Massive Rotator Cuff Tears and Rotator Cuff Arthropathy

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8.1 Introduction: Massive Rotator Cuff Tears (RCT) Criteria

Antonio Cartucho

8.1.1 Incidence and Etiology

Multiple etiologies have been implicated in the pathogenesis of rotator cuff tear mainly of two types: extrinsic, such as subacromial and internal impingement, tensile overload, repetitive stress; intrinsic, such as poor vascularity, alterations in material properties, matrix composition, and aging. The work of Yamamoto [1] statistically identified that the risk factors associated with rotator cuff tears in the general population were a history of trauma, the dominant arm, and age. In subjects who were under 49 years of age, rotator cuff tears were more strongly associated with the dominant arm and a history of trauma. These results indicated that extrinsic factors were more closely associated in the tears of the younger patients. The same study found 6.7 % of patients in their 40s with rotator cuff ruptures, 12.8 % in their 50s, 25.6 % in their 60s, 45.8 % in their 70s, and 50.0 % in their 80s, with the prevalence increasing with age. Despite these results, 16.9 % of the subjects without symptoms have also a rotator cuff rupture.

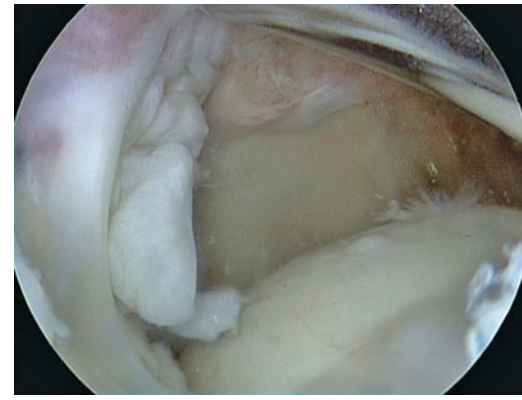


Fig. 8.1

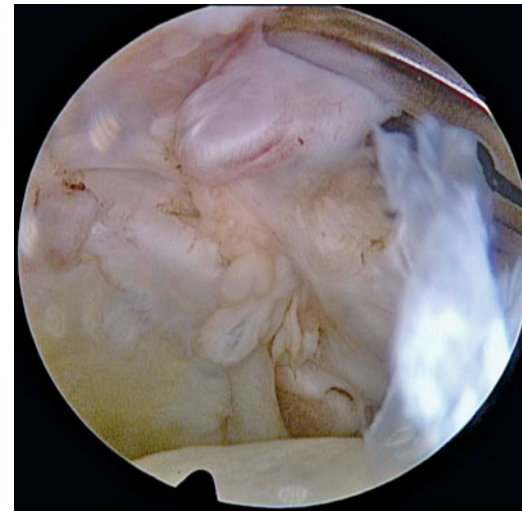


Fig. 8.2

8.1.2 Classification

Rotator cuff tears are characterized by size, location, type of onset, retraction, muscle atrophy, and fatty degeneration. More recently, the presence of supra scapular nerve pathology has been emphasized by Albrighton [2]. Different authors have proposed various classification systems to define a "massive" tear. Cofield [3], for example, defined massive tears as those whose anterior-posterior dimension exceeds 5 cm. More recently, several authors have defined massive tears as those involving at least two complete tendons. According to the tendons involved on the massive tear, we have two distinct anatomic patterns: posterosuperior, involving the supraspinatus and the infraspinatus (Fig. 8.1) and teres minor; and anterosuperior involving the subscapularis, supraspinatus, and most of the times, the long head of the biceps (Fig. 8.2). Massive tears can be further classified by chronicity and are defined as acute, acute-on-chronic, or chronic. An acute tear is relatively infrequent and occurs after a traumatic event usually in young patients. Acute-on-chronic rotator cuff tear is usually middle-aged patients, and chronic massive tears are found almost exclusively in elderly patients. Muscle atrophy has been classified by Thomaseau [4] in three different degrees, and retraction was classified by Patte also in three different types.

The fatty degeneration, another prognostic factor, has been described by Goutalier [5] in 1990 and classified in four degrees according to the percentage of degenerated muscle belly.

8.1.3 Pathomechanics

With massive rotator cuff tears, there may be an uncoupling of the forces between the cuff and the deltoid that results in unstable kinematics. This fact is especially evident if the tear extends into the anterior or posterior cuff tendons. Despite this fact, patients with chronic massive rotator cuff tears may have a functional range of motion being pain and loss of strength as the major complaints.

8.1.4 General Guidelines for Treatment

Conservative treatment should be the choice in elderly patients with acceptable range of motion for daily living activities and little pain. Young patients with acute traumatic tears should be operated on. In patients with acute-on-chronic tears with poor function and/or with pain, evaluation of muscle atrophy, tendon quality, retraction, and fatty degeneration is the key for treatment choice. Operative treatment options include debridement, partial or complete repair with or without tissue substitutes, and tendon transfers. When glenohumeral joint cuff arthropathy is present, a shoulder replacement surgery, usually with an inverted prosthesis, may be considered.

8.2 Biomechanical Studies with JK Spinnaker Technique

Pascal Gleyze

We think that the current reinsertion techniques, more specifically double-row repairs, generate extended and stiff apposition areas [6–8] that lead to shearing effect in the myotendinous junctions in rotation movements.

The implant size, the spaces needed for a double-row repair, and the lack of flexibility of the suture sliding are all constraining factors that demand a larger size construct, heavy in material, and most of all mechanically far too rigid. We are under the opinion that to adapt to all rupture types, we need a system where the implant positioning can be more freely decided.

We therefore have worked in that direction and are presenting the biological and mechanical advantages of a more dynamic and supple "V" or "W" construct (we call it the Spinnaker Technique in reference to the special shape sail) that follows the principle of a lateral anchor to create a large V effect coupled with a tension-free medial row to secure a quality footprint without generating tendinous shearing effect. For this supple construct, we use the JuggerKnot suture anchor. Of a unique design, this suture anchor has demonstrated pullout strengths that satisfy the highest standards [9–11] (Figs. 8.3 and 8.4). The very nature of the JuggerKnot and its very small size allow an almost absolute flexibility in the insertion decision-making process. The direct result is the optimal biomechanical properties of the anchor spread. The pullout strengths, the shearing effects, and the various force spread patterns have been studied in the most common type constructs.

We most often combine the rotator cuff JuggerKnot 2.9 (referring to the size of the drilled hole) with the smaller JuggerKnot 1.4 initially designed for Bankarts or SLAPS. The JuggerKnot 1.4 is probably insufficient for a full-thickness cuff tear but conveniently completes "on demand" construct built on the JuggerKnot 2.9. For smaller arc-shaped tears, we propose a "V" construct (Fig. 8.5) and a double "V" for bigger tears (Fig. 8.6), and "a la Carte" construct for angulated tears with the possibility of deep partial

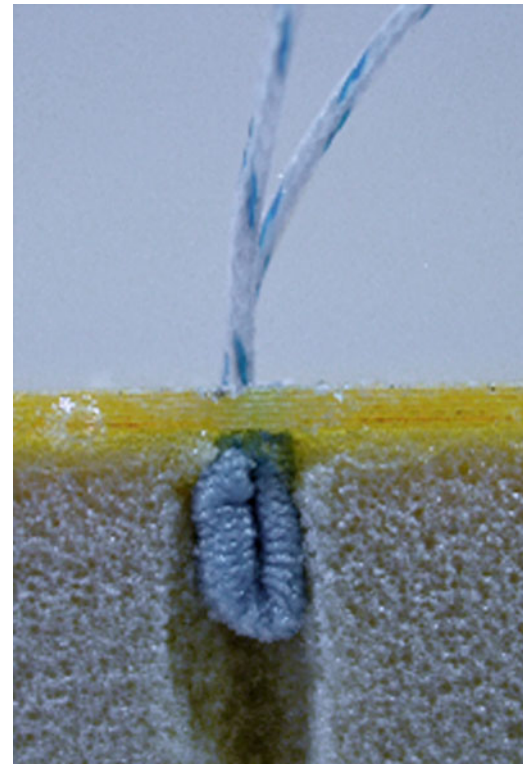


Fig. 8.3

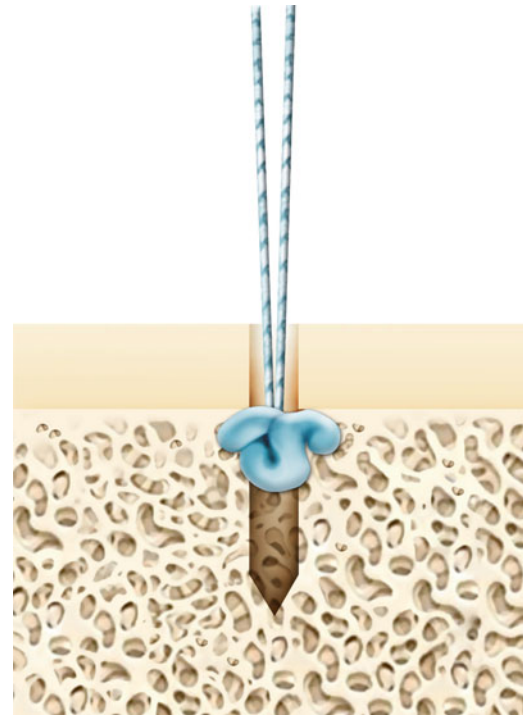
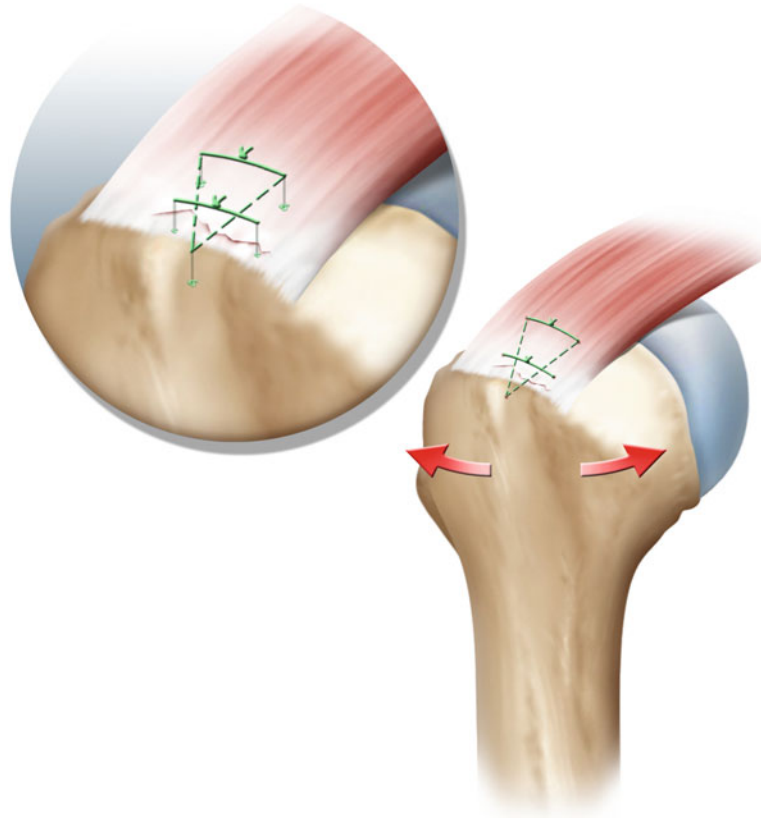


Fig. 8.4

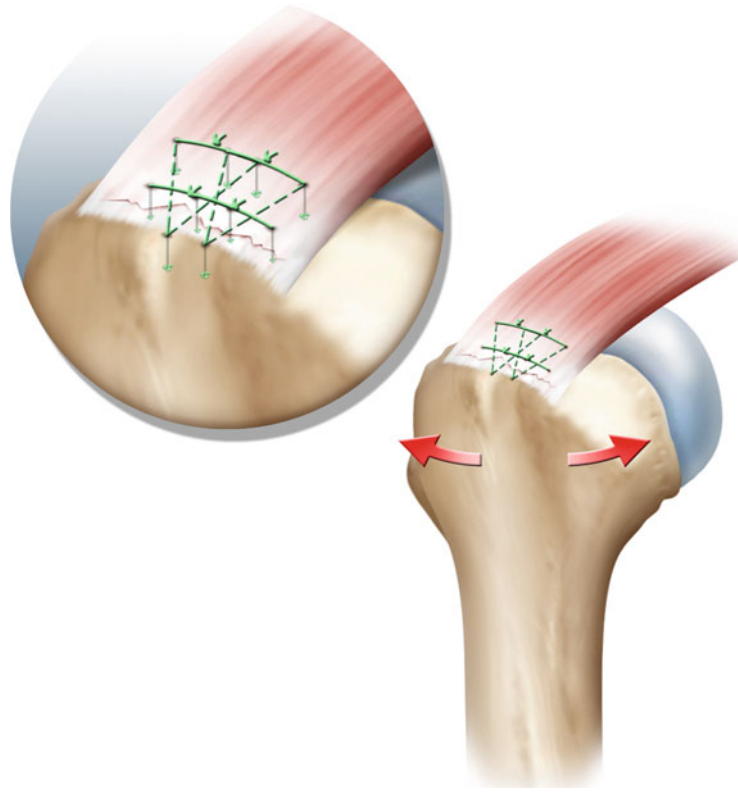
Fig. 8.5



tears repairs with a very small insert (1.4 mm) (Fig. 8.7).

This construct refers to sailing, where the sheeting point receives the sail pivoting and a suture row secures the angular tensions. It follows the principle of a fluid mechanical construct, dynamic because of its spread of the various forces, positioned "a la Carte," and little aggressive to the anatomical structures.

Fig. 8.6



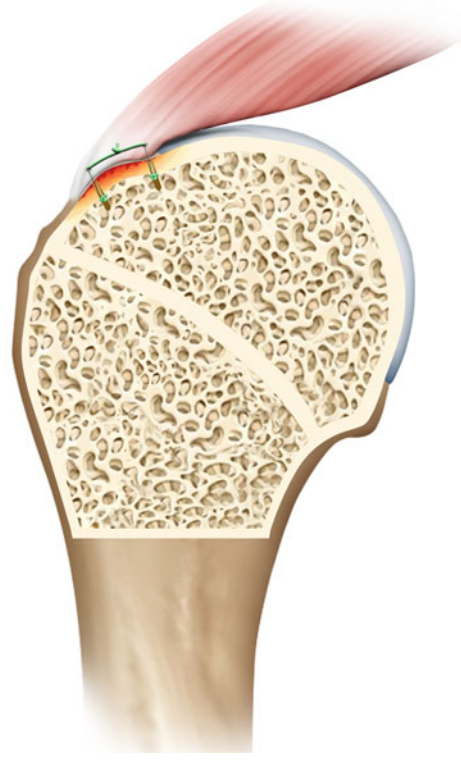


Fig. 8.7

8.3 The Importance of Biology in Rotator Cuff Treatment

Antoon Van Raebroeckx

To improve the outcome of the treatment of rotator cuff tears, different new techniques are being developed. Despite these new fixation techniques, healing rates remain insufficient. Failures are less likely to occur from weak tendon-to-bone fixation but more likely due to biological failure. A lot of research is being done on biological augmentation. Even more important, taking care of the biology of the repair itself using all this new techniques in our daily practice will improve our results.

The biology of a rotator cuff repair starts preoperatively, continues during the surgery, and ends during the revalidation period. There are a lot of factors the surgeon himself can take care of considering the basic principles of tendon-to-bone repair.

Clinical and technical examination will show the degree of fatty infiltration and quality of the muscle and tendon. Communication with the patient regarding these results might clarify the expected result after the repair. The negative effect on potential healing of crystalline glucocorticoid injections in the subacromial bursa needs to be considered if surgery might be necessary in the future. Most important, at this stage, is the importance of biology during the surgery itself. This starts with the examination of the tear and the recognition of the tear pattern. If the tear pattern is not fully understood, the repair will not be anatomical, and biology will fail. Time needs to be taken for a proper debridement of the bursa to have a nice view of the whole rotator cuff. Using a manipulator, the type of tear can be estimated. The importance of restoring the footprint is generally accepted. Time needs to be taken for the preparation of the footprint. For a tendon-to-bone repair, we need as healthy tissue on both sides as possible. All remaining fibers on the footprint need to be removed on an area as large as possible without taking of healthy cuff fibers. Radio-frequency devices are very useful and work quickly. After cleaning with the RF device, all tissue sides that need to heal must be cleaned using a shaver device before the repair, making sure that all death tissue is removed. Using new techniques, an area as big as possible of the footprint should be covered with the tendon. The importance of the tension on the rotator cuff is important, and it is widely accepted that too much tension should be avoided. More studies are needed to support this scientifically.

The importance of the biology continues after the repair. The healing process takes several weeks and can be divided into three stages: the inflammatory stage, the repair stage, and the remodeling stage. The negative effect of nicotine and nonsteroidal anti-inflammatory drugs is very well known. Patients should be asked to stop smoking 8 weeks before and 8 weeks after the repair. Both traditional and cox-2-specific NSAID inhibit tendon-bone healing. A good communication with the general practitioner is obligatory to avoid starting this medication during the period of cuff ingrowth. If possible, glucocorticoid medication should be stopped during the same period. The postoperative rehabilitation protocol should be respecting the healing process during the first 12 weeks. No ingrowth is seen on the first 6 weeks, and it takes up to 12 weeks before the first collagen fibers are strong enough to be loaded. It is generally accepted that active movement on the first 6 weeks should be avoided. There is less agreement on when to start passive motion. In contrast to what many think, to early start the passive motion exercises might lead to stiffness. In general, passive motion exercises should be started between 3 and 6 weeks postoperatively.

Besides all these factors that should be taken care of in our daily practice, a lot of scientific work is being done to further improve the biology of a rotator cuff repair. Tendon augmentation with autograft can be used to decrease the tension on the repair. An extracellular matrix with no cellular components acts as a tissue bridge between tendon and bone or can be used as a reinforcement of a poor-quality tendon in a tendon-to-bone repair. Recently, xenograft, allograft, and synthetic extracellular matrices are being developed and used. While xenografts yield mixed results, allograft extracellular matrices show some promising

results. To avoid the inflammatory response to some DNA in the matrix, synthetic grafts are being developed. The next step is the development of ECM autogenic cell constructs, which were autologous cells that are harvested from undamaged sites on the host and cultured with the ECM. Using gene therapy, these constructs can be manipulated to promote fibroblast proliferation and minimize inflammation. Growth factors have been tested individually for their contribution to rotator cuff healing. Different systems are commercially available to augment the repair with platelet-rich plasma. Until now, no significant difference is being reported using these techniques. Results of randomized control studies using PRP as an augmentation to rotator cuff repair versus a conventional repair are waited for.

All these new techniques and promising new developments may not change the focus we need to put on the basic biology of our daily rotator cuff repair.

8.4 Massive Cuff Tear: Suture Bridge Repair

Bruno Toussaint

Massive cuff tears are not common. Even in clinical practices limited to the treatment of shoulder problems, less than one-third of all rotator cuff tears are massive. Massive anterosuperior rotator cuff tears are even less common.

While there is no universal agreement on the definition, in North America Cofield's definition of a massive tear as one with a diameter of 5 cm or greater is used [12], in France Patte's definition of a massive tear as on with three tendons torn or more is used. Massive cuff tear could not be repaired every time. Different factors modify ability to repair massive cuff tear. A number of treatment options are available to the surgeon when a massive defect of the tendons of the rotator cuff is found, but if the full repair is possible, the suture bridge technique is a good option that it restores the cuff footprint as well [13–16].

8.4.1 The Preoperative Assessment of Ability to Repair Massive Cuff Tear

Massive cuff tears classification will need to be updated. Recognition of the geometric tear patterns described in new classification, described by Burkhart, will remain useful and serve as a basis for communication and comparison of treatment methods and outcomes [17–19].

Fatty degeneration of the rotator cuff muscles, as determined on magnetic resonance imaging (MRI) or computed tomography (CT) scan, is frequently invoked as a contraindication, or at least a relative contraindication, to rotator cuff repair. Superior migration of the humeral head is also invoked as a contraindication to rotator cuff repair. Currently, they are relative contraindications [20]. Some authorities believe that rotator cuff repair in shoulders with 50 % or greater fatty degeneration of the infraspinatus (as shown on MRI or CT scan) is doomed to failure. This philosophy is based primarily on the work of Goutallier et al. who stated that patients with rotator cuff tears associated with stage 3 (50 %) or stage 4 (>50 %) fatty degeneration of the infraspinatus did not improve after surgical repair. Although the original imaging studies were CT scans, Gerber et al. [20] have shown that MRI and CT scans are equivalent in their ability to detect fatty degeneration of muscle. Additionally, MRI, because of improved contrast resolution, can better differentiate muscle from fibrous tissue and fat and has widely replaced CT scanning in the majority of centers for shoulder evaluation. Nakagaki et al. have shown that the fatty degeneration correlated well with the size of the cuff defect and the tendon fiber area. The fatty degeneration in the supraspinatus muscle after a cuff tear is associated with retraction of the tendon fiber rather than with reduction of the muscle size. Burkhart et al. [21] have shown what arthroscopic rotator cuff repair in patients with grade 3 or 4 fatty degeneration (≥50 %) can provide significant functional improvement. Those with 50–75 % fatty degeneration show a much greater degree of improvement than those with >75 % fatty degeneration. However, clinical improvement was observed for some patients having >75 % fatty degeneration and for all patients in the 50–75 % group. Pseudoparalysis, which is often a characteristic symptom of large-to-massive rotator cuff tear, has been focused on recently because it is one of the important indication criteria for performing reverse total shoulder arthroplasty. It is also known to be a negative prognostic factor of rotator cuff repair in cases of large-to-massive tears. Therefore, pseudoparalysis is not an irreversible phenomenon. Further, a fairly large number of the patients could elevate their shoulder above horizontal level after rotator cuff repair [22]. A large number of the patients did recover from pseudoparalysis after rotator cuff repair, and postoperative function was favorable. Functional and anatomic outcomes of the pseudoparalytic groups were comparable to nonpseudoparalytic groups. Considering the complications and longevity of reverse total shoulder arthroplasty, rotator cuff repair should

be the first-line treatment option for nonarthritic large-to-massive tears regardless of the presence of pseudoparalysis.

Which are the factors that influence the tendon-to-bone healing? Bone quality, tendon quality, and muscle retraction are the main factors [23–27].

Although cuff strength may be compromised by inflammatory arthritis and steroids, the primary cause of tendon degeneration is aging. Like the rest of the body's connective tissues, rotator cuff tendon fibers become weaker with disuse and age; as they become weaker, less force is required to disrupt them. Other authors have shown loss of tendon strength with age. Pettersson provides an excellent summary of the early work on the pathology of degenerative changes in the cuff tendons. Citing the research of Loschke, Wrede, Codman, Schaer, Glatthaar, Wells, and others, he builds a convincing case for primary, age-related degeneration of the tendon manifested by changes in cell arrangement, calcium deposition, fibrinoid thickening, fatty degeneration, necrosis, and rents.

Reparability should be confirmed intraoperatively, not judged solely on preoperative criteria.

The surgical treatment of massive, contracted, immobile rotator cuff tears (of the posterosuperior rotator cuff) can be difficult and demanding.

Tauro was the first to describe an arthroscopic interval slide (anterior interval slide) for improving the mobility of contracted tears. The anterior interval slide improves the mobility of the rotator cuff by releasing the interval between the supraspinatus tendon and the rotator interval, effectively incising the coracohumeral ligament, which commonly becomes contracted in the tear patterns [17, 24, 28, 29].

Burkhart et al. [30] have shown that the double-interval slides have demonstrated significant improvements to reestablish the rotator cuff footprint.

According to the rotator cable and crescent theory, it countered more logical today to preserve the rotator cable which is the most resisting tissue element to fix to the bone. The respect of comma sign anteriorly and the connected fibers of supra- and infraspinatus posteriorly seems the key point of the repair technique. And the mechanical strength of repaired tendons is improved as well as possible.

Glenohumeral joint and subacromial side release are very important to recreate a good rotator tendon mobility. In these cases, because of the propensity of the coracohumeral ligament to rigidly shorten and thereby tether the rotator cuff medially, mobilization techniques are required to allow repair of the rotator cuff to a lateral bone bed in a tension-free manner. The comma sign is made from the superficial layer of the rotator interval established by subscapularis superficial fibers connected with supraspinatus superficial fibers and is often stuck on the coracoid process. It must be totally released from the coracoid process. Posteriorly, the release must be careful to avoid damaging the suprascapular nerve just in front of the scapular spine. The articular capsule must be opened superiorly for 3 o'clock to 7 o'clock to improve the rotator cuff tendon mobility.

Cadaver study has shown that the maximum lateral advancement of the cuff that it permitted by the neurovascular structures is 3 cm [31].

The fixation is made then easily on first-row anchors restarted on the whole footprint as parachute. The second-row anchors apply compression over the footprint of the rotator cuff. All sutures should be passed through the rotator cuff tendon in first and have tied in a second time to improve suture passing.

Although arthroscopic rotator cuff repairs have led to excellent clinical results, there has been some criticism of suture anchor repair constructs. This is because when the rotator cuff is repaired with a single row of suture and anchors, the normal footprint of the rotator cuff is not restored. In an elegant study by Apreleva et al., the effect of reconstruction method on three-dimensional repair site area was evaluated. These authors determined that suture anchor repair constructs restored only 67 % of the original "footprint" of the rotator cuff, whereas transosseous simple suture repairs restored approximately 85 % of the surface area. The technique for double-row suture anchor fixation for arthroscopic rotator cuff repair was first described by Lo and

Burkhart. Those authors proposed that by placing two rows of suture anchors, one on the medial side of the footprint and the other on the lateral side, a more anatomic repair configuration could be achieved. The result, they hypothesized, would be a stronger repair construct and a larger contact area for healing, yielding superior clinical outcomes and a more durable rotator cuff repair. Lafosse et al. have reported a rate of structural failure after double-row fixation was only 11 %, and to our knowledge, this value represents the lowest rate of structural failure after either open or arthroscopic repair as reported in the literature. Galatz et al. [32], in a study on the results of all arthroscopic reconstruction of large or massive rotator cuff tears with use of single-row suture anchors and simple sutures, reported recurrence of the tear in 17 of 18 patients as assessed with ultrasonography. The shoulders with repaired large and massive rotator cuff tears had less strength than those with smaller tears. These findings suggest that the double-row suture anchor configuration may be the optimal repair construct for arthroscopic rotator cuff repair. We believe that the transosseous equivalent versus suture bridge technique provides excellent initial repair strength [16, 24, 33–35]. This strength, as well as the compression applied over the footprint of the cuff, allows for increased surface area and healing. Traditional single-row repairs allow only for healing of the edge of the tendon to bone. Double-row techniques provide excellent strength but lack the compressive effect of the suture bridge. The biomechanical study presented by El Attrache et al. [34] is the first comparison of double- and single-row repair techniques that accounts for the tension differential between the two. The results suggest that, when possible, a double-row repair should be performed for the treatment of retracted tears of the rotator cuff.

Arthroscopic revision rotator cuff repair is a reasonable treatment option, even in cases of massive retear. The good midterm improvement in forward elevation could be explained by deltoid integrity that is essential to achieve satisfactory elevation but also by the systematic repair of the subscapularis that provided restoration of the rotator cable and balanced force couples.

8.5 Double-Row Technique Appliance in Massive RC Tears

Roman Brzoska and Adrian Blasiak

8.5.1 Introduction

Massive rotator cuff injuries are the most common cause of pain and movement impairment of the shoulder. New very successful arthroscopic reconstruction methods of repair of RC rapture have been established in a few last years. It has become possible due to use of stronger bone implants (anchors) with improved surgical sutures as well as improvement in visualization of joint's structures (arthroscopic pump, radiofrequency device). The aim of arthroscopic treatment is to achieve strong and durable junction between bone and tendon while allowing both structures to heal. Single-row implantation technique is simpler, faster, and requires less artificial material. Some believe that using fewer sutures with excellent results of repair is a great advantage of this technique. Double-row technique is more challenging; however, it can produce RC junction similar to anatomical. Physiological movements of shoulder postoperatively are fully restored which was confirmed by biomechanical studies [36, 37]. Unfortunately double-row technique requires more artificial material to build up junction, and for some, it is the disadvantage of the technique. It will also lead to increased cost of operation. Some authors proved that the "watertight closure of the rotator cuff is not needed to obtain successful outcome" [38–40]. The aim of the partial repair is to restore of the proper mechanics of the shoulder through the reconstruction of infraspinatus and subscapularis tendon footprint. Both of them give opposition forces to the deltoid muscle force vector. This partial reconstruction prevents upper migration of the humeral head [41].

8.5.2 Technique

The patient is settled in the "beach-chair" position, under general anesthesia following interscalene block. This position gives the best insight into the subacromial space and allows removing all adhesions between the ruptured tendons and undersurface of the acromion and also performing extensive capsulotomy. These two procedures facilitate to mobilize retracted cuff tendons (Fig. 8.8). The next stage is precise definition of the shape and direction of retraction of the tendon margin. With the tissue grasper, the mobility is tested in order to approximate the tendons to the tuberosity (Fig. 8.9).

From the perspective of healing process, it is very important to prepare bony bed until the bleeding of cortical bone surface. The first double-loaded anchor is situated at the cartilage rim

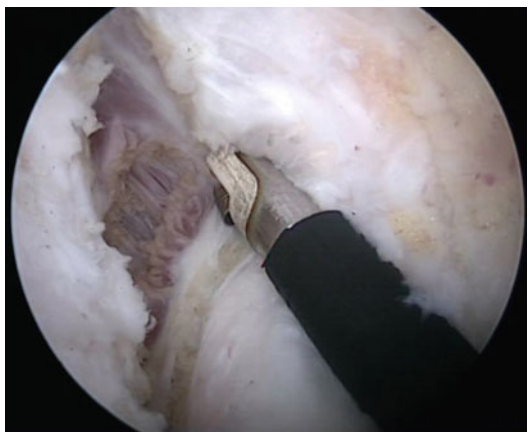


Fig. 8.8

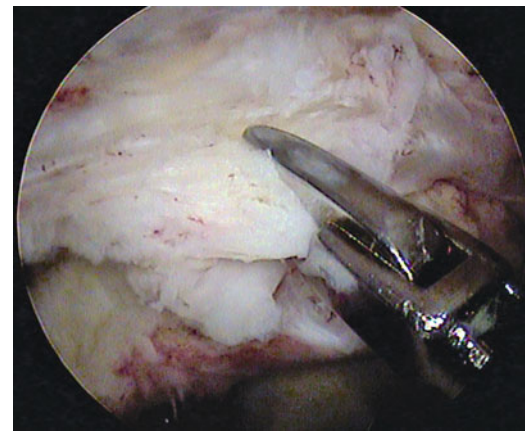


Fig. 8.9

(Fig. 8.10). The most technically demanding step of this procedure is suturing the tendons. The goal of this step is to choose the strongest part of the tendon for passing the sutures, which provides a strong footprint restoration. Using a Clever Hook device, two mattress sutures for each of double-loaded anchors are performed (Fig. 8.11).

Second-row anchor is placed on the lateral aspect of the great tuberosity.

After all anchors are placed and all threads have been passed through the tendon, the cuff is reduced with a locking knot made on the "lasso-loop" stitch at the lateral anchors (Fig. 8.12). After the reduction has been completed, mattress sutures on the medial anchors are tightened [42]. If necessary, acromioplasty and/or acromioclavicular joint resection is performed. No complications were reported during surgeries.

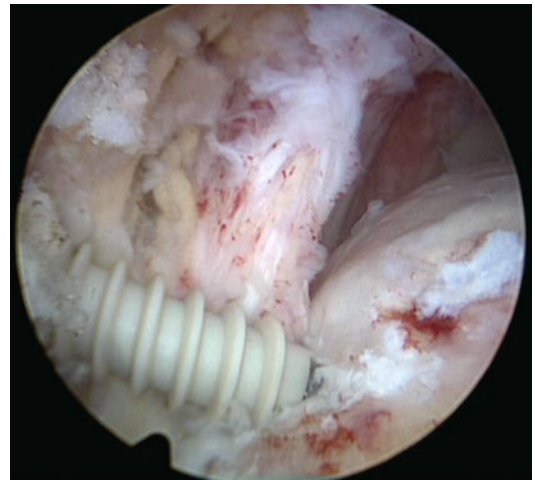


Fig. 8.10

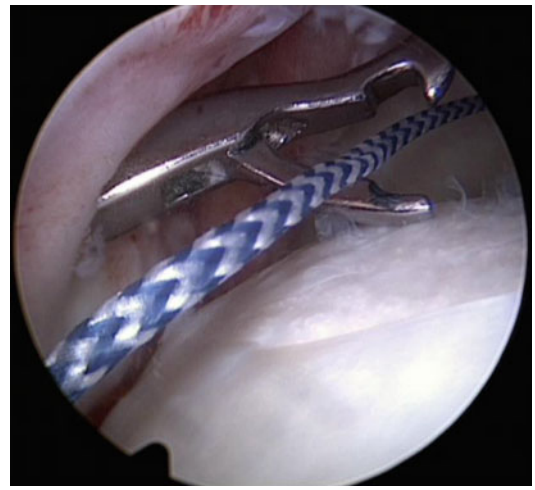


Fig. 8.11

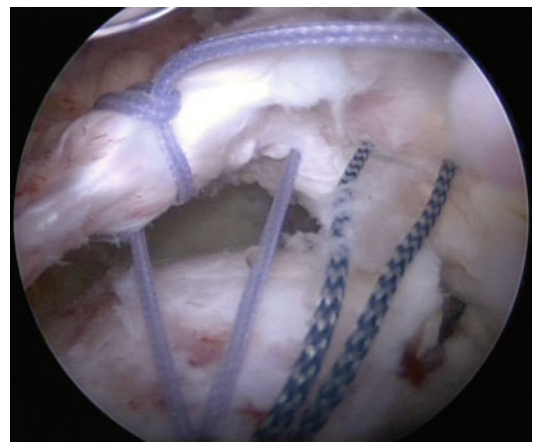
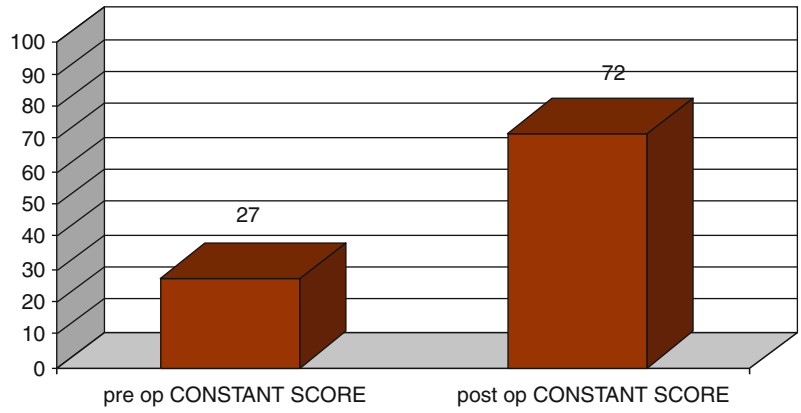


Fig. 8.12

8.5.3 Results

All our patients have been assessed by postoperative Constant score, USG examination, Jobe and Neer tests that were used to evaluate results and recovery postsurgery. From 2006 to 2009, 54 patients (mean age 58 ± 9.3, range 27–79) underwent arthroscopic double-row reconstruction of massive RCT. Results of surgery were assessed 3, 6, and 12 months postoperatively. Massive rupture of supra- and infraspinatus muscle tendon was the most common type of injury. Good results according to Constant score were observed (Table 8.1).

There were twice less reinjuries confirmed by USG examination in 12 months postoperatively in patients with type II infraspinatus retraction (according to Patte classification), comparing with type III injuries of this tendon. Better results in group with smaller infraspinatus ruptures in 3 and 6 months postoperatively according to Constant score suggest less pain and wider range of arm's movements. Older patients (>65 years old) had worst results. Limited movements of arm and pain were still present 12 months postoperatively; however, improvement to preopera-



tive status was still satisfactory according to Constant score.

8.5.4 Conclusions

Double-row technique is effective and adequate to the massive RCT repair. However, the condition must be met to obtain a good mobilization of retracted tendons what allows to tie the knots without excessive tension of sutured tissue.

8.6 The Shoestring Bridge

Maarten van der List and Peer van der Zwaal

Historically, the aim of the rotator cuff repair is to mobilize the tendon, close the defect, and anatomically restore the insertion on the footprint. Large U- and L-shaped tears are usually transformed into smaller tears by side-to-side repair with interrupted sutures in a medial to lateral progression (the margin convergence technique). Then the tendon is fixed by a single or double row of corkscrews or suture anchors. In our opinion, this is the method of choice in small, medium, and large mobile tears. However, in large degenerative and nonelastic tears, there is a significant risk that the tendon will fail after mobilization and fixation onto the anatomic footprint – too much tension. The shoestring bridge technique uses a principally different approach for the repair of these rotator cuff tears. It is a solely side-to-side repair without anatomical reconstruction of the footprint. The shoestring configuration using the broad FiberTape evenly distributes the tension over the tendon. This makes the repair more resilient in spite of the poor-quality tissue. We hypothesize that although there is no restoration of the footprint, there is a functional restoration of the cable bridge of Burkhart. We believe this is an important aspect of the procedure.

From a mechanical point of view, it is interesting to conclude that functional repair is possible without insertion onto the footprint.

We think the shoestring bridge can be a valuable technique for the shoulder surgeon in the treatment these challenging cuff ruptures.

8.7 Orthospace InSpace™ Balloon System in Massive Irreparable Rotator Cuff Tears

Vladimir Senekovic, Boris Poberaj, Ladislav Kovacic, Boštjan Sluga Martin Mikek, Ehud Atoun, Eliyau Adar, and Assaf Dekel

8.7.1 Introduction

Rotator cuff tears (RCTs) are among the commonest tendon injuries seen in orthopedic patients resulting in significant community-borne pain and disability.

Irreparable RCTs are defined by the size of the tear, the presence of tendon retraction, chronicity of the injury, the amount of muscle atrophy, and degree of fatty degeneration. In these situations, direct repair at the point of insertion is usually not feasible despite extensive soft-tissue mobilization and release. A range of surgical options are available including debridement (with or without partial tendon repair), tendon transfer, muscle-tendon slide procedures, the utilization of rotator cuff allograft and synthetic graft materials, arthrodesis, reverse arthroplasty, or hemiarthroplasty. It has been reported in massive RCTs that primary repairs will rerupture in between 20 % and 65 % of patients over time. Although patients with massive RCTs may be capable of generating glenohumeral abduction, methods designed to reduce pain will result in significantly improved shoulder kinematics. Our hypothesis is that the deployment of an inflatable balloon into the subacromial space in patients with massive RCTs will prevent impingement during abduction, resulting in painless activation of the scapulohumeral musculature. Moreover, lowering of the humeral head during balloon inflation may provide an improved balance between the subscapularis anteriorly and the infraspinatus posteriorly and permit better deltoid activation and compensation through the arc of motion. This study assesses the safety and clinical outcome of the use of the copolymer InSpace™ (Orthospace Ltd., Israel) balloon in a group of patients diagnosed with a massive irreparable RCT.

8.7.2 Methods

8.7.2.1 Study Design

Patients were enrolled in the study after signing an informed consent. The study was ethically approved by the hospital's Institutional Review Board and Slovenian Competent Authority. The study was designed to assess the initial safety and efficacy of the InSpace ™ balloon system in subjects with massive irreparable tears, to record surgeon satisfaction with the implantation procedure, as well as procedure and device-related adverse effects. Primary endpoints included pain relief over time (along with relief of night pain), improvement in the range of motion, activities of daily living, and shoulder strength using the Constant score recorded at each follow-up visit. Specific contraindications to InSpace™ deployment included patients with significant shoulder osteoarthritis, evidence of glenohumeral instability, prior shoulder surgery, or those with concomitant shoulder infection or immunosuppression. Patients were clinically assessed preoperatively for the presence of a full-thickness massive RCT with supplementary imaging using ultrasound, CT arthrography, and magnetic resonance (MR) imaging as appropriate. Final confirmation of the RCT size, tendon involvement, and reducibility was made during arthroscopy where the surgeon assessed the feasibility of surgical repair. Prospective postoperative assessment of symptoms, complications, and/or device-related adverse events were recorded with prospective determination of the Constant score as well as at hospital discharge 1, 3, and 6 weeks, 3 and 6 months, 1.5 and 3 years postoperatively. Balloon placement and degradation were assessed by sonographic evaluation at 1 week and 3 and 6 months postimplantation.

8.7.2.2 InSpace™ Balloon System

The InSpace™ system is a biodegradable balloon meant for arthroscopic insertion into the subacromial space following bursa excision. The preshaped balloon is comprised of a copolymer of poly-L-lactide-co-ε-caprolactone in a 70:30 ratio which biodegrades over a period of 12 months. Insertion of the balloon is aided by folding it into a cylindrical shape inside an insertion tube. Once positioned in the subacromial

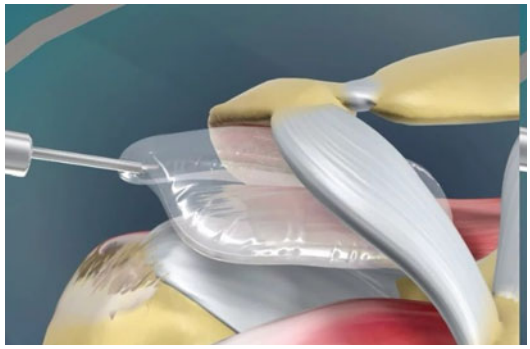


Fig. 8.13 Schematic representation of the InSpace™ balloon deployment and inflation in the subacromial space through an insertion tube (*left* of image)

space, the balloon is inflated with saline permitting frictionless gliding of the humeral head against the acromion. A schematic representation of the balloon deployment is shown in Fig. 8.13a,b. Balloon size (small, medium, or large) is selected based on the surgeon's discretion following measurement of the distance between the lateral border of the acromion and the superior rim of the glenoid as well after defining the extent of any tear extension. The range of motion is determined by balloon inflation and deflation, and the appropriate inflation volume is left in situ by withdrawing the syringe which effectively seals the balloon (Fig. 8.13).

8.7.2.3 Surgical Technique

All operations were performed with the patient in a beach-chair position under general anesthesia using three arthroscopic ports (anterior, lateral, and posterior or posterolateral). After subtotal removal of the subacromial bursa, the tear was debrided, and the rotator cuff was assessed by grasping the edges of the tendons with an arthroscopic clamp in an attempt to draw it to the footprint region. A decision was made to insert the balloon when it was deemed that the RCT was irreparable.

8.7.3 Results

A total of 20 patients (11 males and 9 females; mean age 70.5 years) with massive RCTs were enrolled in the study between the periods of May and October 2008 at the Department of Traumatology at the University Medical Centre Ljubljana and two of its satellite implanting centers, the Valdoltra Orthopedic Hospital and the Department of Surgery at the Novo Mesto General Hospital in Slovenia. In all but one case, where a miniopen approach was used, the balloon was inserted arthroscopically. The mean duration of symptoms prior to surgery was 34.7 months (range 4–95 months) with documented failure of conservative treatment in all patients. The technique of implantation was recorded as relatively straightforward by all surgeons where the approximate time for implantation (from insertion of the InSpace™ balloon to withdrawal of the accessories after deployment) ranged from 2 to 20 min. Two patients were lost from follow-up (one patient died during follow-up from cardiac disease at the time of the 1.5-year visit).

Table 8.2 shows the baseline and follow-up clinical scoring data of the 20 patients analyzed, and Fig. 8.14 shows these changes represented graphically. There was a significant improvement in the subjective pain score (module A of the Constant score), commencing at 1 week following balloon implantation, with a mean change of 2.91 points (95 % CI 1.28–4.54; $P = 0.0021$). This improvement remained statistically significant with a progressive increase throughout the duration of follow-up. At the 3-year visit, the average change reached 6.11 points (95 % CI, 4.34–7.88; $P < .0001$). Night pain statistically improved beginning at 1 week postsurgery (95 % CI 0.41–0.97; $P < 0.0001$) with a sustained statistically significant improvement through to the 3-year follow-up visit (95 % CI 0.69–1.30; $P < 0.0001$). Improvement in night pain was reported in 12/18 patients (66 %) at the first postoperative week, in 14 (77 %) patients at the 1.5-year visit, and sustained at the 3-year follow-up visit (14/18; 77 % patients). One patient had no improvement in pain, where at 6 weeks, an ultrasound showed that the InSpace™ balloon was partially deflated. This patient withdrew consent from further participation in the study and a few months later underwent reverse total shoulder arthroplasty. No other device- or proce-

Table 8.2 Summary of patient efficacy data mean scores (+ SD) from preoperation (baseline) up to 3 years after InSpace balloon deployment

	Baseline N = 20	3 weeks N = 20	6 weeks N = 20	3 months N = 17	6 months N = 18	1.5 years N = 17	3 years N = 17
TCS	33.41 (13.34)	39.05 (13.04)	42.61 (15.00)	44.12 (14.98)	50.36 (19.72)	60.11 (24.30)	60.00 (22.68)
SPS	5.08 (2.76)	7.70 (3.57)	7.70 (3.57)	8.28 (3.94)	8.92 (4.16)	11.56 (4.47)	11.29 (4.09)
Night pain	0.70 (0.66)	1.25 (0.79)	1.30 (0.66)	1.35 (0.49)	1.72 (0.46)	1.53 (0.62)	1.71 (0.47)
Daily activities	7.20 (3.36)	9.77 (4.65)	9.50 (3.44)	10.06 (3.07)	10.94 (3.95)	13.82 (5.36)	15.94 (4.39)
ROM	20.60 (8.95)	21.60 (7.75)	24.70 (9.91)	25.76 (10.27)	27.00 (9.68)	30.00 (11.00)	28.82 (11.94)
Power	0.54 (2.39)	–	–	–	3.50 (7.02)	5.20 (8.43)	3.95 (4.99)

TCS – total constant score, SPS – subjective pain score, ROM – range of motion

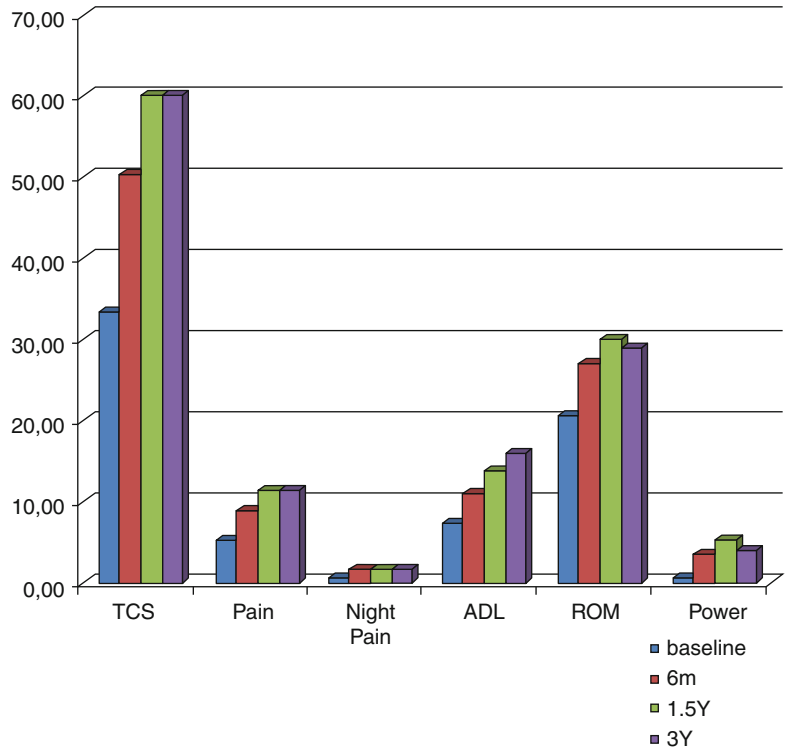


Fig. 8.14 Graphical representation of changes from baseline *during follow-up* in the constant variables following InSpace™ balloon insertion

dure-related adverse events were noted during the entire follow-up period.

Patients reported significant improvement in their activities of daily living beginning at the third week after surgery showing an average of 2.52 points of change (95 % CI 0.82–4.23; P = 0.004) which increased up to 8.76 points (95 % CI 6.91–10.61; P < 0.0001) at 3 years of follow-up. The range of motion also showed significant improvement beginning at 6 weeks postsurgery with a mean change of 3.96 points (95 % CI 0.454–7.48; P = 0.0272). This change progressively increased throughout the study period up to 7.27 points (95 % CI 3.87–11.49; P < 0.0001) at 3-year follow-up. Shoulder power was difficult to evaluate early on in the postimplantation period but showed significant improvement at 1.5 years (95 % CI 2.59–6.84; P < 0.0001) which was sustained at 3 years (95 % CI 1.24–5.5; P = 0.0022). In all measurable parameters, once an improvement reached significance, it was maintained throughout the follow-up period.

8.7.4 Conclusion

This preliminary prospective pilot study has shown clinical safety and efficacy of the InSpace™ device in a small group of patients with massive irreparable rotator cuff tears (RCTs). The insertion of the device was associated with significant early improvement in subjective pain scores and a decrease in reported night pain. The total Constant score showed statistically significant improvement as did scores of activities of daily living and range of motion, each of which was sustained at 3 years of follow-up. Further longitudinal randomized studies are required to determine its place in the management of irreparable massive rotator cuff injury.

8.8 Arthroscopic Assisted Latissimus Dorsi Transfer in Massive Rotator Cuff Tear

Viktoras Jermolajevas

8.8.1 Introduction

Irreparable rotator cuff teas are characterized by the inability to achieve direct repair to proximal humerus despite mobilization. Moreover, not all repaired tissue is able to heal. In 1988, Gerber describes the open technique of latissimus dorsi transfer (LDT) and, in 1992, showed that obtained results are long lasting [43]. First arthroscopic LDT technique was published in 2007 by Gervasi [44]. This technique was adopted to operate in beach-chair position with several improvements in harvesting and fixation.

8.8.2 Material and Technique

Since 2009, 31 patients were operated. Mean age was 62 years, range 41–78, 19 men, 12 women. The essential criteria for inclusion were good deltoid and at least reparable subscapular muscle, arthritis no more than stage II. Mean active elevation was 90, range 10–150. Belly press test was positive in 20 cases, but lift of test was negative in all cases; this suggested for partial subscap rupture. External rotation lag was gross in all cases. All patients were operated in beach-chair position. Portal used as for routine cuff surgery, with addition suprapectoral portal for LD release (Fig. 8.15a).

Definitive decision to perform LDT was made during surgery after tendon mobilization. Operation could be divided in six steps: (1) Posterior view: subs repair, biceps tenotomy (if needed); (2) Lateral view: anterior interval slide, SSc nerve release, circular capsulotomy, bursectomy, decision for LDT; (3) Lateral view: finding of interval between teres minor and deltoid, urinary catheter near long triceps tendon; (4) Anterior view: 1-cm release of Pec major, full LD release from humerus; (5) Posterior axillary incision (Fig. 8.15b), LD distal release from subcutaneous tissue, transfer subacromially; (6) Lateral view: partial cuff insertion (Fig. 8.16), LD insertion, acromioplasty.

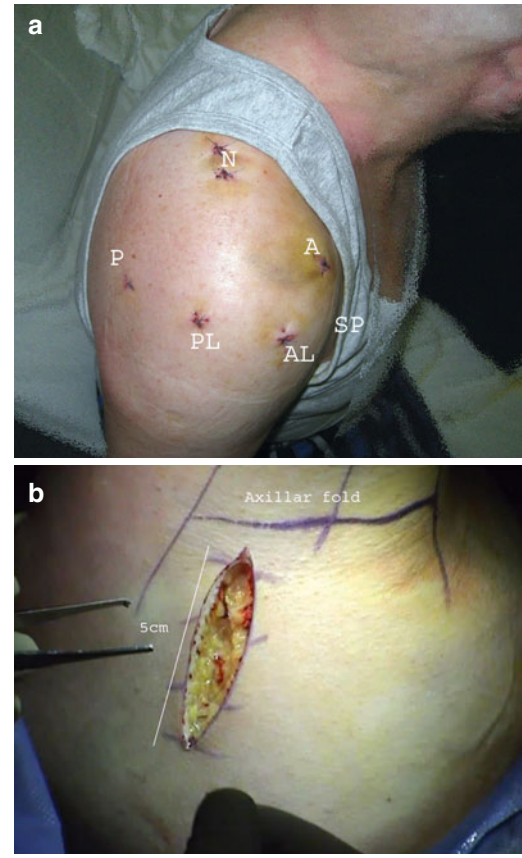


Fig. 8.15 Lateral view of right shoulder. (**a**) portals, (**b**) axillar incision (shoulder in ABD)

8.8.3 Results

Mean of follow-up after operation was 16 month, range 4–33 month. One patient had posterior transient humeral numbness. Twenty-eight patients improved in pain and motion and were happy with results. Mean gain in elevation was 40 °, in external rotation 30 °. Twenty-four patients remain with slight external rotation lag. Pain improvement was more noticeable than gain in motion. In remaining three patients, one patient developed deep infection 10 month after surgery, and two had LD tendon rupture about 4 months after surgery.

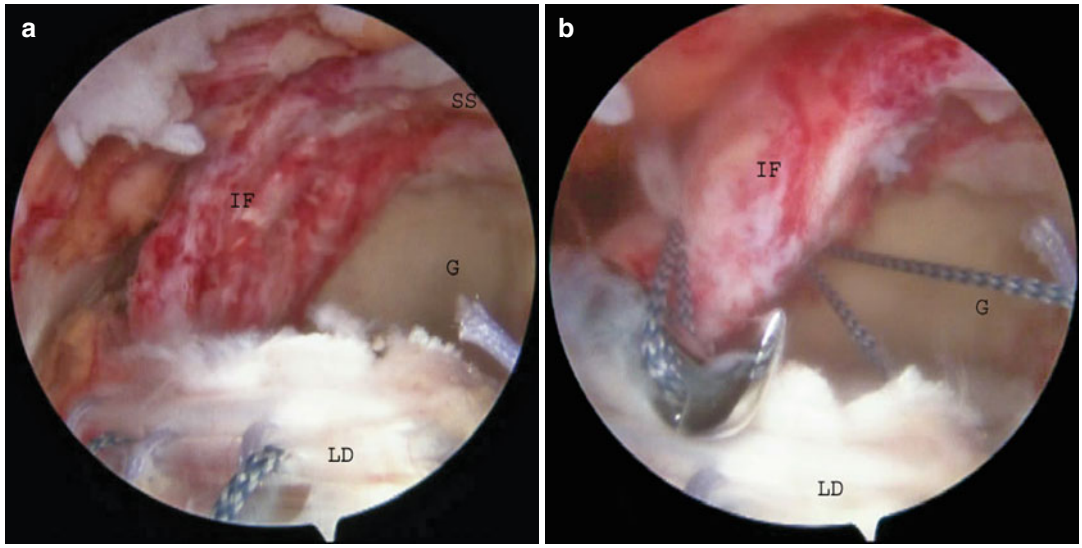


Fig. 8.16 (**a**, **b**) Lateral view of right shoulder. LDT – transferred latissimus dorsi, IF – infraspinatus muscle, SS – supraspinatus, G – glenoid

8.8.4 Discussion

The results of LDT are mostly dependant on deltoid and subscap muscle integrity. With damaged deltoid, age and gender adjusted Constant score reached only to 43 % [45]. In case of subscap insufficiency, CS increased to 49 % [43]. Arthroscopic technique for subs and remaining posterosuperior cuff repair maximally preserves deltoid. It also allows harvest LD with hand in ADD and slight flexion. In this position, axillary and radial nerves are in safest distance from harvest site from bone [46]. In recent study [47], LD harvesting with bone chips shoved better results due to lower rate of late LD tendon rupture. In our group, 2 of 31 develop late tendon rupture. This number should increase in time due to short follow-up, but we hope it will not reach 27 % due to improved fixation. In last few cases, harvesting was done with bone ships under direct arthroscopic visualization as proposed by Tauber et al. (2010).

8.9 The Anatomical Reconstruction of the Rotator Cuff

Ferdinando Battistella and Ettore Taverna

Theoretically, the repair of lesions of the rotator cuff should be able to reconstruct more anatomically possible the cuff. Various techniques have been described, and in recent years, attention has been focused particularly comparing single-row and double-row techniques. Studies with different levels of stresses, however, have shown that there are no differences in clinical outcomes but only in the rates of reruptures. Starting from the observation that the majority of complex lesions (medium and large) are multilayer and that the classifications used do not describe this type of injury is easy to see where is the weakness of these studies. According to recent anatomical studies, the importance of biomechanics component ascending infraspinatus tendon can explain why most of the supraspinatus and infraspinatus lesions are multilayer. Based on these and our own anatomical studies, we introduced a new technique called anatomical multilayer repair. With this technique, it is possible to make tendon-bone fixation without tension, biomechanically more stable and thus more potential with healing abilities.

8.9.1 Aim of This Work

The aim of this work is to evaluate the clinical results of repair of complex lesions (medium and large) of the rotator cuff with anatomical multilayer technique. Type of study: a prospective nonrandomized clinical study with a control group.

8.9.2 Materials and Methods

From 2006 to 2009, we treated with this technique 90 patients (52 men and 38 women), mean age of 56 years. Inclusion criteria were chronic injuries (more than 6 months), with acromion humeral distance greater than 6 mm, and medium cuff lesions (1–3 cm) and large (3–5 cm) evaluated arthroscopically, fatty degeneration less than grade 3 sec. Gouttalier. Exclusion criteria were the presence of rheumatic or autoimmune and metabolic diseases. Preoperative investigations included shoulder MRI, clinical and functional tests. The follow-up by ASES, UCLA, Constant was performed at 3, 6, 12, and 24 months by self-assessment test DASH.

The technique is called multilayer based on the recognition of different layers of the lesion and especially of the various components (horizontal and ascending) of the infraspinatus tendon and switching between infraspinatus and biceps pulley.

In most of the large lesions, the ascendant component of the infraspinatus tendon was involved and repaired first with the technique suture, and then the horizontal component was repaired with the technique anchor first, overlapped to the previous tendon repair in order to have a real anatomic repair. The same technique was performed in case of injury of the rotator cuff to the level of the supraspinatus and infraspinatus transition between. The control group consisted of 100 patients homogenous for the age and cuff lesions and treated with conventional arthroscopic suture system from 2003 to 2009 and valued at the same time follow-up. All operations were performed by the same surgeon. The data of both groups were compared using student's t tests for continuous variables, and the level of statistical significance was set <0.05.

8.9.3 Results

No complications were observed. Only six patients had to undergo reoperation for recurrence within 24 months or for poor results. All patients achieved the follow-up of 12 months, while nine patients were lost at the last follow-up of 24 months because they have not responded to the self-assessment test. Only at the 3-month follow-up, there were no statistical differences between the two groups in the treatment of medium lesions of rotator cuff. For all other follows-up, there were significant statistical

differences between the two groups, with significantly better results for the group with anatomic reconstruction. With regard to the last follow-up with self-assessment test to DASH, there was statistical difference between the two groups, which also identifies a clinical difference, with better results for the anatomical reconstruction.

8.9.4 Conclusions

The anatomical reconstruction of the rotator cuff with multilayer technique gets better results than the standard technique of arthroscopic repair and can be considered a viable treatment option.

8.10 Methods of Conservative Treatment of Cuff Arthropathy and Limits of Acromioplasty

Andrey Korolev and Mansur Khasanshin

8.10.1 Introduction

Rotator cuff deficiency with degenerative shoulder joint is a treatment challenge. Most patients present primer complaint on shoulder pain. Shoulder function can be variable even with significant chronic rotator cuff deficiency. The arthritic condition of the shoulder due to a chronic rotator cuff tear has been named cuff arthropathy [48].

Theories explaining rotator cuff tear arthropathy of the shoulder joint include severe, localized rheumatoid arthritis [49, 50]; hemorrhagic arthritis [51]; microcrystalline-induced arthritis [52]; and arthritis due to chronic attrition, leading to a massive tear of the rotator cuff tendons [46, 48].

Rotator cuff arthropathy is defined as a combination of

- A massive rotator cuff tear
- Fixed upward migration of the humeral head
- Instability of the glenohumeral joint
- Severe glenohumeral arthritis

A massive tear causes the humeral head to be displaced upward, inducing subacromial impingement that in time erodes the anterior portion of the acromion and the acromioclavicular joint. Ultimately the soft, atrophic head collapses, producing the complete syndrome of cuff tear arthropathy. The incongruous head may eventually erode the glenoid so deeply that the coracoid becomes eroded as well.

8.10.2 Presentation

The symptoms in all of the patients are remarkably similar. They all have long-standing and progressively increasing pain that is worsen at night, exacerbated by physical activity, and compression of the humerus to the scapula. Also there are certain changes in XR and MRI.

8.10.3 Management

Treatment of patients with cuff arthropathy is extremely difficult because, at present, there are no perfect solutions to this complex and sometimes disabling problem. Treatment depends on the symptoms (pain and/or disability), age, and functional level. Other issues such as medical comorbidities, possible concomitant glenohumeral arthritis, the presence of an intact coracoacromial arch are also factors that must be considered in the treatment plan. The treatment options range from conservative (nonoperative) to surgical. Surgical treatment include debridement with acromioplasty, tendon transfer, muscle tendon slide procedures, the use of rotator cuff allografts and synthetic grafts, arthrodesis, and shoulder arthroplasty, including the use of reverse ball prostheses.

There is no best treatment. The surgeon has to select the type of treatment that will provide the best outcome as dictated by the specific patient's needs.

Unfortunately, there have been no evidence-based, prospective studies comparing the different nonoperative and surgical options [53].

8.10.4 Nonoperative Treatment

Many chronic irreparable rotator cuff tears can be treated successfully without surgery. A nonoperative approach to relieve pain and create "biomechanically compensated" function with use of the remaining rotator cuff, deltoid, and periscapular muscles is often the best method of initial treatment.

Nonoperative treatment includes nonsteroidal anti-inflammatory medications, steroid injections, and local therapeutic modalities to relieve pain.

Early restoration of the passive range of motion and activity are important initially. As soon as pain relief has been obtained and the range of motion has been restored, specific strengthening exercises for the remaining rotator cuff, deltoid, and scapular muscles can be started in to restore a stabile fulcrum for deltoid function. Strengthening exercises for the internal and external rotators of the shoulder should include resistive exercises below

chest level initially. Deltoid strengthening exercises begin with the patient supine and are then progressed to antigravity positions such as sitting and standing. It may take more than 3 months for conservative treatment to be successful.

8.10.5 Operative Treatment

Arthroscopic irrigation for removing activated enzymes and crystals has been reported only recently and offers only limited, short-term relief. Arthroscopic acromioplasty and tendon debridement could also be used; however, the results were not stratified according to the location of the tear, and this technique should be viewed with caution.

The path of erosion caused by subacromial impingement clearly demonstrates that subacromial impingement occurs against the undersurface of the anterior one-third of the acromion and acromioclavicular joint. This provides further evidence that anterior acromioplasty is the correct treatment for impingement, rather than lateral acromionectomy.

If nonoperative management fails in these patients, a humeral hemiarthroplasty is the procedure of choice as it provides reliable relief of pain and improvement in function.

8.10.6 Conclusion

Chronic irreparable rotator cuff tears can cause shoulder pain and disability. As a result of the complex pathology in shoulders with irreparable rotator cuff tears, there are many different clinical scenarios and many available treatment options. For this reason, careful patient evaluation and treatment selection are critical to ensure a good result. Cuff tear arthroplasty is a disabling condition of the shoulder found in elderly patients. It is variable in its presentation with regard to the extent of degenerative osseous change in the glenoid, humeral head, and acromion. It is variable in its presentation with regard to preoperative active elevation ability and pain level.

Conservative management of cuff arthropathy is the method of treatment in cases of the patients with lesser manifestation of symptoms, contraindications for surgery, or refuse of operative treatment by patients.

Debridement and acromioplasty are best suited for lower-demand individuals, in case there are contraindications for more invasive surgery.

As shoulder arthroplasty, especially with reverse prosthesis, became more available, it may be considered a more preferred method.

8.11 Reverse Shoulder Arthroplasty: The Limits

Philippe Valenti

Reverse shoulder arthroplasty (RSA) is indicated in patients with pseudoparalytic shoulder secondary to irreparable rotator cuff tear. The concept of reversing the shoulder prosthesis reappeared in 1985 with Paul Grammont's biomechanical work [54] after the failures of the reversed constrained prostheses reported by Neer since 1974 [55]. Grammont demonstrated that medialization and distalization of the center of rotation on the glenoid bone increased the lever arm of the deltoid with a low rate of glenoid loosening. So the success of RSA to restore active anterior elevation and painless shoulder [56–60] since two decades has allowed to extend the indications but also to define the contraindications and the limits.

A meta-analysis of the literature performed by Zumstein et al. [61] reported a rate of complications and revisions after RSA of 24 % and 10 %, respectively. Complication rates differed among the different etiologies and were both twice as frequent in the revision of failure of hemi- or total arthroplasty patients as the primary arthroplasty group. Instability and infection were the two most frequent complications leading to revision.

There are two major contraindications to implant an RSA: a history of chronic infection and a nonfunctional deltoid muscle. The deltoid muscle can be paralyzed after an axillary nerve lesion secondary to a fracture dislocation in older patient. The deltoid muscle, after two or three previous surgeries, can be detached particularly, the middle part of the deltoid from the acromion.

Some situations represent a high potential of complications but are not a formal contraindications to implant an RSA:

After a breast cancer treated by radiotherapy, some patients develop an osteoarthritis with a cuff deficiency. The shoulder becomes painful with limited range of motion. The glenoid bone is osteoporotic with a low density, and the fixation of the baseplate is frequently not sufficient to resist to the shearing forces at the beginning of the abduction movement. Parkinson's disease with contracture muscle and involuntary movements can provoke a dislocation of the humerus or a glenoid component avulsion. RSA can be indicated if the Parkinson's disease is perfectly checked with a medical treatment. A high tension between the socket and the ball is recommended to avoid instability. A paraplegic patient who does alone a transfer from the bed to a chair or who used a wheelchair is not a good candidate for an RSA; the shearing forces between the glenoid bone and the back of the baseplate can pull out the glenoid component.

Some situations are not contraindications to implant an RSA, but the surgeon should have a good experience of this procedure with a considerable learning curve to avoid any complication.

A preoperative planning based on standard X-rays (AP view in neutral and external and internal rotation, axillary view) and a CT scan should be performed preoperatively to analyze the glenoid bone stock, the state of the cuff, and particularly the teres minor if the patient has a lack of active external rotation or a hornblower sign lack. In revision case after a failure of hemiarthroplasty for fracture, we have to analyze the size of bone loss at the metaphysis level and the thickness of the cortical bone particularly when the humeral prosthesis is cemented.

Proximal humeral bone loss secondary to a resection for tumor or a failure of hemiarthroplasty for complex fracture can result a high rate of instability and a failure of RSA secondary caused by an inadequate restoration of the length of the humerus. A bone allograft may restore proximal humeral bone stock, thereby helping to maintain the height of the prosthesis bone construct and to optimize the deltoid tension to prevent any instability [62]. Another option is a custom-made prosthesis or the use of spacer can restore the good length of the humerus with an optimal tension of the deltoid [63].

CTA and chronic glenohumeral dislocations often cause significant glenoid bone loss. Classically, severe glenoid bone loss is a contraindication of RSA, but it is often the only way to restore a shoulder function. Anomalies of the glenoid morphology represent a difficult challenge to implant the glenoid component and necessitate adjustments in surgical technique for RSA. A 3D CT reconstruction provides a reliable assessment

of the bone loss [64]. A preoperative planning should be essential to define the direction of the center keel and the length of the screw.

A central erosion with a high medialization of the joint decreases the length of the glenoid bone stock; a special design of the baseplate with a long peg to fix into the native bone associated with an interpositional bone graft improves the press fit of the prosthesis and restores the lateral offset to increase the stability of the prosthesis [65]. (Figs. 8.17 and 8.18).

Superior erosion of the glenoid should be compensated with a bone graft to avoid a superior tilt of the baseplate with a high risk of glenoid loosening.

Anterior and posterior erosion of the glenoid can be corrected with an eccentric reaming in moderate glenoid bone loss. If it is not sufficient, a corticocancellous bone grafting (from humeral head or iliac crest) technique is helpful to provide adequate bone stock for glenoid component fixation. Macaulay et al. [66] reported three cases with an excellent result with a short-term FU (Figs. 8.19, 8.20, 8.21, and 8.22).

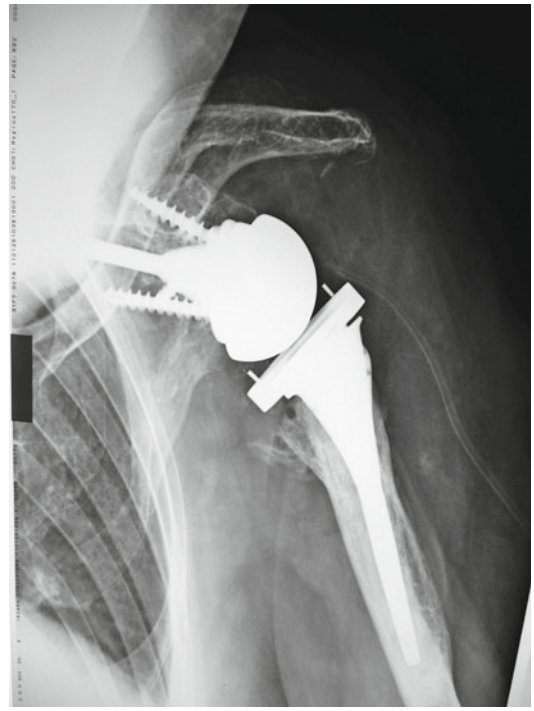


Fig. 8.18 Baseplate with a long stem and a bone graft to improve glenoid fixation in severe glenoid bone loss

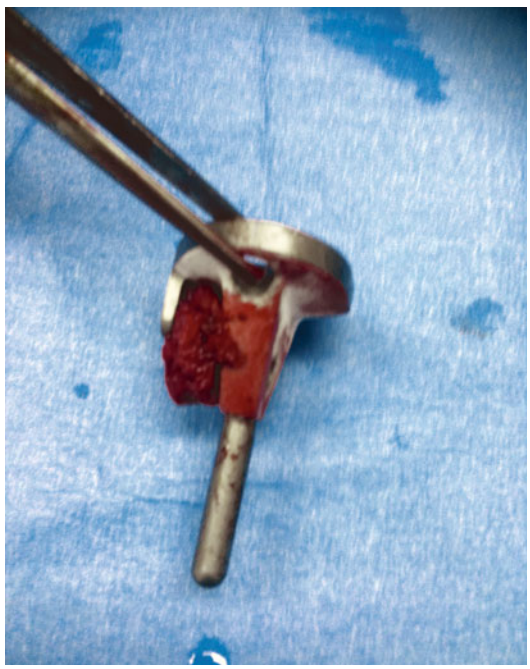


Fig. 8.17 Baseplate with a long stem and a bone graft to improve glenoid fixation in severe glenoid bone loss

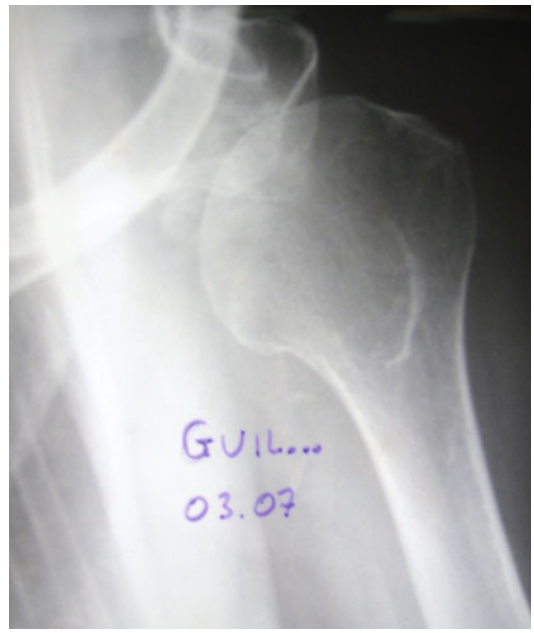


Fig. 8.19 Chronic anterior dislocation with an anterior glenoid bone defect: fixation with two screws of an anterior bone graft and implantation of a baseplate with two frontal screws and one sagittal screw (Courtesy D Katz)

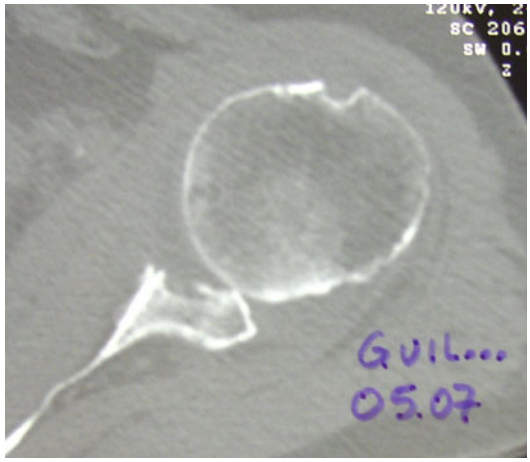


Fig. 8.20 Chronic anterior dislocation with an anterior glenoid bone defect: fixation with two screws of an anterior bone graft and implantation of a baseplate with two frontal screws and one sagittal screw (Courtesy D Katz)

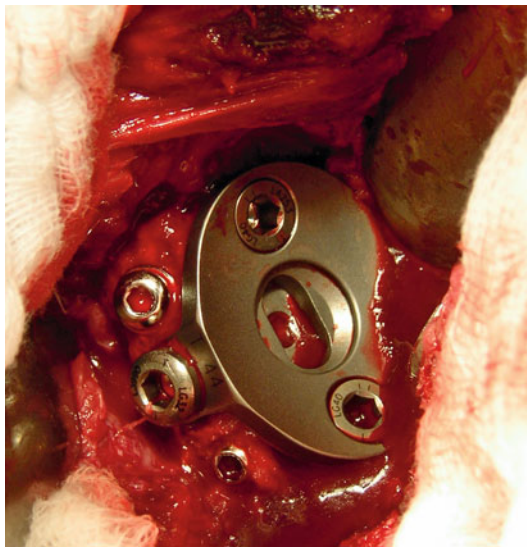


Fig. 8.21 Chronic anterior dislocation with an anterior glenoid bone defect: fixation with two screws of an anterior bone graft and implantation of a baseplate with two frontal screws and one sagittal screw (Courtesy D Katz)

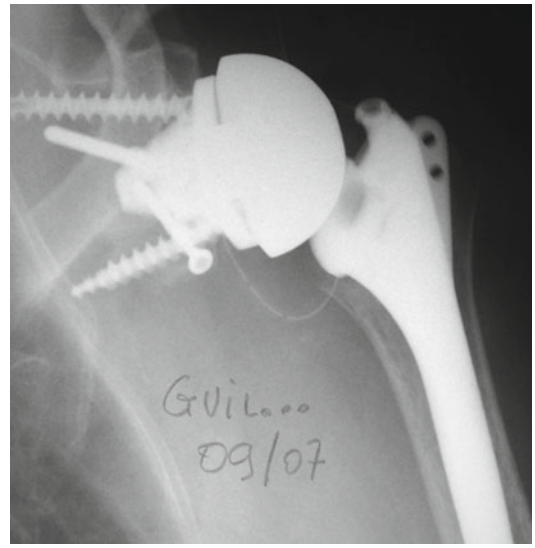


Fig. 8.22 Chronic anterior dislocation with an anterior glenoid bone defect: fixation with two screws of an anterior bone graft and implantation of a baseplate with two frontal screws and one sagittal screw (Courtesy D Katz)

8.11.1 Conclusion

Improvements of the prosthetic design combined with a greater experience of the surgeon can extend the limits of the classical indications of the RSA. In limit cases, the optimization of the fixation of the glenoid component is the key to decrease the rate of complication of RSA.

8.12 Instability of Reverse Total Shoulder Arthroplasty

Srinath Kamineni and Jonathan Chae

8.12.1 Introduction

The reverse total shoulder arthroplasty (RSTA) is an implant that has recently become more popular for the management of rotator cuff tear arthropathy, in addition to several other pathologies involving soft-tissue deficiency [17, 57, 67–73]. Originally the reverse arthroplasty was described by the French surgeon Paul Grammont in 1985 [68, 74] for the rotator cuff deficient shoulder with cranial migration of the humeral head and pseudoparalysis [68], with encouraging early results [41, 57, 59, 67, 69–72, 75–77]. In addition to cuff tear arthropathy, the spectrum of indications has rapidly increased over the past decade [74]. Most of the early reported results highlighted the significant improvements in pain and function. However, the initial enthusiasm has been muted by a growing awareness of complication rates ranging from 19 % to 50 % [28, 57, 68–71, 75, 76, 78, 79] and reoperation rates up to 33 % at 3 years [80]. The list of complications is extensive, but infection, component loosening, hematoma, and scapular notching are among the commonest [81]. Of all the complications, the two commonest that require revision operative intervention are infection and instability.

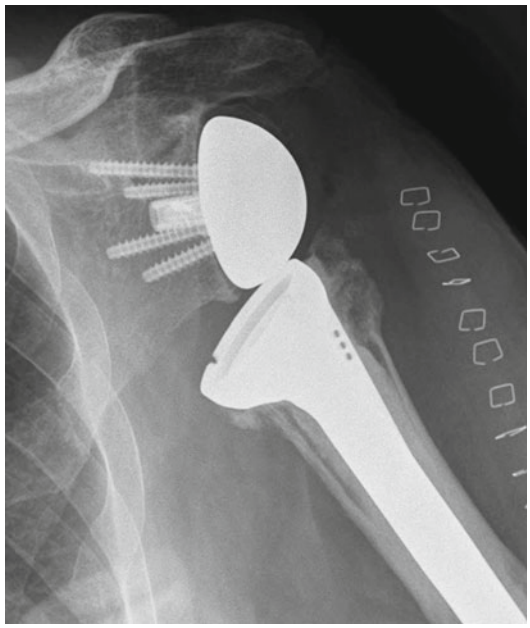


Fig. 8.23

Instability of the reverse shoulder arthroplasty is incompletely understood, almost certainly multifactorial, and ranges from subtle maltracking with impingement, inferior chronic subluxation, recurrent subluxation [81–84] to frank dislocations. Approximately 3–10 % of all reverse total shoulder arthroplasties have an episode of instability [82–84]. Most commonly, instability is evident immediately after surgery (Fig. 8.23) but can be also noticed at more prolonged intervals. The direction of instability is primarily anterior and anteroinferior, usually following an extension, adduction, and internal rotation of the arm. Instability has been widely reported in many series of reverse arthroplasties but in particular with series in which revision arthroplasty constitutes a significant proportion of the analyzed population [73, 85]. Revision arthroplasties frequently have issues of increased scarring from previous surgeries, poorer soft tissues (Fig. 8.24a–c), and fewer routine landmarks to guide the surgeon.

When dealing with such a complication as instability of a reverse shoulder replacement, the multifactorial nature can be better understood when all the factors are individually addressed. Once all the factors have been analyzed, they can individually be applied to one's own patients to better understand the individual circumstances of instability. The remainder of this chapter will try to conglomerate most of the important known factors involved in RTSA instability, without any particular order of importance.

8.12.2 Surgical Approach

The two commonest approaches utilized for the insertion of a reverse total shoulder arthroplasty are the superolateral (trans-deltoid) and deltopectoral approach. Ladermann et al. studied the functional influence between the two approaches and found no difference [86].

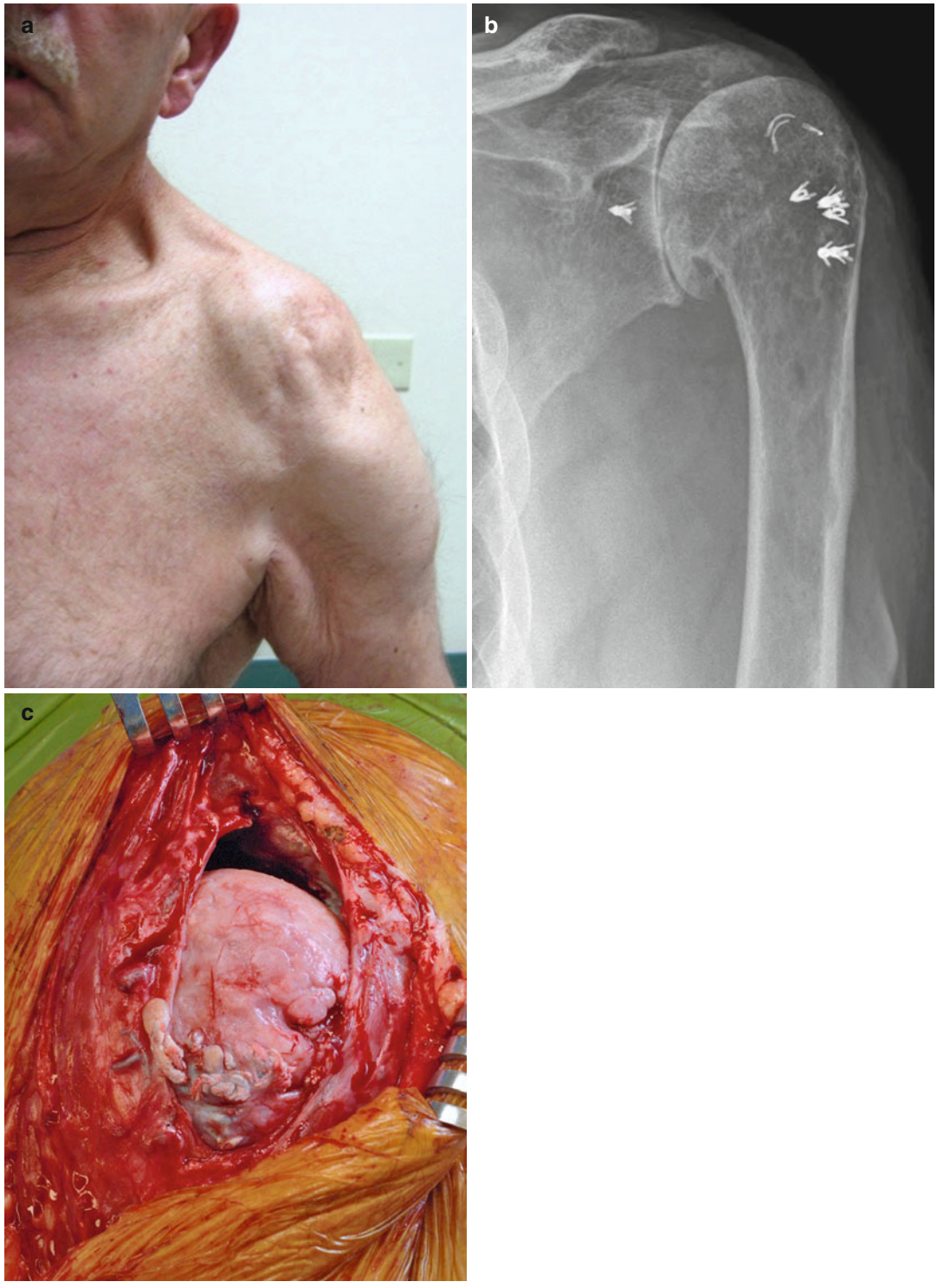


Fig. 8.24

The integrity of the subscapularis has been considered an important feature in the prevention of instability. Edwards et al. reported on a 138-patient prospective series of reverse arthroplasties, all performed by a single surgeon with the deltopectoral approach [82]. The subscapularis was irreparable in 76 patients, and seven dislocations were encountered in total, all in the irreparable group. Lack of subscapularis integrity was considered a significant risk for postoperative dislocation. A confounding feature of this study was that the group in which subscapularis was irreparable was a more complex preoperative group. But more recently, Clark et al. retrospectively reviewed 120 patients, all with deltopectoral approaches, 55 of whom did not have subscapularis repair with three dislocations, and 65 with subscapularis repair with two dislocations [87]. The authors concluded that subscapularis repair was noncontributory to dislocation risk. Hence, there is some conflicting data concerning the role of subscapularis repair, and where ever possible, it should be repaired, until more definitive data is available.

8.12.3 Humeral Component Version

Favre et al. assessed the effect of humeral and glenoid version on intrinsic stability of RTSA. Humeral version was found to be more critical for intrinsic stability than glenosphere version. Physiologic humeral version at 20 ° was found to have low intrinsic stability, and by increasing anteversion, one would be able to increase stability – more than 20 % increase for each 10 ° of anteversion. However, this resulted in limited external rotation and may hinder function [88]. Stephenson et al. demonstrated that humeral component version had a range of tolerances that allow good impingement-free motion [89]. Their cadaveric study demonstrated that in 20 ° anteversion, the external rotation in neutral abduction was almost −1 °. However, 30 ° of abduction considerably improved the ability to externally rotate without impinging. This study demonstrated the disadvantage of an anteverted humeral component, with much better overall motion in neutral or abducted arm positions with a neutral or mildly retroverted humeral component. Gulotta et al. concluded that retroverting the humeral component from 0 ° to 20 ° would allow maximum internal rotation with the arm by the side of the body without limiting the ability to externally rotate when the arm is abducted [90].

8.12.4 Glenoid Component Position

Metaglenes can be positioned according to the native glenoid and are commonly positioned to cover the native glenoid (Fig. 8.25). However, with the interrelated issues of component impingement, scapular notching, and instability, more attention has been focused on positioning the metaglene to minimize such complications.

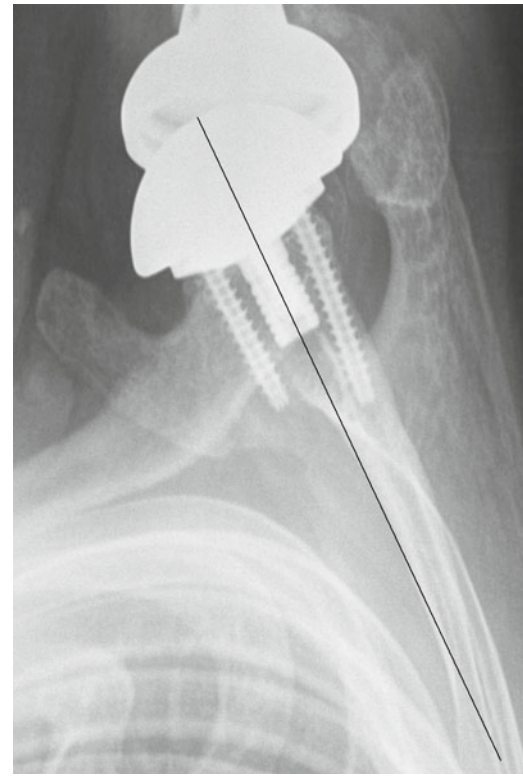


Fig. 8.25

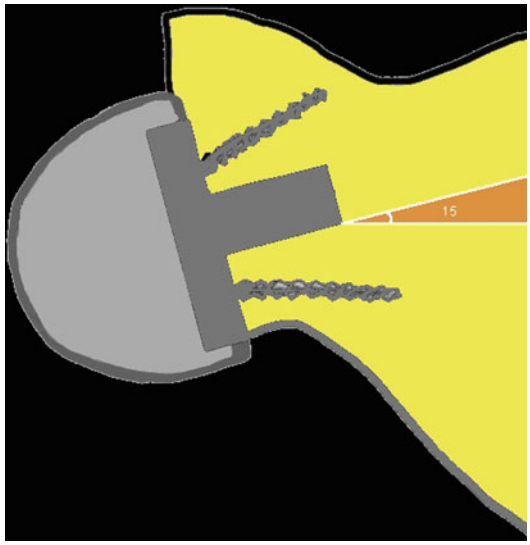


Fig. 8.26

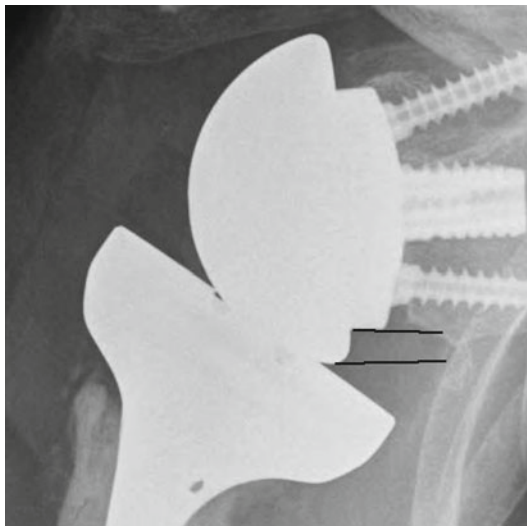


Fig. 8.27

Gutierrez et al. examined glenoid component stability with regard to angle of implantation. Implantation with an inferior tilt of 15 ° reduced the incidence of mechanical failure of the glenoid component, which increased implant stability [91] (Fig. 8.26). Nyffeler et al. performed an in vitro cadaveric study with the delta III reverse implant to compare metaglene position that relates to motion. They found that placement of the baseplate overhanging the inferior glenoid rim significantly improved adduction and abduction, when compared to other positions (centered on the glenoid, flush with the inferior rim, inferiorly tiled) [92] (Fig. 8.27). As is predictable from these two latter studies, every effort should be made to avoid superior metaglene tilt (Fig. 8.28).

8.12.5 Humeral Length

The length of the humerus is essentially an indicator of the length of the deltoid and indirectly a measure of the deltoid tension. The judgment of humeral length can be made using several bony (acromion/tip of greater tuberosity/base of coracoid) or soft-tissue landmarks (insertion of pectoralis major/deltoid muscles). However, this judgment is more difficult in cases of bone and soft-tissue loss, a common scenario in revision surgery (Fig. 8.29). In cases in which the humeral length is shortened, this can lead to instability as was noted by Melis et al. [93]. In their multicenter retrospective review of 37 reverse arthroplasty for aseptically loosened anatomical shoulder arthroplasties, they observed three instabilities, two of which were due to humeral shortening. Both successfully resolved after the addition of a metallic spacer, which effectively lengthened the humerus. The third case of instability was reduced and immobilized, resulting in a stable joint, without further intervention. Ladermann et al. assessed the effect of humeral lengthening and tensioning of the deltoid on its effects on intrinsic stability. He found a strong correlation between

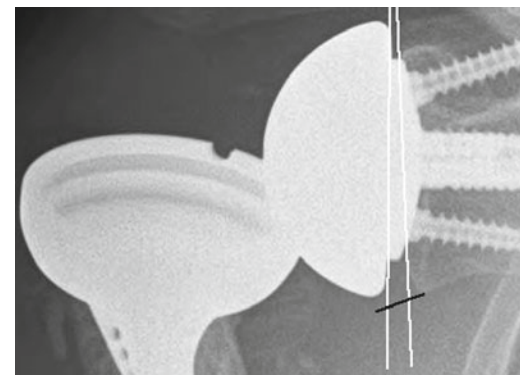


Fig. 8.28

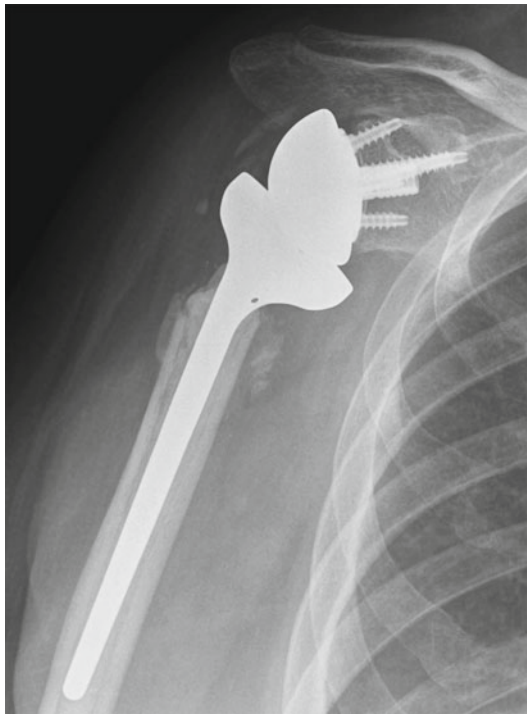


Fig. 8.29

preoperative length compared with contralateral humerus and apparition of dislocation. Shortening of the humerus postoperatively, as compared to preoperatively contralateral humeral lengths, was observed to have a high correlation with dislocation [63, 94]. Failure to restore sufficient tension in the deltoid can be responsible for prosthetic instability.

When inserting the humeral component, several factors influence the final length outcome. The first is obviously the judgment of the surgeon, who uses the bony and soft-tissue landmarks to aid correct implant insertion, when they are available. A third factor is the ability to judge the instability of the inserted components as a function of constraint, to be addressed later, and soft-tissue tension, acting across the joint. Soft-tissue tension, as a function of humeral length, requires surgical judgment. An often quoted method of judging tension is that thumb pressure of the reduced components should not be able to translate the humerus more than 50 % of its articular diameter. However, a confounding feature of this aspect is the increasingly common practice of regional anesthesia and muscle relaxation. No studies are available to help understand the true effect of these interventions and how they influence the intraoperative judgment of soft-tissue tension acting across the implants.

Humeral length, and hence soft-tissue tension, can decrease due to component subsidence [93]. The humeral component can subside for several reasons. With uncemented implants, the initial intraoperative press fit may be inadequate, leading to early component motion, and "settling" leading to loss of humeral length and soft-tissue envelops tension. In cemented and uncemented components, a cortical breach, as is more common in revision surgery with cement removal or with periprosthetic fractures, can allow subsidence into the cortical deficiency. In cemented implants, aseptic loosening can allow distal migration of the humeral component.

8.12.6 Intrinsic Component Stability

Gutierrez et al. examined intrinsic stability in terms of the force required to dislocate the humeral socket from the glenosphere. Joint compressive force was determined to be the most important more so than socket depth and glenosphere size [95]. Increasing tension of the soft tissues may lead to increased stability. Ratio between depth of socket and diameter of the metaglene – higher ratios result in more stable implants [96], although higher ratios are more likely to result in scapular notching [97]. Although scapular notching is one of the commonest observed complications after reverse shoulder arthroplasty, its association with reoperation rates has not been firmly validated. However, the polyethylene wear of the humeral socket can be responsible for aseptic loosening, leading to component migration and implant instability. Such scapular notching related medial polyethylene wear has been corroborated by Nam et al. in a retrieval study [98]. Such notching has been shown to decrease when the metaglene is positioned in an eccentrically inferior position on the glenoid [99].

Compared to conventional shoulder replacements, which utilize relative roll-spin-translation kinematics, reverse shoulder arthroplasties function without roll and translation between the components. The design is inherently more constrained and stable, and Matsen et al. defined the "balance stability angle" [100], the maximum angle that the joint reaction force can form within the concavity of the humeral socket, prior to dislocation. For the reverse geometry implant, this 45°arc of stable motion is greater than for conventional, anatomically designed shoulder arthroplasty (30 °).

Roche et al. examined the jump distance of the glenosphere in relation to instability. Jump distance was defined as lateral distance necessary for the glenosphere to escape from the humeral liner at varying degrees of abduction. Increasing the glenosphere size reduced the jump distance and created more stability in RTSA [101].

8.12.7 Axillary Nerve Dysfunction

Axillary nerve function is critically important for the outcome of reverse shoulder replacements, and any dysfunction can lead to instability of such implants. Dysfunction can be transient or permanent and, when permanent, serves as a contraindication to reverse arthroplasty. Most nerve palsies are temporary neurapraxias resulting from a variety of causes, including nerve traction due to fracture dislocations, shoulder manipulations, retractor malplacement, or overstuffing of the joint. The axillary nerve is prone to a traction neurapraxia during surgical exposure since the humerus is externally rotated, posteriorly retracted, and abducted [80]. Interscalene regional local anesthetic anesthesia can also produce temporary axillary nerve palsy, which can lead to a joint subluxation immediately postoperation.

8.12.8 Acromial Fracture

In the pursuit of stability and optimal reverse shoulder arthroplasty function, a poorly understood parameter is the amount of optimal deltoid tension. Since there are few objective methods available, surgical experience is paramount, with the inherent miscalculation always a possibility. When calculating the intraoperative tension required, the parameters to be borne in mind are the acromial strength (thickness being a surrogate) and deltoid integrity (previous surgical scarring, atrophic thinning, etc.). During the intraoperative tensioning of components, there is a natural tendency to over tension with the insertion of thicker implants, with the belief to gaining greater stability. Whereas short-term stability may indeed be afforded by such a strategy, this may also predispose to fatigue fractures of the acromion, which in turn can result in loss of deltoid tension and consequent implant instability. However, acromial fractures are not universally associated with a loss of active elevation and instability but do represent a complication that is associated with these adverse results [102–104].

8.12.9 Conclusion

Overall, instability is a leading cause of revision operative intervention in RTSA [97]. Achieving a stable and well-functioning reverse total shoulder arthroplasty requires a multifactorial understanding and approach. Basic principles of soft-tissue release and balancing, correct deltoid tensioning, component positioning that allows functional motion without impingement, subscapularis repair, and cautious rehabilitation appear to be the key to avoid this complication. Several factors that have emerged as playing an important role remain incompletely understood, but some basic parameters are now defined, including the importance of adequate deltoid tension.

Treatment guidelines for an unstable RSTA are not well defined, but early joint reduction and a trial of immobilization, correction of a malverted humeral/glenoid component, insertion of a thicker humeral lining when humeral length is inadequate, and ruling out infection as a source of early component loosening are some well-established basics. Revision of components should be considered when a trial of reduction immobilization fails to resolve the instability, although it is

challenging to determine if one or all components need to be revised.

Revision requires focusing on increasing soft-tissue tension. Increasing the compressive forces should be considered a priority [95]. This can be achieved by increasing humeral length, therefore increase deltoid function and converting more torque to compressive forces, with caution on over-tensioning and acromial fractures. Soft-tissue tensioning can also be increased through lateralization of the glenosphere, adjusting the humeral neck-shaft angle, and increasing the thickness of the humeral component and/or the size of the glenosphere [105]. If possible, subscapularis should be repaired which can improve stability as well [82].

References

1. Yamamoto A, Takagishi K, Osawa T et al (2010) Prevalence and risk factors of a rotator cuff tear in the general population. J Shoulder Elbow Surg 19:116–120. doi:10.1016/j.jse.2009.04.006
2. Albritton MJ, Graham RD et al (2003) An anatomic study of the effects on the suprascapular nerve due to retraction of the supraspinatus muscle after a rotator cuff tear. J Shoulder Elbow Surg 12:497–500. doi:10.1016/S1058–2746(03)00182–4
3. DeOrio JK, Cofield RH (1984) Results of a second attempt at surgical repair of a failed initial rotator-cuff repair. J Bone Joint Surg Am 66:563–567
4. Thomazeau H, Boukobza E, Morcet N et al (1997) Prediction of rotator cuff repair results by magnetic resonance imaging. Clin Orthop 344:275–283
5. Goutallier D, Bernageau J, Patte D (1990) Assessment of the trophicity of the muscles of the ruptured rotator cuff by CT scan. In: Post M, Morrey BF, Hawkins RJ (eds) Surgery of the shoulder. St. Louis, Mosby p, pp 11–13
6. Charousset C, Bellaïche L (2005) Accuracy of CT arthrography in the assessment of tears of the rotator cuff. J Bone Joint Surg Br 87(6):824–828
7. Charousset C, Bellaïche L et al (2010) Arthroscopic repair of full-thickness rotator cuff tears: is there tendon healing in patients aged 65 years or older? Arthroscopy 26(3):302–309
8. Grimberg J, Diop A et al (2010) In vitro biomechanical comparison of three different types of single- and double-row arthroscopic rotator cuff repairs: analysis of continuous bone-tendon contact pressure and surface during different simulated joint positions. J Shoulder Elbow Surg 19(2):236–243, Epub 2009 Dec 7
9. Barber FA, Herbert MA (2008) Suture anchor materials, eyelets, and designs. Arthroscopy 24:859–867
10. Gittins M Biomechanical evaluation of the biomet sports medicine JuggerKnot™. soft anchor in porcine bone biomet sports medicine research and development, Warsaw, Indiana
11. Gittins M., Biomechanical Evaluation of the Biomet Sports Medicine JuggerKnot™ SoftAnchor–2.9 mm in Porcine Bone. OrthoNeuro, New Albany Surgical Hospital Foundation The Ohio University
12. Bedi A, Dines J, Warren RF et al (2010) Massive tears of the rotator cuff. J Bone Joint Surg Am 92(9):1894–1908
13. Burkhart SS, Denard PJ, Obopilwe E et al (2011) Optimizing pressurized contact area in rotator cuff repair: the diamondback repair. Arthroscopy. doi:10.1016/j.arthro.2011.07.021
14. Papadopoulos P, Karataglis D, Boutsiadis A et al (2011) Functional outcome and structural integrity following mini-open repair of large and massive rotator cuff tears: a 3–5 year follow-up study. J Shoulder Elbow Surg 20(1):131–137
15. LädermannA DPJ, Burkhart SS (2011) Midterm outcome of arthroscopic revision repair of massive and nonmassive rotator cuff tears. Arthroscopy 27(12):1620–1627
16. Yamaguchi H, Suenaga N, Oizumi N et al (2011) Open repair for massive rotator cuff tear with a modified transosseous-equivalent procedure: preliminary results at short-term follow-up. J Orthop Sci 16(4):398–404
17. Burkhart SS, Danaceau SM, Pearce CE Jr (2001) Arthroscopic rotator cuff repair: analysis of results by tear size and by repair technique-margin convergence versus direct tendon-to-bone repair. Arthroscopy 17(9):905–912
18. Davidson J, Burkhart SS (2010) The geometric classification of rotator cuff tears: a system linking tear pattern to treatment and prognosis. Arthroscopy 26(3):417–424
19. Yoo JC, Ahn JH, Yang JH (2009) Correlation of arthroscopic repairability of large to massive rotator cuff tears with preoperative magnetic resonance imaging scans. Arthroscopy 25(6):573–582
20. Zumstein MA, Jost B, Hempel J et al (2008) The clinical and structural long-term results of open repair of massive tears of the rotator cuff. J Bone Joint Surg Am 90(11):2423–2431
21. Burkhart SS, Barth JR, Richards DP et al (2007) Arthroscopic repair of massive rotator cuff tears with stage 3 and 4 fatty degeneration. Arthroscopy 23(4):347–354
22. Oh JH, Kim SH, Shin SH et al (2011) Outcome of rotator cuff repair in large-to-massive tear with pseudoparalysis: a comparative study with propensity score matching. Am J Sports Med 39(7):1413–1420
23. Hsu JE, Reuther KE, Sarver JJ et al (2011) Restoration of anterior-posterior rotator cuff force balance improves shoulder function in a rat model of chronic massive tears. J Orthop Res 29(7):1028–1033. doi:10.1002/jor.21361

24. Lo IK, Burkhart SS (2004) Arthroscopic repair of massive, contracted, immobile rotator cuff tears using single and double interval slides: technique and preliminary results. Arthroscopy 20(1):22–33
25. Rhee YG, Cho NS, Lim CT et al (2008) Bridging the gap in immobile massive rotator cuff tears: augmentation using the tenotomized biceps. Am J Sports Med 36(8):1511–1518, Epub 2008 Apr 28
26. Rotini R, Marinelli A, Guerra E et al (2011) Human dermal matrix scaffold augmentation for large and massive rotator cuff repairs: preliminary clinical and MRI results at 1-year follow-up. Musculoskelet Surg 95(Suppl 1):S13–S23
27. Schneeberger AG, Schuler L, Rikli D et al (2011) Rotator cuff tears treated with a modified deltoid flap repair technique. J Shoulder Elbow Surg, Aug, 30
28. Bufquin T et al (2007) Reverse shoulder arthroplasty for the treatment of three- and four-part fractures of the proximal humerus in the elderly: a prospective review of 43 cases with a short-term follow-up. J Bone Joint Surg Br 89(4):516–520
29. Burkhart SS (1992) Fluoroscopic comparison of kinematic patterns in massive rotator cuff tears. A suspension bridge model. Clin Orthop Relat Res 284:144–152
30. Lo IKY, Burkhart SS (2003) Current concepts in Arthroscopic rotator cuff repair. Am J Sports Med 31(2):308–324
31. Warner JP, Krushell RJ, Masquelet A, Gerber C (1992) Anatomy and relationships of the suprascapular nerve: anatomical constraints to mobilization of the supraspinatus and infraspinatus muscles in the management of massive rotator-cuff tears. J Bone Joint Surg Am 74(1):36–45
32. Galatz LM, Ball CM, Teefey SA (2004) The outcome and repair integrity of completely arthroscopically repaired large and massive rotator cuff tears. J Bone Joint Surg Am 86-A(2):219–224
33. Beauchamp M, Roy JD (2009) Arthroscopic repair of large and massive rotator cuff tears performed under local anaesthesia and sedation. J Shoulder Elbow Surg 18(5):e18–e20
34. Domb BG, Glousman RE, Brooks A et al (2008) High-tension double-row footprint repair compared with reduced-tension single-row repair for massive rotator cuff tears. J Bone Joint Surg Am 90(Suppl 4):35–39
35. Mihata T, Watanabe C, Fukunishi K et al (2011) Functional and structural outcomes of single-row versus double-row versus combined double-row and suture-bridge repair for rotator cuff tears. Am J Sports Med 39(10):2091–2098
36. Meier SW, Meier JD (2006) The effect of double – row fixation on initial repair strength in rotator cuff repair: a biomechanical study. Arthroscopy: The Journal of Arthroscopic and Related Surgery 22(11):1168–1173
37. Sugaya H, Maeda K, Matsuki K et al (2005) Functional and structural outcome after arthroscopic full-thickness rotator cuff repair: single - row versus dual – row fixation. Arthroscopy: J Arthrosc Rel Surg 21:1307–1316
38. Burkhart SS, Nottage WM, Ogilvie-Harris DJ et al (1994) Partial repair of irrepairable rotator cuff tears. Arthroscopy 10:363–370
39. Calvert PT, Packer NP, Stoker DJ et al (1986) Arthrography of the shoulder after operative repair of the torn rotator cuff. J Bone Joint Surg Br 68:147–150
40. Harryman DT, Mack LA, Wang KY et al (1991) Repairs of the rotator cuff: correlation of functional results with integrity of the cuff. J Bone Joint Surg Am 73:982–989
41. Burkhart S, Tehrany A (2002) Arthroscopic subscapularis tendon repair: technique and preliminary results. Arthroscopy 18:454–464
42. Lafosse L, Van Raebroeckx A, Brzoska R (2006) A new technique to improve tissue grip: “the lasso-loop stitch”. Arthroscopy 22:1246e1–1246e3
43. Gerber C (1992) Latissimus dorsi transfer for the treatment of irreparable tears of the rotator cuff. Clin Orthop Relat Res 275:152–160
44. Gervasi E et al (2007) Arthroscopic latissimus dorsi transfer. Arthroscopy 23(11):1243.e1–1244
45. Warner JJ, Parsons IM 4th (2001) Latissimus dorsi tendon transfer: a comparative analysis of primary and salvage reconstruction of massive, irreparable rotator cuff tears. J Shoulder Elbow Surg 10(6):514–521
46. Cleeman E, Hazrati Y et al (2003) Latissimus dorsi tendon transfer for massive rotator cuff tears: a cadaveric study. J Shoulder Elbow Surg 12(6):539–543
47. Tauber M, Resch H (2010) Latissimus dorsi tendon transfer for irreparable rotator cuff tears: a modified technique to improve tendon transfer integrity: surgical technique. J Bone Joint Surg Am 92(Suppl 1 Pt 2):226–239
48. Neer CS II, Craig EV, Fukuda H (1983) Cuff-tear arthropathy. J Bone Joint Surg 65-A:1232–1244
49. Adams R (1857) Illustrations of the effects of rheumatic gout or chronic rheumatic arthritis on all the articulations: with descriptive and explanatory statements. John Churchill and Sons, London, pp 1–31
50. Adams R (1873) A treatise of rheumatic gout or chronic rheumatic arthritis of all the joints, 2nd edn. John Churchill and Sons, London, pp 91–175
51. DeSeze M (1968) L’épaule sénile hémorragique. L’actualité rhumatologique, vol 1. Expansion Scientifique Française, Paris, pp 107–115
52. McCarty DJ, Halverson PB, Carrera GF et al (1981) “Milwaukee shoulder” – association of microspheroids containing hydroxyapatite crystals, active collagenase, and neutral protease with rotator cuff defects I. Clinical aspects. Arthrit Rheumat 24:464–473
53. David M, Dines DP et al (2006) Irreparable rotator cuff tears: what to do and when to do it; the surgeon’s dilemma. J Bone Joint Surg Am 88:2294–2302

54. Grammont PM, Laffay JP, Deries X (1987) Evaluation of a new shoulder prosthesis [in French]. Rhumatologie 39:407–418
55. Neer CS 2nd, Watson KC, Stanton FJ (1982) Recent experience in total shoulder replacement. J Bone Joint Surg Am 64:319–337
56. Baulot E, Chabernaud D, Grammont PM (1995) Results of Grammont's inverted prosthesis in omarthritis associated with major cuff destruction: a propos of 16 cases [in French]. Acta Orthop Belg 61(Suppl 1):112–119
57. Boulahia A et al (2002) Early results of a reverse design prosthesis in the treatment of arthritis of the shoulder in elderly patients with a large rotator cuff tear. Orthopedics 25(2):129–133
58. Grammont PM, Baulot E (1993) Delta shoulder prosthesis for rotator cuff rupture. Orthopedics 16:65–68
59. Seebauer L, Walter W et al (2005) Reverse total shoulder arthroplasty for the treatment of defect arthropathy. Oper Orthop Traumatol 17(1):1–24
60. Valenti PH, Bouttens D, Nerot C (2001) Delta 3 reversed prosthesis for osteoarthritis with massive rotator cuff tear: long term results (5 years). In: Walch G, Boileau P, Mole D (eds) Shoulder prostheses: two to ten year follow-up. Sauramps Medical, Montpellier, pp 253–259
61. Zumstein M, Pinedo M et al (2011) Problems, complications, reoperations, and revisions in reverse total shoulder arthroplasty: a systematic review. J Shoulder Elbow Surg 20:146–157
62. Chacon A, Virani N, Shannon R et al (2009) Revision Arthroplasty with Use of a Reverse Shoulder Prosthesis-Allograft Composite. J Bone Joint Surg Am 91:119–127
63. Ladermann A et al (2009) Objective evaluation of lengthening in reverse shoulder arthroplasty. J Shoulder Elbow Surg/Am Shoulder Elbow Surgeon… [et al] 18(4):588–595
64. Frankle M, Teramoto A et al (2009) Glenoid morphology in reverse shoulder arthroplasty: classification and surgical implications. J Shoulder Elbow Surg 18:874–885
65. Norris T, Kelly J II et al (2007) Management of glenoid bone defects in revision shoulder arthroplasty in: a new application of the reverse total shoulder prosthesis. Techn Shoulder Elbow Surg 8(1):37–46
66. Macaulay A, Raymond BS, Greiwe M et al (2011) Reverse total shoulder replacement in patients with severe glenoid bone loss. Oper Tech Orthop 21:86–93, © Elsevier Inc
67. Frankle M et al (2006) The reverse shoulder prosthesis for glenohumeral arthritis associated with severe rotator cuff deficiency: a minimum two-year follow-up study of sixty patients surgical technique. J Bone Joint Surg Am 88(Suppl 1 Pt 2):178–190
68. Grammont PM, Baulot E (1993) Delta shoulder prosthesis for rotator cuff rupture. Orthopedics 16(1):65–68
69. Paladini P et al (2005) The inverse prosthesis as a revision prosthesis in failures of shoulder hemiarthroplasty. Chir Organi Mov 90(1):11–21
70. Rittmeister M, Kerschbaumer F (2001) Grammont reverse total shoulder arthroplasty in patients with rheumatoid arthritis and nonreconstructible rotator cuff lesions. J Shoulder Elbow Surg/Am Shoulder Elbow Surgeon… [et al] 10(1):17–22
71. Sirveaux F et al (2004) Grammont inverted total shoulder arthroplasty in the treatment of glenohumeral osteoarthritis with massive rupture of the cuff. Results of a multicentre study of 80 shoulders. J Bone Joint Surg Br 86(3):388–395
72. Wall B et al (2007) Reverse total shoulder arthroplasty: a review of results according to etiology. J Bone Joint Surg Am 89(7):1476–1485
73. Werner CM et al (2005) Treatment of painful pseudoparesis due to irreparable rotator cuff dysfunction with the Delta III reverse-ball-and-socket total shoulder prosthesis. J Bone Joint Surg Am 87(7):1476–1486
74. Boileau P et al (2005) Grammont reverse prosthesis: design, rationale, and biomechanics. J Shoulder Elbow Surg/Am Shoulder Elbow Surgeons … [et al] 14(1 Suppl S):147S–161S
75. Boileau P, Award N et al (2005) The Grammont reverse shoulder prosthesis: results in cuff tear arthritis, fracture sequelae, and revision arthroplasty. J Shoulder Elbow Surg/Am Shoulder Elbow Surgeon… [et al], 2006 15(5):527–540
76. Guery J et al (2006) Reverse total shoulder arthroplasty: survivorship analysis of eighty replacements followed for five to ten years. J Bone Joint Surg Am 88(8):1742–1747
77. Vanhove B, Beugnies A (2004) Grammont's reverse shoulder prosthesis for rotator cuff arthropathy: a retrospective study of 32 cases. Acta Orthop Belg 70(3):219–225
78. Frankle M et al (2005) The severse shoulder prosthesis for glenohumeral arthritis associated with severe rotator cuff deficiency: a minimum two-year follow-up study of sixty patients. J Bone Joint Surg Am 87(8):1697–1705
79. Seebauer L (2007) Total reverse shoulder arthroplasty: European lessons and future trends. Am J Orthop 36(12 Suppl 1):22–28
80. Lynch NM et al (1996) Neurologic complications after total shoulder arthroplasty. J Shoulder Elbow Surg/Am Shoulder Elbow Surgeon… [et al] 5(1):53–61
81. Farshad M, Gerber C (2010) Reverse total shoulder arthroplasty-from the most to the least common complication. Int Orthop 34(8):1075–1082
82. Edwards TB et al (2009) Subscapularis insufficiency and the risk of shoulder dislocation after reverse shoulder arthroplasty. J Shoulder Elbow Surg/Am Shoulder Elbow Surgeon… [et al] 18(6):892–896
83. Gallo RA et al (2011) Instability after reverse total shoulder replacement. J Shoulder Elbow Surg/Am Shoulder Elbow Surgeons… [et al] 20(4):584–590
84. Trappey GJ, O'Connor DP et al (2011) What are the instability and infection rates after reverse shoulder arthroplasty? Clin Orthop Relat Res 469(9):2505–2511

85. Levy J et al (2007) The use of the reverse shoulder prosthesis for the treatment of failed hemiarthroplasty for proximal humeral fracture. J Bone Joint Surg Am 89(2):292–300
86. Ladermann A et al (2011) Influence of surgical approach on functional outcome in reverse shoulder arthroplasty. Orthop Traumatol Surg Res 97(6):579–582
87. Clark JC et al (2011) Complication rates, dislocation, pain, and postoperative range of motion after reverse shoulder arthroplasty in patients with and without repair of the subscapularis. J Shoulder Elbow Surg/Am Shoulder Elbow Surgeons… [et al.]
88. Favre P, Sussmann PS, Gerber C (2010) The effect of component positioning on intrinsic stability of the reverse shoulder arthroplasty. J Shoulder Elbow Surg/Am Shoulder Elbow Surgeon… [et al] 19(4):550–556
89. Stephenson DR et al (2011) Effect of humeral component version on impingement in reverse total shoulder arthroplasty. J Shoulder Elbow Surg/Am Shoulder Elbow Surgeon… [et al] 20(4):652–658
90. Gulotta LV et al (2011) Humeral component retroversion in reverse total shoulder arthroplasty: a biomechanical study. J Shoulder Elbow Surg/Am Shoulder Elbow Surgeons… [et al.],
91. Gutierrez S et al (2007) Biomechanical comparison of component position and hardware failure in the reverse shoulder prosthesis. J Shoulder Elbow Surg/Am Shoulder Elbow Surgeon… [et al] 16(3 Suppl):S9–S12
92. Nyffeler RW, Werner CM, Gerber C (2005) Biomechanical relevance of glenoid component positioning in the reverse Delta III total shoulder prosthesis. J Shoulder Elbow Surg/Am Shoulder Elbow Surgeon… [et al] 14(5):524–528
93. Melis B et al (2012) Glenoid loosening and failure in anatomical total shoulder arthroplasty: is revision with a reverse shoulder arthroplasty a reliable option? J Shoulder Elbow Surg/Am Shoulder Elbow Surgeon… [et al] 21(3):342–349
94. Ladermann A et al (2012) Influence of arm lengthening in reverse shoulder arthroplasty. J Shoulder Elbow Surg/Am Shoulder Elbow Surgeon… [et al] 21(3):336–341
95. Gutierrez S et al (2008) Hierarchy of stability factors in reverse shoulder arthroplasty. Clin Orthop Relat Res 466(3):670–676
96. Gutierrez S et al (2009) Arc of motion and socket depth in reverse shoulder implants. Clin Biomech 24(6):473–479
97. Gerber C, Pennington SD, Nyffeler RW (2009) Reverse total shoulder arthroplasty. J Am Acad Orthop Surg 17(5):284–295
98. Nam D et al (2010) Observations on retrieved humeral polyethylene components from reverse total shoulder arthroplasty. J Shoulder Elbow Surg/Am Shoulder Elbow Surgeon… [et al] 19(7):1003–1012
99. Chou J et al (2009) Biomechanical evaluation of different designs of glenospheres in the SMR reverse total shoulder prosthesis: range of motion and risk of scapular notching. J Shoulder Elbow Surg/Am Shoulder Elbow Surgeon… [et al] 18(3):354–359
100. Matsen FA 3rd et al (2007) The reverse total shoulder arthroplasty. J Bone Joint Surg Am 89(3): 660–667
101. Roche C et al (2009) An evaluation of the relationships between reverse shoulder design parameters and range of motion, impingement, and stability. J Shoulder Elbow Surg/Am Shoulder Elbow Surgeon… [et al] 18(5):734–741
102. Hattrup SJ (2010) The influence of postoperative acromial and scapular spine fractures on the results of reverse shoulder arthroplasty. Orthopedics 33(5)
103. Wahlquist TC, Hunt AF et al (2011) Acromial base fractures after reverse total shoulder arthroplasty: report of five cases. J Shoulder Elbow Surg/Am Shoulder Elbow Surgeon… [et al] 20(7):1178–1183
104. Walch G et al (2009) Acromial insufficiency in reverse shoulder arthroplasties. J Shoulder Elbow Surg/Am Shoulder Elbow Surgeon… [et al] 18(3):495–502
105. Cheung E et al (2011) Complications in reverse total shoulder arthroplasty. J Am Acad Orthop Surg 19(7):439–449
106. Baulot E, Garron E, Grammont PM (1999) Grammont prosthesis in humeral head osteonecrosis. Indications – results. Acta Orthop Belg 65(Suppl 1):109–115
107. Burkhart SS, Athanasiou KA, Wirth MA (1996) Margin convergence: a method of reducing strain in massive rotator cuff tears. Arthroscopy 12(3):335–338
108. Codman EA (1934) The shoulder: rupture of the supraspinatus tendon and other lesions in or about the subacromial bursa. Thomas Todd Company, Boston, pp 478–480