



Treatment options for massive rotator cuff tears

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Various classifications of rotator cuff tears have been proposed.^{18,53,68,81} Many authors currently define a tear as massive if there is a detachment of at least 2 complete tendons.³⁸ Whereas small tears can occur without symptoms,^{73,87} massive tears are always associated with weakness⁶⁰ and, especially in young patients, often with painful disability.^{38,78} Massive tears are only rarely due to an acute injury; rather, they are usually chronic and are associated with myotendinous retraction,^{71,112,113} loss of musculotendinous elasticity,⁵⁶ fatty infiltration of muscles,⁴⁷ static (superior) subluxation of the humeral head,^{22,50,53,85,98,102} and ultimately, osteoarthritis.¹¹² If fatty infiltration of the respective muscles is beyond Goutallier stage 2^{47,49} and/or if there is cranial migration of the humerus resulting in an acromiohumeral distance of less than 7 mm,⁹⁸ the probability that successful cuff repair can be achieved becomes so low that these massive tears are called irreparable.

Whereas small tears with no or little retraction relatively frequently remain small,¹⁰⁹ large, reparable tears usually increase in size and can rapidly become irreparable with no further increase in pain or disability.^{112,114} It is therefore important to determine the definitive treatment of a massive, reparable tear at the time of its identification. The key parameters that are decisive for the definitive treatment are the patient's symptoms, reparability of the lesion, and short- and longer-term functional demands.

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Assessment of key parameters in decision-making process

If it appears acceptable to define decisive parameters for treatment selection, a simple listing of these parameters is insufficient. These parameters should be quantitatively and reproducibly assessed. Unfortunately, even with quantitative clinical and imaging information, the scientific literature does not contain enough data to allow establishment of an evidence-based, universally acceptable treatment algorithm. Any proposed assessment and treatment algorithm therefore includes personal experience and scientific data. The following criteria have proven helpful in the assessment of the key parameters in the decision-making process for massive rotator cuff tears in our experience and are offered for consideration.

Assessment of symptoms

Pain

Assessment of pain must most importantly ascertain that the pain reported by the patient is caused by the massive cuff tear. Stiffness caused by adhesive capsulitis often accompanies traumatic extensions of tears. Limitations of passive external rotation tested with the arm at the side or limitations of passive glenohumeral abduction are never due to a cuff tear but are signs of concomitant adhesive capsulitis. Conservative treatment of stiffness is almost universally successful and, surprisingly, often results in sufficient pain relief and restoration of function, making operative treatment superfluous. Acromioclavicular joint pain, though different from the usual rotator cuff pain,³⁹ is the second most common cause of pain that is not caused by, but is occasionally

attributed to, a massive rotator cuff tear. Conversely, we have found cervical spine problems to be a rare cause of pain occurring concurrently with rotator cuff failure.

If the surgeon has determined that the pain is related to cuff failure and if glenohumeral stiffness and acromioclavicular pain are excluded, the patient determines whether he or she is willing and able to cope with the type and intensity of pain. If the patient believes that the pain is beyond his or her tolerance, treatment becomes mandatory, and the type of treatment will be determined by the other decisive parameters.

Disability

The main disability caused by rotator cuff tears is weakness with the arm away from the body. Although weakness of internal rotation is present in anterosuperior tears,^{62,82} it is rarely sufficiently disabling to warrant treatment. Anterosuperior tears usually require treatment for painful weakness of elevation. Posterosuperior tears and global tears cause weakness of elevation and external rotation.³⁷ This weakness can be quantified by various semi-objective means^{84,111} and reaches from hardly perceived weakness to so-called pseudoparalysis of elevation and/or external rotation. Pseudoparalysis of anterior elevation describes the inability to elevate the arm to 90° in the presence of unrestricted passive range of glenohumeral motion and in the absence of any neurologic impairment.¹⁰³ Pseudoparalysis of external rotation describes complete loss of active external rotation power in the presence of unrestricted passive external rotation and in the absence of neurologic impairment. It is synonymous with the Neer drop-arm sign,⁷⁷ with the inability to actively externally rotate the adducted arm beyond 0° despite the absence of stiffness or neurologic impairment,^{77,94} or a severe external rotation lag sign.⁵⁷ Winging of the elbow away from the body, while attempting external rotation, with concurrent internal rotation of the forearm is also known as hornblower's sign.^{4,43,94}

The disability has to be assessed after successful treatment of stiffness or after relief of acromioclavicular pain by injection of a local anesthetic into the joint. Even though loss of strength can then be measured¹¹¹ and correlated to disability scores,^{20,67} it is ultimately the patient who determines whether this disability is acceptable for him or her or whether he or she desires improvement. Only if the patient does not wish to accept his or her disability or if a highly likely progression of a currently acceptable disability could be halted by an operative procedure should operative treatment be considered.

Assessment of tear reparability

If a tear is sufficiently disabling to warrant operative treatment, repair is the preferred method of treatment because it provides lasting pain relief and improves strength over the preoperative state.^{7,38,65} Attempts at repair that result in persistence or even enlargement of the tear should, however, be prevented.

A tear is irreparable if the defect cannot be closed intraoperatively or if it has empirically been determined that a successful closure during surgery will almost certainly be associated with structural failure of the repair. The following clinical and imaging criteria have been identified as predictors of irreparability.

Clinical findings indicating irreparability of rotator cuff tears

We have found that anterosuperior tears, with obvious, static anterosuperior subluxation with the head under the skin in front of the anterior acromion and associated pseudoparalysis of anterior elevation (Fig. 1), cannot be repaired. In addition, tears associated with dynamic anterosuperior subluxation of the humerus upon resisted abduction (Fig. 2) have been found to have a very low likelihood for healing after attempted repair. For posterolateral and global tears, a pseudoparalysis of anterior elevation is suggestive of irreparability if it is chronic, if it is not associated with pain, and if the arm that is passively elevated to 90° of elevation cannot actively be stabilized by the patient. A true dropping sign indicates that the infraspinatus muscle has Goutallier stage 2 fatty infiltration or greater^{49,94} and will not heal after attempted, direct repair. If, in addition, there is a hornblower's sign, the teres minor has likely undergone substantial fatty infiltration and will not be amenable to successful repair.⁹⁴ Thus, static and dynamic clinical subluxations of the glenohumeral joint and chronic, very substantial lag signs are the key clinical predictors of irreparability of a tear.

Imaging findings suggesting irreparability of rotator cuff tears

Static superior subluxation of a glenohumeral joint with an acromiohumeral interval of 7 mm or less (Fig. 3) on an anteroposterior radiograph with the arm in neutral rotation is associated with an exorbitantly high repair failure rate^{26,99} and considered indicative of irreparability of a tear.³⁸ Static anterior subluxation, as detected on computed tomography (CT) or magnetic resonance imaging (MRI), though less well studied, appears to be indicative of irreparability of an anterosuperior tear.

Stage 3 or 4 fatty infiltration of the rotator cuff muscles⁴⁷ (Fig. 4) as determined by CT or MRI has repeatedly been associated with irreparability of rotator cuff tears.^{48,49} Thus an acromiohumeral interval of less than 7 mm and fatty infiltration of muscle of stage 3 or greater indicate irreparability of a tear.

As opposed to the results of repair, the results of biceps tenotomy, subacromial debridement, partial repairs, tendon transfers, and reverse total shoulder arthroplasty (rTSA) have not been documented to be strongly dependent on the delay between rupture and treatment. Therefore, the diagnosis of an irreparable tear provides the patient and surgeon with time for observation of the natural history, as well as attempts at conservative treatment including physical



Figure 1 Patient with clinically visible superior subluxation of right humeral head and associated, chronic pseudoparalysis of anterior elevation, indicating an irreparable, massive tear.

therapy and subacromial (and thereby intra-articular) corticosteroid injection, because the possible operative treatment options can also be applied with a very similar prognosis at a later date.

Assessment of functional demands

Rotator cuff disease does not cause disability with the arm at the side. Therefore, functional demands are considered high if the patient wishes to use the arm in space (ie, with the elbow away from the body). Conversely, if the patient accepts the ability to only use the hand with the arm at the side, functional demands are considered low. Thus, the relevance of the documented or expected dysfunction is determined by the patient alone, as is the tolerance level of pain. Patients are informed about the natural history of large tears¹¹² and the results of various forms of treatment,^{7,15,43,52,96,103,113,114} but it is their responsibility to match their demands with the expected outcome of the possible treatment options. The decision of the patient is respected unless it appears clear that the treatment expectations of the patient remain unrealistic despite optimal counseling.

Etiology

Acute, traumatic massive tears

Massive tears are only exceptionally purely traumatic and often constitute case reports.^{36,95} Massive trauma may

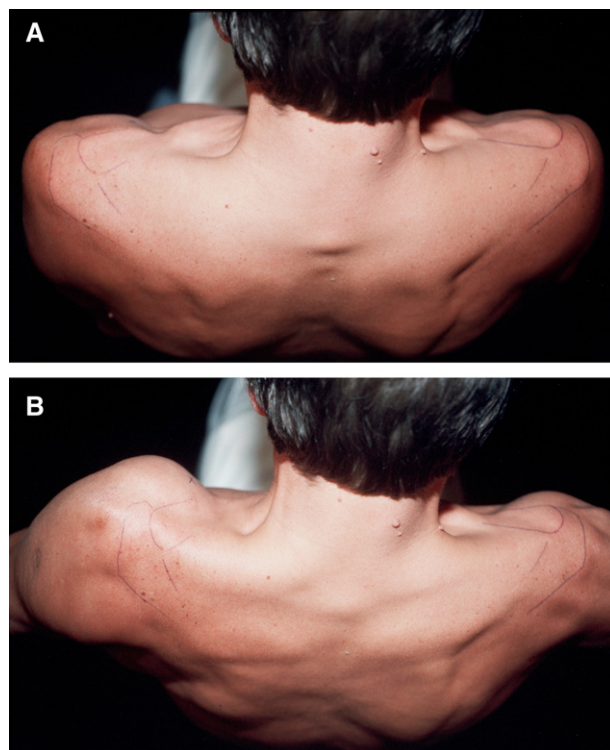


Figure 2 In the resting position, both shoulders appear centered (A); upon resisted abduction of the minimally abducted arm, the humeral head subluxates anterosuperiorly (B). This suggests irreparable anterosuperior rotator cuff failure.

exceptionally avulse the entire, healthy cuff or the cuff of a patient with predisposing factors such as severe osteopenia due to, for example, long-term administration of systemic steroid medication. Patients with a truly traumatic, massive tear present in the emergency department with a completely pseudoparalytic shoulder. Radiographic imaging excludes a fracture but may document a wide joint space due to interposition of an avulsed cuff. MRI or CT is used to exclude previously asymptomatic rotator cuff degeneration with atrophy and fatty infiltration. If massive tendon failure and absence of fatty muscle infiltration greater than stage 1 are documented, earliest possible repair is the most rational approach.

Chronic massive tears

Chronic massive tears are defined as tears with detachment of at least 2 tendons and chronic degenerative changes of tendon and muscle. A traumatic event may have enlarged a smaller pre-existing tear, and the so-called acute-on-chronic tears are considered chronic, because they usually exhibit substantial degenerative musculotendinous changes as evidenced by imaging studies. Exceptionally, a very small non-retracted tear may become enlarged by major trauma. Then, the imaging criteria (no fatty infiltration of the respective muscles, no static subluxation) for a



Figure 3 On an anteroposterior radiograph of the shoulder of a standing patient, who has his arm near neutral rotation, the acromiohumeral distance (*achd*) is about 1 mm. An acromiohumeral distance of less than 7 mm is associated with an exorbitantly high repair failure rate.

chronic tear are not fulfilled, and the tear is considered an acute tear.

Treatment options

Nonoperative treatment

The value of nonoperative treatment using physical therapy or subacromial corticosteroid injection (which is also intra-articular in massive tears) is not well established.^{2,12,44,55,105} There is also no proof that conservative treatment substantially alters the course of the natural history of massive tears. In a small cohort, Zingg et al¹¹² have documented a surprisingly good clinical outcome using nonoperative treatment but substantial structural deterioration of cartilage, tendon, and muscle. This is in agreement with studies of cuff debridement that also documented good clinical outcome but increase in tear size and joint deterioration after conservative treatment.¹¹⁴ It is therefore our interpretation of current knowledge that conservative treatment may lead to a very satisfactory clinical situation in selected, mainly low-demand patients but to an inevitable increase in joint degeneration. Therefore, conservative treatment is often appropriate if a tear is already irreparable but should not be used for reparable tears in patients with high midterm to long-term functional demands.

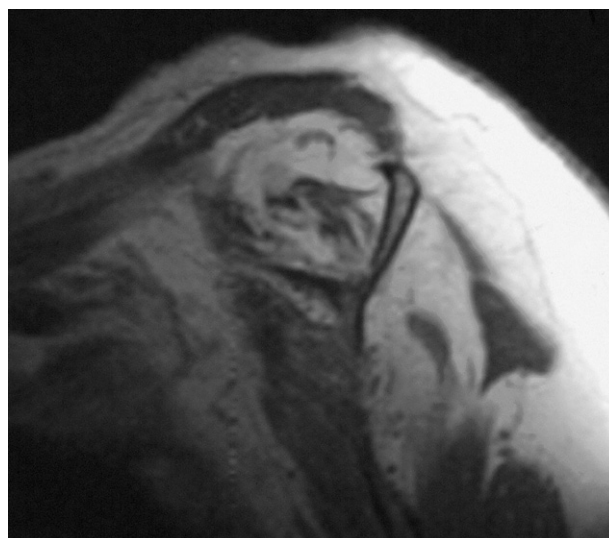


Figure 4 Magnetic resonance parasagittal image at level of scapular spine in a patient with a massive cuff tear. Fatty infiltration of the infraspinatus muscle is stage 4; of the supraspinatus muscle, stage 4; and of the subscapularis, stage 2. If fatty infiltration exceeds stage 2, repair failure is extremely likely.

Biceps tenotomy and tenodesis

The biomechanical role of the tendon of the long head of the biceps (LHB) is still controversial. However, tendinopathy of LHB has been identified as a common source of pain in patients with rotator cuff tears,⁸⁹ and arthroscopic tenotomy of the biceps was introduced as a routine pain treatment in rotator cuff disease by Walch et al⁹⁷ in 1997. The surprisingly positive results were subsequently confirmed in a multicenter study involving 210 rotator cuff tears, which identified a major benefit of LHB tenotomy particularly in the subgroup of patients with massive tears.⁶³ A review of 307 patients in which arthroscopic biceps tenotomy was the sole procedure for the treatment of rotator cuff pain showed an 87% satisfaction rate after a mean of 57 months. Somewhat less success was observed in shoulders with fatty infiltration of the subscapularis and a very low preoperative Constant-Murley score. Despite the excellent clinical outcome, this study did show progression of degenerative joint disease over time.⁹⁶ These results have further been confirmed by another independent study that showed a satisfaction rate of 78% irrespective of whether biceps tenotomy or tenodesis was selected.⁸

Scientifically speaking, the current literature provides only fair evidence in favor of biceps tenotomy,⁵ but clinical experience supports the value of this procedure and we are unaware of any report contesting good results of biceps tenotomy or tenodesis for the treatment of pain in massive rotator cuff tears. It is also currently uncontested that biceps tenotomy does not lead to pseudoparalysis or loss of function; rather, it is very often associated with functional improvement, which may be a result of improved pain.

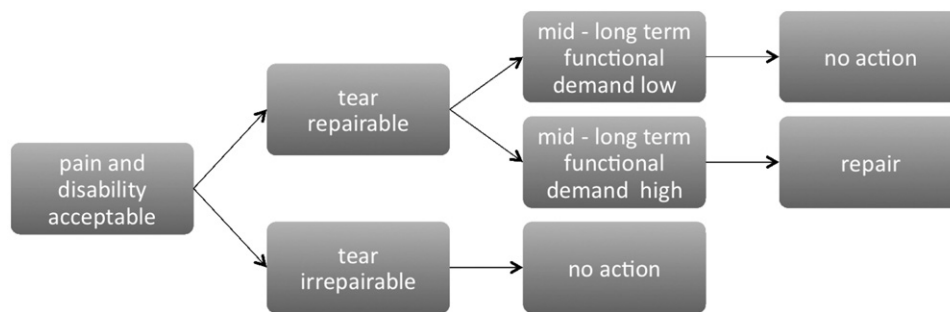


Figure 5 Treatment algorithm for patients with documented massive rotator cuff tears who can accept their symptoms.

Isolated tenotomy of the biceps, however, has not proven to prevent further degeneration of the joint, and therefore, it may not be an ideal long-term option for patients with repairable tears and high functional demands.

Subacromial debridement and decompression

In one study of 50 patients, debridement of rotator cuff tendon stumps with subacromial decompression led to satisfactory clinical results in 83% of those studied.⁸³ Although this approach appears to decrease pain and increase range of motion, it also appeared to decrease strength of elevation in another series of patients undergoing a similar procedure.³⁵ Today, the coracoacromial ligament is considered to be a major restraint against superior migration of the humeral head,^{31,108} and at most, it should be detached but not resected, especially not in massive rotator cuff tears. Tuberopecty has been suggested as an alternative to achieve a higher degree of sphericity of the acromiohumeral articulation during elevation²⁹ if acromioplasty does not suffice. A similar approach has been named reverse arthroscopic subacromial decompression and led to a minimal superior humeral head migration of less than 1 mm with a mean follow-up of 40 months.⁸⁶ These treatment options appear to have lost their indications somewhat and to have mostly been superseded by either biceps tenotomy or rTSA.

In a randomized trial of large but repairable lesions, debridement resulted in substantially less clinical success and in significantly more glenohumeral joint degeneration than tendon repair.⁷⁶

Cuff debridement of rotator cuff tears is associated with a satisfactory short-term outcome²⁴ in patients with low demands.^{64,66,69,79} It has previously been established, however, that subacromial debridement is much less effective in massive tears than in small tears,^{27,114} and there is no proof that debridement is superior to biceps tenotomy alone. Furthermore, there is no evidence of the efficacy of debridement in shoulders with massive tears and rupture of the LHB. In contrast, debridement alone has been associated with progressive joint degeneration, so its role is limited in the treatment of massive rotator cuff tears.

Rotator cuff repair

If a massive rotator cuff tear can successfully be repaired, short- and long-term clinical results are excellent and joint degeneration is halted or at least markedly decelerated.^{1,5-7,14,19,38,80} There is a lack of strong evidence showing that either arthroscopic or open rotator cuff repair is superior. If the repair heals by either approach, the results are comparable. Structural failure of repair of massive tears can and does occur but does not necessarily imply a poor clinical outcome.^{33,54,61} Repair failure is associated with inferior restoration of strength, lower shoulder scores, and substantially more rapid progression of degenerative joint changes than structural healing of a repair.^{38,113} There is no evidence that repairs that do not structurally heal yield better results than biceps tenotomy.

The rate of healing of a repair is closely related to the size of the tear, the acromiohumeral distance, the degree of muscular atrophy,⁹¹ and the amount of fatty infiltration. All these degenerative changes inevitably progress in unrepaired, massive tears and transform repairable tears into irreparable tears.^{70,112} Reparability is therefore dependent on the time between tearing and repair. A repairable tear in a patient with high functional demands, as previously defined, should consequently be repaired as soon as possible. Patients with low functional demands are informed that treatment of pain will also be possible in the future but that functional restoration may later be less reliable.

The role of augmentation devices or scaffolds is currently considered to be undetermined and is the subject of various reviews by authors with laboratory and clinical expertise.²³ Whereas there is substantial interest and very encouraging early results have been reported with some of these augmentation devices,^{13,107} there is conclusive evidence that some materials such as porcine small intestine submucosa are detrimental rather than helpful.⁵⁸ We therefore do not exclude that new horizons of repair may have been opened, but further results have to be seen before widespread use of these scaffolds can be recommended.

Tendon transfers

Tendon transfers are palliative procedures that are used to treat irreparable tears. Their role in augmentation of

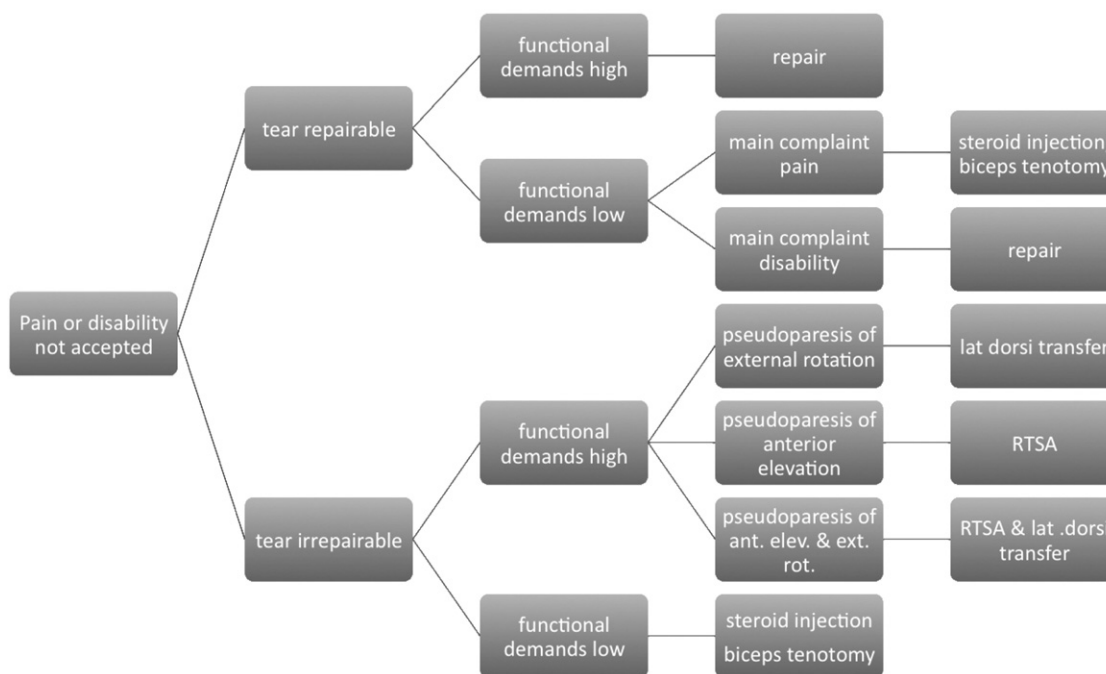


Figure 6 Treatment algorithm for patients who are not willing to accept their symptoms. ant. = anterior; elev. = elevation; ext. = external; rot. = rotation; lat. = latissimus; RTSA = reverse total shoulder replacement

reparable tears is not established. Although various tendon transfers, including transfer of the middle third of the deltoid insertion to the stump of the posterosuperior cuff,^{3,90} as well as transfer of the trapezius insertion to the greater tuberosity, passing underneath the acromion,^{46,72,110} have been proposed, the most frequently used and best-studied transfers have been latissimus dorsi transfer⁴³ and its modifications^{16,52} for posterosuperior lesions and pectoralis major transfer^{40,82,93,106} for irreparable subscapularis tears.

Latissimus dorsi transfer

Latissimus dorsi transfer has been used as a salvage procedure for irreparable superolateral rotator cuff tears for over 20 years.⁴³ Multiple authors have concurred that it is a valuable treatment option for painful or pain-free pseudoparesis of external rotation provided that the subscapularis is intact.^{17,41,52,59,74,101} Results are better if there is no chronic pseudoparesis of anterior elevation and if the teres minor does not show advanced fatty infiltration.^{21,41}

Pectoralis major transfer

Pectoralis major transfer either above^{93,106} or below⁸² the conjoined tendon is a valuable salvage procedure for isolated, irreparable subscapularis lesions.^{34,40,82} In massive, anterosuperior tears, pain can be improved but functional restoration is rather disappointing,^{34,62,106} and it appears that the transfer is even somewhat disappointing in the revision of isolated subscapularis failures after deltopectoral approaches for unconstrained prostheses.²⁵ If a massive anterosuperior rotator cuff tear is associated with

pseudoparesis of anterior elevation, it appears that rTSA or arthrodesis is a better alternative.

Shoulder arthroplasty

Humeral head replacement

Hemiarthroplasty has been used to treat painful massive rotator cuff tears associated with glenohumeral and/or subacromial osteoarthritis. Although some centers report acceptable results,⁴⁵ most reports indicate fair to good pain relief and poor restoration of lost function.^{30,104} If a massive rotator cuff tear is associated with pseudoparesis, the results of hemiarthroplasty are so much inferior to those of rTSA that hemiarthroplasty has almost lost its role in the treatment of massive rotator cuff tears, although level I studies comparing the two are lacking.²⁸

Reverse total shoulder arthroplasty

rTSA has proven to be the best short-term solution for treatment of the disability caused by irreparable rotator cuff tearing and rotator cuff arthropathy.^{10,11,23,92} It reliably and often dramatically improves function and pain in patients with irreparable rotator cuff tears associated with pseudoparesis of anterior elevation,^{32,75,88,100,103} and very satisfactory results can even be obtained in patients who have undergone a previously failed rotator cuff repair.¹⁰ The long-term prognosis of rTSA for irreparable tears is considered somewhat guarded, but the currently available literature documents an implant survival rate of 91% at 120 months.⁵¹ Therefore, the currently available literature

documents not only that irreparable rotator cuff tears are the most successful indication for rTSA but also that rTSA is the most successful and reliable treatment for irreparable rotator cuff tears with pseudoparalysis of anterior elevation. For patients aged 70 years or greater, it has, indeed, replaced the other procedures.

Unfortunately, rTSA alone is biomechanically unable to correct the often subjectively important pseudoparalysis of external rotation so that in the case of combined pseudoparalysis of anterior elevation and external rotation, functional restoration must be obtained by combining rTSA with variants of latissimus dorsi transfer.^{9,42}

Treatment algorithms

With precise understanding of the potential of the different treatment possibilities, a thorough evaluation of the patient's symptoms and functional demands, and assessment of the reparability of the cuff, the most adapted treatment option is proposed to the patient following a treatment algorithm. We have found the algorithms presented in [Figures 5 and 6](#) to be helpful. It is understood that during the course of treatment, a patient can change his or her decision because symptoms change from acceptable to unacceptable (or vice versa) and he or she may change from the low-functional demand group to the high-demand group (or vice versa). In addition, a tear may change from repairable to irreparable. Accordingly, the treatment options have to be reconsidered and adapted to the actual situation.

Conclusion

There are currently multiple treatment options. Their technical details are described elsewhere, and often, the choice of the best treatment option is more difficult than the execution of a procedure. Therefore, a careful analysis of the patient's situation and of the potential of the different treatment options is mandatory.

Disclaimer

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