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Diagnosis of tears in rotator-cuff-injuries

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Abstract

Pathology of the rotator cuff is the cause of most common problems at the shoulder joint. Acute injuries are not as frequent as chronic cuff disease, but often they aggravate inflammatory or degenerative tendon alterations, even if they are of minor severity. Traumatic rotator cuff tears predominantly affect the supraspinatus tendon or the rotator interval. The subscapularis tendon is involved in anterior dislocations of the glenohumeral joint or in direct trauma. Plain film radiography still remains the base of all further imaging studies. If only full-thickness tears must be ruled out, double-contrast arthrography and ultrasound are acceptable imaging modalities. However, the former has a drawback in being invasive and does not detect partial tears at the bursal site of the cuff or rotator cuff tendinopathy, whereas the latter heavily depends on the experience of the radiologist and is restricted to the rotator cuff. Nowadays the most comprehensive imaging method is magnetic resonance (MR) imaging. MR imaging enables the detection or exclusion of complete rotator cuff tears with a reasonable accuracy and is also suitable to diagnose further pathologies of the shoulder joint. MR arthrography is valuable in the detection of subtle anatomic details and further improves the differentiation of rotator cuff diseases. Although in comparison MR imaging is still the most expensive imaging method, its high negative predictive value for the diagnosis of complete rotator cuff tears and its reliability evaluating different shoulder joint pathologies make it the preferred imaging modality. © 1997 Elsevier Science Ireland Ltd.

Keywords: Tears; Rotator-cuff-injuries; Magnetic resonance imaging

1. Introduction

The shoulder joint stability is given predominantly by soft tissue structures. Correspondingly, correct diagnosis and treatment of diseases of the soft tissue structures around the glenohumeral joint are of major importance. This article especially deals with the diagnostic imaging of rotator cuff injuries. The rotator cuff is composed of the musculo-tendinous parts of the subscapularis, supraspinatus, infraspinatus and teres minor muscles, which are affected with different frequencies by degeneration and trauma. There are findings on diagnostic images, which indicate a certain etiology of rotator cuff disease, e.g. the configuration of the acromion, potentially leading to impingement. In individual cases, however, an etiologic differentiation might be difficult and most important for the assessment of different imaging modalities is their ability to detect combined pathologies of the shoulder joint.

1.1. Anatomy of the rotator cuff

The rotator cuff forms a reinforcement of the fibrous shoulder joint capsule except at its inferior portion. Anteriorly the subscapularis tendon inserts at the minor humeral tubercle and blends with the transverse humeral ligament, which passes over the intertubercular groove. Superiorly the supraspinatus tendon is the part of the rotator cuff most often affected by degenerative and traumatic tears or inflammation around its tendinous insertion at the greater tuberosity. More posteri-

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orly at the middle and lower third of the greater tuberosity there are the tendinous insertions of the infraspinatus and teres minor muscles. The rotator interval is a relatively week portion of the cuff located anteriorly between the supraspinatus and subscapularis tendons, where the long tendon of the biceps brachii muscle penetrates the rotator cuff and passes into the intertubercular groove.

Biomechanically the rotator cuff functions as a dynamic stabiliser of the glenohumeral joint and retain the humeral head from the coracoacromial arch during abduction and elevation. The coracoacromial arch consists in the coracoid process, the coracoacromial ligament and the acromion. The subacromial-subdeltoid bursa is interposed between the rotator cuff and the coracoacromial arch and allows gliding of these two structures. Most remarkable as regards to the etiology of rotator cuff disease, however, is the intimate relationship of the supraspinatus tendon to the acromion, the acromioclavicular joint and the coracoacromial ligament and to a lesser degree the relationship of the subscapularis tendon to the coracoid process.

1.2. Etiology of rotator cuff lesions

The concept of rotator cuff impingement, introduced by Neer in 1983, is the most widely accepted etiologic explanation of rotator cuff disease [1]. Originally Neer described progressive stages of rotator cuff impingement in the space beneath the coracoacromial arch [1]. Stage 1 disease, which might be reversible under conservative treatment, consists of edema and hemorrhage of the tendon due to occupational or athletic overuse. More progressive inflammatory changes of the rotator cuff tendons and the subacromial-subdeltoid bursa are detectable in Stage 2 disease, which should be treated by removing the bursa and dividing the coracoacromial ligament when conservative management has failed. At stage 3 disease patients suffer from partial (3A) or complete (3B) tears of the rotator cuff and secondary bone changes at the anterior acromion, the greater tuberosity or the acromioclavicular joint may occur [1]. Ninety-five percent of rotator cuff tears are due to chronic impingement [1]. There are various factors, which are thought to be predisposing for an impingement, such as a type 3 acromion, subacromial spurs or osteophytes at the acromioclavicular joint [1,2]. Furthermore, there are descriptions of rotator cuff impingement other than subacromial. The coracoid process might cause an anterior impingement when the coracohumeral distance is decreased anatomically or during forward flexion and medial rotation [3]. A posterosuperior impingement of the undersurface of the rotator cuff has been documented in throwing athletes with MR arthrography, where the supraspinatus tendon is folded and compressed in the glenohumeral joint cavity during abduction and external rotation [4]. Another cause of rotator cuff disease in throwing athletes should be anterior in stability, which is described as the primary lesion succeeded by secondary impingement [5].

Another explanation of lesions of the rotator cuff is the assumption of degenerative changes at a so called critical zone close by the humeral cuff insertion, supposedly related to a diminished vascularisation [6]. Further factors in rotator cuff disease are overuse and contractile overload [7]. Traumatic lesions of the shoulder joint, such as anterior dislocation with or without fractures of the greater tuberosity or avulsion fractures of the major tubercle, are also frequently associated with rotator cuff tears (Fig. 1) [8]. In conclusion there are multiple etiologic factors in rotator cuff disease being influenced by the age of the patients and their occupational and sports activities [9].

1.3. Classification of rotator cuff lesions

Defects of the rotator cuff can be classified into partial-thickness and full-thickness tears irrespective whether they are due to impingement or of traumatic or degenerative-ischemic etiology. Full-thickness tears create a communication between the articular cavity and

Fig. 1. Anteroinferior dislocation of the glenohumeral joint with avulsion fracture of the greater tuberosity. A complex tear of the supraspinatus tendon was found arthroscopically and repaired. The cranial to caudal angulation of the AP view enables the assessment of the acromial undersurface.

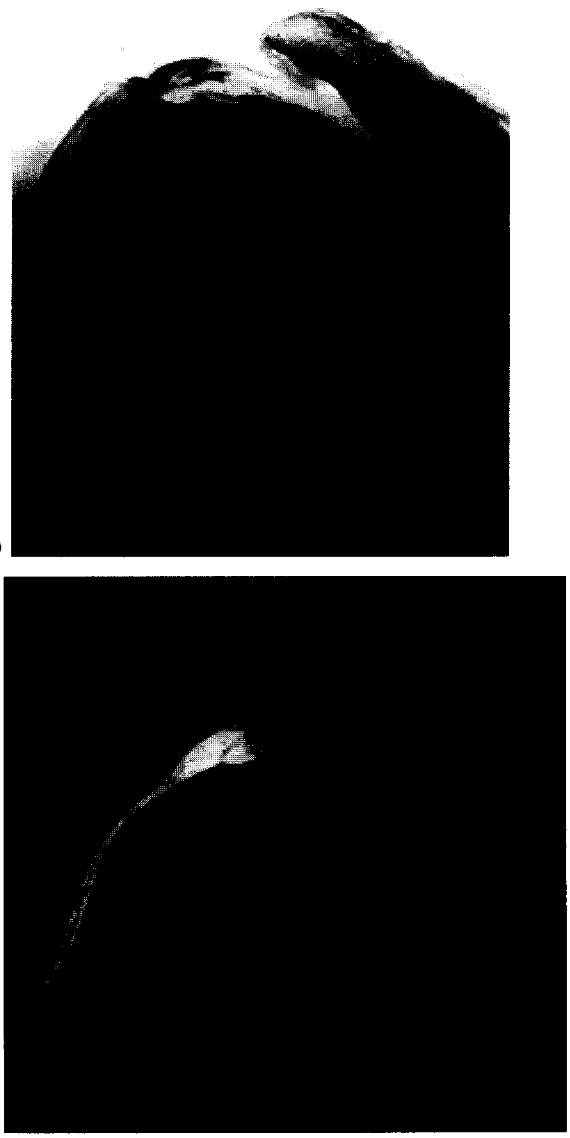

Fig. 2. (a) Conventional arthrogram before MR arthrography. The contrast solution consisted of 10 ml iodinated contrast material and 10 ml of a 2 mmol/l paramagnetic gadolinium solution. Arthrography demonstrates a partial cuff tear without contrast leakage to the subacromial bursa. There is a subacromial osteophyte, which probably produced the patient's impingement syndrome. (b) On the coronal oblique, T1-weighted spin-echo image (600/15) the intararticular contrast material shows a lower signal intensity than a pure 2 mmol/l gadolinium solution. Nevertheless the imbibition of the supraspinatus tendon is clearly visible and the quality of the partially ruptured tendon can be assessed.

the subdeltoidal-subacromial bursa. They could be longitudinal or transverse, with or without complete interruption of a tendon. Furthermore, a complex type of full-thickness defects does exist. Partial tears do not establish a communication between the shoulder joint cavity and the subacromial-subdeltoidal space and may be located at the articular or the bursal side of the rotator cuff. Intrasubstance tears are partial-thickness defects situated inside the tendinous tissue without connection to any surface.

2. Imaging techniques for diagnosis

2.1. Plain films

Standard radiography of the shoulder joint remains the first study in any patient suffering from a shoulder trauma, chronic shoulder pain or shoulder joint instability. There are many different radiographic projections, which were invented for specific indications prior to the introduction of cross-sectional imaging (e.g. the supraspinatus outlet view to assess the acromial shape, the groove view to evaluate the intertubercular sulcus or the West Point view to detect osseous Bankart lesions). Conventional X-rays will show gross osseous trauma, distrophic calcifications or spurs, predisposing to impingement. However, for soft tissue lesions their value is limited and also dependent on the radiologist's experience. Therefore, it is advisable to restrict the number of different views of the shoulder joint to a few standard projections.

The routine shoulder trauma series consists of an anteroposterior (AP) view with medial to lateral (30–45°) and cranial to caudal (20°) angulation completed by the scapular Y view. These two X-rays, which are perpendicular to each other, enable the diagnosis of fractures, osseous detachments of muscle tendons and luxations with a reasonable accuracy, even if the shoulder joint mobility is limited. Rotator cuff injuries are not detectable directly on conventional X-rays, but may be assumed in certain osseous lesions and depending on the mechanism of the trauma (Fig. 1). The cranial to caudal angulation of the AP view facilitates the assessment of the acromial undersurface for subacromial spurs or osteophytes.

In patients with chronic shoulder pain accompanied by limited joint mobility or aggravated by traumatic events the Y view can be replaced by an abduction view. This series consist of AP views in internal and external rotation with cranial to caudal angulation (20°) and an AP view the arm hold in abduction. On these images calcifications of the rotator cuff, subacromial osteophytes and fibroostotic alterations are detectable. The diagnosis of a rotator cuff defect can be inferred, when the humeral head is riding high and possibly even a neoarthrosis with the acromial undersurface has developed. Additionally, an AP view of the acromioclavicular joint with caudal to cranial angulation (10–30°) is advisable to assess the extent of acromioclavicular arthrosis, which also might cause an impingement syndrome.

2.2. Double-contrast arthrography

Arthrography of the shoulder joint has been well established for many years and refined by the addition of air for double-contrast technique [10]. The overall accuracy of single and double-contrast arthrography for the diagnosis of complete rotator cuff tears has been reported to be nearly 100% [11,12]. Furthermore, shoulder joint arthrography is still used to evaluate and to treat adhesive capsulitis, although specific MR findings have been described recently [11,13]. Subsequently to standard arthrography CT-arthrography should be performed whenever lesions of the labro-ligamentous complex and shoulder joint instability are suspected [14].

Double-contrast arthrography of the shoulder joint is performed after the intra-articular injection of 5 ml iodinated, water-soluble contrast material and 10–15 ml room air under fluoroscopic guidance. In complete tears and when the subacromial-subdeltoid bursa is filling rapidly by the contrast leakage, fluoroscopy is essentially to detect the exact location and extension of the cuff defect. The sensitivity of plain film arthrograms for complete rotator cuff tears is excellent and can be further improved especially for small partial-thickness tears by exercise before plain film radiographs are taken [12]. Nevertheless there remain a few drawbacks of double-contrast arthrography. First, it is an invasive procedure and can be associated with complications such as infectious arthritis, though nowadays these complications are rare and arthrography should not be a very painful examination. Second, the arthrographic detection of rotator cuff lesions is restricted to complete ruptures or partial ruptures located at the undersurface of the cuff, whereas intratendinous tears or defects at the bursal side of the cuff can not be diagnosed (Fig. 2a,b). Third, in our experience the size of the tears and the quality of the ruptured tendons can not be assessed sufficiently even using the double-contrast technique. CT arthrography, which is rarely complementary to standard arthrography in the detection of rotator cuff tears, might provide additional information in this respect.

2.3. Ultrasound

The ultrasound examination of the shoulder seems to be very attractive at first, because it is a quiet simple, non-invasive, frequently available and relatively inexpensive technique. However, the reported sensitivity and specificity of ultrasound studies of the rotator cuff vary between 57–91% and 76–100%, respectively [15,16]. Also the reported criteria for diagnosis of rotator cuff lesions vary [17,18]. Reliable findings of cuff tears are the detection of a focal cuff defect and the partial or complete absence of tendon visualization (Fig. 3) [15,18]. A focal tendon thinning and the detection of an echogenic focus within a tendon are further signs of rotator cuff lesions [17,18]. The latter is especially not widely accepted, because it can be due to intratendinous calcifications or technical artifacts and therefore the specificity of shoulder ultrasound will be decreased (Fig. 4) [15,18].

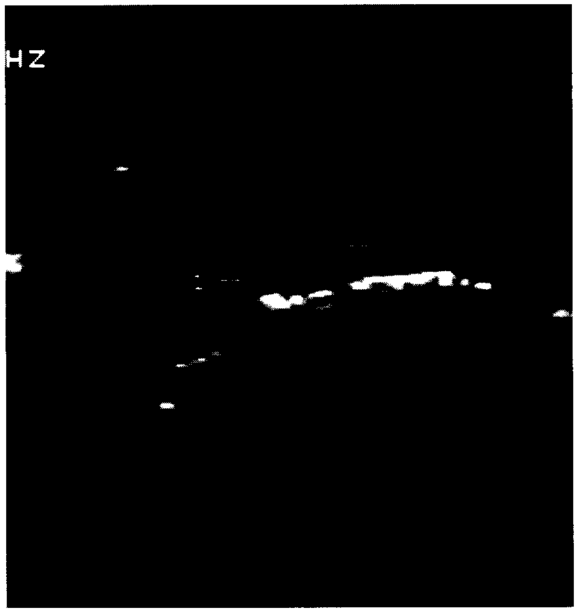

Fig. 3. Complete, post-traumatic rotator cuff tear on a longitudinal sonogram of the supraspinatus tendon visible as a fluid filled defect communicating with the subacromial bursa.

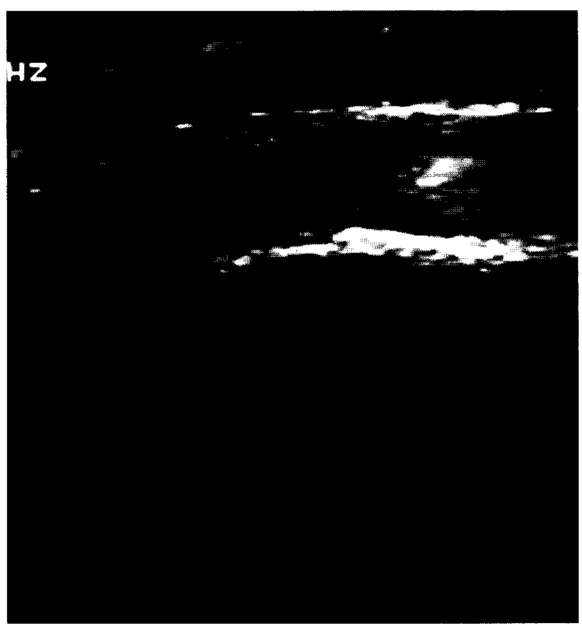

Fig. 4. Echogenic focus within the supraspinatus tendon on a longitudinal sonogram due to suboptimal positioning of the transducer. Careful interpretation of this unspecific finding and differentiation from a cuff defect is important.

There are some requirements for high quality ultrasound studies, particularly a linear transducer with ≥ 7.5 MHz. The examination procedure has to be standardized comprising the visualization of all cuff tendons and the long biceps tendon in a transverse and longitudinal plane. The comparison with the opposite side is advisable and to avoid misleading artifacts, perpendicular positioning of the transducer with regard to the tendon structures is of extreme importance. There is still a long learning curve for ultrasound of the shoulder joint and therefore a regular correlation between sonographic, arthroscopic and surgical findings is

(a)
(b)

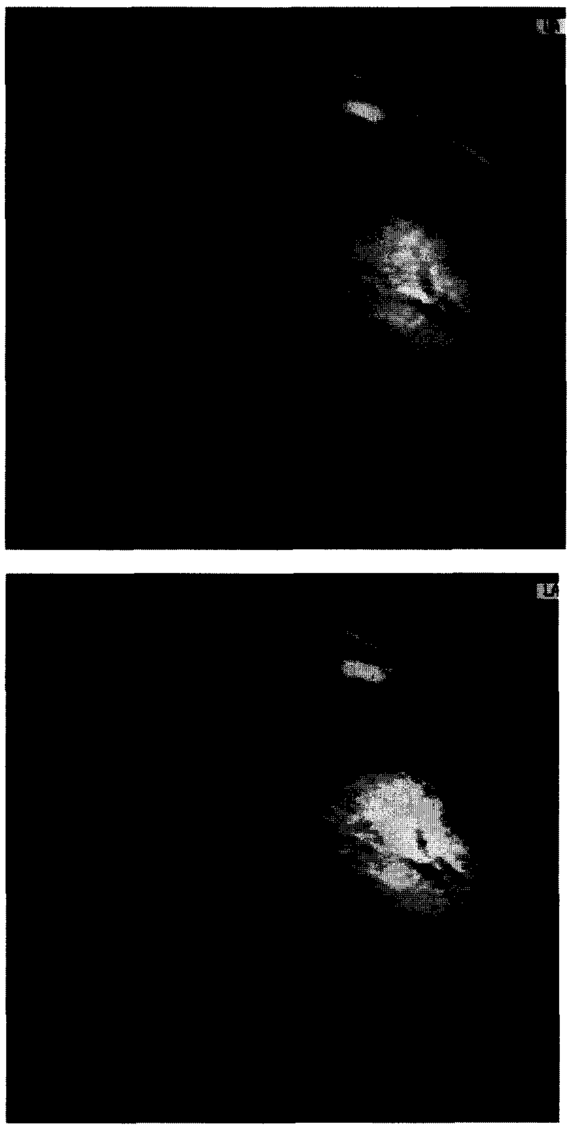

Fig. 5. (a) MR arthrography after intraarticular application of 15 ml of ringer lactat. On the proton-density-weighted coronal oblique spin-echo image (2000/20) there is focal signal increase about 1 cm beside the supraspinatus insertion at the greater tubercle. (b) It was thought to be due to the 'magic angle' phenomenon, because the T2-weighted image (2000/80) shows a normal signal intensity of the supraspinatus tendon.

(a)
(b)
(c)

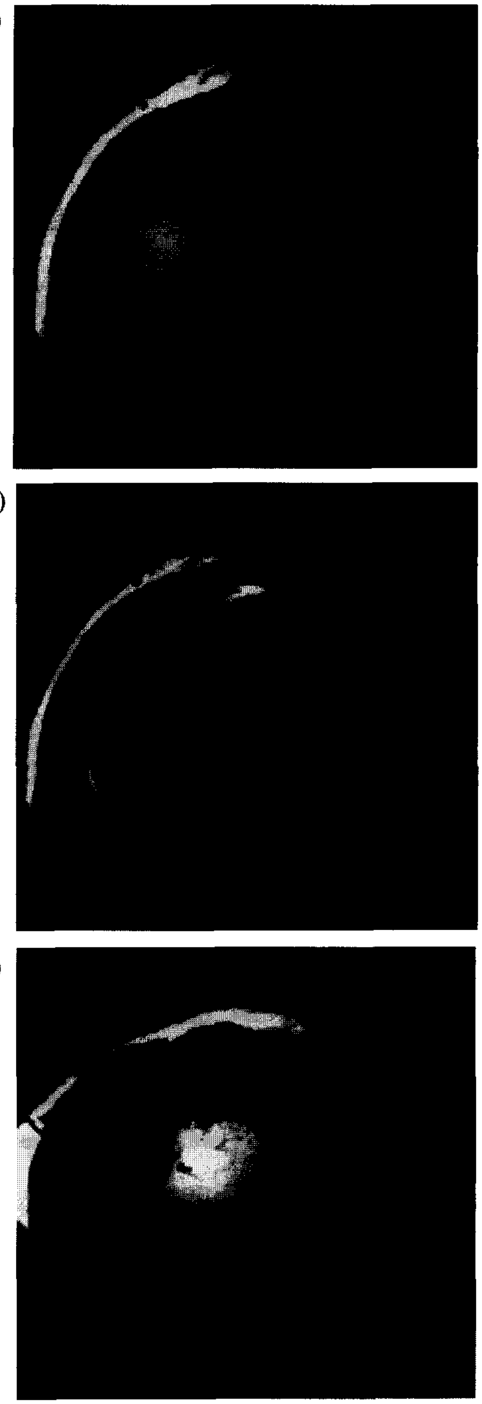

Fig. 6. Typical findings of a complete rotator cuff tear. (a) Irregular and extended signal increase of the supraspinatus tendon on the proton-density-weighted coronal oblique spin-echo image (2000/20). (b) The signal increase persists on the T2-weighted spin-echo image (2000/80). Furthermore, there is a fluid collection in the subacromial-subdeltoid bursa. (c) The sagittal oblique plane is useful to depict the anteroposterior extend of the lesion (T1-weighted spin-echo, 600/15).

Fig. 7. MR arthrography with a paramagnetic gadolinium solution. There is a small complete rupture of the subscapularis tendon due to a recent trauma with contrast leakage into the subdeltoid bursa. As a further pathologic finding a small anterior labral lesion is unmasked by the intra-articular contrast material on this transaxial T1-weighted spin-echo image (600/15).

necessary [19]. Thus the conclusion "that sonography of the shoulder can be a very useful screening modality for those few individuals with a combination of ultrasound expertise, motivation, large volume of patients, and available follow-up" is still justified [20]. A final limitation of ultrasound is its restriction to the soft tissues around the humeral head, when frequently a complete evaluation of all structures of the shoulder joint is required.

2.4. Magnetic resonance imaging (MR imaging) and arthrography (MR arthrography)

MR imaging has been intensively investigated for the assessment of shoulder joint diseases since appropriate surface coils are available. There are many reports on shoulder joint MR anatomy and normal variants [21,22] and the MR evaluation of rotator cuff disease [23–27], shoulder joint instability [28,29] and other pathologies for instance of the long bicipital tendon [30,31]. As in many ultrasound papers MR studies frequently do not differentiate between certain etiologies of rotator cuff tears, but many of them have assessed cuff impingement, partial tears and complete ruptures separately. As a typical, sport related tendon injury in throwing athletes posterior glenoid impingement was assessed by MR imaging and MR arthrography [4].

In interpreting MR images of the rotator cuff two common variants have to be considered. A focal signal intensity on T1- and proton-density-weighted spin-echo images in the region of the critical zone of the supraspinatus tendon is a frequent finding in asymptomatic volunteers (Fig. 5a,b) [21,22]. It should not be mistaken as a pathologic finding and could be best explained by the 'magic angle' phenomenon (Fig. 5a,b) [32]. Also a focal obliteration of the subacromial fat stripe is a rather unspecific finding, which was present in 95% of asymptomatic shoulders [22]. Reliable findings have been described for complete cuff tears, whereas the signs of an impingement tendinopathy or a partial tendon rupture are still under discussion. Interruption of tendon continuity with or without musculotendinous retraction, interpositioning of signal intense fluid within a tendon on T2-weighted images and presence of fluid in the subacromial space are sensitive and specific findings of complete tendon ruptures (Fig. 6a–c) [24–27]. A scoring system based on these findings has been developed to increase the objective reproducibility of the image interpretation. Improved results have been obtained with it [25]. For complete tears sensitivity and specificity of MR imaging are reported to be 80–97% and 94%, respectively and the negative predictive value of this diagnosis is over 90% [23,26,27]. However, partial tears are not easy to detect or to distinguish from tendon degeneration or an impingement tendinopathy and there are no data, whether the distinction between complete and partial ruptures can be made with a sufficient reliability on MR images [33].

MR arthrography was introduced to overcome the limitations of MR imaging in diagnosing rotator cuff disease and shoulder instability [34–36]. It can be done with different fluids, such as pure saline and ringer lactate, or with a mixture of saline and gadolinium contrast media. The latter enhances both the T1- and

Table 1
Protocol for MR imaging and MR arthrography

Slice orientation	Imaging sequence	TR (ms)	TE (ms)	Flip angle α (°)	Slice thickness (mm)	Matrix	FOV (mm)	Gap (%)
Transversal	GRE	600	18	60	4	140 × 256	150	10
Coronal oblique	FSE	4000	21–103		4	192 × 256	150	10
Sagittal oblique	SE	600	15		4	192 × 256	150	10
Coronal oblique	GRE	850	15	90	4	192 × 256	150	10

GRE, gradient recalled echo; FSE, fast spin echo; SE, spin echo; FOV, field-of-view.

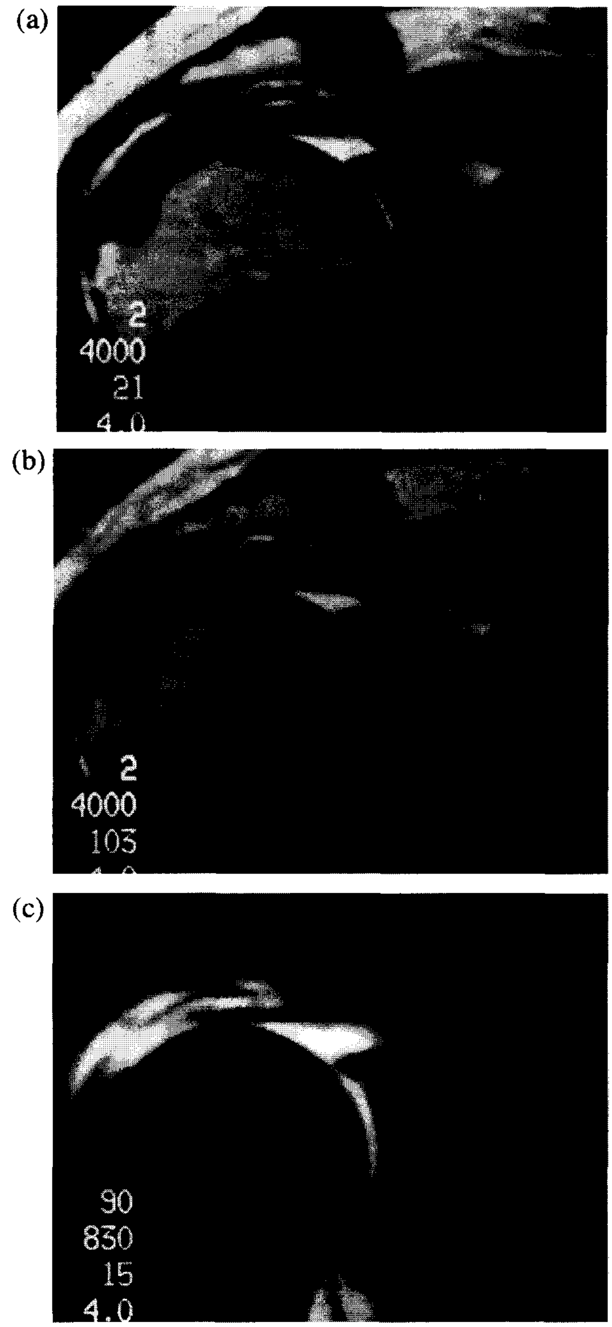

Fig. 8. Coronal oblique MR arthrograms of a complete supraspinatus cuff tear. On the proton-density (a) and the T2-weighted (b) fast spin-echo images (4000/21-103) the paramagnetic contrast media is as bright as the subcutaneous fat. (c) The contrast leakage into the subacromial-subdeltoid bursa is reasonably detectable only on the T1-weighted spin-echo image (830115) with fat saturation.

the T2-contrast of the articular cavity, but paramagnetic contrast media for intra-articular applications still have not been approved by any authority (Fig. 5a,b). In order to confirm needle placement during intra-articular injection the addition of a small amount of iodinated contrast material has been recommended [34–36].

Table 2
Shoulder imaging fees

Study	Total charge (CHF)
Arthrography	236.00
CT arthrography	414.00
Ultrasound	76.00
MR imaging	606.00
MR arthrography	745.00

However, this will decrease the signal intensity of the intra-articular paramagnetic contrast media significantly, even if the iodinated contrast media makes up only 15% of the total volume (Fig. 2b) [37].

In comparison with unenhanced MR imaging, MR arthrography tended to improve the differentiation and detection especially of partial rotator cuff tears and showed better results for the evaluation of labral tears as well [29,34,35]. However, the number of patients, on which these published conclusions are based, is relatively low. In our experience MR arthrography enables the delineation of subtle anatomical details and makes

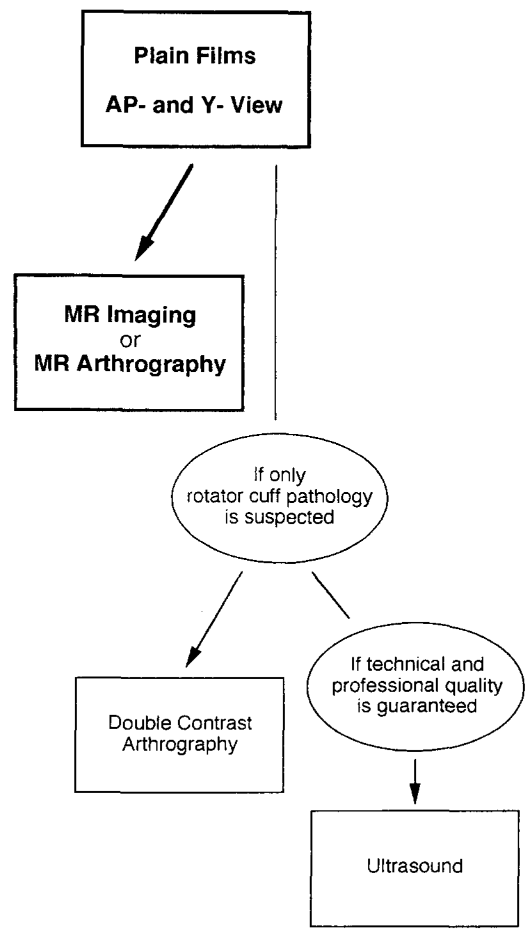

Fig. 9. Algorithm for diagnostic imaging of rotator cuff injuries.

the diagnoses of rotator cuff diseases and labro-ligamentous lesions more reliable (Fig. 7). Two technical factors have to be pointed out. Even if a paramagnetic contrast media is injected intra-articularly, T2-weighted, coronal oblique angulated images are useful to assess the rotator cuff (Table 1). Furthermore, fat-saturation techniques are an important addition to MR arthrography in order to differentiate the subacromial-subdeltoidal fat plane from a contrast leakage due to a complete rotator cuff tear (Table 1) (Fig. 8a–c) [38]. These techniques therefore improve the detection of partial thickness tears and are helpful to avoid false positive diagnoses of complete rotator cuff tears [38].

3. Conclusion

The diagnostic application of the different imaging modalities in the shoulder joint and especially the rotator cuff is still controversially discussed [19]. The final decision for one or the other imaging method is likely to depend on personal experience, preference and local availability. Furthermore, any paper on imaging would be incomplete, if examination fees were not considered (Table 2). There are clear differences between the fees of the various imaging methods and a cost saving diagnostic approach must be aimed for.

Above all, however, the diagnostic algorithm will ultimately be influenced by the therapeutic approach. Focused on the rotator cuff, clinical treatment may be determined on the basis of the detection or exclusion of a complete cuff tear (Fig. 9). A more sophisticated approach, however, is based on detailed findings at the rotator cuff including degenerative or inflammatory tendinopathy, the extent of tendon tears and the quality of ruptured tendons. Moreover, considering traumatic injuries of the rotator cuff associated pathologies of the glenohumeral joint should be diagnosed before treatment planning. Therefore, a comprehensive imaging modality is necessary. These requirements are fulfilled best by MR imaging or MR arthrography, which give the best overall roadmap prior to arthroscopy or surgery.

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