Double-row Rotator Cuff Repair Strategies

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Abstract: Repair of the torn rotator cuff has evolved considerably over the past several decades. Traditionally, open surgical repairs were used to achieve tendon-to-bone fixation. As arthroscopic skill and instrumentation improved, a similar evolution of arthroscopic repair techniques has occurred. In many respects, arthroscopic repair strategies have evolved to replicate and improve upon the biomechanical properties of traditional transosseous rotator cuff repair. This review discusses the rationale responsible for this evolution, current technical strategies, and indications for different types of arthroscopic rotator cuff repair constructs.

Key Words: rotator cuff repair, double-row repair, single-row repair, rotator cuff repair augmentation, rotator cuff repair strategies

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Rotator cuff tears are common and can be responsible for considerable functional loss in some patients.[1] Although nonoperative management is frequently the preferred method of initial treatment, the rotator cuff tear size, patient age, and activity level may also influence surgical decision making.[2–6] Failure of nonoperative management or specific tear characteristics may indicate the need for surgical intervention.

Surgical repair of the torn rotator cuff has evolved dramatically over the past 2 decades. Initially repaired through large open surgical approaches, rotator cuff repair strategies have transitioned to mini-open, and now arthroscopic techniques. Similarly, arthroscopic repair techniques have also progressed. Traditionally, arthroscopic rotator cuff repairs were completed using a single medial row of anchors. As skill with arthroscopic techniques improved, several generations of double-row repair constructs have been described in an effort to maximize repair strength and surface area for healing.[7–9]

The data to support and indications for the use of these new repair techniques remain controversial.[10–12] Current evidence suggests that the biomechanical properties and footprint restoration of double row, and more recently the linked, interconnected, self-reinforcing constructs are superior to single-row techniques.[9,13,14] Reported clinical outcomes, however, have not shown dramatic differences between repair techniques to date.[11,12] To this end, we describe the rationale, current indications, and technical strategies for different types of rotator cuff repair constructs.

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ROTATOR CUFF REPAIR STRATEGIES

Insertional Anatomy and Tendon-to-Bone Healing

The rotator cuff tendon attaches to the greater tuberosity through a specialized fibrocartilagenous tissue known as the enthesis. This structure encompasses a 4-zone transition including tendon, fibrocartilage, mineralized fibrocartilage, and bone.[15] This transition is believed to minimize stress on the tendon-bone interface, thereby enabling it to withstand physiological loading. Anatomic studies suggest the mean insertional area of the supraspinatus, infraspinatus, and teres minor on the greater tuberosity is approximately 6.24 cm^2 and the minimum medial-to-lateral insertional footprint is 14.7 mm.[16] These dimensions represent the maximal surface area available for load transfer with complete footprint repair.

This rotator cuff insertional enthesis is not recreated after rotator cuff repair.[15] Rather, histologic studies indicate that rotator cuff repair tissue is much less organized and is comprised primarily of fibrovascular scar tissue interposed between the greater tuberosity and reapproximated tendon.[17] To this end, Oguma et al[18] reported that bone forms within this tissue and eventually results in collagen continuity between tendon and bone. The authors also showed that the magnitude of bony ingrowth is related to the surface area of repair. Considering the biomechanical properties of this fibrovascular repair tissue are inferior to the native enthesis, maximizing the surface area of repair would seem to be important especially in larger tears.

These findings therefore provide the basic rationale in support of the recently described anatomic footprint repair techniques. Considering physiological loading of the supraspinatus and infraspinatus tendons may be in excess of 175 and 900 N, respectively, it is intuitive to maximize the surface area of repair in an effort to optimize rotator cuff healing characteristics.[19] These tensile forces, if applied over a smaller surface area, may exceed the failure load of the repair construct or healing tissue and result in failure.

Gerber et al[20] described the ideal rotator cuff repair as providing high fixation strength that minimizes gap formation during biological healing. Traditional open transosseous rotator cuff repairs largely satisfied these criteria. They were capable of providing robust fixation and both restoring and compressing the torn rotator cuff against its greater tuberosity footprint.[21,22] For this reason, transosseous repairs have historically been considered by some surgeons as the optimal biomechanical technique for rotator cuff repair.[21,22]

Tear Pattern Identification, Margin Convergence, and Interval Slides

It is established that excessive tension on a rotator cuff repair predisposes it to failure.[23] Therefore, it is not only important to maximize repair construct strength but also minimize the tension on repaired tissue. Improper mobilization and nonanatomic repair can lead to increased tension on the repaired margin, ultimately leading to failure. Therefore, tear patterns should be defined to determine optimal repair configuration.[4,5,23,24] In some cases side-to-side repair, margin

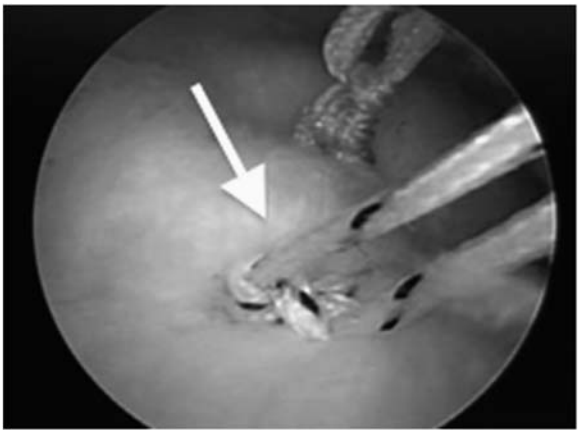

FIGURE 1. Arthroscopic image of the right shoulder viewing from a posterolateral portal demonstrating a single-row rotator cuff repair. In the depicted case mattress stitches were used (arrow).

convergence, and interval release techniques as described by Burkhart et al[25–27] can be used to minimize repair tension regardless of the repair configuration used.

Single Row

Open rotator cuff repair techniques were complicated by deltoid muscle avulsions and cosmetic concerns.[28] These drawbacks partially drove the development of mini-open and later, arthroscopic rotator cuff repair techniques. Because arthroscopic experience was minimal and only limited instrumentation was available, arthroscopic rotator cuff repairs were initially performed using a single row of suture anchors (Fig. 1).[7] In contrast to transosseous repairs, this construct was not capable of maximizing the surface area for healing and did not provide direct compression of the tendon-bone interface.[14,22] Particularly in larger rotator cuff tears, this resulted in suboptimal results.

Numerous biomechanical studies indicate that single-row repair techniques are capable of withstanding approximately 275 N of force.[20] Considering that the rotator cuff is capable of considerably greater physiological load, single-row repair characteristics may be sufficient when surrounding tissue is present to share these stresses.[29] To this end, single-row repair techniques may be adequate for the treatment of partial or small full-thickness rotator cuff tears.

Nonlinked Double Row

Arthroscopic implants and surgical technique quickly evolved in an effort to improve upon the biomechanical properties of arthroscopic single-row rotator cuff repairs. The introduction of stronger suture and more secure anchors provided increasingly reliable tendon-to-bone fixation such that the weak link in arthroscopic rotator cuff repair was transferred to the tendon itself. In addition, the use of a second, more lateral, row of anchors was also described.[30]

These second-generation rotator cuff repair techniques used 2 linear rows of suture anchors that were intended to maximize the surface area for rotator cuff healing and improve fixation strength.[31] In vitro biomechanical studies indicate the double-row rotator cuff repair decreased gap formation under load as compared with single-row repairs. Its ultimate failure load also increased to approximately 340 N.[9,20] Others reported that its capacity to withstand cyclic loading was also superior to single-row constructs.[9] To this end, Kim et al[14] found the ultimate load to failure increased 48% and stiffness increased 42% with the addition of a second row of anchors.

Although double-row repair improved fixation strength compared with open transosseous techniques,[23,32,33] the footprint restoration characteristics of nonlinked double-row repairs remained inferior to those of transosseous techniques.[34] With nonlinked double-row repair each anchor represents an isolated point of fixation. Therefore, individual anchors are subject to focal overload secondary to the vector of tensile forces created by glenohumeral rotation. Under these circumstances these isolated anchors are subject to failure. Although a systematic review has demonstrated improved structural healing with double-row compared with single-row techniques,[35] 3 prospective clinical trials have failed to reveal a difference in functional outcome between the 2 constructs at short-term follow-up.[36–38]

Suture-bridging Double Row

With the limitations of nonlinked double-row repair constructs in mind, third-generation rotator cuff repair techniques were developed in an effort to replicate and improve upon the footprint characteristics of transosseous rotator cuff repairs. These anchor-based suture-bridging constructs are characterized by sutures that link and interconnect the medial and lateral anchor rows (Fig. 2). This maximizes footprint apposition for healing and acts to provide compression of the rotator cuff to the greater tuberosity.[22]

It is also suggested that this repair construct becomes self-reinforcing as greater loads are applied.[39,40] With similarity to a tension band mechanism, greater tensile loads result in increasing tendon-bone compression applied by the bridging

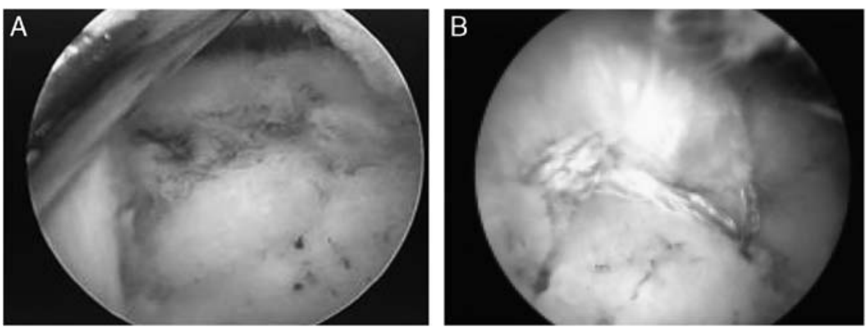

FIGURE 2. Arthroscopic image of the right shoulder viewing from a posterolateral portal demonstrating a "transosseous equivalent" linked, intereconnected double-row rotator cuff repair. Rotator cuff tear is visualized (A) and ultimately repaired (B). Sutures are seen to "bridge" the medial and lateral anchor rows to increase contact surface area.

sutures. Moreover, loading may contribute to "wedging" of the tendon between suture limbs and bone.[39] These mechanisms consequently result in greater friction between the surfaces, thereby resisting tensile forces. This has resulted in biomechanical and footprint restoration characteristics superior to nonlinked double-row rotator cuff repairs.[13,41]

Biomechanical analysis reveals these suture-bridging constructs are capable of enduring tensile loads of 443 N and provide improved compression of the healing footprint.[41] Park et al[41–43] directly compared suture-bridging and nonlinked double-row repair constructs. The authors reported that the suture-bridging repair resulted in significantly improved failure loads and tendon-to-bone compression. In contrast to nonlinked double-row configurations, anchor interconnection improves load sharing thereby minimizing tension mismatch on any given anchor with glenohumeral motion.

Despite these biomechanical data, available clinical reports have yet to clearly define superiority of either technique.[44] Limited data suggest outcomes after repair of a large (>3 cm) tear using a double-row construct may be superior to single-row repairs,[45] however, equivalent results have been reported by many others.[46–48] Because these reports use various double and single-row repair techniques and include heterogeneous cohorts of rotator cuff tears, conclusions are difficult to interpret. Therefore linked, interconnected, and self-reinforcing double-row repairs are likely not critical for certain partial thickness or small full-thickness rotator cuff tears. They may, however, provide an added measure of security when challenging tear characteristics or tissue quality is encountered. To this end, early clinical reports on the use of suture-bridging double-row repair techniques have been encouraging even in the setting of massive rotator cuff tears.[49,50] Conversely, advanced repair techniques may facilitate more reliable fixation when there is poor quality tissue or when there is insufficient tendon mobility to perform a double-row repair (ie, a double-row repair would result in excessive tension).

SUTURE REINFORCEMENT

Disuse atrophy, fibrosis, and fatty infiltration occur after massive rotator cuff tears with time.[51] This can result in less compliant tissue and consequently, increased repair tension when mobilized to the greater tuberosity. This progression can also result in suboptimal tissue quality, leading to sutures pulling though the incompetent tendon. In these circumstances specialized suture or suture configuration can improve fixation strength.

The modified Mason-Allen stitch is frequently used during open rotator cuff repair because of its reported increased tissue security.[8,20] Because it is difficult to place arthroscopically, the massive cuff stitch ("mac" stitch) was developed.[52,53] This stitch is capable of withstanding failure loads comparable with the modified Mason-Allen stitch by interlocking simple and horizontal suture limbs, thereby providing a rip-stop effect. This stitch effectively distributes forces over a larger surface area and is significantly more secure than simple or horizontal suture techniques.[52,54] In addition, this suture configuration has improved loop security compared with the Mason-Allen stitch, which will cinch upon itself under a tensile load.

Suture placement location within the tendon is also reported to exhibit biomechanical implications. Histologic evidence suggests that the mean diameter and density of collagen fibers within the rotator cuff tendon becomes more robust medially near the musculotendinous junction. This results in superior pullout resistance and increased stiffness of medially placed sutures and may partially explain the higher load to failure described with simple double-row repair constructs.[55] The increased medial anchor stiffness and lack of anchor interconnection may also contribute to the anchor overload phenomenon reported with simple double-row repair configurations.

Conceptually similar to a scalpel blade, fine sutures are more likely to cut through tissue when compared those with a larger surface area. For this reason suture tapes have been introduced in an effort to provide an additional measure of surface area distribution. Bisson and Manohar recently reinforced this concept in a cadaveric model.[8] The authors report that suture tape was capable of withstanding a significantly greater ultimate tensile load when compared with the standard suture using a simple suture configuration. Each specimen failed as a result of longitudinal tendon disruption at the site of suture penetration, indicating that tissue fixation is the weakest link within repair systems. Therefore, greater suture surface area may be beneficial in cases where tissue quality is not optimal.

Suprascapular Nerve Management

It has been postulated that retraction of large rotator cuff tears can result in entrapment of the suprascapular nerve, leading to pain and functional loss. For that reason, some authors have recommended routine release of the transverse scapular ligament to minimize potential suprascapular nerve dysfunction. There is evidence to suggest, however, that simply repairing the rotator cuff is capable of relieving nerve entrapment.[56] Therefore, in the absence of a compressive lesion, we believe that routine release of the transverse scapular ligament is unnecessary. It is also our clinical experience that patients routinely do well after arthroscopic rotator cuff repair despite not routinely performing a suprascapular nerve release.

Our indications for suprascapular nerve decompression are patients with sustained weakness after suffering a direct blow to the supraspinatus fossa, or those who demonstrate electromyographic evidence of persistent suprascapular neuropathy despite rotator cuff repair. In cases of suprascapular nerve compression secondary to a spinoglenoid cyst, it is our experience that performing a suprascapular nerve release is often not necessary, and that decompression of the cyst through a sublabral approach, followed by labral repair, is sufficient.

Augmented Rotator Cuff Repair

Repair of retracted rotator cuff tears can result in high tensile loads on repair constructs. Poor tissue quality resulting from chronically torn or previously repaired tissue can also predispose repairs to failure. Under these circumstances graft

FIGURE 3. Cadaveric example of a double-row rotator cuff repair using graft augmentation (asterisk). The graft has been incorporated into a linked-bridging double-row rotator cuff repair.

augmentation of repaired tissue is theoretically beneficial to structurally reinforce the tendon-to-bone repair (Fig. 3). Clinical outcome data are currently limited regarding the augmentation of rotator cuff tears.

Existing literature indicates that outcomes are variable based on graft type and its method of utilization. To this end, graft augmentation of repaired tissue seems to be more successful than graft interposition when the rotator cuff cannot be reapproximated to the greater tuberosity. One recent series described rotator cuff repair augmentation in 10 patients with massive rotator cuff tears. The authors report statistically significant improvement in mean Constant score, pain score, and range of motion.[57] By contrast, Iannotti et al[58] reported significantly lower mean postoperative functional scores after use of porcine small intestine submucosa for augmentation of large rotator cuff tears. Others have recommended against use as an interposition graft due to poor results.[57,59] Although larger and more robust prospective studies are necessary to determine the true efficacy of biological grafts, they seem to be a reasonable consideration for augmentation purposes. Although Bond et al[60] have reported some encouraging results by bridging large defects with acellular human dermal allograft, most current literature, does not support their use as an interposition graft.[57,59]

Platelet-rich Plamsa

In general, the biological environment for healing is enhanced by strong biomechanical fixation. Platelet-rich plasma (PRP) has recently been proposed as a means of enhancing rotator cuff healing. This autologous product is characterized by an increased concentration of platelets compared with whole blood. Platelet-rich preparations have been highly valued due to their ability to retain their α and dense granules and to deliver a balanced preparation of healing factors. When activated in vivo or in vitro, various growth factors or cytokines are released including platelet-derived growth factors, transforming growth factor β, insulin-like growth factor, basic fibroblast growth factor, and vascular endothelial growth factor. By concentrating platelets, the concentration of these growth factors increases linearly. Despite the theoretical advantages of adding such growth factors to the healing environment, there is currently no firm clinical evidence that PRP increases rotator cuff healing after arthroscopic rotator cuff repair.[61,62] However, it should be noted that not all PRP is the same in preparation and the majority of the current studies are limited to small and medium-sized rotator cuff tears. Our current practice is to use PRP (ACP; Arthrex Inc., Naples, FL) for massive tears and revision cases in which there is a higher risk of tear recurrence.

CONCLUSIONS

Rotator cuff repair techniques have evolved considerably over the past several decades. Outcomes reported after arthroscopic rotator cuff repair currently seem to be similar to those reported after open procedures. Arthroscopic single-row repair constructs are best used for repair of partial thickness or small full-thickness tears. When more challenging biology is encountered, advanced double-row repair constructs may be more advantageous. Continued research will be necessary to determine additional methods to improve the biology of rotator cuff healing.

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