No prosthetic management of massive and irreparable rotator cuff tears

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Abstract

A massive rotator cuff tear is not necessarily irreparable. Number of tendons involved, muscle-tendon unit quality, and decreased acromionhumeral distance (AHD) are as important as tear size in determining reparability of lesion. Massive and irreparable rotator cuff tears cannot be anatomically repaired to the bone and are a common source of pain and disability even in middle-aged patients. In these patients when conservative management has failed, it is possible to perform different surgical techniques. A functional repair can help to restore the horizontal force couple of the cuff on the humeral head and to increase the AHD. Debridement of irreparable tears and biceps tenotomy or tenodesis can have a role in low functional demand patients but results deteriorate over time. Recently, several commercially available tissue-engineered biological and synthetic scaffolds have been developed to augment rotator cuff repairs. The aim is to provide a mechanical improvement in case of poor quality tissue at time zero and give a support to have a better cuff healing. In selected cases, the scaffold can be used also to bridge tendon defect. Patients who not have pseudoparalysis, cuff tear arthropathy and with intact deltoid function can benefit from tendon transfers with satisfactory outcomes. These different procedures should be chosen for each patient with selected criteria and after a satisfactory explanation about the really possible expectation after surgery.

Keywords

Rotator cuff tears, tendon transfers, scaffold, massive, irreparable, functional repair, inspace

Introduction

Massive (i.e. where one tendon is largely or completely gone or more than one tendon is torn) and irreparable rotator cuff tears (RCT) are a common source of pain and disability in the shoulder even in middle-aged patients. A RCT is present in 20.7% of the general population, and the prevalence increases with age.¹

The incidence of patients with symptoms related to the shoulder affected by a cuff lesion is 36% in the general population, whereas 16.9% of people without symptoms also had RCT. Rotator cuff tears in the general population occur most common in elderly male patients, the dominant arm, patients engaged in heavy labour, or patients having a history of trauma.² When conservative treatment fails, operative treatment is an option to improve the patient's condition.^{3,4}

Operative repair of small- and medium-size RCT consistently yields good and satisfactory outcomes in a high percentage of patients.^{5–7} By contrast, the surgical treatment of large or massive RCT can be technically difficult, and the results are less reliable. The size of tendon tear and fatty infiltration of the muscles have been correlated with clinical outcomes.^{8–10} In particular, arthroscopic repair of large and massive RCTs can

lead to excellent pain relief and improvement in the ability to perform activities of daily living at short-term follow-up, despite a high rate of recurrent tears. However, after 2 years of follow-up, clinical outcomes appear to deteriorate.^{11,12} Although most RCTs and a number of massive RCTs can be repaired to bone,¹³ a significant proportion of these cannot be sutured by these traditional techniques because of the size of the tear and the retraction of the tendon.¹⁴

Numerous operative techniques have been described for the treatment of massive RCTs with severe retraction where anatomic repair is not possible, such as arthroscopic debridement and/or biceps tenotomy, tendon transfers and grafting, and partial repair of the remaining rotator cuff tendons.¹⁵

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Partial repair, margin convergence

Burkhart et al. first introduced the concept of functional repair of the cuff to restore the force couple of the humeral head and to increase the acromiohumeral distance (AHD).¹⁶ In these arthroscopic procedures, complete closure of the defect was not considered to be essential to restore the normal cuff and shoulder biomechanics.¹⁷ In the 'margin convergence' technique, the free margin of the tear converges toward the greater tuberosity as side-to-side repair progresses (Fig. 1). As the margin converges, the strain at the free edge of the cuff is reduced significantly, leaving an almost tension-free converged cuff margin overlying the humeral bone bed. Side-to-side closure of two-thirds of a U- or V-shaped tear reduces the strain at the cuff margin to one-sixth of the strain that existed at the pre-converged cuff margin. This strategy gives a lower probability of failure of fixation to bone. If the supraspinatus tendon retraction means that direct reinsertion of tendon to bone is not possible, the infraspinatus can be sutured to the bone in an attempt to cover its anatomic footprint. This technique allows repair of the peripheral margins of the tear to restore the force couples, anteriorly and posteriorly, and the 'suspension bridge' system of force transmission in the shoulder. Clinical outcomes are obviously not as good as after a complete rotator cuff repair^{14,16,18} but remain stable up to medium-term follow-up.¹⁹

Previous studies have introduced the radiographic measurement of the AHD as a standard technique in routine orthopaedic assessment. A decreased AHD is the most reliable radiographic finding for RCTs²⁰⁻²³ and, in particular, an AHD < 6 mm is a sign of rotator cuff rupture almost always involving a longstanding total infraspinatus tear, which is not always amenable to suture repair as a result of advanced fatty degeneration.^{24,25} AHD $\geq$ 6 mm is of no diagnostic relevance and gives no indication as to whether there is

subscapularis tear and, if so, whether suture repair is feasible (Fig. 2).

Porcellini et al. supported the assumption that partial repair of a massive RCT may improve the biomechanics of the shoulder by re-establishing the shoulder's essential force couples, thus converting a 'dysfunctional symptomatic' RCT into a 'functional tear'.²⁶ The study indicates that, in cases of massive RCT with no subscapularis tear, long-term results of partial repair of the posterior cuff with covering of the infraspinatus footprint showed improved outcome scores. In addition, AHD increased minimally and was stable at final follow-up. These results are superior to those of

Figure 2. X-ray of a right shoulder in a 67-year-old male patient with a degenerative massive rotator cuff tear. The measured acromiohumeral distance in this case was less than 6 mm, indicating a not completely reparable rotator cuff tear.

Figure 1. (a) Massive superior and posterior rotator cuff tear in a right shoulder observed with the scope through the lateral portal. A lateral anchor is placed on the greater tuberosity and is used after a margin convergence. (b) Same shoulder after two laterolateral non-absorbable sutures are passed (margin convergence technique).

arthroscopic debridement alone in active patients. The ideal patient for partial repair of the cuff has good cuff balancing without signs of complete disruption of the posterior cuff (automatic internal recall), with no drop-arm or Hornblower sign, and with good function of the subscapularis. Postoperative outcomes of this investigation are comparable with those in the available literature. In a study performed in 24 patients with massive rotator cuff tear undergoing partial repair, Duralde and Bair reported that 67% of patients showed good to excellent results using the American Shoulder and Elbow Surgeons score, and 92% of patients were subjectively satisfied after this surgery.²⁷

Berth et al. reported good or satisfactory outcomes after partial rotator cuff repair, regardless of the high rates of structural failure.²⁸ Specifically, the results of arthroscopic partial rotator cuff repair showed slightly better functional outcome than debridement alone.²⁸ In a study by Franceschi et al., patients with massive rotator cuff tear received either debridement or a partial repair.²⁹ Postoperatively, both groups demonstrated highly significant improvements compared to pre-operative values, and all scores in the partial repair group were superior to the outcome of the debridement group. These differences may be a result of the ability of the partial repair to restore the functional anatomy of the shoulder, allowing a near-to-normal arc of movement, strength and function.²⁹ Kim et al., in a more recent study comparing pre- with postoperative results in a case series of 27 patients undergoing partial repair, showed that all shoulder scores (simple shoulder test, Constant and UCLA) had a significant improvement.³⁰ Arrigoni et al. also showed similar clinical results in their case series.³¹

Iagulli et al. compared two groups of patients, one in which a complete cuff repair was achieved, and the other in which only a partial repair was possible.³² Forty-one patients with only partial repair achieved a postoperative mean University of California–Los Angeles (UCLA) shoulder score of 29.49, and 45 patients with complete repair achieved a mean UCLA shoulder score of 29.64: no statistically significant differences in postoperative outcomes were noted. In a cadaver laboratory study, Oh and colleagues confirmed that, if the complete repair of massive cuff tear is not possible, posterior cuff (infraspinatus) repair is necessary to restore abnormal glenohumeral kinematics.³³ Margin convergence anteriorly was also recommended to decrease gap formation of the repaired tendon edge, which will then provide a better biomechanical environment for healing. Recently, Denard et al. demonstrated that repair of massive rotator cuff tears with advanced mobilization techniques can lead to reversal of pre-operative pseudoparalysis in 90% of patients

who have not had previous surgery.³⁴ In these patients, functional improvement can be obtained with a low rate of complications. However, in the setting of a revision and pseudoparalysis, only 43% of patients regained forward flexion above 90°.

Debridement

When partial repair is not possible because of the size, retraction or fatty infiltration of the cuff, other treatment for RCTs, such as arthroscopic debridement or tenotomy/tenodesis of the long head of the biceps (LHB), can be undertaken.^{35,36} However, some studies have shown that the initial satisfactory results with debridement can deteriorate with long-term follow-up.³⁷ For example, Zvijac et al. found a significant increase in pain and deteriorating shoulder function at 3 years to 6 years of follow-up in patients treated by arthroscopic subacromial decompression alone for irreparable RCT.³⁸ Conversely, Lee et al. reported on 32 patients treated by arthroscopic decompression and tuberooplasty showing significant improvement in postoperative Constant and UCLA shoulder scores.³⁹ The advantages of arthroscopic subacromial decompression and rotator cuff debridement include a shorter operative time, an accelerated rehabilitation program and lower reported complication rates compared to the more extensive reconstructive procedures.³⁷

Lesions of the biceps tendon are frequently associated with a RCT and have been identified as a source of persistent pain that can resolve with spontaneous rupture. This has led to the introduction of biceps tenotomy/tenodesis as a treatment option for patients with massive and/or irreparable RCTs. So far, discussions concerning this procedure have noted longevity of pain relief and a possible progression of arthritic changes in the glenohumeral joint. In addition, loss of elbow flexion strength is often a concern for patients who are presented with the option of cutting the LHB. After spontaneous rupture, loss of elbow flexion strength is found to be up to 16%. However, arthroscopic biceps tenotomy in the treatment of RCTs in selected patients yields good objective improvement and a high degree of patient satisfaction. Despite these improvements, arthroscopic tenotomy or tenodesis can increase superior translation of the humeral head during active abduction of the shoulder in the scapular plane,⁴⁰ although this does not appear to alter the progressive radiographic changes that occur with long-standing RCT.⁴¹ Walch et al. reported the long-term results of 307 biceps tenotomies, 110 of which were performed with a concomitant acromioplasty, as palliative treatment for RCTs.⁴² At a mean of 57 months postoperatively, 87% of the patients were

satisfied or very satisfied and the mean Constant score had improved to 67.6 points compared to 48 points preoperatively. As expected, active external rotation was not improved after surgery.

Boileau et al. evaluated the clinical and radiographic outcomes of isolated arthroscopic biceps tenotomy or tenodesis as treatment for irreparable RCT associated with a biceps lesion.⁴³ They found a significant decrease in AHD by 1.1 mm but only one patient progressed to a full RCT arthropathy. They concluded that pseudoparalysis of the shoulder and severe rotator cuff arthropathy are contraindications to this procedure. Klinger et al. compared the results of arthroscopic debridement in massive, irreparable RCTs with and without tenotomy of the LHB in 41 cases.⁴⁴ They concluded that additional LHB tenotomy did not significantly influence the postoperative results at the latest follow-up. In addition, they did not note any significant humeral head migration or development of rotator cuff arthropathy. Recently, Su et al., in a cadaveric study, investigated the biomechanical effects of posterior–superior RCT size and loading the LHB tendon.⁴⁵ They showed that, if the inferior infraspinatus remained intact, there was no significant difference in glenohumeral translation for any of the different loads studied. Once the supraspinatus and the entire infraspinatus were released, 50 N of load led to significantly increased translation in both directions: superior and anterosuperior. For intact specimens and for all sizes of RCTs, biceps loading led to a significant decrease in glenohumeral translation.

We postulate that this biomechanical data can justify the preventive role of partial repair on composite tissue allograft development in cases where repair of the infraspinatus tendon into the original footprint has been undertaken.⁴⁶ The good results of infraspinatus tendon repair alone can be indirectly shown by the maintenance of AHD at long-term follow-up compared

to the decrease in AHD with increasing size of the cuff tear.²⁶

Recently, some studies have proposed the use of biodegradable spacer in case of massive irreparable RCT.⁴⁷ This spacer can be utilized alone or associated with a partial rotator cuff repair (Fig. 3). The rationale for using this device is to create a space between the acromion and humeral head by lowering and re-centering the humeral head itself. In this manner, the remaining rotator cuff can work at a better angle so to improve shoulder function. However, to date, there are no clinical data available concerning the use of this device.

Augmentation

All open and arthroscopic techniques have their limitations in treating this problem, and a number of different treatment options depending on patient age, activity level and degree of disability have been proposed. The biceps tendon interposition technique for massive RCT offers a possible improvement in clinical outcomes and is comparable to that of conventional repair. In addition, the augmentation technique using biceps as a potential graft for RCT is particularly useful in bridging the gap in immobile massive RCTs with posterior defects and retraction.

Finally, in an effort to augment the deficient rotator cuff tissue at the same time as maintaining the anatomic integrity of the shoulder, some surgeons are incorporating biological tissue scaffolds into the cuff deficiency.^{48–51} Graft augmentation provides stability for torn tendons and increases the rate of healing. However, tissue autografts and tendon transfers are subject to donor-site morbidity. Tendon augmentation grafts are derived from allografts, xenografts or synthetic materials. Selection of augmentation grafts depends on the tissue of origin, graft processing,

Figure 3. (a) Left shoulder viewed with the scope through a posterior portal. A biodegradable spacer is introduced through the lateral portal. In this case, the spacer is associated with a partial posterior cuff repair. (b) The same shoulder after the biodegradable spacer is inflated with a saline solution.

cross-linking of the material, surgeon experience and physical properties of the tissue. Augmentation grafts can provide strength by acting as conductive scaffolding for tissue ingrowth and provide a collagen reservoir for fibroblasts. Compared to tendon alone, augmentation grafts provide higher resistance to failure and minimize stress shielding.⁵² Biomechanically, the stress-strain curve of each augmentation graft varies, depending on its origin and production process.⁵³ Further variation depends on the surgical method (e.g. whether the graft is interpositional or an on-lay device). Augmentation grafts increase stiffness⁵⁴ with strength approaching that of native tendons.⁵⁵ However, some loss of mechanical strength can be expected as the augmentation graft integrates and remodels with the native tissue. One concern with using allografts or xenografts is the host-tissue morphological response. The cellular response depends on both the origin of the graft and the processing techniques and the host-tissue medium. Enhancing mechanical properties through over-chemical cross-linking may result in a foreign body response by the host tissue. Therefore, a balance between the biomechanical and biocompatibility properties of the grafts is needed. Chemical and physical properties of synthetic grafts can be controlled, although the trade-off is a lack of biocompatibility, which usually makes the graft non-absorbable. In addition, a high rate of immune and inflammatory response has been reported.⁵⁶

A porcine submucosa subintestinal graft named Restore (DePuy, Warsaw, IN, USA) was found to increase pain and lead to poor tendon healing. Its clinical outcome in humans was in contrast to the outcome of many preclinical animal studies. This suggests that Restore may not be suitable for human rotator cuff repair.⁵⁷ GraftJacket (Wright Medical Group, Memphis, TN, USA) is derived from human dermis and has been used as interpositional graft in case of massive and not repairable RCT (Fig. 4). An improvement in UCLA shoulder scores at the 2-year follow-up has been demonstrated. Furthermore magnetic resonance imaging demonstrated tissue incorporation into the graft.⁵⁸ Synthetic scaffolds include polytetrafluoroethylene (PTFE) felts and polyester grafts. PTFE improved pain scores in 30 patients with massive rotator cuff tears.⁵⁹ Teflon (PTFE graft) provided satisfactory functional results and strength in 23 out of 25 patients, again with massive rotator cuff tears.⁶⁰ Gore-Tex (PTFE graft) improved the mean Japanese Orthopaedic Association score of 27 patients from 57.7 to 88.7.⁶¹ Dacron (polyester) improved the Constant score in 15 of 17 patients. The Leeds-Keio graft (polyester) used in subscapular transposition augmentation showed superior clinical results to those with augmentation grafts.⁶²

Figure 4. Right shoulder observed through a lateral portal. A GraftJacket patch is used to bridge the cuff defect in this massive rotator cuff tear (courtesy of S. S. Snyder MD). The Southern California Orthopedic Institute, Van Nuys, CA, USA.

Augmentation grafts can also deliver cells and bio-active molecules. Repairing the supraspinatus of rabbits with mesenchymal stem cell-impregnated alginate beads enabled the production of better organized tendon fibres and a higher ultimate failure load after 12 weeks.⁶³ Augmenting the infraspinatus of sheep with bovine type-I collagen containing recombinant human platelet-derived growth factor BB improved biomechanical strength and anatomic appearance compared to controls.⁶⁴ Finally, using a platelet rich fibrin matrix suture construct in patients with rotator cuff tears produced a lower re-tear rate (despite not being clinically significant).⁶⁵ Mori et al. compared the arthroscopic patch graft procedure and partial repair for irreparable large or massive RCTs in shoulders with low-grade fatty degeneration of the infraspinatus (stage 1 or 2 according to Goutallier et al).⁹ in terms of the functional and structural outcomes. The patch graft procedure showed an 8.3% re-tear rate for the repaired ISP with both improved clinical scores and recovery of muscle strength, whereas the partial repair had a re-tear rate of 41.7%.⁶⁶

Transfers

Muscle transfers of the latissimus dorsi (LD)^{67–69} and pectoralis major⁷⁰ have also been described to improve pain and function, usually in young and active patients with irreparable RCTs.^{71–72} Patients without glenohumeral arthritis but with marked weakness and pain in the setting of a massive, irreparable rotator cuff tear can often benefit from a tendon transfer.⁷³ Latissimus dorsi transfer to reconstruct a massive posterosuperior rotator cuff tear was originally developed by Gerber.⁷⁴

Patients with functional impairment who have loss of external rotation strength can be considered for this procedure if they do not have pseudoparalysis.⁷⁴ The transferred LD was proposed to act as an effective depressor in restricting cranial migration of the humeral head. However, postoperative radiographs showed minimal or no depression, especially in the neutral or externally rotated position. With internal rotation, nine of 14 treated patients showed slightly improved positioning of the humeral head in relation to the glenoid.^{71,72} Iannotti et al. found that pre-operative shoulder function and general strength influence the outcome after LD transfer.⁷⁵ In their study of 14 patients undergoing LD transfer for massive rotator cuff tear, women with poor shoulder function had a greater probability of a poor result. The investigators reported that the most significant predictors of outcome were pre-operative active range of motion, and strength in forward flexion and external rotation. The transfer does not overcome pseudoparalysis.

Recently, a systematic review of the literature was performed via a search of electronic databases. Ten studies that fulfilled all inclusion and exclusion criteria were included. The frequency-weighted mean age was 58.7 years. Patients were followed for a frequency-weighted mean of 45.5 months (range, 24 months to 126 months). Patients had a frequency-weighted mean adjusted Constant score of 45.9 pre-operatively compared to 73.2 postoperatively ($p < 0.001$). The frequency-weighted mean active forward elevation improved from 101.9° pre-operatively to 137.4° postoperatively ($p < 0.001$) and the frequency-weighted mean active external rotation improved from 16.8° to 26.7° ($p < 0.001$). Subscapularis muscle insufficiency, advanced teres minor muscle atrophy and the need for revision surgery were correlated with poor functional outcomes in some studies.⁷⁶ Recently, transfer of the LD tendon has been reported to yield good-to-excellent long-term results in carefully selected patients, with substantial and durable improvements in shoulder function and pain relief. Shoulders with fatty infiltration of the teres minor muscle and insufficiency of the subscapularis muscle tended to have inferior results, as did those with a large critical shoulder angle.⁷⁴ It remains unclear whether the clinical results of this technique are achieved either by active muscle contractions or by a passive tenodesis effect of the transfer. Henseler et al. compared the muscle activity with surface electromyography (EMG) against the clinical outcome of the LD transfer in selected patients.^{77,78} They demonstrated that LD has synergistic muscle activity after transfer. Apart from a tenodesis effect, directional muscle activity seems relevant for improved clinical outcome and pain relief. A specific gain was observed for external rotation in elevated arm positions, a

motion essential for daily living tasks. The transfer remained active in all cases, as reflected by increased LD EMG activity and shifted from pre-operative antagonistic co-activation in adduction to synergistic activation in abduction.^{77,78} In addition, a number of studies found less favourable results for revision cases where detachment and/or atrophy of the anterior deltoid seemed to be a major risk factor, whereas less aggressive previous surgery such as arthroscopic debridement, acromioplasty or LHB tenotomy were felt to be more favourable. These results would suggest that preserving deltoid muscle is important for success in a LD tendon transfer surgery.^{79–81} A thorough examination of the literature on LD tendon transfer for irreparable posterosuperior tears and our own clinical experience showed that, with the correct indications, this surgical procedure gives significant improvement in terms of pain, active elevation, active external rotation and function of the shoulder. Strength is usually improved, although this is not always statistically significant. However, LD tendon transfer does not appear to stop osteoarthritis progression or superior humeral head migration, although those two issues have had no influence on postoperative subjective and objective results. EMG analysis of the LD muscle after transfer shows muscle activity mostly in active external rotation, suggesting an active participation and not only merely a tenodesis effect. In our opinion, this technique is the only solution in nonpseudoparalytic young patients who have no osteoarthritis after failure of previous surgery for massive posterosuperior cuff tears to allow restoration of active external rotation. Recent advances in the technique with the assistance of arthroscopy and tubularization are clearly a benefit because there is less danger to the deltoid muscle and stronger resistance of the transferred tendon to traction. Longer follow-up will be needed to determinate in which clinical situations LD tendon transfer is the best surgical option.^{82,83}

Declaration of conflicting interests

None declared.

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