13 Irreparable Rotator Cuff Tears

Fabrizio Campi, Raffaele Garofalo,
and Alessandro Castagna

13.1 Introduction

Rotator cuff tears (RCT) are one of the most commonly treated orthopaedic pathologies. It is present in 20.7% of the general population, and the prevalence increases with age [1, 2]. The rate of patients with symptoms related to the shoulder affected by a cuff lesion is 36% in the general population, whereas 16.9% of the subjects without symptoms also had RCT. RCTs in the general population occur most commonly in elderly patients, 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 patient condition [3, 4]. Most surgeons agree that an acute painful tear in young people should be treated operatively in order to decrease pain and provide satisfactory long-term function. However, great controversy exists with regard to tears that are large, chronic in nature, and not tractable to repair by standard means. These tears, considered "irreparable" or "massive", provide an ongoing challenge for the orthopaedic surgeon. Authors have attempted to classify these tears based on their size and location [5]. Others consider a massive rotator cuff tear to be one involving two or more tendons. A massive tear is not necessarily irreparable, and an irreparable tear does not mean it is massive in size. However, an irreparable tear can be defined surgically as a tear in which direct tendon-to-bone repair and healing are not possible. An irreparable tear was described by Warner and Parsons [6] as "the inability to achieve a direct repair of the native tendon to the humerus despite mobilizing the soft tissues". Small chronic tears in contradistinction to massive tears may be small and friable and unable to be repaired primarily to bone. Irreparable rotator cuff tears are usually large and retracted with nonfunctional muscle bellies and severe fatty degeneration. The true determination of an irreparable cuff tear, however, is definitively performed under direct visualization under the surgery.

Irreparable RCTs may occur through different mechanisms including acute (i.e. traumatic), acute on chronic, and chronic (i.e. degenerative) tears. Generally, acute massive tears greater than 5 cm are reparable, assuming fatty degeneration is minimal. Gerber et al. [7] showed that fatty infiltration in a sheep model of rotator cuff tears is a necessary consequence following macro-architectural change rather than degenerative process. As the tendon tears and the muscle

F. Campi (✉)
Orthosport Group, Private Hospital Villa Igea, Forlì, Italy

R. Garofalo
Unit of Shoulder Surgery, Miulli Hospital, Bari, Italy

A. Castagna
Shoulder and Elbow Unit, Humanitas Institute IRCCS, Milan, Italy

S. Gumina et al. (eds.), *Reverse Shoulder Arthroplasty*,
https://doi.org/10.1007/978-3-319-97743-0_13

retracts, the pennation angle of the muscle decreases, enabling the space between individual muscle fibres to become replaced with fat. As the muscle retracts and becomes filled with fat, it becomes stiffer and less compliant and has less strength.

The muscles of the rotator cuff provide dynamic stability to the shoulder. Burkhart described the force-couple concept of the rotator cuff after performing fluoroscopic evaluations of patients with massive rotator cuff tears. He stated that normal shoulder function is possible as long as there are balanced forces between the two force couples, i.e. the first force couple in the transverse plane and the second force couple in the coronal plane [8]. When this force couple is intact (or reparable), the shoulder moves perfectly without pain.

13.2 Clinical Evaluation and Imaging

We know that irreparable rotator cuff tears are unpredictable with respect to their clinical presentation. The spectrum of pain and functional disability varies widely. A shoulder may function well in the setting of a painless tear, whereas a small painful tear may result in substantial shoulder dysfunction and disability.

The physical examination should begin with inspection of both upper extremities with the shoulders exposed. The supraspinatus and infraspinatus fosse should be closely examined for signs of atrophy. Massive tears involving the infraspinatus will typically present with increases in passive internal rotation as well as an external rotation lag sign. Similarly, massive tears involving the subscapularis will often present with an increase in passive external rotation and an internal rotation lag sign. Further, supraspinatus tears may demonstrate a drop-arm sign.

Palpation of the long head of the biceps (LHB) tendon within the bicipital groove is essential during the examination, as lesions to the LHB are strongly associated with rotator cuff tears. The surgeon must also assess for concomitant symptomatic acromioclavicular joint arthritis through palpation as well as by assessing for pain with cross-body adduction.

Strength testing of all rotator cuff muscles is imperative. Posterosuperior cuff tears are associated with a positive lag sign when the patient is unable to maintain the shoulder externally rotated at 90° of abduction and adducted to the side.

Furthermore, special attention should be paid to the subscapularis, of which lesions to the upper part of the tendon are often correlated with biceps tendon lesions and LHBT instability. Tests for the subscapularis include the belly press test, the lift-off test, and the bear-hug test [9–11].

The imaging of the shoulder should include a standard set of three X-rays: true anteroposterior, axillary lateral, and outlet (scapular Y). Although plain radiographs will not clearly identify soft tissue, they are highly valuable in elucidating the chronicity of massive tears as well as identifying the presence of glenohumeral arthritis or rotator cuff arthropathy. The outlet view is used to assess the acromial morphology.

The magnetic resonance imaging is the preferred method to evaluate the structural integrity of the rotator cuff. Magnetic resonance imaging can be used to assess the size and location of the tear, the quality of the tendon, and the chronicity of the tear. The sagittal T2 image may show atrophy or fatty infiltration of the involved musculature, which can highlight the chronicity of the tear and also provide prognostic information (Fig. 13.1) [12]. Axial views can evaluate the integrity of the subscapularis as well as associated LHBT tendinosis, tears, or static instability.

13.3 Management Options

13.3.1 Nonsurgical Treatment

Nonsurgical treatment for patients with an irreparable RCT is generally reserved for low-demand patients who are not experiencing significant pain. The mainstay of nonoperative management is physical therapy, subacromial injections, and non-steroidal anti-inflammatory drug (NSAIDs).

Physical therapy focuses to strengthen the intact portion of the rotator cuff and deltoid as

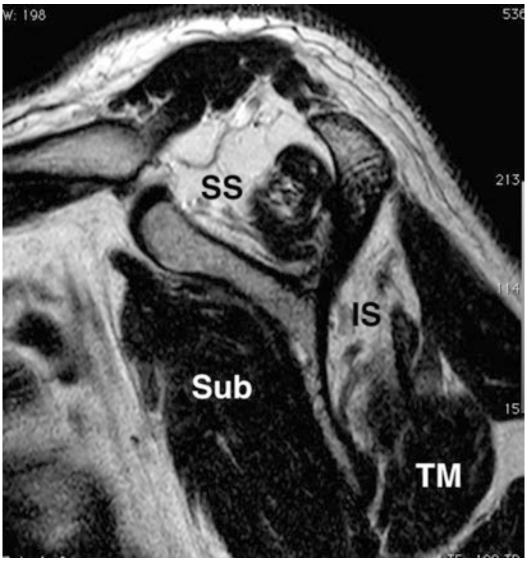

Fig. 13.1 Sagittal magnetic resonance image T2 weighted of a shoulder demonstrating a fatty infiltration of the supraspinatus and infraspinatus muscles. *IS* infraspinatus muscle, *SS* supraspinatus muscle, *Sub* subscapularis muscle, *TM* teres minor

well as the periscapular musculature. Strengthening the intact rotator cuff and scapular stabilizers, in theory, should offload the tear edges and provide a strong foundation for maintenance of a strong force couple to prevent progressive rotator cuff arthropathy [13–15].

13.3.2 Surgical Treatment

This chapter does not describe the use of reverse shoulder arthroplasty in the treatment of irreparable rotator cuff tears.

When patients have failed nonsurgical management, surgical treatment should be considered. According to the AAOS guidelines, the only recommendation regarding irreparable rotator cuff tears was for partial repair when possible, debridement, or tendon transfers which all earned a weak recommendation [16].

Many 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, partial repair of the remaining rotator cuff tendons, and a superior capsular reconstruction (SCR) [17].

13.4 Partial Repair, Margin Convergence

Burkhart et al. [18] first introduced the concept of functional repair of the cuff to restore the force couple of the humeral head and to increase the acromion-humeral distance (AHD). In these arthroscopic procedures, complete closure of the defect was not considered to be essential to restore the normal cuff and shoulder biomechanics [19]. In margin convergence technique, the free margin of the tear converges towards the greater tuberosity as side-to-side repair progresses (Fig. 13.2).

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 for partial or anatomic repair. 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 made direct reinsertion of tendon to bone not possible, the infraspinatus can be sutured to the bone in an attempt to cover its anatomic footprint. The technique allows repair of the peripheral margins of the tear to restore the force couples, anterior and posterior, and the “suspension bridge” system of force transmission in the shoulder. Clinical outcomes are obviously lesser than after complete rotator cuff repair [18–20] but remain stable for AHD even at medium-term follow-up [21].

Previous authors have introduced the radiographic evaluation of the AHD as a standard technique in routine orthopaedic treatment. A decreased AHD is the most reliable radiographic finding for RCTs [22–25], and in particular an AHD < 6 mm is a sign of rotator cuff rupture almost systematically involving long-standing total infraspinatus tear, not always amenable to

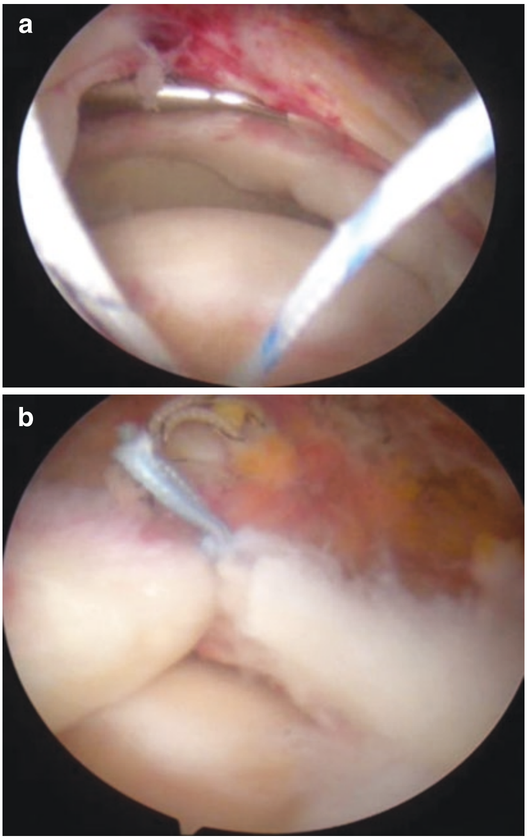

Fig. 13.2 (**a**) Massive superior and posterior RCT in a right shoulder observed with the scope through the lateral portal. A lateral anchor is placed on the greater tuberosity and is used after a margin convergence. (**b**) Same shoulder after that two latero-lateral nonabsorbable sutures are passed (margin convergence technique)

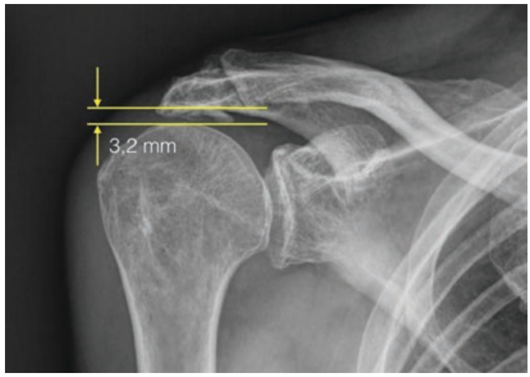

Fig. 13.3 X-ray in AP view of a right shoulder in a 67-year-old male patient with a degenerative massive rotator cuff tear. The measured AHD in this case in less than 6 mm indicating a not completely reparable RCT

suture repair due to advanced fatty degeneration [26, 27]. AHD equal to or greater than 6 mm is of no diagnostic relevance and in no way indicates whether there is subscapularis tear and, if so, whether suture repair is feasible (Fig. 13.3).

Porcellini et al. [28] support the assumption that partial repair of a massive RCT may improve the biomechanics of the shoulder while re-establishing the shoulder's essential force couples, thus converting a "dysfunctional symptomatic" RCT into a "functional tear". This study indicates that, in cases of massive RCT with no subscapularis tear test, 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 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 of the available literature. In a study on 24 patients with massive rotator cuff tear undergoing partial repair, Duralde et al. reported that 67% of patients showed good to excellent results at ASES score and 92% of patients were subjectively satisfied after this surgery [17].

Berth et al. reported good or satisfactory outcomes after partial rotator cuff repair, and regardless of the high rates of structural failure, the results of arthroscopic partial rotator cuff repair showed slightly better functional outcome than debridement [29]. In a study by Franceschi et al., patients with massive rotator cuff tear received either debridement or a partial repair. Postoperatively, both groups demonstrated highly significant improvements compared with preoperative values, and all scores in the partial repair group were superior to the outcome of the debridement group. These differences may be due to 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 [30]. Kim et al. in a recent report comparing pre- to 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 [31]. Arrigoni et al., recently, also showed similar clinical results in their case series [32].

In a cadaver laboratory study, Lee et al. [33] confirmed that if complete repair of massive cuff tear is not possible, posterior cuff (infraspinatus) repair is necessary to restore abnormal glenohumeral kinematics, and margin convergence anteriorly is recommended to decrease gap formation of the repaired tendon edge, which may provide a better biomechanical environment for healing. In 2012 Burkhart et al. demonstrated that repair of massive rotator cuff tears with advanced mobilization techniques can lead to reversal of preoperative pseudoparalysis in 90% of patients who have not had previous surgery. 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 FF above 90° [34].

13.5 Debridement and LHB Tenotomy/Tenodesis

When partial repair is not possible because of the size, retraction, or fatty infiltration of the cuff, one can perform other palliative treatments for RCTs such as arthroscopic debridement or tenotomy/tenodesis of the LHB [35, 36]. There exists some strong evidence that the satisfactory results with debridement deteriorate during long-term follow-up [37]. For instance, Zvijac et al. [38] found a significant decrease in pain assessment and shoulder function at 3–6 years' follow-up in patients treated with arthroscopic subacromial decompression for irreparable RCT. Lee et al. [39] reported on 32 patients treated with arthroscopic decompression and tuberoplasty showing significant improvement in postoperative Constant and UCLA shoulder scores. The advantages of arthroscopic subacromial decompression and rotator cuff debridement include a short operative time, an accelerated rehabilitation program, and lower reported complication rates compared with the more extensive reconstructive procedures [37].

Lesions of the biceps tendon are frequently associated with 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 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, function of the biceps tendon in terms of generating 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%. 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] and does not appear to alter the progressive radiographic changes that occur with long-standing RCT [41]. Walch et al. [42] reported the long-term results of 307 biceps tenotomies, 110 of which were performed with a concomitant acromioplasty, as palliative treatment for RCTs. 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 with 48 points preoperatively. As expected, active external rotation was not improved after the surgery.

Boileau et al. [43] evaluated the clinical and radiographic outcomes of isolated arthroscopic biceps tenotomy or tenodesis as treatment for irreparable RCT associated with a biceps lesion. They found a significant decrease in AHD by 1.1 mm, but only one patient progressed to a full RCT arthropathy, and they concluded that pseudoparalysis of the shoulder and severe rotator cuff arthropathy are contraindications to this procedure. Klinger et al. [44] compared the results of arthroscopic debridement in massive, irreparable RCTs with and without tenotomy of the LHB in 41 cases. They concluded that additional LHB tenotomy did not significantly influence the postoperative results at the latest follow-up, and they did not note significant humeral head migration or developing rotator cuff arthropathy after surgery. Recently, Su et al. [45] in a cadaveric study investigated the biomechanical effects of posterosuperior RCT size and loading the LHB tendon in the presence of various sized RCTs. They showed that if the inferior infraspinatus remained intact, there was no significant difference in glenohumeral translation for any different load 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 these biomechanical data can justify the preventive role of partial repair on CTA development in cases of a good functional repair of the infraspinatus tendon on the original footprint, as recently demonstrated [46]. The good results of infraspinatus tendon repair can be indirectly shown by maintenance of the AHD at long-term follow-up for the well-known decrease in AHD with widening of the size of the cuff tear [28].

Some authors 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. The rationale using this device is to create a space between the acromion and humeral head by lowering and recentring the humeral head itself. In this manner the remaining rotator cuff can work in a better angle so to improve shoulder function.

13.6 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 the biceps as a potential graft for RCT is particularly useful in bridging the gap in immobile massive RCTs with posterior defects and retraction. In an effort to augment the deficient rotator cuff tissue while maintaining the anatomic integrity of the shoulder, some surgeons are incorporating biologic tissue scaffolds into the cuff deficiency [48–51].

Graft augmentation provides stability for torn tendons and increases the rate of healing. 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, 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 stiffness [54] with strength approaching that of native tendons [55]. Some loss of mechanical properties is 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. 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 of the biomechanical and biocompatibility properties of the grafts is needed. Chemical and physical properties of synthetic grafts can be controlled, but the trade-off is a lack of biocompatibility, which is usually being nonabsorbable by the tissue. A high rate of

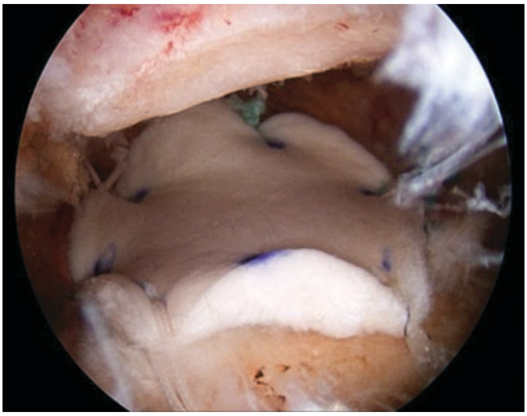

Fig. 13.4 Right shoulder observed through a lateral portal. A graft jacket patch is used to bridge the cuff defect in this massive RCT (Courtesy by SJ Snyder MD)

immune and inflammatory response has been reported [56]. A porcine submucosa subintestinal graft named Restore (DePuy, USA) was found to increase pain and lead to poorer tendon healing. Its clinical outcome 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, USA) is derived from human dermis and has been studied as interpositional graft in case of massive and not reparable RCT (Fig. 13.4). 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].

Augmentation grafts can deliver cells and bioactive molecules. Repairing the supraspinatus of rabbits with mesenchymal stem cell-impregnated alginate beads enabled production of more well-organized tendon fibres and a higher ultimate failure load after 12 weeks [59]. Augmenting the infraspinatus of sheep with bovine type I collagen containing rhPDG-BB improved biomechanical strength and anatomic appearance, compared to controls [60]. Using a platelet-rich fibrin matrix suture construct in patients with rotator cuff tears enabled a lower retear rate (despite not being clinically significant) [61].

Mori et al. compared the arthroscopic patch graft procedure and partial repair for irreparable large or massive rotator cuff tears (RCTs) in shoulders with low-grade fatty degeneration of the infraspinatus (stage 1 or 2 according to Goutallier et al.) in terms of the functional and structural outcomes. The patch graft procedure showed an 8.3% retear rate for the repaired ISP with both improved clinical scores and recovery of muscle strength, whereas the partial repair had a retear rate of 41.7% [62].

13.7 Tendon Transfer

Tendon transfers of the latissimus dorsi [63–65], pectoralis major [66], and the pectoralis minor [67] have also been described to improve pain and function, usually in young and active patients with irreparable RCTs [68, 69]. Patients without glenohumeral arthritis but with marked weakness and pain in the setting of a massive, irreparable rotator cuff tear can benefit from a tendon transfer [70].

Latissimus dorsi transfer to reconstruct a massive posterosuperior rotator cuff tear was originally developed by Gerber et al. [71]. Patients with functional impairment who may also have loss of external rotation strength can be considered for this procedure if they do not have pseudoparalysis. The transferred latissimus dorsi was postulated 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, 9 of 14 treated patients showed slightly improved positioning of the humeral head in relation to the glenoid [68, 69]. Iannotti et al. [72] found that preoperative shoulder function and general strength influence the outcome after latissimus dorsi transfer. In their study of 14 patients undergoing latissimus dorsi 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 preoperative 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, 24–126 months). Patients had a frequency-weighted mean adjusted Constant score of 45.9 preoperatively compared with 73.2 postoperatively ($p < 0.001$). The frequency-weighted mean active forward elevation improved from 101.9° preoperatively 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 [73]. Recently transfer of the latissimus dorsi tendon has been reported to yield good-to-excellent long-term results in well-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 [71]. 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. evaluated the muscle activity with surface electromyography (EMG) and the clinical outcome of the latissimus dorsi transfer in selected patients. They demonstrated that latissimus dorsi 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 latissimus dorsi EMG activity and shifted from preoperative antagonistic co-activation in adduction to synergistic activation in abduction [74, 75]. In conclusion a majority of authors found less favourable results for revision cases besides detachment and/or atrophy of the anterior deltoid which seemed to be a major risk factor for postoperative lower results, whereas less aggressive previous surgery like arthroscopic debridement, acromioplasty, or LHB tenotomy might be more favourable. Those results may suggest that preserving deltoid muscle is important for success in a LD tendon transfer surgery [76–78]. A thorough examination of the literature on LD tendon transfer for irreparable posterosuperior tears and our own clinical experience showed that with 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 but not always in a statistically significant manner. LD tendon transfer does not seem to stop osteoarthritis progression or superior humeral head migration although those two issues have had no influence on postoperative subjective and objective results of the procedure so far. EMG analysis of the LD muscle after the transfer shows muscle activity mostly in active external rotation suggesting an active effect and not only a tenodesis effect to explain the new balance of the shoulder. In our opinion, this technique is the only solution in non-pseudoparalytic young patients who have no osteoarthritis after failure of a previous treatment for massive posterosuperior cuff tears to allow restoration of active external rotation. Recent advances in the technique with assistance of arthroscopy and tubularization are clearly a benefit as there are less danger for 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 will be the best surgical option [79, 80].

13.8 Superior Capsular Reconstruction

Mihata et al. [81] described a novel technique termed arthroscopic superior capsule reconstruction (ASCR) to restore stability of the glenohumeral joint after irreparable RCT [81]. A patch graft was used to reconstruct the superior capsule of the glenohumeral joint (Fig. 13.5); medially the graft is attached to the superior glenoid (Fig. 13.6) and laterally attached to the greater tuberosity. The graft demonstrated biomechanical evidence to decrease subacromial contact pressures [82]. In a clinical study of 24 patients with large or massive irreparable RCT, ASES scores improved from 23.5 to 92.9 postoperatively, and 84% of patients were free from graft tear at a mean of 34 month follow-up [82], even though Burkhart (et al.) concludes in a recent publication: "arthroscopic SCR using dermal allograft provides a successful outcome in approximately 70% of cases in an initial experience. The preliminary results are encouraging in this difficult to manage patient population, but precise indications are important and graft healing is low in our initial experience" [83].

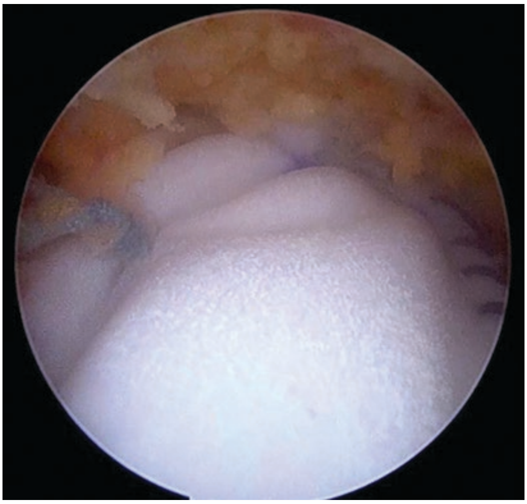

Fig. 13.5 Right shoulder observed through a lateral portal. Superior capsular reconstruction (note, on the left side, one of the two posterior sutures between the dermal matrix and the infraspinatus used to avoid the superior-posterior migration of the humeral head)

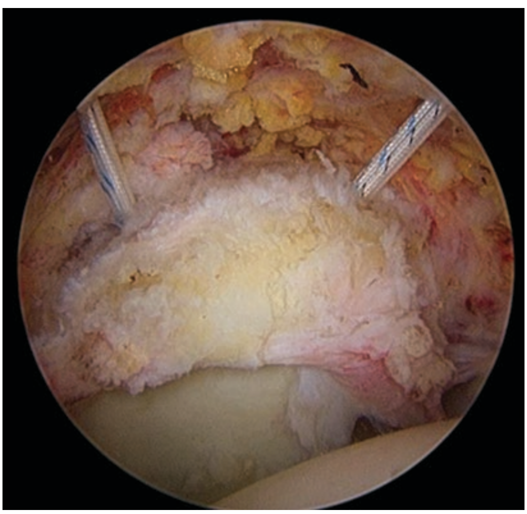

Fig. 13.6 Right shoulder observed through a lateral portal. Two anchors placed over the glenoid in the superior capsular reconstruction

13.9 Conclusion

Irreparable rotator cuff tears can be a challenging task for the orthopaedic surgeon. Treatment depends on patient functional status as well as the skill of the surgeon. Tendon transfer has become more recently popularized, with lower trapezius tendon transfer on the horizon. Salvage options for continued pain and decreased function include reverse total shoulder arthroplasty and hemiarthroplasty. Dermal allograft augmentation has shown some promise in small clinical and biomechanical series; however, larger long-term studies need to be done before definitive conclusions can be made.

References

1. Cofield RH. Current concepts review: rotator cuff disease of the shoulder. J Bone Joint Surg Am. 1985;67:974–9.
2. Yamamoto A, Takagishi K, Osawa T, Yanagawa T, Nakajima D, Shitara H, et al. Prevalence and risk factors of a rotator cuff tear in the general population. J Shoulder Elb Surg. 2010;19:116–20.
3. Iannotti JP. Full-thickness rotator cuff tears: factors affecting surgical outcome. J Am Acad Orthop Surg. 1994;2:87–95.
4. Williams GR Jr, Rockwood CA Jr, Bigliani LU, Iannotti JP, Stanwood W. Rotator cuff tears: why do we repair them? J Bone Joint Surg Am. 2004;86:2764–76.
5. Patte D. Classification of rotator cuff lesions. Clin Orthop Relat Res. 1990;(254):81–6.
6. Warner JJ, Parsons IM. Latissimus dorsi tendon transfer: a comparative analysis of primary and salvage reconstruction of massive, irreparable rotator cuff tears. J Shoulder Elb Surg. 2001;10(6):514–21.
7. Gerber C, Meyer DC, Schneeberger AG, Hoppeler H, von Rechenberg B. Effect of tendon release and

delayed repair on the structure of the muscles of the rotator cuff: an experimental study in sheep. J Bone Joint Surg Am. 2004;86A(9):1973–82.
8. Burkhart SS. Arthroscopic treatment of massive rotator cuff tears. Clinical results and biomechanical rationale. Clin Orthop Relat Res. 1991;(267):45–56.
9. Barth JR, Burkhart SS, De Beer JF. The bear-hug test: a new and sensitive test for diagnosing a subscapularis tear. Arthroscopy. 2006;22:1076–84.
10. Bartsch M, Greiner S, Haas NP, Scheibel M. Diagnostic values of clinical tests for subscapularis lesions. Knee Surg Sports Traumatol Arthrosc. 2010;18:1712–7.
11. Gerber C, Hersche O, Farron A. Isolated rupture of the subscapularis tendon. J Bone Joint Surg Am. 1996;78:1015–23.
12. Thomazeau H, Boukobza E, Morcet N, Chaperon J, Langlais F. Prediction of rotator cuff repair results by magnetic resonance imaging. Clin Orthop Relat Res. 1997;344:275–83.
13. Ainsworth R. Physiotherapy rehabilitation in patients with massive, irreparable rotator cuff tears. Musculoskeletal Care. 2006;4(3):140–51.
14. Ainsworth R, Lewis JS. Exercise therapy for the conservative management of full thickness tears of the rotator cuff: a systematic review. Br J Sports Med. 2007;41(4):200–10.
15. Merolla G, Paladini P, Saporito M, Porcellini G. Conservative management of rotator cuff tears: literature review and proposal for a prognostic. Prediction Score. Muscles Ligaments Tendons J. 2011;1(1):12–9.
16. Tashjian RZ. AAOS clinical practice guideline: optimizing the management of rotator cuff problems. J Am Acad Orthop Surg. 2011;19(6):380–3.
17. Duralde XA, Bair B. Massive rotator cuff tears: the result of partial rotator cuff repair. J Shoulder Elb Surg. 2005;14:121–7.
18. Burkhart SS, Nottage WM, Ogilvie-Harris DJ, Kohn HS, Pachelli A. Partial repair of irreparable rotator cuff tears. Arthroscopy. 1994;10:363–70.
19. Nove-Josserand L, L_evigne C, No€el E, Walch G. The acromiohumeral interval. A study of the factors influencing its height (in French). Rev Chir Orthop Reparatrice Appar Mot. 1996;82:379–85.
20. Burkhart SS. Arthroscopic treatment of massive rotator cuff tears. Clin Orthop Relat Res. 2001;(390):107–18.
21. Yoo JC, Koh KH, Woo KJ, Shon MS, Koo KH. Clinical and radiographic results of partial repairs in irreparable rotator cuff tears: preliminary report (SS-05) [abstract]. Arthroscopy. 2010;26(Suppl):e3.
22. Golding FC. The shoulder-the forgotten joint. Brit J Radiol. 1962;35:149–58.
23. Gruber G, Bernhardt GA, Clar H, Zacherl M, Glehr M, Wurnig C. Measurement of the acromiohumeral interval on standardized anteroposterior radiographs: a prospective study of observer variability. J Shoulder Elb Surg. 2010;19:10–3.
24. Lehtinen JT, Lehto MU, Kaarela K, Kautiainen HJ, Belt EA, Kauppi MJ. Radiographic joint space in rheumatoid glenohumeral joints. A 15-year prospective follow-up study in 74 patients. Rheumatology (Oxford). 2000;39:288–92.
25. Saupe N, Pfirrmann CW, Schmid MR, Jost B, Werner CM, Zanetti M. Association between rotator cuff abnormalities and reduced acromiohumeral distance. Am J Roentgenol. 2006;187:376–82.
26. Liem D, Lengers N, Dedy N, Poetzl W, Steinbeck J, Marquardt B. Arthroscopic debridement of massive irreparable rotator cuff tears. Arthroscopy. 2008;24:743–8.
27. Keener JD, Wei AS, Kim HM, Steger-May K, Yamaguchi K. Proximal humeral migration in shoulders with symptomatic and asymptomatic rotator cuff tears. J Bone Joint Surg Am. 2009;91:1405–13.
28. Porcellini G, Castagna A, Cesari E, Merolla G, Pellegrini A, Paladini P. Partial repair of irreparable supraspinatus tendon tears: clinical and radiographic evaluations at long-term follow-up. J Shoulder Elb Surg. 2011;20(7):1170–7.
29. Berth A, Neumann W, Awiszus F, Pap G. Massive rotato cuff tears: functional outcome after debridement or arthroscopic partial repair. J Orthop Traumatol. 2010;11(1):13–20.
30. Franceschi F, Papalia R, Vasta S, Leonardi F, Maffulli N, Denaro V. Surgical management of irreparable rotator cuff tears. Knee Surg Sports Traumatol Arthrosc. 2012;23(2):494–501.
31. Kim SJ, Lee IS, Kim SH, Lee WY, Chun YM. Arthroscopic partial repair of irreparable large to massive rotator cuff tears. Arthroscopy. 2012;28(6):761–8.
32. Arrigoni P, Fossati C, Zottarelli L, Ragone V, Randelli P. Functional repair in massive immobile rotator cuff tears leads to satisfactory quality of living: results at 3-year follow-up. Musculoskelet Surg. 2013;97(Suppl 1):73–7.
33. Oh JH, McGarry MH, Jun BJ, Gupta A, Chung KC, Hwang J, Lee TQ. Restoration of shoulder biomechanics according to degree of repair completion in a cadaveric model of massive rotator cuff tear: importance of margin convergence and posterior cuff fixation. Am J Sports Med. 2012;40(11):2448–53.
34. Denard PJ, Lädermann A, Jiwani AZ, Burkhart SS. Functional outcome after arthroscopic repair of massive rotator cuff tears in individuals with pseudoparalysis. Arthroscopy. 2012;28(9):1214–9.
35. Gartsman GM. Massive, irreparable tears of the rotator cuff. Results of operative debridement and sub-acromial decompression. J Bone Joint Surg Am. 1997;79:715–21.
36. Rockwood CA Jr, Williams GR Jr, Burkhead WZ. Debridement of degenerative irreparable lesions of the rotator cuff. J Bone Joint Surg Am. 1995;77:857–66.
37. Mellio AS, Savoie FH, Field LD. Massive rotator cuff tears: debridement versus repair. Orthop Clin North Am. 1997;28:117–24.
38. Zvijac JE, Levy HJ, Lemak LJ. Arthroscopic subacromial decompression in the treatment of full

thickness rotator cuff tears: a 3- to 6-year follow-up. Arthroscopy. 1994;10:518–23.
39. Lee BG, Cho NS, Rhee YG. Results of arthroscopic decompression and tuberoplasty for irreparable massive rotator cuff tears. Arthroscopy. 2011;27(10):1341–50.
40. Warner JJ, McMahon PJ. The role of the long head of the biceps brachii in superior stability of the glenohumeral joint. J Bone Joint Surg Am. 1995;77:366–72.
41. Szabo I, Boileau P, Walch G. The proximal biceps as a pain generator and results of tenotomy. Sports Med Arthrosc Rev. 2008;16:180–6.
42. Walch G, Edwards TB, Boulahia A, Nove-Josserand L, Neyton L, Szabo I. Arthroscopic tenotomy of the long head of the biceps in the treatment of rotator cuff tears: clinical and radiographic results of 307 cases. J Shoulder Elb Surg. 2005;14:238.
43. Boileau P, Baque F, Valerio L, Ahrens P, Chuinard C, Trojani C. Isolated arthroscopic biceps tenotomy or tenodesis improves symptom in patients with massive irreparable rotator cuff tears. J Bone Joint Surg Am. 2007;89:747–57.
44. Klinger HM, Spahn G, Baums MH, Steckel H. Arthroscopic debridement of irreparable massive rotator cuff tears comparison of debridement alone and combined procedure with biceps tenotomy. Acta Chir Belg. 2005;105:297–301.
45. Su WR, Budoff JE, Luo ZP. The effect of posterosuperior rotator cuff ears and biceps loading on glenohumeral translation. Arthroscopy. 2010;26:578–86.
46. Mochizuki T, Sugaya H, Uomizu M, Maeda K, Matsuki K, Sekiya I, et al. Humeral insertion of the supraspinatus and infraspinatus. New anatomical findings regarding the footprint of the rotator cuff. Surgical technique. J Bone Joint Surg Am. 2009;91(Suppl 2 Pt 1):1–7.
47. Savarese E, Romeo R. New solution for massive, irreparable rotator cuff tears: the subacromial "biodegradable spacer". Arthrosc Tech. 2012;1(1):e69–74.
48. Ahmad Z, Henson F, Wardale J, Noorani A, Tytherleigh-Strong G, Rushton N. Regenerative techniques for repair of rotator cuff tears. J Orthop Surg. 2013;21(2):226–31.
49. Bond JL, Dopirak RM, Higgins J, Burns J, Snyder SJ. Arthroscopic replacement of massive, irreparable rotator cuff tears using a Graft-Jacket allograft: technique and preliminary results. Arthroscopy. 2008;24:403–9.
50. Cho NS, Yi JW, Rhee YG. Arthroscopic biceps augmentation for avoiding undue tension in repair of massive rotator cuff tears. Arthroscopy. 2009;25:183–91.
51. Rhee YG, Cho NS, Lim CT, Yi JW, Vishvanathan T. Bridging the gap in immobile massive rotator cuff tears: augmentation using the tenotomized biceps. Am J Sports Med. 2008;36:1511–8.
52. Barber FA, Herbert MA, Boothby MH. Ultimate tensile failure loads of a human dermal allograft rotator cuff augmentation. Arthroscopy. 2008;24:20–4.
53. Derwin KA, Baker AR, Spragg RK, Leigh DR, Iannotti JP. Commercial extracellular matrix scaffolds for rotator cuff tendon repair. Biomechanical, biochemical, and cellular properties. J Bone Joint Surg Am. 2006;88:2665–72.
54. Schlegel TF, Hawkins RJ, Lewis CW, Motta T, Turner AS. The effects of augmentation with Swine small intestine submucosa on tendon healing under tension: histologic and mechanical evaluations in sheep. Am J Sports Med. 2006;34:275–80.
55. Nicholson GP, Breur GJ, Van Sickle D, Yao JQ, Kim J, Blanchard CR. Evaluation of a cross-linked acellular porcine dermal patch for rotator cuff repair augmentation in an ovine model. J Shoulder Elb Surg. 2007;16(5 Suppl):S184–90.
56. Chen J, Xu J, Wang A, Zheng M. Scaffolds for tendon and ligament repair: review of the efficacy of commercial products. Expert Rev Med Devices. 2009;6:61–73.
57. Iannotti JP, Codsi MJ, Kwon YW, Derwin K, Ciccone J, Brems JJ. Porcine small intestine submucosa augmentation of surgical repair of chronic two-tendon rotator cuff tears. A randomized, controlled trial. J Bone Joint Surg Am. 2006;88:1238–44.
58. Wong I, Burns J, Snyder SJ. Arthroscopic GraftJacket repair of rotator cuff tears. J Shoulder Elb Surg. 2010;19(2 Suppl):104–9.
59. Chen CH, Chang CH, Wang KC, Su CI, Liu HT, Yu CM, et al. Enhancement of rotator cuff tendon-bone healing with injectable periosteum progenitor cells-BMP-2 hydrogel in vivo. Knee Surg Sports Traumatol Arthrosc. 2011;19:1597–607.
60. Hee CK, Dines JS, Dines DM, Roden CM, Wisner-Lynch LA, Turner AS, et al. Augmentation of a rotator cuff suture repair using rhPDGF-BB and a type I bovine collagen matrix in an ovine model. Am J Sports Med. 2011;39:1630–9.
61. Barber FA, Hrnack SA, Snyder SJ, Hapa O. Rotator cuff repair healing influenced by platelet-rich plasma construct augmentation. Arthroscopy. 2011;27:1029–35.
62. Mori D, Funakoshi N, Yamashita F. Arthroscopic surgery of irreparable large or massive rotator cuff tears with low-grade fatty degeneration of the infraspinatus: patch autograft procedure versus partial repair procedure. Arthroscopy. 2013;29(12):1911–21.
63. Gerber C, Maquieira G, Espinosa N. Latissimus dorsi transfer for the treatment of irreparable rotator cuff tears. J Bone Joint Surg Am. 2006;88:113–20.
64. Habermeyer P, Magosch P, Rudolph T, Lichtenberg S, Liem D. Transfer of the tendon of latissimus dorsi for the treatment of massive tears of the rotator cuff: a new single-incision technique. J Bone Joint Surg Br. 2006;88:208–12.
65. Warner JJ. Management of massive irreparable rotator cuff tears: the role of tendon transfer. Instr Course Lect. 2001;50:63–71.
66. Resch H, Povacz P, Ritter E, Matschi W. Transfer of the pectoralis major muscle for the treatment of irrep-

arable rupture of the subscapularis tendon. J Bone Joint Surg Am. 2000;82:372–82.
67. Paladini P, Campi F, Merolla G, Pellegrini A, Porcellini G. Pectoralis minor tendon transfer for irreparable anterosuperior cuff tears. J Shoulder Elb Surg. 2013;22(6):e1–5.
68. Weening A, Willems J. Latissimus dorsi transfer for treatment of irreparable rotator cuff tears. Int Orthop. 2010;16:1239–44.
69. Nove-Josserand L, Costa P, Liotard JP, Safar JF, Walch G, Zilber S. Results of latissimus dorsi tendon transfer for irreparable cuff tears. Orthop Traumatol Surg Res. 2009;95:108–13.
70. Omid R, Lee B. Tendon transfers for irreparable rotator cuff tears. J Am Acad Orthop Surg. 2013;21(8):492–501.
71. Gerber C, Rahm SA, Catanzaro S, Farshad M, Moor BK. Latissimus dorsi tendon transfer for treatment of irreparable posterosuperior rotator cuff tears: long-term results at a minimum follow-up of ten years. J Bone Joint Surg Am. 2013;95(21):1920–6.
72. Iannotti JP, Hennigan S, Herzog R, et al. Latissimus dorsi tendon transfer for irreparable posterosuperior rotator cuff tears. Factors affecting outcome. J Bone Joint Surg Am. 2006;88(2):342–8.
73. Namdari S, Voleti P, Baldwin K, Glaser D, Huffman GR. Latissimus dorsi tendon transfer for irreparable rotator cuff tears: a systematic review. J Bone Joint Surg Am. 2012;94(10):891–8.
74. Henseler JF, Nagels J, van der Zwaal P, Nelissen RG. Teres major tendon transfer for patients with massive irreparable posterosuperior rotator cuff tears: short-term clinical results. Bone Joint J. 2013;95-B(4):523–9.
75. Henseler JF, Nagels J, Nelissen RG, de Groot JH. Does the latissimus dorsi tendon transfer for massive rotator cuff tears remain active postoperatively and restore active external rotation? J Shoulder Elbow Surg. 2014;23:553–60.
76. Pearsall AW, Madanagopal S, Karas SG. Transfer of the latissimus dorsi as a salvage procedure for failed debridement and attempted repair of massive rotator cuff tears. Orthopedics. 2007;30:943–9.
77. Debeer P, De Smet L. Outcome of latissimus dorsi transfer for irreparable rotator cuff tears. Acta Orthop Belg. 2010;76:449–55.
78. Irlenbusch U, Bracht M, Gansen HK, Lorenz U, Thiel J. Latissimus dorsi transfer for irreparable rotator cuff tears: a longitudinal study. J Shoulder Elbow Surg. 2008;17:527–34.
79. Delaney RA, Lin A, Warner JJ. Nonarthroplasty options for the management of massive and irreparable rotator cuff tears. Clin Sports Med. 2012;31(4):727–48.
80. Grimberg J, Kany J. Latissimus dorsi tendon transfer for irreparable postero-superior cuff tears: current concepts, indications, and recent advances. Curr Rev Musculoskelet Med. 2014;7:22–32.
81. Mihata T, Lee TQ, Watanabe C, Fukunishi K, Ohue M, et al. Clinical results of arthroscopic superior capsule reconstruction for irreparable rotator cuff tears. Arthroscopy. 2013;29(3):459–70.
82. Mihata T, McGarry MH, Pirolo JM, Kinoshita M, Lee TQ. Superior capsule reconstruction to restore superior stability in irreparable rotator cuff tears: a biomechanical cadaveric study. Am J Sports Med. 2012;40(10):2248–55.
83. Denard PJ, Brady PC, Adams CR, Tokish JM, Burkhart SS. Preliminary results of arthroscopic superior capsule reconstruction with dermal allograft. Arthroscopy. 2018;34:93–9.