Rotator Cuff Tears

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1.1 Introduction

In 1834, G.A. Smith was the first to describe tears of the shoulder joint capsule and the supraspinatus tendon [1]. One hundred years later, in 1934, Codmann was convinced that these injuries predominantly occur during a trauma to the shoulder girdle [2]. Later, in 1939, Meyer and Burman hypothesized that all rotator cuff tears were the result of overuse or abrasion. In the ensuing years, our knowledge about etiology, diagnostics, and therapy has increased continuously. Treatment options include the full spectrum of nonoperative therapy and open, mini-open, and arthroscopic procedures. The latter seems to be today's gold standard. In massive cuff tears, tendon transfers might be considered. In cases of cuff tear, arthropathy shoulder replacement using reversed shoulder arthroplasty shows promising results.

1.2 Epidemiology

Rotator cuff tears are common injuries and are frequently seen by both general physicians and specialized shoulder surgeons. With increasing age, the prevalence of degenerative rotator cuff tears rises [3]. However, the true incidence of full-thickness and partial-thickness tears of the rotator cuff remains unknown. In cadaver observations the percentage of rotator cuff tears ranges from 17 to 19 %. Full-thickness tears were seen in people under 60 years in 6 % and in people over 60 years in 30 % [4, 5]. Yamamoto estimates the prevalence of rotator cuff tears in the general population by physical and ultrasonographic examinations. Of 1,366 shoulders, 20.7 % had full-thickness rotator cuff tears. Logistic regression analysis revealed a history of trauma, dominant arm, and age to be risk factors for a rotator cuff tear [6]. The prevalence of rotator cuff tears was 6.7 % in the age range from 40 to 49 years, 12.8 % in the range from 50 to 59 years, 25.6 % in the range from 60 to 69 years, 45.8 % in the range from 70 to 79 years, and 50 % in people older than 80 years.

1.3 Etiology

Multiple factors contribute to the development of a rotator cuff tear. These factors can be divided into two major categories: intrinsic factors and extrinsic factors [7, 8]. Age, vascularization, and tendon metabolism are considered intrinsic factors. Extrinsic factors are subacromial impingement, shoulder instability (typically anterior), blunt trauma, and repetitive micro-trauma.

1.4 Classifications

Several classification systems have been proposed for describing rotator cuff tears. This chapter outlines those relevant for preoperative planning and decision-making.

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Table 1.1 Classification of partial-thickness tears according to Ellman [9]

Partial-thickness tear (P): classification according to Ellman	
Grade	**Size**
I	<3 mm deep
II	3–6 mm deep
III	>6 mm deep
Localization	
A	Articular surface
B	Bursal surface
C	Interstitial

Table 1.2 Classification of partial-thickness tears according to Snyder [10]

Partial-thickness tears: classification according to Snyder	
Type	**Location of the tear**
A	Articular surface
B	Bursal surface
Type	**Severity of the tear**
0	Normal cuff, with smooth coverings of synovia and bursa
I	Minimal, superficial bursal or synovia irritation or slight capsular in a small localized area; usually <1 cm
II	Actually fraying and failure of some rotator cuff fibers in addition to synovial, bursal or capsular injury, usually <2 cm
III	More severe rotator cuff injury, including fraying and fragmentation of tendon fibers, often involving the whole surface of a cuff tendon (most often the supraspinatus); usually <3 cm
IV	Very severe partial rotator cuff tear that usually contains, in addition to fraying and fragmentation of tendon tissue, a sizable flap tear and often encompasses more than a single tendon

Table 1.3 Classification of full-thickness tears according to Ellman [9]

Full-thickness tear (F): classification according to Ellman		
Grade	**Size**	**Description**
I	<2 cm	Small
II	2–4 cm	Large
III	>4 cm	Massive
IV		Cuff arthropathy
Localization:		
A	Supraspinatus	
B	Infraspinatus	
C	Teres minor	
D	Subscapularis	

The tear size is estimated in the sagittal plane

Table 1.4 Classification of full-thickness tears according to Bateman [11]

Full-thickness tear: classification according to Bateman		
Grade	Size	Description
I	<1 cm	Small
II	1–3 cm	Medium
III	3–5 cm	Large
IV	>5 cm	Massive

The tear size is estimated in the sagittal plane

Table 1.5 Classification of full-thickness tears regarding the amount of tendon retraction according to Patte [12]

Full-thickness tear: classification according to Patte	
Grade	Description
I	Tendon between greater tuberosity and apex humeri
II	Tendon between apex humeri and glenoid
III	Tendon medial to glenoid

The tear size is estimated in the frontal plane

Rotator cuff tears can be distinguished in the following ways:

- Tendons affected
- Tear localization
- Tear size
- Retraction of the tendons
- Degeneration of the muscles

For partial-thickness tears, the classifications according to Ellman and to Snyder are commonly used. A special entity is the PASTA lesion (*p*artial *a*rticular *s*upraspinatus *t*endon *a*vulsion), which is an articular sided tear involving the supraspinatus footprint. This lesion can be defined as a type A-3 and A-4 lesion according to Snyder (Tables 1.1 and 1.2).

Most classifications of full-thickness tears involve the superior and posterior rotator cuff. They comprise the involved tendons and their tear size in the sagittal and frontal plane. The classifications according to Ellman, Bateman, and Patte are commonly used (Tables 1.3, 1.4, and 1.5).

Evaluation of muscle atrophy and fatty degeneration is important. This information provides valuable prognostic factors in addition to the tear size and retraction. Thomazaeu suggests that the ratio (R) of the supraspinatus muscle belly surface (S1) and the supraspinatus fossa surface (S2) is a good tool for estimating the degree of supraspinatus muscle atrophy [13]. Alternatively, according to Zanetti [14], the tangent sign is a quick, commonly used diagnostic procedure (Tables 1.6 and 1.7).

Subscapularis tendon tears can also be classified according to Fox and Romeo (Table 1.8).

Table 1.6 Classification of supraspinatus atrophy according to Thomazeau [13]

Supraspinatus atrophy: classification according to Thomazeau		
Grade	Ratio muscle/fossa supraspinata	Description
I	1.00–0.60	Normal or mild atrophy
II	0.60–0.40	Moderate atrophy
III	<0.40	Severe atrophy

Table 1.7 Classification of supraspinatus atrophy according to Zanetti [14]

Supraspinatus atrophy in MRI: classification according to Zanetti	
Positive tangent sign	A line (“tangent”) is drawn through the superior borders of the scapular spine and the superior margin of the coracoid. Supraspinatus muscle lies underneath the tangent.
Negative tangent sign	A line (“tangent”) is drawn through the superior borders of the scapular spine and the superior margin of the coracoid. Supraspinatus muscle lies above the tangent.

Table 1.8 Classification of subscapularis tears according to Fox and Romeo [15]

Tears of the subscapularis: classification according to Fox and Romeo	
Type	Description
I	Partial thickness tear
II	Complete tear of the upper 25 % of the tendon
III	Complete tear of the upper 50 % of the tendon
IV	Complete rupture of the tendon

1.5 Diagnostics

1.5.1 History

The typical history contains pain at night and painful elevation of the arm above the horizontal plane. Additionally, a loss of power may be observed. In advanced or acute cases, the patient is unable to elevate the arm at all; a pseudo-paralysis occurs. Many patients report a recent moderate trauma, however, most of cuff tears derive from a degenerative disease.

1.5.2 Clinical Examination

The clinical examination begins with the inspection of the complete shoulder girdle. Atrophies of the supraspinatus and infraspinatus muscles can be easily detected. Palpation of the anatomic landmarks is helpful to elicit pain spots. The active and passive range of motion should be documented according to the neutral zero method and functionally as well. Signs of capsular stiffness are crucial. Functional isometric testing of each rotator muscle is helpful but should be considered with care inasmuch as the powerful deltoid muscle might distort the involvement of the rotator cuff muscles. In these cases, the lag signs according to Hertel are valuable tests [16]. Additionally, impingement tests, according to Neer, Hawkins, and Kennedy, may underline the diagnosis. Specific tests for detecting pathologies of the long head of the biceps are also useful because they are seen frequently in association with rotator cuff tears and may influence later surgical therapy.

Finally, it is important to evaluate the cervical spine as well, inasmuch as many pain syndromes can derive from this area.

1.5.3 Plain X-Rays

Conventional X-rays should be carried out in all symptomatic patients. Without being able to view the rotator cuff tear itself, X-rays provide much crucial information. They can display differential diagnosis (e.g., calcifying tendinitis, severe acromioclavicular and glenohumeral joint arthritis). Moreover, they demonstrate the centering of the humeral head. An upward migration of the humeral head is a valuable diagnostic and prognostic factor in terms of rotator cuff tears. The acromiohumeral distance (AHD) is defined as the distance between the acromion and the top of the humeral head. If the AHD is smaller than 1 cm, the presence of a rotator cuff tear is indicated. An AHD greater than 7 mm implies a good prognosis for cuff repair [17]. AHD less than 5 mm indicates a poor prognosis. A cuff repair should be considered with care (Fig. 1.1).

1.5.4 Ultrasound

Ultrasound is a noninvasive and easy accessible method for investigation of the rotator cuff. In a recent meta-analysis, ultrasonography provided good sensitivity and specificity for the assessment of partial thickness rotator cuff tears (sensitivity: 0.84; specificity: 0.89). Even higher rates could be achieved in detection of full-thickness rotator cuff tears (sensitivity: 0.96; specificity: 0.93) [18]. A limitation of the method is that the detection of fatty muscle atrophy or tendon retraction underneath the acromion is impaired by technical limitations.

Fig. 1.1 Plain ap-view X-ray demonstrating an upward-migrated humeral head. The acromio-humeral distance is significantly reduced (4 mm)

1.5.5 Magnetic Resonance Imaging (MRI)

As with other joints, MRI has become a standard examination tool for investigation of the injured shoulder. In a recent meta-analysis of 44 studies with 2,710 patients, the pooled sensitivity and specificity values for the detection of partial-thickness rotator cuff tears were 0.80 (95 % confidence interval (CI): 0.79–0.84) and 0.95 (95 % CI: 0.94–0.97), respectively. The sensitivity and specificity values for the detection of full-thickness tears were 0.91 (95 % CI: 0.86–0.94) and 0.97 (95 % CI: 0.96–0.98), respectively [19]. In addition to the detection of the rotator cuff tear itself, it provides additional information such as tear size, morphology, retraction, muscle atrophy and fatty degeneration, tendon thickness, and quality [14] (Fig. 1.2).

1.6 Treatment

1.6.1 Nonoperative Treatment

1.6.1.1 Indications

- All forms of asymptomatic chronic rotator cuff tears
- All chronic rotator cuff tears, symptomatic <6 weeks

Fig. 1.2 Parasagittal sequence of MRI demonstrating a marked fatty degeneration of the supraspinatus muscle

1.6.1.2 Treatment

Nonoperative treatment of rotator cuff tears should include anti-inflammatory medication together with subacromial injection of local anesthetics and steroids no more than twice. This treatment should be supported by physical therapy. Physical therapy should aim for maintenance or restoration of free active and passive range of motion and strengthening of the shoulder girdle.

1.6.1.3 Results

Only a few studies have reported on the outcome of nonoperative treatment of rotator cuff tears. Additionally, most of these suffer a selection bias, as the study population was asymptomatic at the time of decision-making or undesirable for operative treatment. However, Bokor et al. reported on 53 patients treated nonoperatively with rotator cuff tears [20]. After 7 years, 74 % of patients had minor or no pain and 86 % rated their result as satisfactory. Two-thirds of the patients complaining of pain less than 3 months stayed asymptomatic until follow-up. Only 56 % of patients with symptoms for longer than 6 months remained asymptomatic. Patients with moderate symptoms can be managed nonoperatively over several years without significant progression of degenerative structural joint. But there is a risk of progression from a reparable to an irreparable tear within 4 years [21].

1.6.2 Operative Treatment

1.6.2.1 General Considerations

Christian Gerber once stated that the ideal tendon repair should have high initial fixation strength, allow minimal gap formation and maintain mechanical stability until solid healing has occurred [22]. Today, several fixation techniques meet these requirements. However, depending on the shape and size of the cuff tear or stage of tendon degeneration, tears reoccur in 11–94 % [3].

Fortunately, even after a re-rupture, the majority of patients experience significant increase of the shoulder scores, predominantly as a result of a reduction in pain.

Several studies demonstrate that clinical outcome and number of re-ruptures are comparable after arthroscopic or mini-open procedures for reconstruction of supraspinatus and subscapularis tears [23–25]. Therefore, the choice of the operative procedure should depend on the surgeon's skills. Further, there is no evidence for superiority of performing subacromial decompression at the time of rotator cuff reconstruction [26]. An evolution of fixation techniques can be seen in arthroscopic cuff repair. Single-row repair was followed by the development of double-row repair and double-row suture bridge repair techniques. In biomechanical testing, the primary stability of the double-row suture bridge technique seems to be superior in comparison to single-row fixation. They provide a higher load to failure, self-reinforcing characteristics (stronger under load), and better resistance to shear and rotational forces. In clinical studies, the double-row suture bridge repair tends to have higher outcome in shoulder scores and lower re-tear rates compared with single-row reconstruction in small and moderate tears [27–29]. However, in massive rotator-cuff tears, double-row fixation of the tendon provides significantly superior clinical and radiologic outcome [30].

1.6.2.2 Indication and Timing

Operative rotator-cuff reconstruction should be carried out after unsuccessful conservative treatment of 6–12 weeks or longer. Conservative treatment should not exceed 1 year, however, because significantly worse functional outcome can be expected [31]. This is probably because of the fatty degeneration of the muscles. Fatty muscle atrophy is hypothesized to begin after only a few weeks. Therefore, in young patients with traumatic rotator cuff tears early reconstruction should be the goal.

However, recent studies have not found fatty degeneration in the supraspinatus or subscapularis muscle within the first 12 weeks after trauma [32, 33]. In patients with chronic rotator cuff tears, operative treatment can be scheduled without hurry.

1.6.2.3 Patient Positioning

For arthroscopic treatment and open surgery of rotator cuff tears, two positions are commonly in use, depending on the procedure performed: the beach-chair position and the lateral decubitus position.

The beach-chair position can be used in almost all cases. It is used for the arthroscopic and open surgery of the rotator cuff. The lateral decubitus position is only used for arthroscopic treatment of the rotator cuff (Fig. 1.3).

1.6.3 Full-Thickness Tears of the (Postero-) Superior Rotator Cuff

1.6.3.1 Indications

- Traumatic rotator cuff tears
- Persistent shoulder impairment of longer than 3 months after physiotherapy

1.6.3.2 Contraindications

- Stiff shoulder/frozen shoulder
- AHD <5 mm
- Cuff tear arthropathy

1.6.3.3 Positioning

- Beach chair (arthroscopic, mini-open, and open repair)
- Lateral decubitus position (arthroscopic repair)

1.6.4 Arthroscopic Cuff Repair

1.6.4.1 Common Portals Used in Arthroscopic Cuff Repair

- Posterior portal
- Posterolateral portal
- Anterolateral portal
- Additional portals for anchor placement and/or suture management (Fig. 1.4)

1.6.4.2 Stepwise Technique

- Positioning in lateral or beach chair position
- Marking of anatomic landmarks and portals
- Placement of a posterior portal
- Standard glenohumeral inspection

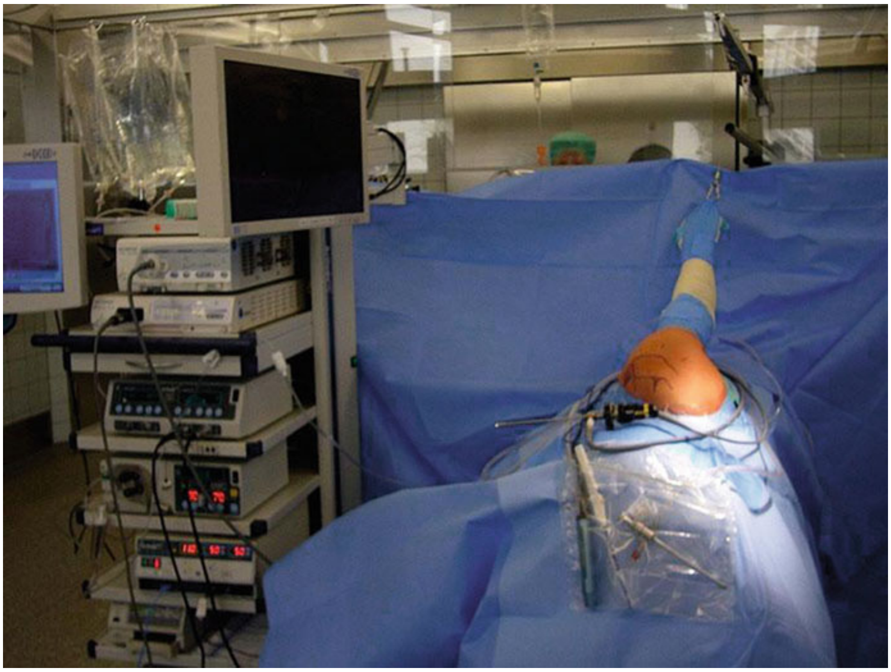

Fig. 1.3 Lateral decubitus position

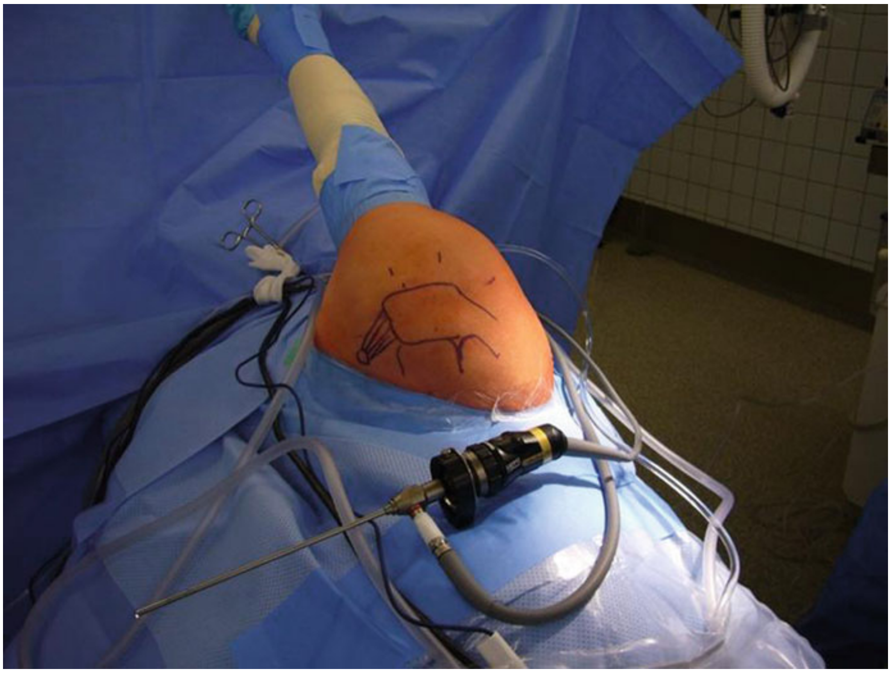

Fig. 1.4 Preoperative drawing of anatomical landmarks and portal placement

- In cases of pathologies and/or involvement of the long head of the biceps, arthroscopic tenotomy, and/or later tenodesis
- Redirection of the arthroscope into the subacromial space
- Subacromial bursectomy
- Evaluation of the subacromial space, the tear, the acromion, and the AC joint
- Performing an anterior-inferior acromioplasty
- Thorough rotator cuff release
- Identifying mobility of the cuff
- Debridement of the footprint using a burr

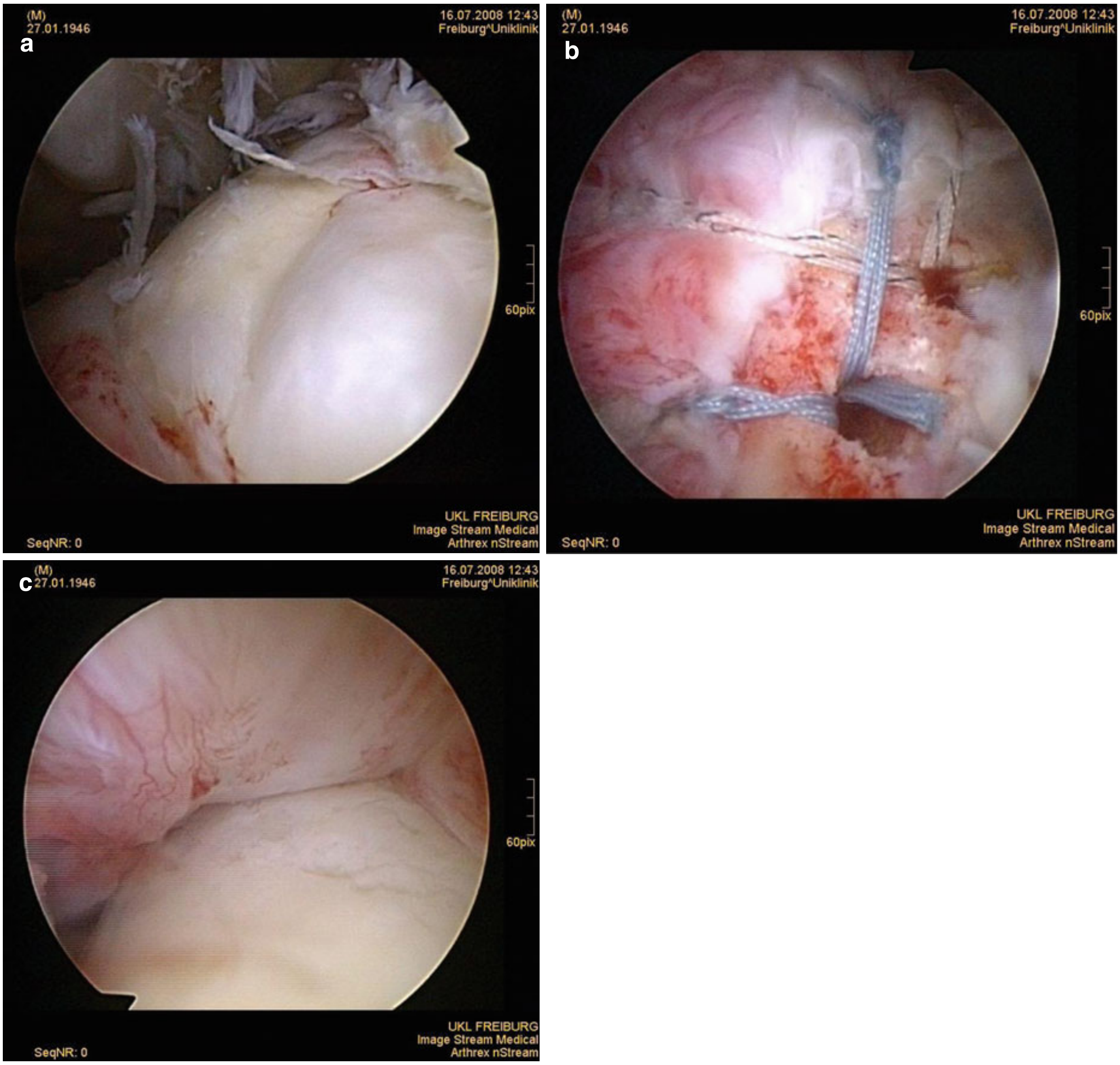

Fig. 1.5 (**a**–**c**) Arthroscopic cuff repair of a full-thickness supraspinatus tear. (**a**) Posterior view of the crescent-type tear. (**b**) Final control of double-row suture bridge repair. Subacromial view. (**c**) Final control. Intraarticular view

- Placement of a posterolateral optic portal//switching of the scope
- Switching the scope into the posterolateral portal
- Cuff repair using single-row or double-row suture bridge technique. Depending of the tear morphology, the following techniques are used:

Crescent type:	Lateral traction
L-shaped type:	Side-to-side closure, lateral fixation
U-shaped type:	Side-to-side closure, lateral fixation
Massive tear:	Side-to-side closure, lateral fixation (Figs. 1.5 and 1.6)

1.6.5 Mini-Open Repair

Mini-open repair begins with diagnostic arthroscopy of the shoulder joint followed by subacromial decompression (see above).

1.6.5.1 Stepwise Technique

- Anterolateral deltoid split in the line of fibers
- Thorough rotator cuff release
- Placement of stay sutures in the cuff for later manipulation

- Debridement of the footprint
- Creation of a trough in cases of foreseen transosseous fixation
- Reconstruction of the cuff tear with either single-row, double-row suture bridge, or transosseous techniques

1.6.5.2 Rehabilitation

A distinct postoperative rehabilitation protocol is crucial for a successful clinical outcome. Typically, the affected arm is placed on an abduction cushion for 6 weeks immediately after surgery. Continued passive motion exercises in this period can be performed but are not mandatory [34]. The rehabilitation program should be adapted to the fixated tendon. Recently, a prospective, randomized study demonstrated that aggressive rehabilitation has significantly higher rates of re-ruptures compared with a more moderate rehabilitation program within the first 6–8 weeks [35]. In the latter, the shoulder was predominantly fixed in a brace. Only guided movement supported by a well-trained physiotherapist was allowed (Table 1.9).

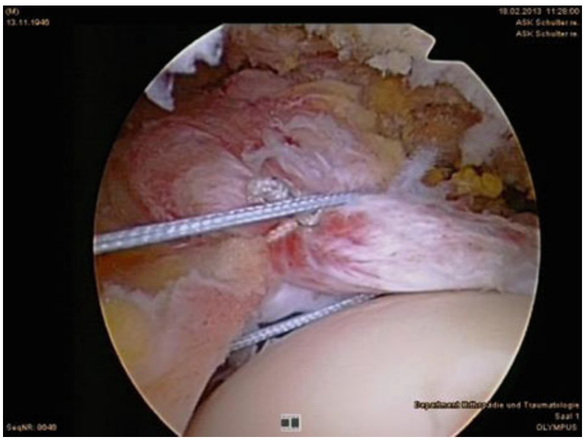

Fig. 1.6 Arthroscopic cuff repair of a U-shaped tear. Closure using side-to-side sutures and lateral fixation

1.6.5.3 Results

Mini-open and arthroscopic cuff repairs are a reliable treatment option. In a recent meta-analysis performed by DeHaan et al., a significant improvement was seen after a follow-up of 2 years [27]. The Constant-Murley score at the latest follow-up increased by 30 points after arthroscopic single- or double-row cuff repair, respectively. Complete re-tear rates were seen in 19 % of single-row and 14 % of double-row repair. Including partial tears, the re-tear rates were 43 % after the single row and 27 % after double-row repair. These are comparable results to mini-open surgery [24, 36]. Re-tearing is significantly influenced by patient's age, size, and extent of the tear, fatty degeneration of the rotator cuff muscles, and bone mineral density [37].

1.6.6 Full Thickness Tears of the Subscapularis Tendon

1.6.6.1 Indication

- All tears of the subscapularis tendon

Table 1.9 Proposal for a postoperative rehabilitation program after cuff repair

	1 p.o. day, week 1–3	Week 4–6	After 6 weeks	After 8 weeks
Brace	15° Shoulder abduction brace		None	None
Physiotherapy/CPM	Straining of the shoulder muscles Oscillation according to Maitland (Detonization of the capsule) Glenohumeral centering			
Range of motion	No active glenohumeral motion	Active moderate Flexion/Extension Slight internal and external rotation	Free No limitations for abduction and adduction	Free Strengthening of abduction and adduction
Training	Training of the forearm Training of the contralateral arm		Abduction 90° Adduction 90° External rotation up to 0° Internal rotation up to 0°	Training of coordination and 3D motion Increasing of power Isokinetic training of the internal and external rotation

Table 1.10 Proposal for a postoperative rehabilitation program after subscapularis repair

	1–2 p.o. day,	After 3 p.o. day, week 1–3	After 3 weeks	After 6 weeks
Brace	Sling/Gilchrist	Daytime: Omomed® Nighttime: Sling/Armfix®	None	
Physiotherapy/CPM	Assisted abduction 90° Preservation of scapular motion Glenohumeral stabilization Isometric Contraction		Free range of motion Straining of the subscapularis muscle	Active and passive motion against force
Range of motion	Abduction Extension passively up to 90° External rotation up to 0° No internal rotation against resistance		Motion in pain free range	Free

1.6.6.2 Contra-indication

- Stiff shoulder/frozen shoulder
- Chronic tears with fatty degeneration and marked narrowing of the subcoracoideal space

1.6.6.3 Positioning

- Beach chair (arthroscopic, mini open and open repair)
- Lateral decubitus position (arthroscopic repair)

1.6.7 Arthroscopic Repair

1.6.7.1 Common Portals Used in Arthroscopic Cuff Repair

- Posterior portal
- Anterolateral portal
- Anterolateral portals
- Additional portals for anchor placement and/or suture management

1.6.7.2 Stepwise Technique

- Beach chair position
- Marking of anatomic landmarks and portals
- Placement of a posterior portal
- Diagnostic glenohumeral evaluation
- Identifying intraarticular pathology
- Tenotomy/Tenodesis of the long head of the biceps
- Switch of the optic into an anterolateral portal
- Placement of additional anterior portals
- Bursectomy
- Thorough rotator cuff release
- Preparation of the bony footprint at the lesser tuberosity
- Reconstruction of the cuff tear with either single-row or double-row suture bridge technique

1.6.8 Open Repair

- Beach chair position
- Anterior deltopectoral approach
- Incision of the clavipectoral fascia
- Bursectomy
- Identification of the supraspinatus and the subscapularis tendon and placement of stay sutures
- Tenotomy of the biceps tendon
- Thorough release of the subscapularis tendon
- Preparation of the bony bed at the lesser tuberosity
- Reconstruction of the cuff tear with either single-row or double-row suture bridge technique. Transosseous techniques can be performed.

1.6.8.1 Rehabilitation

The rehabilitation program addresses the fixed subscapularis tendon. In the first 6 weeks any stress on this fixation should be avoided, giving a range of motion of abduction up to 90° and external rotation up to 0° (Table 1.10).

1.6.8.2 Results

It is shown that arthroscopic repair of the subscapularis tendon can lead to good or excellent results in most cases. However, open subscapularis repair is commonly performed and has proven to be sufficient over the years [38]. A recent meta-analysis conducted by Mall et al. demonstrates comparable results after arthroscopic and open subscapularis repair. The mean postoperative Constant score was 88.1 points [33]. In both procedures, concomitant treatments such as biceps tenodesis were frequently performed. Biceps tenodesis was observed in 54.8 %, followed by biceps tenotomy and biceps recentering. Healing was reported in 90–95 % of all patients.

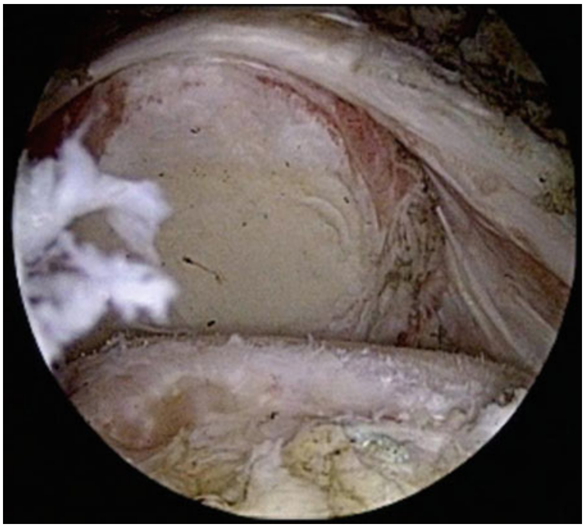

Fig. 1.7 Massive posterosuperior tear. Arthroscopic view from lateral portal

1.6.9 Massive Rotator Cuff Tears

1.6.9.1 Indication

- Symptomatic tears

1.6.9.2 Contraindication

- Stiff shoulder/frozen shoulder
- Fatty degeneration
- Acromiohumeral distance less than 5 mm

1.6.9.3 Positioning

- Beach chair (arthroscopic, mini-open, and open repair)
- Lateral decubitus position (arthroscopic repair)

1.6.9.4 Stepwise Technique

Open, mini-open, and arthroscopic cuff repair are comparable to the above-mentioned technique.

In cases of arthroscopic procedures, it is recommended to switch the optic even in the lateral portal in order to access a frontal view of the cuff tear. It is crucial to evaluate the method of closure properly inasmuch as only a few cuff tears can be closed with a straight lateral pull maneuver (Fig. 1.7).

1.6.9.5 Results

Denard et al. published a study pointing out the importance of performing a double-row fixation whenever possible in this population. They reported a good or excellent outcome in 78 % of the whole population. Comparing double- with single-row repairs, they found that after double-row repair, UCLA gain was greater and this group was 4.9 times more likely to have a good or excellent result [30]. In cases of massive tears, a partial closure like a margin convergence is a reasonable alternative. This should be considered if a high load remains on the repair even after an excessive tissue release. It is well demonstrated that functional repair of the force couple gives good results in terms of pain relief, patient satisfaction, and function [35]. Iagulli et al. reported that patients with massive rotator cuff tears had a comparable outcome after partial closure compared with a complete closure using double-row reconstruction [34]. They stressed that the reconstruction of the force couple is crucial. A reconstructed force couple is likewise responsible for a good outcome in their population of partial repairs [39, 40].

1.6.9.6 Rehabilitation

See Rehabilitation scheme of the supraspinatus tendon repair (see Table 1.9 and Chap. 1.6.5.2).

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