosseous repair has been created with 4 fixation points (Fig 5). It could stand alone if deemed to be sufficient, but the addition of a knotless anchor will allow additional tensioning and independent backup fixation with cortical anchor support. All of the previously placed superior sutures are brought out of the cannula and secured with a knotless anchor below the horizontal limb of the X box, creating a self-reinforcing construct that creates more surface compression over the repair site (Fig 6).

Rehabilitation

The patient wears a sling for 6 weeks. Elbow range of motion and pendulums are allowed. Progressive active motion is implemented at 6 weeks, followed by strengthening at 12 weeks. If there is concern over stiffness or repair quality is excellent, passive self-directed external rotation to 0° and table slides may be implemented for passive motion at 2 to 4 weeks.

Discussion

The arthroscopic true transosseous hybrid repair updates a tried-and-true transosseous technique into the arthroscopic era, while also respecting principles of value-based practice and addressing concerns over bone quality, OR time, and fixation strength by synergizing with pre-existing technology. The limitation of this technique is a learning curve in suture management, developing confidence in assessing bone quality, and knot tying. There is a theoretical risk of suture cut through soft bone that may be mitigated by the addition of an anchor or hybrid construct. The risk of a placing small-diameter tunnel in bone is likely low and does not obviate future placement of anchors in the same location. Similarly, suture cut-through of the bone may be less detrimental than anchor pullout in severely osteoporotic clinical situations, bone voids, and revisions.¹⁶ This technique requires introduction of a reusable tunneling device but does not rely on tunnel-specific hardware fixation other than commercially available anchors, which may be used synergistically.

Because of ceiling effects in the study of evidence-based medicine, the most achievable findings of new products or techniques will likely be equivalence and noninferiority.¹⁷ In this setting, value may become a more important metric to evaluate techniques in the future. There is evidence to support decreased early pain, improved vascularity, satisfactory outcomes, similar OR time, and lower cost of arthroscopic transosseous repairs.^{1,9-12} The true transosseous hybrid construct allows for a high fixation point per surface area repair, excellent access to biologically active

marrow elements, no inert material in the footprint to consider in the revision setting, and redundant high-strength fixation. Moreover, cost reproducibility may be achieved regardless of tear size in this value-based era of surgery.

References

1. Steinitz A, Buxbaumer P, Hackly M, Buess E. Arthroscopic anchorless transosseous rotator cuff repair using the X-box technique. *Arthrosc Tech* 2019;8:e175-e181.
2. Castagna A, Gumina S, Garofalo R, et al. Technique for a novel arthroscopic transosseous rotator cuff repair. *Tech Shoulder Elbow Surg* 2019;20:12-18.
3. Murphy M, Tashjian R, Burks R. Rotator cuff repair technique with transosseous knotless anchor system. *Arthrosc Tech* 2018;7:e927-e937.
4. Sanders B. Novel reusable transosseous tunnel based soft tissue repair techniques about the shoulder: a rational, value-based approach. *MOJ Ortho Rheumatol* 2016;5:00164.
5. Kummer FJ, Hahn M, Day M, Muslin RJ, Jazrawi LM. Laboratory comparison of a new arthroscopic transosseous rotator cuff repair technique to a double row transosseous equivalent repair using anchors. *Bull Hosp Joint Dis* 2013;71:128-131.
6. Tashjian RZ, Hoy TW, Helgeson JR, Guss AD, Hennigen HB, Burks RT. Biomechanical comparison of transosseous knotless rotator cuff repair versus transosseous equivalent repair: Half the anchors with equivalent biomechanics? *Arthroscopy* 2017;34:58-63.
7. Tashjian RZ, Belisle J, Baran S, et al. Factors influencing direct clinical costs of outpatient arthroscopic rotator cuff repair surgery. *J Shoulder Elbow Surg* 2018;27:237-241.
8. Black EM, Austin LS, Narzikul A, et al. Comparison of implant cost and surgical time in arthroscopic transosseous and transosseous equivalent rotator cuff repair. *J Shoulder Elbow Surg* 2016;25:1449-1456.
9. Randelli P, Stoppani CA, Zaolino C, Menon A, Randelli F, Cabitza P. Advantages of arthroscopic rotator cuff repair with a transosseous suture technique: a prospective randomized controlled trial. *Am J Sports Med* 2017;45:2000-2009.
10. Kuroda S. Advantages of arthroscopic transosseous suture repair of the rotator cuff without the use of anchors. *Clin Orthop Relat Res* 2013;471:3514-3522.
11. Flanagan BA, Garofalo R, Lo EY, et al. Midterm clinical outcomes following arthroscopic transosseous rotator cuff repair. *Int J Shoulder Surg* 2016;10:3-9.
12. Srikumaran U, Hannan C, Chappidi M, et al. Arthroscopic transosseous anchorless vs anchored rotator cuff repair: a comparison of clinical and patient reported outcomes, structural integrity, and costs. *Arthroscopy* 2016;32:e22-e23.
13. Plachel F, Traweger A, Vasvary I, et al. Long-term results after arthroscopic rotator cuff repair. *J Shoulder Elbow Surg* 2019;28:706-714.
14. Johst PW, Khair MM, Chen DX, Wright TM, Kelly AM, Rodeo SA. Suture number determines strength of rotator cuff repair. *J Bone Joint Surg Am* 2012;94:e100.
15. Kilcoyne KG, Guillaume SG, Hannan CV, Langdale ER, Belkoff SM, Srikumaran U. Anchored transosseous

- equivalent versus anchoreess transosseous rotator cuff repair. A biomechanical analysis in cadaver model. *Am J Sports Med* 2017;45:2364-2371.
16. Sanders B, Spencer E. Arthroscopic repair of severe rotator cuff tears. In: McMahon PJ, ed. *Rotator Cuff Injuries: A Clinical Casebook*. Berlin: Springer, 2018;137-152.
17. Stengel D. The changing landscape of product development and randomized trials. *J Bone Joint Surg Am* 2012;94:85-91 (suppl 1).