Tears of the Rotator Cuff. Causes – Diagnosis – Treatment

Trhliny rotátorové manžety. Příčiny – diagnostika – léčení

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SUMMARY

Rotator cuff ruptures are the most common degenerative tendon injury and occur mainly in older patients as multifactorial disorders manifesting the main symptoms of pain and restricted range of motion. Thorough clinical examination of the shoulder includes testing the function of the rotator cuff and leads to a tentative clinical diagnosis that is the prerequisite for diagnostic imaging procedures. Sonography of the shoulder gives rapid access to a very good sensitive overview of the rotator cuff. Conventional radiological imaging permits differential diagnosis since a reduced acromiohumeral interval is understood as a direct sign of rotator cuff rupture. The gold standard in imaging diagnostics is MRI because it not only delivers images of rotator cuff defects, but also permits interpretation of degenerative changes in the musculature. Significant pain relief can be achieved by conservative therapy such as analgesia, manual therapy and physiotherapeutic exercises and leads to improvements in the active range of motion. Persistent pain or progressive pain during conservative therapy are indications for surgical intervention. Arthroscopy-assisted treatment is tissue friendlier than open surgery and is today considered the standard for surgical treatment of rotator cuff rupture because of higher patient acceptance. Recent studies report that surgical rotator cuff repair leads to significant improvement in function, pain relief, and greater patient satisfaction. The principles of postoperative care after surgical rotator cuff repair are immobilization and gradual loading with passive and active exercises.

INTRODUCTION

Rotator cuff ruptures are the most common degenerative tendon injury and occur mainly in older patients as multifactorial disorders and in the younger after high energy accident manifesting the main symptoms of pain and restricted range of motion. The decision for treatment, i.e. conservative or operative (arthroscopically versus open) is still discussed controversially. With this review we will demonstrate the different aspects presented in the literature.

1. Epidemiology

Ruptures of the rotator cuff are among the most frequent shoulder injuries to present at the clinic and are among the most common tendon injuries in man (15, 52, 77). In the majority of cases these injuries are associated with pain and loss of function, but they may also be clinically asymptomatic (15, 52, 77).

In 1931 Codman conducted an autopsy study on 52 cadavers and found complete rupture of the rotator cuff in more than one-third of the specimens (15). Ogata and Uhthoff identified an age-related prevalence of rotator cuff ruptures with an increase in prevalence of up to 70% in the population over 70 years of age (52). In a more recent investigation by Yamamoto et al. the prevalence of sonographically diagnosed complete rotator cuff ruptures in the general population independent of age was identified as 20.7% (77). The same study confirmed

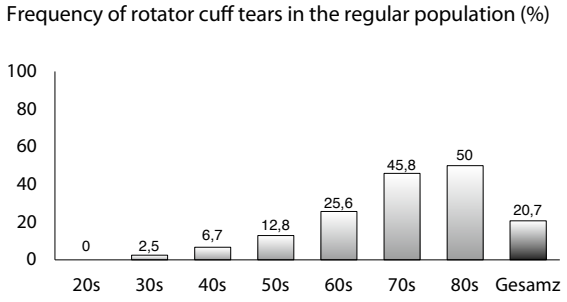


Fig. 1: Yamamoto with age-related distribution of rotator cuff rupture.

a statistically significant age-related prevalence for rotator cuff injuries (Fig. 1). Although a prevalence of 6.7% in a population of under 40-year-olds may appear low, the figure rises to 45.8% in 70-year-old patients (77). Depending on study sample and benchmarks the data on prevalence given in the literature show wide variation, however, it is clear that prevalence increases with age.

Interestingly, some patients with rotator cuff rupture are clinically asymptomatic (41, 68, 77). Tempelhof et al. sonographically identified complete rotator cuff ruptures in an asymptomatic patient sample and found a prevalence of 23% (68). It was shown that almost half the asymptomatic patients manifest symptoms after three years, however, only some of these patients showed sonographic progression of the rotator cuff defect (76).

2. Etiology

With regard to rotator cuff injuries it is essential to differentiate between two types of etiology, namely, intrinsic causes, i.e. processes that take place within the tendon itself, and extrinsic causes, i.e. external factors affecting the tendon. In 1931 Codman conducted his cadaver study on the pathology of supraspinatus tendon rupture and, thus, opened up the discussion of etiological factors. He asserted that there were extrinsic factors (trauma, impingement) and intrinsic factors (degenerative changes within the tendon with necrosis and calcification) (15). Neer developed a theory based on his clinical postoperative outcomes after acromioplasty for rotator cuff rupture that reciprocal obstruction of the acromial arch and the rotator cuff (so-called "outlet impingement") creates a mechanical conflict for the rotator cuff tendon and is therefore the cause of 95% of all ruptures (48). The importance of impingement in the pathogenesis of rotator cuff rupture is supported by various studies that have also confirmed a correlation between the 3 types of acromia defined by Bigliani and the incidence of rotator cuff rupture (3, 44).

Uhthoff et al. later conducted a large cadaver study and found a correlation between degenerative changes in the tendinous tissue of the rotator cuff and rotator cuff rupture and concluded that the most common causes of rotator cuff rupture were intrinsic degenerative processes (69). The tendinous tissue of the rotator cuff is subject to an aging process. Cadaver studies have revealed that mucoid degeneration, calcification and fatty infiltration of rotator cuff occurs with advancing age (49). The biomechanical factors specific to the shoulder are particularly important because the tendons of the rotator cuff, in contrast to other tendons, are subject to shear forces during rotation of the shoulder joint. Microscopically, repetitive loading leads to disruption of the longitudinal orientation of the collagen fibers with kinking and enlargement of the interfibrillar space (49).

A traumatic event acting on the shoulder will often play a role in the etiology of acute rotator cuff ruptures and will generally be regarded by the patient as the cause of the injury (73). In younger patients, traumatic rotator cuff rupture is often the result of sports or traffic accidents or follows shoulder dislocation (37). Lin et al. found that in patients under the age of 45 years 60% of all rotator cuff ruptures were caused by a traumatic event. Surprisingly, Rickert et al. in their biomechanical study on the tensile strength of the supraspinatus tendon found that even in a 65-year-old patient tensile forces of up to 900 N are necessary to cause rupture (62). Thus, it is clear that even in older patients defects of the rotator cuff are not the result of degenerative processes alone. On the other hand, it was also shown that, even for massive defects, there is no traumatic event in the patient's history in 50% of cases. Etiological importance is also given to overloading of the rotator cuff by excessive over-head work or maximal loading by athletes that may cause repetitive microtraumata so that, in the end, a minor incident can cause complete rupture. Overall, it can be said that traumatic factors frequently trigger rupture in the presence of existing degenerative processes. Trauma as the sole cause is mainly seen in younger patients with a typical indirect accident mechanism in the case history (37).

Today, the concept has gradually emerged that the etiology of rotator cuff injuries should be perceived as a multifactorial entity comprised of degenerative processes in the natural course of physiological aging, outlet impingement at the acromial arch, and traumatic factors (77).

3. Classification

To classify rotator cuff ruptures and take proper decisions on their management it is necessary to consider the pathophysiological processes associated with lesion of the rotator cuff. Various classifications have been introduced to identify the extent of this injury since categorization of the degree of severity permits an initial tentative statement on prognosis. Early classifications focused on description of the intraoperative findings. According to Bateman complete rupture of the rotator cuff is based on defect size: Grade I < 1 cm, Grade II 1–3 cm, Grade III 3–5 cm and Grade IV, so-called mass ruptures with a defect size > 5 cm (2). Retraction of the affected tendon occurs after rupture. Patte reported a correlation between the degree of tendon retraction and the outcome after surgical treatment and proposed classification of tendon retraction severities (56) (Fig. 2). Habermeyer's classification of the rotator cuff is based on localization of the lesions with reference to ventral, cranial and dorsal sectors (25). Ellman and Gartsman identify different patterns of rotator cuff rupture according to size and extent of the defect including mass rupture with involvement of at least 3 tendons or 2 tendons with retraction of at least 5 cm (21). The classification is based on the most common rupture patterns, and it is essential to understand them fully before embarking on surgical reconstruction (21).

The introduction of arthroscopic techniques at the shoulder joint with exploration of the articular and subacromial regions has permitted an arthroscopic classification of the defect into complete (affecting the entire tendon) and partial ruptures. According to Ellman arthroscopic classification of partial ruptures based on localization, i.e. articular-sided, bursa-sided or intratendinous, and according to the size of the defect (19) (Fig. 3). Snyder et al. expanded the classification based on their arthroscopic experience on 41 patients to include the macroscopic aspect at the defect site in partial rupture (66). They described a spectrum of tendon injuries from Grade I with bursitis and/or synovitis and slight, localized fraying of the capsule to Grade IV with fraying and tears in the tendinous fibers and including flap formation and retraction of partial thickness flaps $>$ 3 cm in size (66).

MRI tomography not only permits preoperative assessment of the rotator cuff defect, but also the identification of any pathological changes in the adjacent anatomical structures, thus setting a new challenge for the classification systems. It has to been emphasized that the rotator cuff tendon cannot be evaluated in isolation because

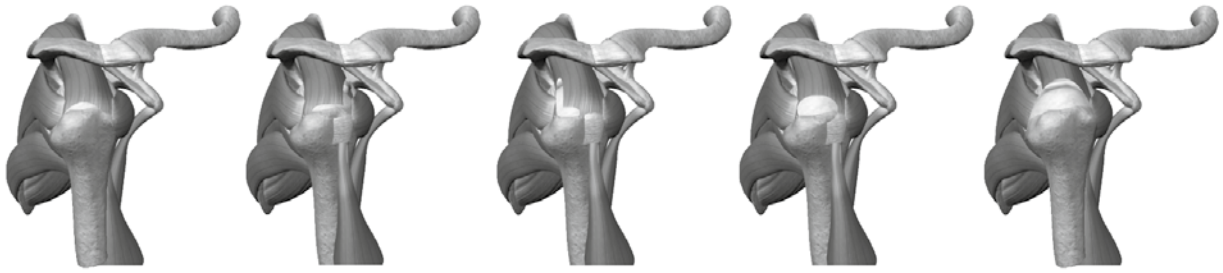
Fig. 2. Retraction of the tendon after full thickness t occurs after rupture. Patte classification (22)

Stage 1: Proximal stump close to bony insertion

Stage 2: Proximal stump at level of humeral head

Stage 3: Proximal stump at glenoid level

Fig. 3. Full thickness rotator cuff tear: Ellman and Gartsman classification (25)



1 – Crescent *2 - Reverse L* *3 - L shaped* *4 – Trapezoidal* *5 - Massive tear full thickness rotator cuff tears*

a chronic tendon defect leads to deficient contraction of the affected muscle and, ultimately, to fatty infiltration and atrophy. Zanetti described atrophy of the supraspinatus muscle after tendon rupture based on MRI-morphological criteria (78). Goutallier et al. developed his classification of fatty degeneration of the rotator cuff musculature after tendon rupture based on CT criteria (24). They were able to show that the extent of fatty degeneration affected the clinical outcome after rotator cuff suture (24). Pathological changes in tendon and muscle after rotator cuff rupture have an influence on the choice of treatment and its success and, therefore, must be evaluated preoperatively utilizing relevant diagnostic procedures.

4. Diagnostics

Case history

The main symptom of rotator cuff rupture is shoulder pain, which is recognized by the majority of patients as pain in the anterior and lateral regions of the shoulder and is generally described as a dull ache (30). Typically, patients complain of nighttime pain that disturbs sleep. The patient will often also complain of loss of shoulder function with painful limitations to movement, e.g. when working overhead as well as strength deficits when raising the arm and even pseudoparalysis (30).

Even though, as mentioned above, rotator cuff rupture should be regarded as a degenerative tendon disorder in the majority of cases, patient histories indicate that a traumatic event triggered the symptoms in 55–100% of cases depending on the study; in contrast, some patients suffered a progressive course with symptoms developing over a long period of time (73). Loew describes various mechanisms that might lead to traumatic injury to the rotator cuff: passive forced rotation, passive traction or axial compression in a cranioventral or ventromedial direction (37). In contrast, an accident involving direct impact is not considered adequate to cause rupture (37, 73).

Clinical examination

The clinical examination is essential to the diagnostic workup and differential diagnosis of rotator cuff lesions. The aim of the clinical examination is to formulate a tentative diagnosis, which will be the basis for well directed additional diagnostics including imaging procedures, if required, and their proper interpretation.

Conventional radiology

If rotator cuff rupture is suspected based on the clinical examination, conventional radiological diagnostics will require 3 views: true a.p. view with the arm hanging down in neutral rotation and the chest rotated by 30–45° towards the affected shoulder, outlet view (Y-view) and transaxillary view. The Y-view permits classification of acromial shape according to Bigliani in flat (type 1), curved (type 2) and hooked (type 3). Bigliani found a higher correlation of rotator cuff rupture for type 3 acromia (3).

Pearsall et al. found a high correlation between subchondral sclerosis, cyst formation and osteophytic growths in the region of the greater tuberosity and arthroscopically confirmed rotator cuff defects of medium size (57). They found no significant relationship between complete rotator cuff ruptures and changes in the region of the acromion, clavicula or acromioclavicular joint. Rotator cuff ruptures may cause cranialization of the humeral head (51). This is confirmed by an interrupted Maloney line and a diminished acromiohumeral interval seen on the true a.p. view (see Figure).

Ultrasound diagnostics

The advantage of ultrasound is that the moving joint can be examined in real time which, in turn, permits dynamic investigation of muscle function. Various formal and structural changes relating to the sonographic assessment of the rotator cuff have become established. Rotator cuff rupture is seen as an interruption in the echogenic tendon with a zone of hypoechogenic fluid. Sonography allows the assessment of the retraction of the tendon, provided the tendon has not retracted too far below the acromion.

Data on the sensitivity of ultrasound diagnostics for complete rotator cuff ruptures vary in the literature between 80 and 100% (65).

Computer tomography

Computer tomography (CT) of the shoulder is gradually becoming less important as a tool in the diagnosis of rotator cuff injuries due to the increased availability of magnetic resonance imaging (MRI) because the latter offers good differentiation of the soft tissues, which CT does not. Furthermore, CT is also associated with not inconsiderable levels of radiation exposure. CT is mainly utilized when MRI is contraindicated, e.g. metal implants or claustrophobia. CT-arthrography as an extension of native diagnostics facilitates improved assessment of the rotator cuff. Sensitivities of up to 99% have been reported in the literature for ruptures of the supraspinatus tendon (11).

Magnetic resonance imaging

MRI permits good differentiation of the soft tissue structures at high resolution and, consequently, facilitates interpretation of the rotator cuff, bursae, and rotator cuff musculature in different spatial planes (transverse, axial, parasagittal). MRI criteria indicative of rotator cuff rupture are signal increase in the tendon in the T1-weighted image with a further increase in the T2-weighted image, interrupted continuity with retraction of the tendon and evidence of fluid in the subacromial space and/or joint fluid communicating with the subdeltoid and subacromial bursae.

In native MR-imaging there are uncertainties with regard to the diagnostic indicators of partial rupture. Injection of a contrast medium into the joint space causes a certain distension of the adjacent structures, thus enhancing visibility. Entry of the contrast medium into partial defects on the articular side of the rotator cuff is the reason for the high sensitivity and specificity in the diagnosis of these defects. So far it has not been proven that MR-arthrography reveals partial defects on the bursa-side better than native MR-imaging. MRI diagnostics reveal nothing about the acromiohumeral interval since the images are taken with the patient in supine position.

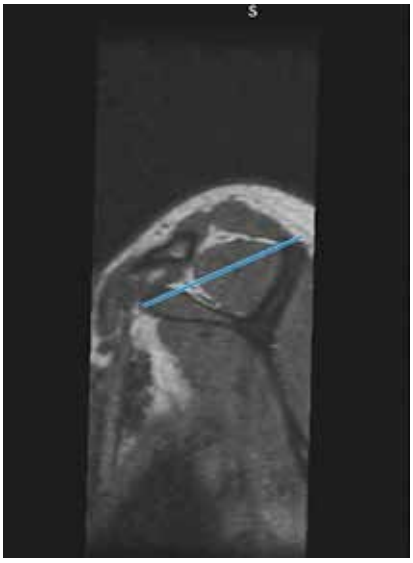


Fig. 4. In a parasagittal orientation a line is drawn connecting the superior border of the scapular spine and the superior aspect of the coracoid process. The Zanetti sign is considered as positive if the supraspinatus muscle does not cross this line.

MR-imaging of the shoulder permits evaluation of degeneration and atrophy of the rotator cuff musculature, whereby this requires the relevant T1-weighted sequences to be carried out. A quick estimate of atrophy of the supraspinatus muscle can be based on the so-called tangent sign (78). This requires a line to be drawn from the scapular spine to the coracoid in a parasagittal plane parallel to the glenohumeral plane. If the muscle belly of the supraspinatus tendon lies below this line there is a positive tangent sign (Fig. 4). Goutallier modified his classification, originally conceived for CT-imaging, to suit application in MR-imaging (22). It has been demonstrated in various studies that the degree of atrophy and degeneration of the musculature plays a determining role in prognosis after surgical repair of the rotator cuff, making it essential to analyze these changes carefully (24).

5. Therapeutic management 2004

5.1. Choice of conservative or surgical management

The very first therapeutic consideration is whether to choose or start with conservative treatment or to choose early surgical intervention. It is difficult to offer general recommendations in this regard since the decision is a response to the specific injury to the rotator cuff and must accommodate the requirements and expectations of the individual patient. Basically there are two indications for conservative treatment: partial or small asymptomatic or moderately symptomatic complete defects, and massive, chronic defects with significant, irreversible changes where clinical experience and published studies have shown that surgery is unlikely to lead to a successful outcome. A precondition for the choice of adequate therapy in line with these criteria is completion of the full range of clinical and diagnostic imaging procedures.

As contraindications for initial conservative management Habermeyer specifies acute trauma without history of preexisting disorder, primary subscapularis and infraspinatus involvement, and an active patient with high functional demands (25). Böhm et al. in their recent study were able to show that outcomes after surgical reconstruction of rotator cuff defects in older patients were comparable to the outcomes in younger patients (4). Djahangiri et al. obtained good outcomes after reconstruction of the supraspinatus tendon and therefore recommend that conservative treatment should not be the main preference for older patients as they are being denied surgical treatment options (18).

Various authors take a critical view of an initial conservative treatment regime for complete rotator cuff ruptures: they state that rotator cuff defects increase in size over time and patients with initially asymptomatic defects gradually develop symptoms (40, 76). Yamaguchi et al. showed that over a period of 3 years an average of 50% of initially asymptomatic patients had developed painful conditions (76). Maman et al. showed that after 18 months defects had enlarged in size in almost 50% of conservatively treated patients (40). Even though a certain regenerative potential with revascularization and fibroblastic activity has been identified for rotator cuff defects depending on their size, there is no evidence to show that rotator cuff defects heal spontaneous with defect closure (76). In summary, early surgical reconstruction within 3 months is indicated for acute, complete, and symptomatic rotator cuff ruptures and it should not be delayed by attempts at conservative treatment unless the patient absolutely refuses to have surgery.

5.2. Conservative treatment

Conservative treatment is primarily indicated to treat partial defects and small, asymptomatic or mildly symptomatic complete defects. It is also important for defects that cannot be surgically reconstructed and when surgical treatment is contraindicated.

Different conservative treatment regimens have been proposed in the literature, but what they have in common is a procedure in 3 phases (26). In the first phase acute pain and inflammatory reaction is treated, phase 2 introduces passive mobilization of the glenohumeral joint, and phase 3 active physiotherapeutic exercises (26).

Therefore, in the acute phase, analgesic and antiphlogistic treatment is only administered in the form of oral non-steroidal anti-inflammatory drugs (NSAID) so that physiotherapeutic exercises of any kind can take place. Local antiphlogistic and analgesic therapy may be administered in addition to systemic medication. Intraarticular injection of a corticosteroid of low solubility, in combination with a local anesthetic if necessary, has been recommended by various authors (5). Injection of corticosteroid should however only be given a maximum of 3 times since experimental findings have confirmed tendon damage after multiple injections. In the acute phase adjuvant physiotherapy using manual therapy techniques can help.

In the second phase passive, physiotherapeutic shoulder exercises are commenced, which is a prerequisite for transition to the third phase of conservative treatment with active exercising and muscular workout. The aim of active exercises to strengthen muscle in the third phase of conservative treatment is to achieve optimal centering of the humeral head in the glenoid (26).

Injuries to the rotator cuff and subacromial impingement are often secondary to scapular dyskinesia and spinal deformity. Physiotherapy cannot focus on the glenohumeral joint alone, but should also integrate postural correction and stabilization of the scapula and the spine into the exercise program (9, 30).

5.3. Prognosis for conservative treatment

Conservative therapy leads to a reduction in shoulder pain and improves the active range of shoulder motion (5, 31). Itoi et al. found significant pain relief over an average follow-up period of 3.4 years (31). Given the fact that shoulder pain is the main symptom of rotator cuff injury pain relief is a valuable benefit of conservative treatment. However, after an observation period of more than 6 years the pain-relieving effect of conservative therapy can no longer be identified (31).

Existing studies of conservative treatment did not find any resultant improvement in shoulder strength (5, 31). On the contrary, Bokor observed muscle atrophy in 56% of his patients over the long-term clinical course (5). Maman et al. described an increase in fatty degeneration of the muscles over a medium observation period of 20 months in 17% of patients receiving conservative treatment (40).

Persistent or progredient pain under conservative therapy should be understood as an alarming symptom and should trigger renewed MR-imaging and ultrasound diagnostics to discover whether to terminate conservative treatment and move to surgical reconstruction of the defect (40).

6. Surgical intervention

Surgical management and reconstruction of the rotator cuff was initiated in 1911 by Codman who described satisfactory postoperative outcomes after 3 months in 2 patients whose total thickness rotator cuff rupture with retraction of the supraspinatus tendon have been treated by open surgical suture (14). In 1972 Neer published his postoperative results after subacromial decompression through an anterosuperior approach with deltoid split to 5 cm distal to the acromioclavicular joint as a treatment for extrinsic rotator cuff rupture (47).

As surgical experience increases and given the enormous expansion of technical options in the context of arthroscopic technique at the shoulder joint, arthroscopy-assisted intervention is discussed as the standard surgical treatment for rotator cuff rupture (7, 39, 70).

6.1. Indications for surgical intervention

Various studies in the past have shown that the prognosis after rotator cuff repair is less positive as age increases, therefore, for a long time surgical intervention

was only tentatively indicated for patients over the age of 65. However, more recent studies have found comparable postoperative outcomes for older patients (4). Given these findings surgical treatment cannot be withheld on principle from older patients. Wolf et al. recommend that for the first 6–12 weeks full advantage should be taken of conservative treatment options in patients > 50 with a tentative clinical diagnosis of rotator cuff rupture (75). Due to the risk of muscle retraction and histological, degenerative changes in the muscle, younger patients with MRI-assisted diagnosis of total rotator cuff rupture should receive surgical treatment as first choice (75). It should however be noted that there is no evidence for this procedure based on clinical studies. Studies that focused on duration of symptoms as a prognostic factor for outcome after reconstruction have led to contradictory findings. Ellman regarded duration of symptoms as a negative factor, whereby Romeo did not discover any effect of symptom duration on the postoperative outcome (20, 63). We inform patients in good time about surgical treatment options and regard surgical reconstruction as indicated after 3 months of unsuccessful conservative treatment. There is consensus for the recommendation that traumatic ruptures in young and middle-aged patients should be repaired surgically in good time (60).

Absolute contraindications to surgical rotator cuff repair are advanced degenerative disease of the shoulder joint, cuff arthropathy, florid infection of the shoulder, paresis of the suprascapular nerve or the brachial plexus and a relative contraindication is lack of compliance. For the decision on whether to operate or not it is essential to look for any fatty muscle atrophy, retraction of the tendon, and/or a reduced acromiohumeral interval since these are seen as negative prognostic criteria for the postoperative outcome (20, 24). Surgical intervention must be considered very hesitantly in cases of third degree tendon retraction as described by Patte, fatty muscle atrophy classified as stage III or IV according to Goutallier, and reduction of the acromiohumeral interval to less than 7 mm because postoperative outcomes have been partially unsatisfactory and, in some cases of fatty infiltration, surgery has significantly increased the risk of re-rupture (20, 24, 51). Walch et al. were able to show that an acromiohumeral interval of less than 7 mm correlated with lower postoperative results on the Constant Score and less strength recovery.

6.2. Open surgical, mini-open and arthroscopy-assisted surgical techniques

Currently, it is basically possible to manage all rotator cuff ruptures from partial to massive by arthroscopy (7, 76). Arthroscopically-assisted repair compared to open surgical procedures is considered gentler to the tissues and only requires small skin incisions without incision of the deltoid muscle. Arthroscopically-assisted rotator cuff repair can however only be performed by a surgeon with adequate experience, which, in turn, can only be acquired by conducting numerous arthroscopic interventions. It is important to note that arthroscopic technique is subject to a steep learning curve and should be performed at a specialized center.

The technique of arthroscopy in contrast to open surgery allows good visualization of the subacromial space and functional and dynamic assessment of the rotator cuff injury. Arthroscopy of rotator cuff rupture also permits precise analysis of associated intraarticular pathologies. Thorough arthroscopy is considered the diagnostic gold standard for rotator cuff injuries and must precede any kind of therapeutic intervention whether by open surgery or by arthroscopy. Diagnostic arthroscopy facilitates verification of the surgical indication as well as the assessment of tendon quality, tendon retraction, type of rupture and whether the shoulder can be mobilized.

As more and more experience with shoulder arthroscopy has been gained, the first studies have been published and have reported good postoperative outcomes after arthroscopy-assisted reconstruction of rotator cuff rupture (23). Various clinical studies and meta-analyses have also been conducted to compare outcomes achieved by open and mini-open techniques and arthroscopic rotator cuff repair and to analyze these outcomes based on scores, clinical examination and imaging procedures. There is no prospective study that compares all three techniques. Comparison of two treatment techniques did not reveal any important differences in clinical outcome or re-rupture rate after reconstruction, therefore, the treatment techniques can be regarded as equally valid (6, 42, 46, 71). Comparison of reconstruction by open surgical and/or mini-open technique with arthroscopic technique achieved better postoperative pain relief and earlier postoperative mobilization for arthroscopic technique in the short-term, whereby the clinical outcomes were much the same in the long-term (6, 46). Verma et al. did not find differences in re-rupture rate between arthroscopic and mini-open therapies at their 2-year follow up (71).

Arthroscopic repair of complete ruptures of the subscapularis muscle is to be viewed hesitantly since few studies have looked at the clinical outcomes (8). The available studies by specialists in arthroscopy-assisted rotator cuff repair found comparable postoperative outcomes compared with open surgical technique (45). Nonetheless, the tendon of the subscapularis muscle is often difficult to treat using arthroscopy. This could be the reason why reconstruction in this cases in open surgical technique may be indicated. We prefer a deltoideopectoral approach because our experience has shown that it is tissue-friendly and allows good visualization.

Repair of mass ruptures with a defect larger than 5 cm and involvement of at least two tendons is considered an indication for an open procedure (72), whereby good clinical outcomes have also been described for arthroscopy-assisted repair of mass ruptures (29).

In summary, it can be said that development of technical options in arthroscopy-assisted shoulder surgery and experience with these techniques continues to advance. With regard to choosing between open surgery mini-open or arthroscopy-assisted procedures, an expert

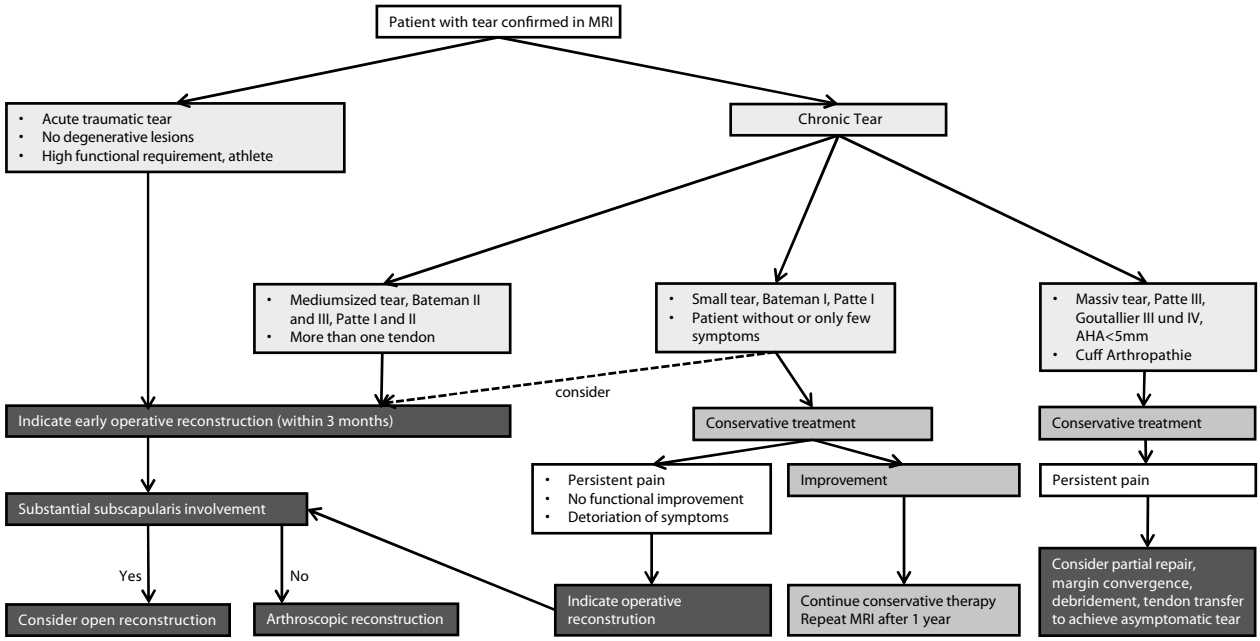


Fig. 5. Treatment algorithm for rotator cuff tears.

committee of the AAOS in 2011 in its published guidelines based on existing studies was not able to offer any specific recommendation as to the superiority of any particular technique (59). However, the trend in surgical rotator cuff repair continues to move towards arthroscopy-assisted techniques because of its theoretical advantages and better acceptance by the patients.

6.3. The importance of acromioplasty in the surgical treatment of rotator cuff rupture

Anterior acromioplasty was introduced by Neer as a treatment for impingement syndrome at the shoulder (47). The procedure has been modified since the introduction of arthroscopic techniques and is now known as arthroscopic subacromial decompression (ASD) with arthroscopy-assisted resection of the lower margin of the acromion, subacromial bursectomy, and resection of the coraco-acromial ligament. Experience has shown that the long-term outcomes after ASD to treat patients with subacromial impingement are superior to those achieved with open subacromial decompression. The importance attached to acromioplasty in the treatment of rotator cuff injuries originates from the theory of subacromial impingement as a cause of rotator cuff injuries as propagated by Neer and Bigliani (3, 47). However, various other intrinsic factors have now come to light that also need to be considered as causes of rotator cuff injury and that cannot be addressed therapeutically by acromioplasty alone (49, 69).

Hyvönen found that arthroscopic decompression alone could not prevent the natural progression of partial rupture to complete rupture (27). Metaanalysis did not uncover any significant differences in outcomes after arthroscopic rotator cuff repair with or without ASD (10). We recommend subacromial debridement with bursectomy, partly because it improves visibility of the rotator cuff. Routine ASD is not indicated and should only be performed for Bigliani's Acromion Type III and in cases of confirmed supraspinatus rupture or insertion tendopathic traction osteophytes (3, 10).

6.4. Refixation of the rotator cuff – double-row versus single-row fixation

Various suture techniques have been described for rotator cuff repair ranging from simple transosseous suture to the so-called "double row suture bridge" (Figs 6 and 7). Since open surgical and arthroscopic procedures lead to equivalent results, efforts have been made to design new suturing techniques and to identify a superior suturing technique that improves postoperative outcomes. This has led to the introduction of the double-row suture technique, whereby a second row of sutures is placed further medially and thus nearer to the articular tendon insertion (36) (Fig. 7). Double-row tendon fixation was introduced to achieve a reconstruction of the tendon that is more like the anatomical configuration of the "footprint" (36). Biomechanical testing in cadaver studies confirmed the superiority of double row suture in terms of stability and better anatomical reconstruction of the footprint (33). Based on CT scans Charousset et al. were able to prove a higher incidence of superior structural healing after double-row suture compared to single-row suture (12) (Fig. 6). Surprisingly, the effect on postoperative outcome is less obvious. Various studies comparing double-row and single-row suture failed to confirm an effect on functional outcome (12). Sheibani-Rad et al. compared single-row and double-row repairs in a very recent meta-analysis of five prospective random-

ized studies and reported no significant differences in Constant Score, ASES Shoulder Score or UCLA Score (64).

However, Park et al. achieved better scores for function and shoulder strength for double-row compared to single-row repairs in patients with rotator cuff ruptures larger than 3 cm (53). These results are supported by a meta-analysis showing that better functional outcomes are achieved after double-row repair in patients with serious rotator cuff defects larger or equal to 3 cm. Based on these findings and on its biomechanical superiority and higher rate of healing, a double-row suture should, in our opinion, be preferred in the treatment of larger rotator cuff defects.

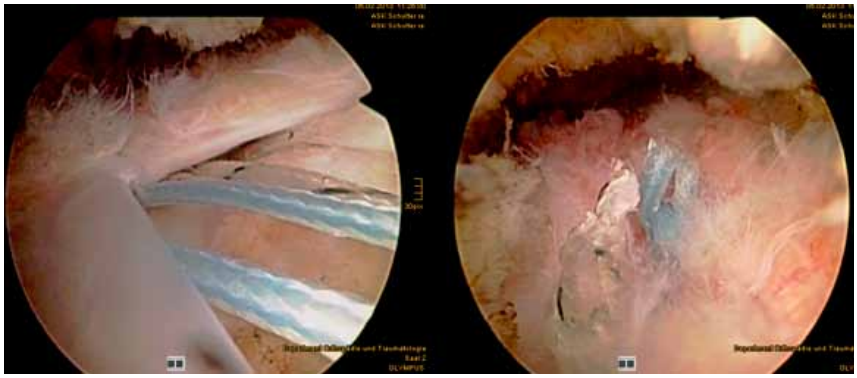


Fig. 6. Displayed is a single row reconstruction using a single BioCorkscrew (FT). A complete coverage of the footprint was achieved.

Fig. 7. Displayed is a double row suture bridge repair of therotator cuff. A BioCorkScrew and a BioPushLock were used. The BioPushLock is placed at the lateral edge of the greater tubercle.

6.5. Postoperative outcomes and prognosis after surgical repair

The findings of the most recent studies investigating outcomes for rotator cuff repair after injuries of different severities are encouraging overall and support the choice of a surgical procedure. In current studies the preference is generally for an arthroscopy-assisted procedure. A purely arthroscopic reconstruction of the rotator cuff was the method of choice in all the studies presented here unless stated otherwise. However, outcomes after open surgical and arthroscopic intervention do not differ significantly.

For partial defects postoperative values of at least 80 are achieved on the ASES Shoulder Score and values above 31 on the UCLA activity score (17, 32, 34, 61, 67, 74) (Tab. 1). Deutsch achieved values of 93 on the ASES Shoulder Score and a satisfactory outcome (at least ”good”) in 98% of patients over a follow-up period of more than 3 years (17). It has also been found that after surgical treatment of partial ruptures there is significant pain relief (17, 32, 34, 67).

For complete small and medium rotator cuff defects current studies have reported postoperative ASES Shoulder Scores of between 88 and 95 with significant pain relief and high patient satisfaction (1, 35, 43, 50, 58, 71) (Tab. 2). Pearsall et al. reported on long-term outcomes at a mean follow-up time of 51 months and found values of 31 on the UCLA activity score and a pain reduction of 4.4 on the Visual Analog Scale (VAS) Pain (58). A point for reflection is that in this study relatively high values were recorded after 4 years with an average of 3.4 points on the VAS Pain scale (58). Outcomes after the repair of small to medium-sized complete rotator cuff ruptures are comparable to the postoperative outcomes after repair of partial ruptures.

As might be expected postoperative outcomes are not as good for the repair of mass ruptures, and satisfactory outcomes were only recorded for a maximum of 75% of patients (13, 16, 28, 54) (Tab. 3). Values of between 29 and just over 30 points were achieved on the UCLA activity score. It should be noted that the significant relief of pain reported in all the above-mentioned studies reduced scores from 0.9 to 1.3 for VAS Pain. Denard et al. observed good long term results for a mean follow-up period of over 10 years with 87 points on the ASES Shoulder Score and satisfactory outcomes in 78% of patients (16).

POSTOPERATIVE CARE

Postoperative care is of crucial importance to a long-term positive outcome after surgical rotator cuff repair (38). The main aims are to avoid postoperative shoulder stiffness and to improve function and strength. Physiotherapeutic exercises have to be adapted to suit the individual according to the postoperative findings and the reconstruction. Postoperative care starts with passive assisted exercising followed by active physiotherapeutic shoulder exercises (38). The physiotherapeutic methods are similar to those utilized in conservative treatment.

At the start of postoperative care fixation in a shoulder abduction pad is indicated to encourage proper healing of the tendon. The use of a shoulder abduction pad for up to 6 weeks does not lead to a significant limitation

Table 1. Partial rotator cuff injuries

Studie	N	Follow-up (months)	Postoperative outcomes (preoperative/postoperative)
Deutsch A., 2007	41	38	ASES 93 98% satisfactory outcomes VAS 6.5/0.8
Kim K. C., 2013	32	17	ASES 79 UCLA 35.7 VAS 6.1/1.9
Kamath G., 2009	37	39	ASES 83 VAS 6.5/2.7 93% patient‘s satisfaction
Porat S., 2008	36	42	UCLA 31.5 83% satisfactory outcomes
Tauber M., 2008	16	minimum 18	UCLA 32.8 VAS 7.9/1.2 94% patient‘s satisfaction
Weber S. C., 1999	33	38	UCLA 31.6

Table 2. Complete rotator cuff injuries

Studie	N	Follow-up (months)	Postoperative outcomes (preoperative/postoperative)
Verma N. N., 2006	71	39	ASES 95 VAS <1.0 99% patient‘s satisfaction
Neyton L., 2013	107	16	Constant 54,5/80
Ames J. B., 2012	115	36	ASES 59/93
Pearsall A. W., 2007	52	51	UCLA 14/31 VAS 7.8/3.4
Lee E., 2007	36	16,5	ASES 46/89
Millett P. J., 2011	217	75,6	ASES 88 patient‘s satisfaction: mean 8 on the scale 0–10

Table 3. Massive rotator cuff injuries

Studie	N	Follow-up (months)	Postoperative outcomes (preoperative/postoperative)
Iagulli N. D., 2012	86	24	UCLA: partial reconstruction 29.5 complete reconstruction 29.6 satisfactory outcomes: partial reconstruction 76% complete reconstruction 71%
Denard P. J., 2012	126	99	ASES 86.6 UCLA 30.5 VAS pain 6.3/1.3 78% satisfactory outcomes
Chung S. W., 2013	108	32	ASES 83 VAS 5.0/1.3 65% satisfactory outcomes
Park J. Y., 2013	36	37,6	ASES 88.1 VAS 6.4/0.9

in range of motion after 12 months (55). Furthermore, Klintberg et al. found that early active and passive exercising from postoperative day 1 did not have a negative influence on the functional outcome, whereby no significant improvement of outcome was found for their small study population of 9 patients.

We prefer fixation in a shoulder abduction pad for 6 weeks with because this can reduce the postoperative tension in the rotator cuff. We commence passive abduction and flexion on postoperative day 1, active flexion/extension and rotation is trained from week 4 and after 6 weeks the patient is permitted free movement in abduction and adduction.

Early adjuvant treatment with continuous passive motion (CPM) leads to a significantly earlier restoration of motion at the shoulder joint. We work with CPM with both inpatients and outpatients and achieve good outcomes.

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