7 Special Techniques in Evaluation of the Failed Rotator Cuff

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7.1 Introduction

Imaging of the shoulder joint, in particular for rotator cuff pathology, has improved tremendously over the past few years. Beyond plain radiographs, imaging capabilities that clinicians can rely on include MRI, MR arthrogram, CT scans, ultrasound scans, vascular Doppler studies, and more recently US Elastography. This chapter will focus on imaging capabilities and possibilities in failed cuff repairs. While it is known that failure to heal occurs in about 20% of cases [1], what is needed is to define a common understanding of failure of cuff repair, what is accepted as failure to heal as opposed to re-tear, and understand the various causes. The presence of high signals, thinning and even gaps in post repair tendons may not constitute a pathological state as patients remain relatively asymptomatic. Hence, an understanding of "normal" changes that might occur in tendons after cuff repair, and how these changes may change over time, is necessary.

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Plain radiographs remain useful despite modern imaging, and we discuss here the role of radiographs in cuff pathology and re-tears. Advanced imaging like ultrasounds and MRI serve to help clinicians navigate these questions: *Is there a re-tear? Where and how big? What are the possible causes? Is it reparable and if so, can imaging help my surgical options?*

7.2 Definition of Failed Cuff Repair

What is understood as failure of cuff repair as a surgical event? Desmoineaux defined it as the need for revision surgery in the short- and mid-term, without defining these time periods [1]. Quoting a 10-year study, Collin et al. cited a revision rate of about 7% after cuff repair (35 out of 511 patients) [2]. Cuff et al. [3] chose to define failure more objectively, defining failed cuff repair as an American Shoulder and Elbow Surgeons (ASES) score lower than 70 or a range of forward elevation below 90°. However, this may not have correlation with structural cuff integrity nor clinically important improvements, albeit subjectively, that patients may experience after surgery. A more coherent definition could be the presence of pseudo-paralysis, the lack of improvement or worsening of symptoms compared to pre-op, coupled with a structural defect in the cuff, which was proposed by Gasbarro et al. [4].

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Thus, the understanding or perception of cuff failure may be different to different people involved [1]. To the patient, clinical events like prolonged post-op pain and stiffness, persistent weakness or pseudo-paralysis, and even the Popeye sign, may be viewed as failures. The inability or delay in return to work and sports may be disappointing and viewed as a failure to meet patients' expectations. To the surgeon, failure is more objective, such as the occurrence of infection, worsening of symptoms and scores, failure of the repaired tendon to heal, or the recurrence of a tear.

Recurrence of tears, as opposed to the presence of gaps, occur in 11–68% of patients after cuff repair [5, 6]. A repaired tendon is not always water tight. If during post-op MR arthrography contrast is seen communicating into the subacromial space, it may represent a normal postoperative appearance [7]. Relatively asymptomatic patients may demonstrate tendon thinning, partial-thickness, or even full-thickness tendon tears on MR images. In their study, Zanetti et al. [8] found that symptomatic postoperative patients tended to have larger rotator cuff defects (>11 mm).

7.3 Changes seen after Cuff Repair

Repaired rotator cuff tendons demonstrate a wide variety of appearance in MRI and ultrasound. Even in asymptomatic patients, "normal" morphology of the tendon has similar appearance to non-operated tendon in only 10% of the cases [9]. Morphology is influenced by temporal interval since surgery, technical variance in surgical repair and most crucially, the presence of complications [10, 11].

There is considerable overlap between the spectrum of expected atypical appearance and imaging morphology suspicious for tendon re-tear. An adroit method to interpret these findings is to utilise an established visual grading system, in MRI as suggested by Sugaya et al. and modified for ultrasound by Barth et al. [12, 13] (Table 7.1).

In both grading systems, grade I is interpreted as completely normal, grade II and III as a spectrum of normal to partial tears, grade IV as small tear, and grade V as major tears. This interpretation is more established in the peripheral grades (I and V) but remains controversial in the middle (grades II to IV). Partial tears are known to be indistinguishable from intact repaired tendons, making the differentiation of grade II and III less helpful [14]. On MRI, increased signal may reflect not just tendinopathy and low-grade partial tears but also postoperative inflammation, suture material or granulation tissue formation (Fig. 7.1) [15]. Studies tracking temporal evolution of MRI signal intensity and ultrasound echotexture of repaired tendon found that most severe signal and echotexture alteration are found in early post operation; often but not always, these tendons may demonstrate eventual normalisation after 1 year in MRI and after 6 months in ultrasound [16, 17].

Table 7.1 MRI and ultrasound grading system for interpretation of post repair cuff tendons

Tendon Grade	Sugaya (MRI grading using oblique coronal, oblique sagittal and transverse T2-weighted spin echo sequences) [5]	Barth (Ultrasound grading using frontal, sagittal, and transverse B-mode images) [4]
I	Sufficient thickness compared to normal cuff and homogeneously low signal intensity	Sufficient thickness (>2 mm) with normal echostructure as normal tendon hyperechoic and fibrillar on each image
II	Sufficient thickness compared with normal cuff and partial high signal intensity area	Sufficient thickness (>2 mm) with partial hypo-echogenicity or heterogenicity
III	Insufficient thickness with less than half thickness compared with normal cuff but without discontinuity	Insufficient thickness (<2 mm) without discontinuity
IV	Presence of minor discontinuity in 1 or 2 slices on both oblique coronal and sagittal sequences	Presence of minor full-thickness discontinuity of which borders are well visible
V	Presence of major discontinuity in more than 2 slices of both oblique coronal and sagittal sequences	Presence of major discontinuity of which borders are not visible

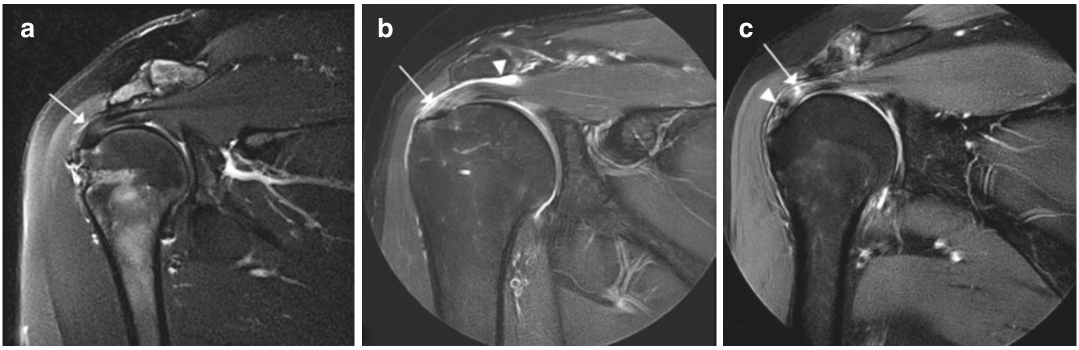

Fig. 7.1 MRI signal changes in asymptomatic patients after cuff repair. Coronal oblique T2-weighted fat suppressed MRI images of the shoulder post supraspinatus tendon repair in three different patients. (**a**) Repaired tendon demonstrates dark signal without defect (arrow) compatible with Sugaya grade I. (**b**) Repaired tendon demonstrates diffusely raised signal without defect compatible with Sugaya grade II. Adjacent bursal fluid distention (arrowhead). (**c**) Repaired tendon demonstrates raised signal with small fluid-filled defect that is less than 1 cm, compatible with Sugaya grade III. Focal dark signal within the tendon represents repair sutures (arrowhead)

Studies investigating the significance of tendon thickness are also contentious. Tham et al. performed serial ultrasounds for patients post repair and found no predictable changes in tendon thickness nor association with symptoms [18]. Temporal charting of MRI changes post repair by Crim et al. also revealed no consistent pattern pertaining to tendon thickness [16]. Both studies however presented an increase in footprint width over time suggestive of tendon-to-bone healing. This stands as a precaution against misinterpreting poor footprint coverage as surgical failure in the 6 weeks to 3 months postoperative imaging [16]. There are also contrasting studies that demonstrate progressive decrease in tendon thickness on sequential ultrasound post repair, but none have been able to correlate with symptoms or function [17, 19].

Small residual defects in the repaired cuff of up 1 cm in size are often seen in both MRI and ultrasound of asymptomatic patients, ranging from 21% to 48% in prevalence [8, 20]. Possible explanations provided include reparative scars and non-watertight repair that convert debilitating tears to “functional cuff tears” [8, 20]. Not all portions of a tendon tear may be repaired due to limitations of tissue quality and in these instances, the unrepaired defects remain [11]. It is also interesting to note that in a study with 5-year follow-up, some of these defects diagnosed earlier by ultrasound eventually demonstrated healing, lending strength to the hypothesis of reparative scars [21]. These findings reiterate our understanding that post-op imaging should not be performed any earlier than 6 months, before which time tendon appearances are undergoing changes. In the early post-op period, signal changes in the tendon, thinning and even small gaps may not be abnormal.

“Normal” post-op changes after cuff repair can thus be summarised as such: in the early phase (3–6 months), there could be appearance of “gaps”, high signal changes, hypervascularity, and disorganised fibrillar pattern in the tendon. In the late phase (at around 12 months), the fibrillar pattern becomes more organised, there is reduced vascularity and less high intensity signal changes.

7.4 Role of Radiographs in Failed Rotator Cuff Tears

Imaging of rotator cuff pathology frequently employs advanced imaging like MRI, CT scans, ultrasonography, or bone scans [22]. Yet, there is agreement among musculoskeletal radiologists that the initial imaging evaluation of the majority of musculoskeletal pathologies, including rotator cuff injuries, should begin with routine radiography [23], despite findings of plain radiographs being seemingly non-specific. Radiographs are widely available, relatively cheap, technically easy to perform, acceptable as a screening tool, and are able to provide adequate information about fractures and arthritis of the shoulder. But what information can plain radiographs give us about rotator cuff pathologies, especially in the failed cuff repair?

Standard views to take:

1. **True Shoulder AP (Grashey) view**: This is taken with the beam pointing 45 degrees laterally, oblique to the torso but in the true plane of the glenohumeral joint, in contrast to the conventional AP wherein the beam and cassette are perpendicular to the torso and hence oblique to the glenohumeral joint (Fig. 7.2).
2. **The Supraspinatus Outlet view**: The supraspinatus view is preferred to view the morphology of the acromion and classify it. This view is done with the cassette on the affected shoulder and the torso about 40 degrees oblique to it, with the beam tilted 10 degrees caudally (Fig. 7.3). This view is useful to visualise the

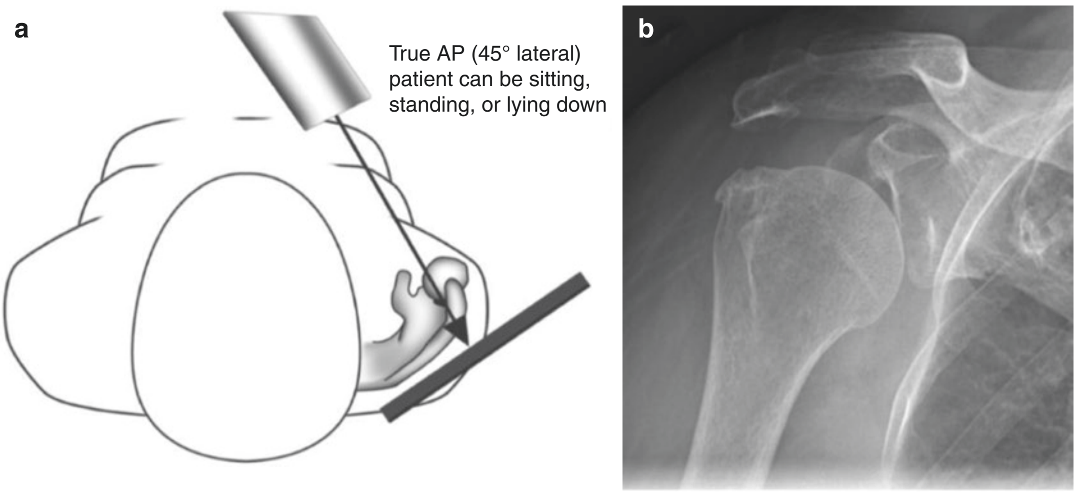

Fig. 7.2 True AP shoulder view. (**a**) Patient positioning for a true shoulder AP view and (**b**) is an example

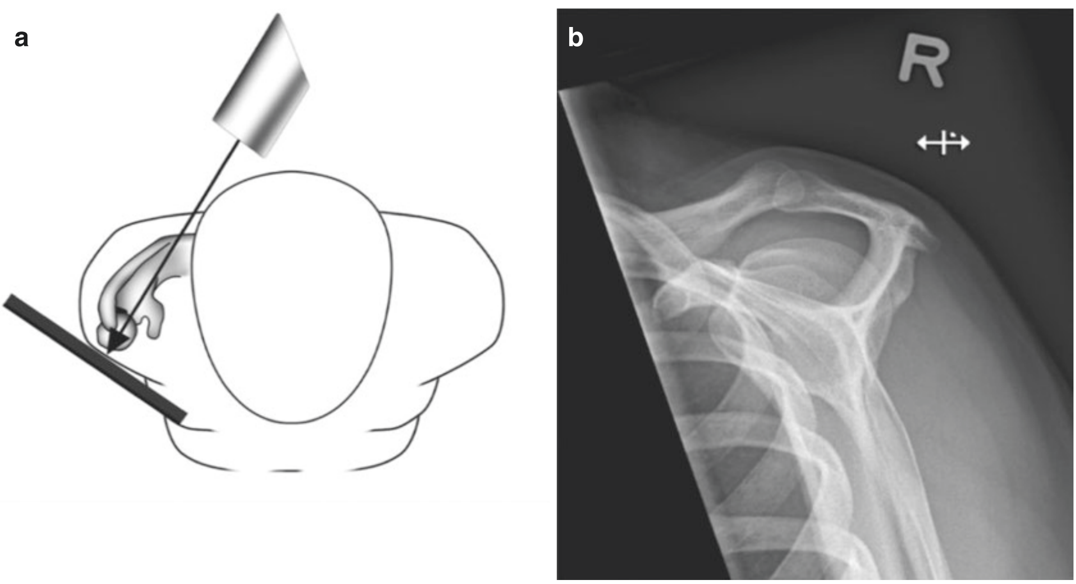

Fig. 7.3 Supraspinatus outlet view.(**a**) Patient positioning for the supraspinatus outlet view and (**b**) is an example showing type I acromion

keeled acromion [24], acromial spurs [25] and classify morphology of the acromion [26].

Radiographic features to note:

1. **Metal artefacts:** The presence of metallic anchors is evidence of previous cuff surgery performed and could shed light on possible causes of failed cuff repair (Fig. 7.4). Metal anchors could have pulled out of the bone, alluding to possible low bone density [27], though this is not common. The presence of metal artefacts determines which further imaging is required [28], in which case ultrasound (or CT scan) may be required. Most current anchors are non-metallic, and MRI can be performed without any modifications.
2. **Osteophytes**: The presence of osteophytes may be subtle but should be looked for. These tend to occur in longstanding cuff tears [29] and may be progressive leading to cuff arthropathy. Kyoung et al. have compared the true AP view with conventional AP in 160 consecutive shoulders. Using five signs of rotator cuff tears (greater tuberosity (GT) sclerosis, GT osteophyte, subacromial (SA) osteophyte, GT cyst, and humeral head osteophyte), they found the true AP view is more sensitive in detecting pathognomonic findings of rotator cuff tear compared to the conventional AP view [29].
3. **Acromiohumeral interval and Moloney's lines (Superior migration of the head)**: True shoulder AP radiographs also permit measurement of the acromiohumeral interval (AHI) and congruence of Moloney's line, which can be used to identify superior migration of the humeral head (Fig. 7.5). The AHI is measured from the inferior most level of the acromion to the superior most point of the humeral head. In a landmark study in 2011, X-rays of 109 shoulders were studied, which showed that an AHI <6 mm is a sign of rotator cuff rupture almost systematically involving longstanding total infraspinatus tear [30]. The authors state that AHI equal to or greater than 6 mm is of no diagnostic relevance. The accuracy of AHI to predict cuff tears is increased when studied with Moloney's line [31]. In a study of 116 X-rays of shoulders with ultrasound-proven rotator cuff tears, abnormal AHI (<8 mm) was seen in 89.7% of severe rotator cuff tears. There was also positive correlation between disruption of Moloney's line with tears of the infraspinatus, subscapularis, and long head of biceps tendons. However, there was a wide inter-observer variability when measuring AHI on AP radiographs alone [32]. The use of AHI in the studies above were suggestive of the diagnosis of cuff tears. But can AHI be used to predict re-tears and hence, be of used in radiography of failed cuff repairs? Shoulder MRI of 83 patients who had undergone cuff repair were studied with an overall re-tear rate was 57.8% [33]. Independent prognostic factors of re-tear were degree of tendon retraction and AHI (6.8 mm in re-tear vs 8.7 mm in intact) on preoperative MR images.
4. **Critical Shoulder Angle, Acromial Index:** The CSA, first described by Moor et al. [34],

Fig. 7.4 Radiographs of patient with recurrent tear. The shoulder AP radiograph shows metal artefacts in the humeral head, which is high riding with an acromial humeral interval (AHI) <6 mm. There are mild degenerative changes. These changes on the plain radiograph suggest a recurrent tear of the tendon

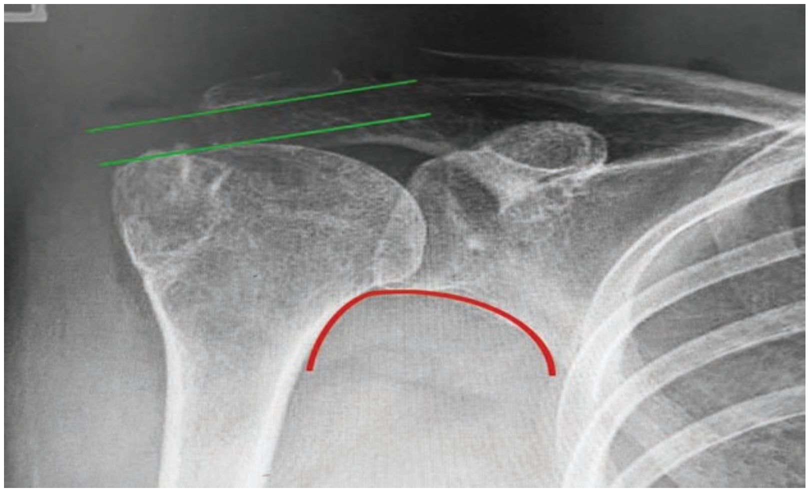

Fig. 7.5 Acromiohumeral interval (AHI) and Moloney's line. AHI is the distance between the green lines and Moloney's line is marked in red

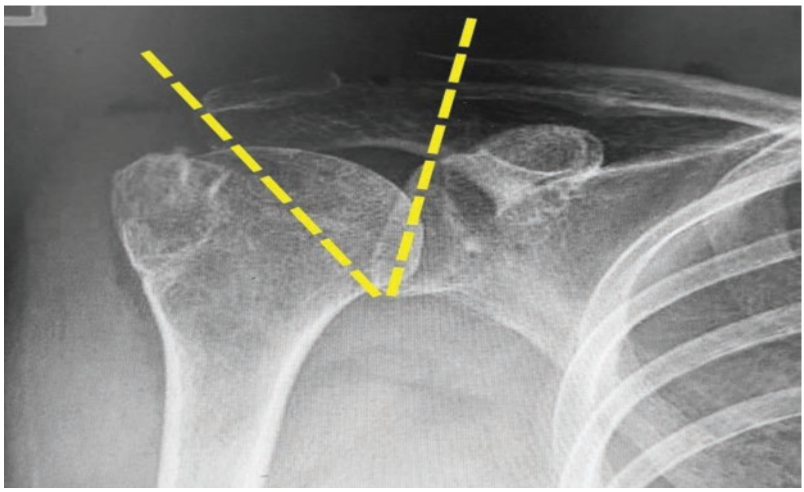

Fig. 7.6 Critical shoulder angle (CSA). The CSA is the angle subtended between these lines; a line from the lateral edge of the acromion to the inferior glenoid and a line in the plane of the glenoid

combines the measurements of the inclination of the glenoid and the lateral extension of the acromion (Fig. 7.6). It has been shown to be a predictor of the occurrence of cuff tears [35]. A CSA greater than 35 degrees is associated with cuff tears, and a CSA less than 30 degrees is associated with glenohumeral osteoarthritis. While CSA may have a role in the pathogenesis of cuff tears, it does not appear to affect functional outcomes after 24 months [36] nor does it affect re-tear rates [37]. The acromial index (AI), which describes the lateral extension of the acromion (Fig. 7.7), has similarly been shown to be associated with full-thickness cuff tears [38] but does not influence outcomes nor re-tear rates [36].

5. **Bone mineral density (BMD) and cortical thickness of humeral shaft:** Another factor to study from the true shoulder AP view is cortical thickness of the humeral shaft, used as a surrogate of BMD of the humeral head [39]. Tingart et al. described the combined cortical thickness (CCT) of the proximal humerus as a reliable and reproducible predictor for localised BMD (Fig. 7.8). The CCT determined from conventional AP shoulder radiographs correlated well with BMD measured after cutting the proximal

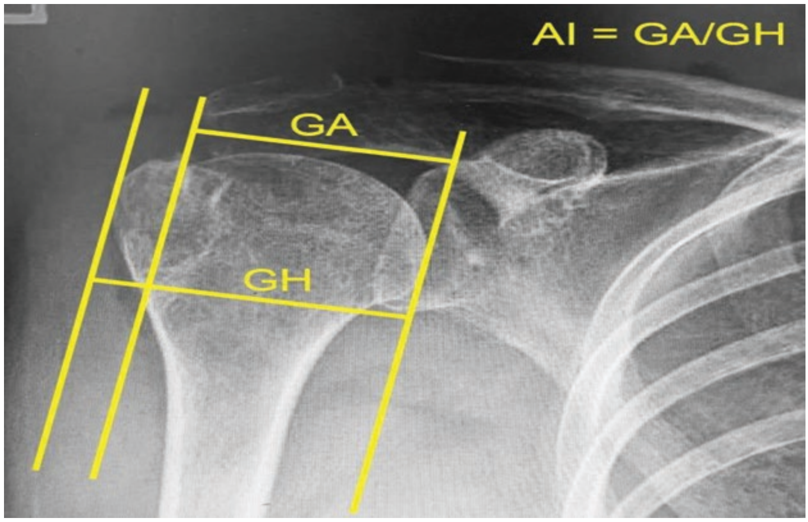

Fig. 7.7 Acromial index (AI). The AI is obtained by dividing (GA) the distance from the plane of the glenoid to the lateral edge of the acromion, over (GH) the distance from the plane of the glenoid to the lateral aspect of the humeral head

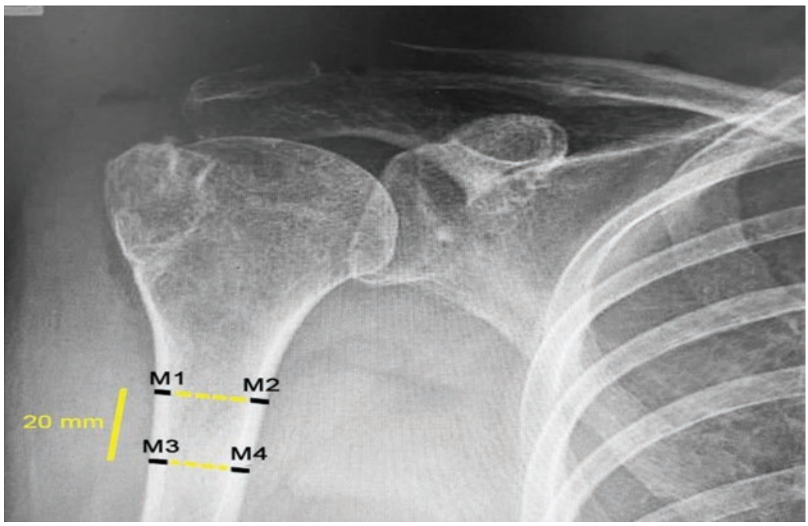

Fig. 7.8 Combined cortical thickness (CCT). CCT is the mean of medial and lateral cortical thicknesses at two levels. The first level is measured where the endosteal borders are parallel and the second level is measured 20 mm distal to that. M1 and M2 are the medial and lateral cortical thicknesses at the first level, while M3 and M4 are the medial and lateral cortical thicknesses at the second

humerus diaphysis, with CCT <4 mm being highly indicative of a low BMD. Chung et al. found that the failure rate of rotator cuff healing correlated with BMD, with high rates of failure in patients with osteopenia and osteoporosis [40]. A lower BMD may thus compromise the strength of rotator cuff repair by suture anchor loosening or pull-out before adequate tendon-to-bone healing can occur [27]. In a study by Lee et al., CCT of pre-op radiographs were measured; functional scores after cuff repair were significantly higher in those with higher CCT at 6, 12, and 24 months [41].

6. **Acromial morphology:** Although Bigliani's classification system of acromial morphology utilising the standard outlet radiograph has become an accepted method for evaluating patients with rotator cuff disease, its reproducibility is questionable. In a study of 40 patients' outlet views [42], viewed 4 months apart by six reviewers, including two shoulder surgeons, a musculoskeletal radiologist, an orthopaedic surgery sports

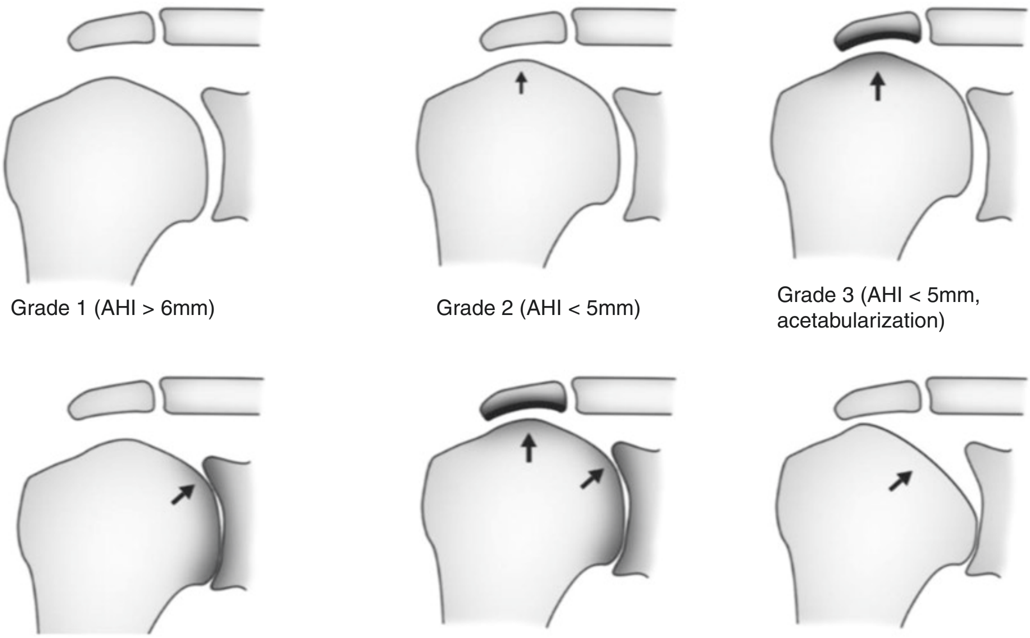

Fig. 7.9 The Hamada classification of massive cuff tear and cuff arthropathy. Grade 1: Preserved AHI or greater than 6 mm. Grade 2: AHI of 5 mm or less. Grade 3: AHI < 5 mm with acetabularization of the acromion. Grade 4A: Glenohumeral arthritis without acetabularization, AHI < 7 mm. Grade 4B: Glenohumeral arthritis with acetabularization, AHI ≤ 5 mm. Grade 5: humeral head collapse and cuff tear arthropathy (CTA)

fellow, and two orthopaedic residents (PGY-2 and PGY-5), all six observers agreed only 18% of the time on classifying each film as type I, II, or III acromion. Inter-observer reliability among the six observers ranged from 0.01 to 0.75 (mean 0.35, fair), and intra-observer repeatability ranged from 0.26 (fair) for PGY-5 residents to 0.80 (excellent) for the fellowship-trained surgeons, with a mean of 0.55 (moderate).

7. **Arthritis of the glenohumeral joint**: Cuff tear arthropathy develops in about 4% of patients with massive cuff tears [43]. Risk factors for cuff arthropathy include advanced age, smoking, hypercholesterolemia, family history, large cuff tear, and history of trauma [44]. The onset of cuff arthropathy in failed cuff repair heralds a different approach and requires a replacement arthroplasty option as opposed to revision cuff repair. The Hamada classification [45] divides patients with massive rotator cuff tears and cuff arthropathy based on the acromiohumeral interval (AHI) and can provide a mechanistic explanation to the findings seen on the radiograph (Fig. 7.9) (Table 7.2).

7.5 After the Radiographs, MRI, CT, or Ultrasound? A Radiologist's Perspective

In the American College of Radiology Appropriateness criteria, imaging work-up for shoulder pain post-rotator cuff repair is recommended as—either MR arthrogram, MRI of the shoulder without IV contrast, or ultrasound, should be performed when initial radiographs are normal or inconclusive [46]. Radiographs are helpful to evaluate alignment while guiding the appropriate further investigation based on the types of indwell-

Table 7.2 Summary of radiographic features to note in failed cuff repair

Views to take	Features to note
True AP view	• Metal artefacts: Evidence of cuff surgery and determines further imaging to be done • Osteophytes (GT osteophytes, sclerosis, cysts, humeral head, and subacromial cysts): Common in post cuff repair • Superior migration of the humeral head (Acromiohumeral interval and Moloney's line): Seen in massive cuff tears and may be indicative of re-tears • Critical shoulder angle and acromial index: Postulated to be involved in pathogenesis of cuff tears but not predictive of re-tears • Combined cortical thickness: Low BMD postulated to be associated with increased failure rates of cuff repair • Onset of arthritis and cuff arthropathy: Influences therapeutic options in re-tears
Supraspinatus outlet view	• Metal artefacts • Osteophytes (GT osteophytes, sclerosis, cysts, humeral head, and subacromial cysts) • Acromial morphology: Involved in pathogenesis of cuff tears but not predictive of re-tears and low reproducibility

ing hardware and their associated imaging artefacts [47]. MRI or ultrasound scans are targeted at assessing for complications of repair including retear, as well as other concomitant conditions resulting in pain such as adhesive capsulitis.

In our centre, imaging post-cuff repair is usually done when patients are symptomatic, presenting with prolonged pain, weakness, scores that are not improving or worsening, or after any new trauma. If such imaging is done routinely, as previously discussed, caution is required when interpreting imaging within 3 months post-repair as appearances may appear more sinister due to acute reactive changes [16, 17]. It is recommended that any routine imaging like MRI or ultrasound be done at least 6 months after cuff repair.

CT scans are not common in the usual workup for failed cuff repairs, but can show the osseous changes similar to a plain radiograph with greater spatial resolution, including visualisation of bony tunnels in a transosseous rotator cuff repair, location of suture anchors with respect to tendon insertion, muscle atrophy, and fatty infiltration. There may be apparent muscle enlargement with lateralisation of the muscle-tendon unit after a repair. Effusion can be detected by the presence of fluid in the glenohumeral joint. Heterotopic ossification may be visualised with greater resolution compared to a plain radiograph. CT scans can be used to plan for revision of a failed rotator cuff repair to an arthroplasty [28].

With the use of intra-articular contrast in CT arthrogram, the thickness of the rotator cuff tendon can be assessed. Leakage of contrast from the glenohumeral joint into the subacromial space would be indicative of a rotator tear. However, the absence of contrast leakage across a tendon may not exclude a failed repair as this may represent scar tissue. Likewise, the presence of contrast leakage across a tendon may not represent a failed repair as the repair may not be watertight across the footprint. Delaminated tears can be detected by layering of contrast. Absence of subacromial peribursal fat may be a sign of a previous bursectomy. The articular cartilage can be assessed and this, in the setting of a failed rotator cuff repair, may affect the decision between an attempt at revision of a failed rotator cuff repair or an arthroplasty [28].

7.6 The Diagnostic Value of Imaging: Is there a re-tear?

The aim of postoperative imaging in symptomatic patients is to investigate for complications. Complications that can be detected on imaging

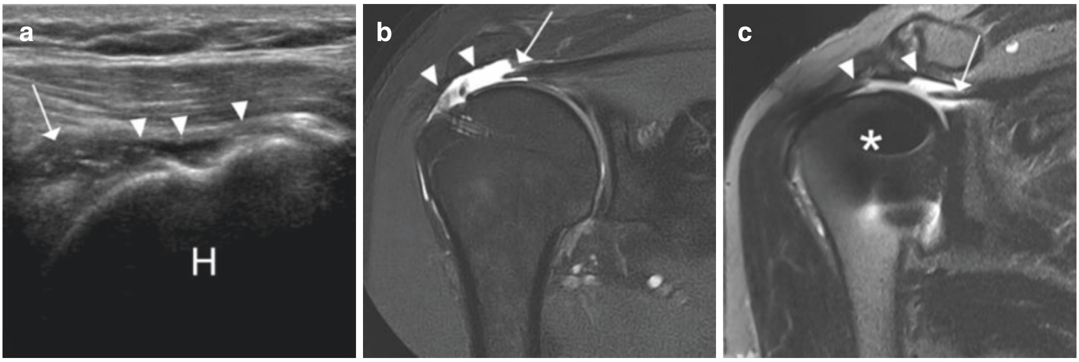

Fig. 7.10 Recurrent tears seen on imaging. (**a**) Longitudinal B-mode ultrasound and (**b**) coronal oblique T2-weighted fat suppressed MRI images of the same patient post supraspinatus tendon repair demonstrates a large fluid defect (arrowheads) in keeping with re-tear/ Sugaya grade V. The tendon stump is retracted medially (arrows) and appears like a type 1 re-tear. *H* humeral head. (**c**) Coronal oblique T2-weight fat suppressed MRI with metal artefact reduction protocol of another patient reveals a re-tear of the repaired tendon (arrowheads) with retracted of the tendon medially (arrow) and a stump of tendon at the footprint, making it a type 2 re-tear. Metal susceptibility artefacts (*) from metal anchor within the humeral head

include recurrent tendon tear, suture displacement, subacromial spur formation, infection, adhesive capsulitis, deltoid detachment, heterotrophic ossification, and acromial fracture [11, 28]. Any fluid-filled full-thickness defect within the tendon (approximating Sugaya and Barth grade IV and V) in a symptomatic patient that is not seen on preoperative imaging is **suspicious for a re-tear** [10, 28]. Defects larger than 1 cm or with medial retraction of proximal tendon (approximating Suyaga and Barth grade V) are more likely to **represent re-tears** [8, 10]. Muscle atrophy and fatty infiltration may also provide clues to re-tear, as studies show patients with failed repair are found to have substantial progression of muscle degeneration [11].

Two patterns of cuff repair re-tears have been described (Fig. 7.10). Type 1 re-tears occur due to failure at the bone-tendon junction, while type 2 re-tears occur medially, approximately 2 cm medial to the tendon insertion at the myotendinous junction, resulting in a cuff of remnant tissue still attached to the greater tuberosity. It is theorised that Type 1 re-tears occur early in the postoperative phase and are secondary to the mechanical failure of bone-tendon fixation, whereas type 2 re-tears occur secondary to failure of biological healing [48].

7.7 The Forensic Value of Imaging: Why Did the Repair Fail?

Re-tears are known to occur between 11% and 68% of patients after cuff repair [5, 6]. Broadly speaking, causes of failed cuff repairs can be classified into three categories: (1) failure of healing, (2) technical errors, and (3) traumatic failure [49]. However, it is important to note that the majority of failed cuff repairs are multifactorial in aetiology and numerous factors can be identified as contributing to the failure of any one cuff repair. Imaging can help uncover possible causes of the failure of cuff repair. These include:

1. **Size of original tear**
   Le et al. [50] found the greatest predictive factor for recurrence of tears to be the size of the original tear, specifically, the anteroposterior and mediolateral dimensions of the tear, with tears with a larger anteroposterior dimension and higher grade tears to be at greater risk.
2. **Poor tissue quality**
   Recurrence of tears is related to failure of tendons to heal, and this in turn is due to poor tissue quality [15]. But can tissue quality be assessed by imaging? One surrogate of tissue quality could be thinning of the repaired tendon.

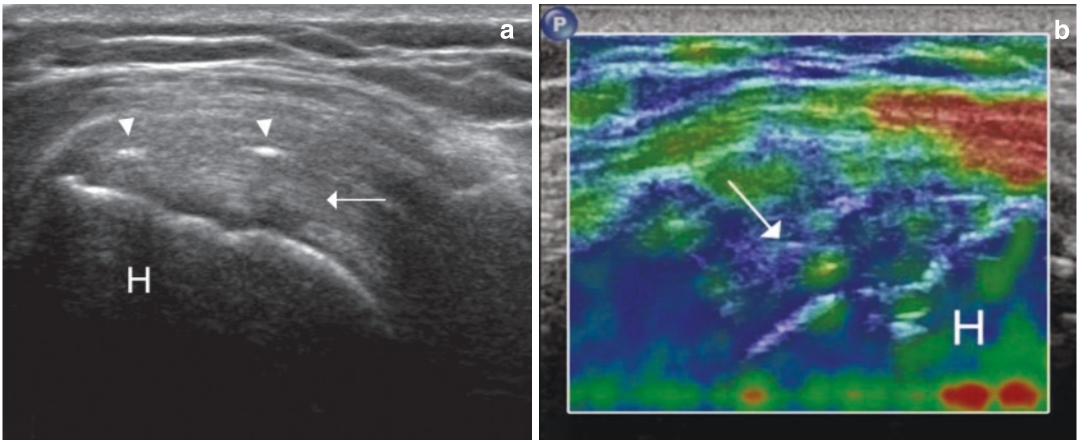

Fig. 7.11 Ultrasound elastography. (**a**) Longitudinal B-mode and (**b**) longitudinal axial-strain elastography ultrasound images of a normal supraspinatus tendon post repair (arrows). The tendon demonstrates fibrillated echotexture with adjacent repair sutures (arrowheads). Absence of focal red colour overlay within the tendon on elastography signifies no abnormal softening of the repair tendon. *H* humeral head

Thinning of tendons and disorganisation of collagen fibres, presence of granulation tissue, increased levels of glycosaminoglycans, fibrocartilaginous metaplasia, calcification, fatty infiltration, and necrosis of the tendon margin with cell apoptosis, along with biochemical changes, are all histopathological hallmarks of degeneration that occur in cuff tears [51].

In a study of 63 patients above 70 years of age who underwent cuff repair, Zhang et al. found smoking and thinner cuffs (<4 mm) were found to be associated with poorer two-year outcomes in terms of Constant and Oxford Shoulder scores independent of age, comorbidities, duration of symptoms, and tear sizes [52]. This suggests that in elderly patients, tendon thickness of 4 mm could determine good to poor outcomes. However, the critical tendon thickness below which the tendon quality is detrimental and re-tears are likely to happen, is still unknown.

Blood supply to the repaired tendon could be another factor to affect tissue quality and hence tendon healing. Vascular flow in and around the repaired tendon has been investigated with contrast-enhanced power Doppler ultrasound [53, 54]. The repaired tendon itself is typically avascular. The peritendinous region demonstrates the most hypervascularity, which is more prominent immediately post repair and decreases with time. This is postulated to represent conduit of blood flow in the peritendinous region, which is thought to promote healing. However, there is currently no convincing data correlating tendon or peritendinous vascularity with clinical outcomes or re-tear rate [17].

Newer axial-strain or shear-wave ultrasound elastography techniques (Fig. 7.11) are potentially useful adjuncts to assess tendinopathy and tendon healing by quantifying differential stiffness of tendons [55]. Early investigations into the temporal evolution of the repaired tendon demonstrate high elastic modulus immediately post repair, which subsequently decreases as tendon heals [56]. This may provide more information about tendon quality, but further studies for validation is required.

3. **Muscle Atrophy and Fatty Degeneration**
   Chronic cuff tears undergo muscle atrophy with time and subsequently, undergo fatty infiltration. These changes profoundly affect the functional outcome after cuff repair [57]. Poor clinical outcomes after surgery were correlated with increasing muscle atrophy and fatty infiltration [58]. Cuff repairs that healed reported no progression or even improvement of the muscle atrophy, while in failed repairs, there was reported substantial progression of muscle atrophy and fatty

Fig. 7.12 Muscle atrophy on MRI sagittal views. In this example of a recurrent cuff tear, the sagittal views of the MRI show significant atrophy (Goutallier 3) of the supraspinatus and infraspinatus muscles with fatty infiltration

infiltration [57]. Thus, the quality of the cuff muscles and fatty infiltration needs to be evaluated before revision surgery is decided, underscoring the importance of imaging in the work-up of the failed cuff (Fig. 7.12). There could exist a "point of no return" where the atrophic changes the muscles have undergone are irreversible [57] in which case revision repair may be unsuccessful. As per Savoie et al., this point could be Goutallier stage 3 [59].

4. **Implant failure and suture breakage**
   While the incidence of suture breakage causing cuff failure is low, it is noted earlier that healing rates of tendon correlated with bone mineral density, with higher rates of failure in patients with osteopenia and osteoporosis [40]. In patients with low BMD, the anchor could loosen or pull-out before adequate tendon-bone healing could take place, compromising the strength of the cuff repair and possibly leading to failure (Fig. 7.13) [27].

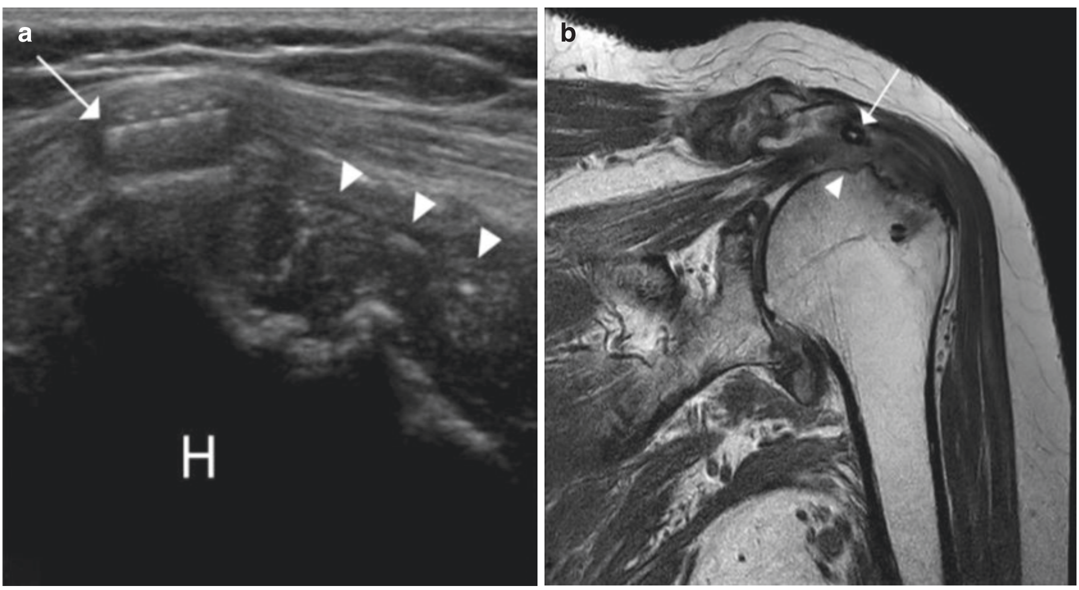

Fig. 7.13 Failed cuff repair due to implant pull-out. (**a**) Longitudinal B-mode ultrasound and (**b**) coronal oblique PD-weighted MRI images of the same patient post supraspinatus tendon repair. Fractured tendon anchor (arrows) is dislodged into the subacromial space. Granulation tissue formation within the defect of the supraspinatus tendon (arrowheads) in keeping with re-tear

7.8 The Prognostic Value of Imaging: What Can Be Done?

Imaging plays an important role in the work-up of the failed cuff repair. From plain radiographs to advanced imaging such as MRI, CT scans, or ultrasounds, imaging is instrumental in aiding the clinician in diagnosing the causes of failed cuff repair, the possible causes of failure of tendon healing, and subsequently, the surgical options available based on the evidence gathered so far. Figure 7.14 proposes a treatment algorithm based on clinical and radiological findings. A thorough clinical history and examination is the initial step. Evidence for diagnoses of infections and capsulitis are gathered at this stage and other investigations with appropriate treatment may need to be started, if indicated.

The initial question would be answered with plain radiographs, which assesses for evidence of arthritis (Hamada stage 4 or more). If there is gross arthritis in the presence of failed cuff repair, then a reverse shoulder arthroplasty is warranted [43]. If there is no or minimal arthritis, then what would drive the decision-making is the presence and size of re-tears and the severity of muscle atrophy with fatty infiltration. If there are changes such as signal intensity, small gaps, and thinning of the tendon with no discernible tear >10 mm (Sugaya 1–3), then the patient would benefit from physiotherapy and may benefit from PRP injections [1, 60], stem cell injections [60], and biological augments [60], as such changes may be partly physiological and not necessarily pathological [8, 10, 11, 20].

Tears >10 mm in a symptomatic failed cuff repair warrant surgical intervention [58]. Revision surgery can be done with good results, with a view to perform biceps tenotomy/tenodesis if not done already and revision acromioplasty [1]. The role of biological augments in this group of patients with failed cuff repairs is controversial [60]. In larger tears (3–5 cm) with minimal muscle atrophy (up to Goutallier 3), a partial repair can be attempted, with possible use of patches and balloon spacers. In massive tears (>5 cm) with significant muscle atrophy (Goutallier 3 and

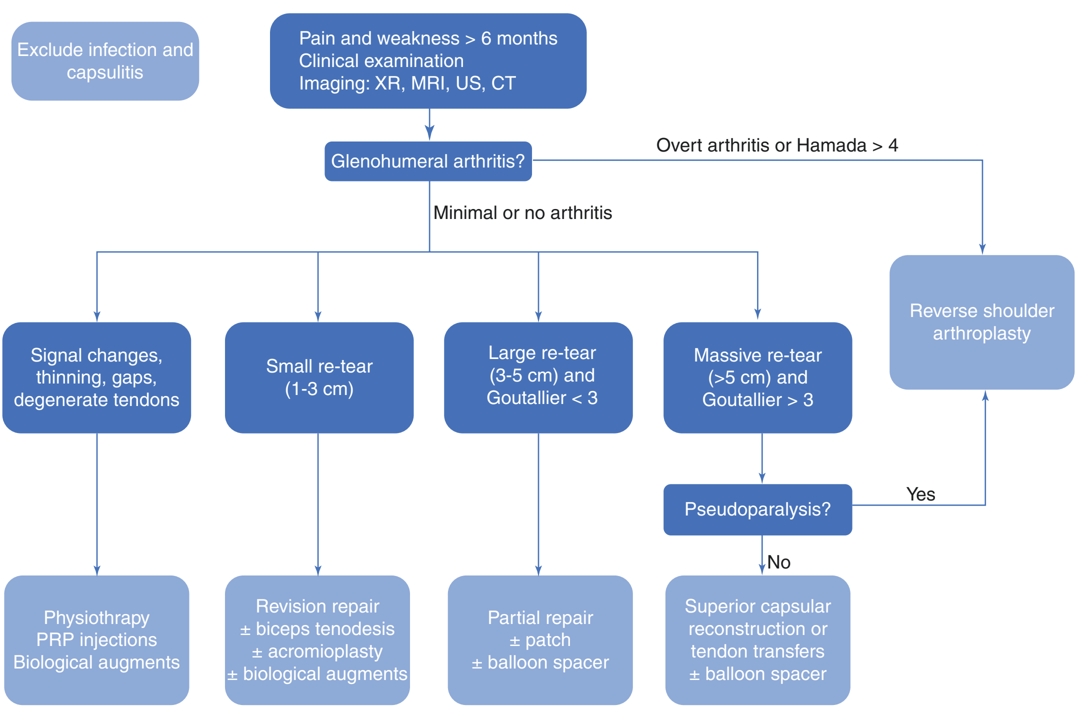

Fig. 7.14 Suggested algorithm based on clinical findings and imaging studies

above), the decision rests on the presentation of pseudo-paralysis. If there is some degree of elevation and rotation is present but weak, consider a superior capsular reconstruction or the appropriate tendon transfer. If pseudo-paralysis is evident, then a reverse shoulder arthroplasty is thus indicated [1].

The radiological criteria of irreparable rotator cuff tears are a fixed high-riding humeral head, an AHI <5 mm, a non-functioning deltoid muscle, and severe rotator cuff muscle atrophy and fatty infiltration [61].

7.9 Conclusion

Imaging plays a vital role in the postoperative evaluation of the failed rotator cuff. Findings that are diagnostic for abnormalities before surgery may actually be expected changes in the postoperative setting and may not correlate with worsened symptoms clinically [61]. Plain radiographs can shed information on pathogenesis of tears and may have bearing on recurrence of tears. Advanced imaging like MRI, CT scans, and ultrasounds are the key modalities in diagnosing tear recurrences, reveal possible causes of failure, and guide surgeons on surgical options available. The role of the radiologist who understands the expected postoperative findings after rotator cuff repair and correlates these changes with the surgery performed would be critical to the team and would add immense value to patient care.

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