Rotator Cuff Tears

43

Mark Tauber

43.1 Clinical Diagnostics

The spectrum of the clinical image of rotator cuff tears (RCT) is broad. Usually, patients suffering from rotator cuff tears present with pain. Typically, they complain pain at night or under physical load. Furthermore, loss of strength or function in dependence from the tear extent is responsible for the patient's limitation during daily or sports activities. An important role plays the long head of the biceps tendon, which often is involved in RCT and may contribute a meaningful part to clinical symptoms.

Before starting the clinical examination, the patient's history should be checked for trauma or some kind of chronic professional or sports activity-related shoulder overuse. Traumatic RCT are characterized by a sharp pain in the shoulder with immediate loss of function for a variable period of time ranging from hours to several days depending from the underlying cuff tear extension. Usually, pain relieves within some days with full recovery of shoulder function if tear compensation is possible.

A thorough clinical examination is of utmost importance and often allows an exact diagnosis of the RCT. Inspection of the shoulder may reveal muscle atrophies, especially at the posterior aspect involving the infraspinatus and teres minor muscle (Fig. 43.1). A gross neurological check should exclude peripheral nerve lesions or complaints deriving from the cervical spine. The sensory branch of the axillary nerve should be evaluated, especially in patients with a history of trauma. The range of motion in all planes including forward elevation, abduction and external and internal rotation has to be evaluated in comparison to the uninvolved side. Also the amount of passive motion has to be proven in order to detect shoulder stiffness which sometimes can evolve

Fig. 43.1 Patient suffering from chronic posterosuperior RCT at the right shoulder. Note the evident hollow at the fossa infraspinata due to atrophy of the underlying muscle belly

M. Tauber, MD, PhD (✉)
Shoulder and Elbow Unit, ATOS Clinic Munich, Munich, Germany

Department of Traumatology and Sports Injury, Paracelsus Medical University Salzburg, Salzburg, Austria
e-mail: tauber@atos-muenchen.de

P. Randelli et al. (eds.), *Arthroscopy: Basic to Advanced*, DOI 10.1007/978-3-662-49376-2_43

secondary to RCT. Capsular stiffness is characterized by a hard stop which usually is painful in active capsulitis. Muscle strength should be rated according to the Medical Research Council (MRC) [26]. To evaluate strength for forward elevation and abduction, the arm is in 90° at the horizontal level. Rotational force is evaluated with the arm at the side and in neutral rotation position. Thus, gross estimation of muscle function and functional shoulder compensation is possible. However, full range of motion with good muscle strength cannot exclude RCT due to full functional compensation. Already in 1971 Neviaser et al. reported this observation and showed that the active range of motion does not correspond to tear size [31].

43.1.1 Specific Clinical Tests

43.1.1.1 Impingement

A frequent accompanying pathology in RCT is subacromial bursitis due to a mechanical outlet impingement. A series of clinical tests can provoke subacromial pain caused by compression of the inflamed bursa. The Neer test is the most frequently used test for clinical diagnosis of subacromial impingement [30]. The examiner is behind the patient and fixes with one hand his scapula, whilst the other hand lifts the arm into a forced elevation (between flexion and abduction). Pain is validated as a positive sign indicating subacromial impingement of every grade. Table 43.1 shows involved structures, sensitivity, specificity and positive predictive value (PPV) for all clinical relevant tests handling with RCT.

43.1.2 Supraspinatus Tendon

With the empty-can and full-can tests, the integrity of the supraspinatus tendon can be proved. With the empty-can test (Fig. 43.2a), the posterior aspect of the supraspinatus can be tested, whereas the full-can test (Fig. 43.2b) involves more the anterior insertional parts. The arm is brought in a position of 90° abduction, 30° horizontal flexion and full internal rotation for the empty can and 45° of external rotation for the full-can test, respectively [23].

The drop-arm sign is positive if the patient is not able to actively start the abduction. Furthermore, if the arm is brought passively in 90° of abduction, the patient cannot hold it in this position, or at least only under highest effort. Under minimal resistance the arm drops down.

43.1.3 Infraspinatus Tendon

Tests detecting isolated lesions of the infraspinatus were not described yet. Usually, if an infraspinatus tendon tear is present, external rotation is compensated by the teres minor muscle with a certain loss of strength. Once the teres minor shows fatty infiltration grade 3 or 4, external rotation insufficiency is present resulting in a positive hornblower sign. For this test the patient is asked to bring his hand to the mouth. Due to complete loss of external rotation, the arm deviates in internal rotation. The patient tries to compensate this by glenohumeral abduction. Hereby, often the elbow is higher than the hand itself.

For evaluation of the external rotation lag sign, the arm is positioned in 20° of abduction and in maximum external rotation with the elbow flexed in 90°. If the patient is not able to keep the arm in this position with the elbow supported by the examiner and the arm returns in an internal position, the test is positive. With this test the supraspinatus, infraspinatus and teres minor muscles are evaluated. It has been shown that the extent of the lag sign correlates with the tear size [7].

43.1.4 Subscapularis Tendon

The standard test for subscapularis function evaluation is the belly-press test (Fig. 43.3). In this test, the patient presses the abdomen with the hand flat and attempts to keep the arm in maximum internal rotation. If active internal rotation is strong, the elbow does not drop backward, meaning that it remains in front of the trunk. If the strength of the subscapularis is

Table 43.1 Shows involved structures, sensitivity, specificity and positive predictive value (*PPV*) for all clinical relevant tests handling with RCT

Author	Structure	Sensitivity (%)	Specificity (%)	PPV (%)
Impingement				
Park et al. [36]	Tendinitis/bursitis	85.7		20.9
	Partial RCT	75.4	48	18.1
Silva et al. [41]		88.7	68.4	30
Calis et al. [6]		88.7	Low	Low
Supraspinatus	*Empty can*			
Noel et al. [32]	Muscle weakness	95	65	
Itoi et al. [22]	Muscle weakness and/or pain	89	50	
	Only muscle weakness	77	68	
	Full can			
Itoi et al. [22]	Muscle weakness and/or pain	86	57	
	Only muscle weakness	77	74	
Drop-arm sign				
Park et al. [36]	Complete RCT	34.9	87.5	69.1
	Bursitis/tendinitis	13.6		8.0
Calis et al. [6]	Subacromial with involvement of RC	7.8	97.2	87.5
Infraspinatus	*Hornblower sign*			
Walch et al. [49]	ISP and TM insufficiency	100	93	
	ER lag sign			
Hertel et al. [21]	SSP	70	100	
Castoldi et al. [7]	SSP	56	98	
Subscapularis	*Belly press*			
Bartsch et al. [3]	SSC	80	88	
Barth et al. [2]	SSC	40	97.9	
	Belly off			
Bartsch et al. [3]	SSC±SSP, ISP	86	91	
	Bear hug			
Barth et al. [2]	SSC±SSP, ISP	60	91.7	
	Lift off			
Scheibel et al. [39]	Complete SSC	100		100
	IR lag sign			
Hertel et al. [21]	SSC	95	96	97

SSC subscapularis, *SSP* supraspinatus, *ISP* infraspinatus, *TM* teres minor, *ER* external rotation, *IR* internal rotation

impaired, maximum internal rotation cannot be maintained, the patient feels weakness, and the elbow drops back behind the trunk. According to Scheibel et al., the test can be modified with measurement of the wrist flexion angle in maximum internal rotation (elbow brought in front) during the belly-press manoeuvre [40]. A wrist flexion angle of 90° (positive result) indicates a complete tear, whereas with an angle of 30–60°, a partial tear of the upper two-thirds has to be assumed. An electromyography study could show that the belly-press test activates more the superior aspects of the subscapularis and the lift-off test more the inferior aspects, respectively [47].

Another test for evaluation of subscapularis integrity is the belly-off sign (Fig. 43.4). It represents the inability of the patient to maintain the palm of the hand attached to the abdomen with the arm passively brought into flexion and internal rotation. It is likely that the patient is unable to keep this position due to predominant external

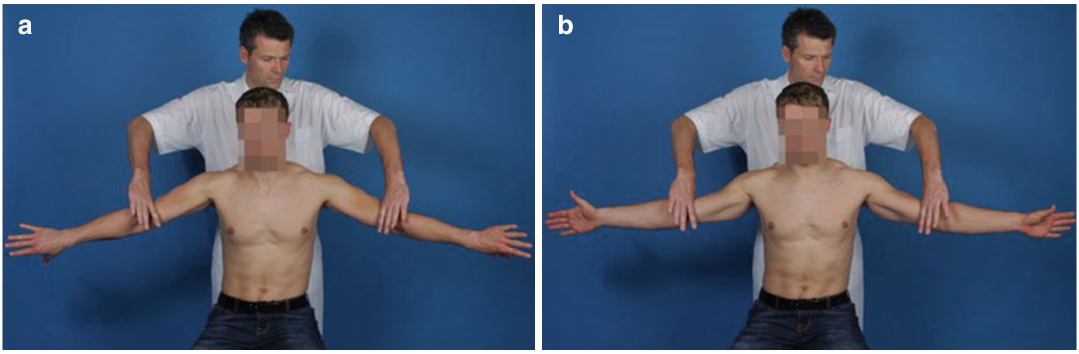

Fig. 43.2 (**a**) The empty-can test is performed with the arm in 90° of abduction in the scapular plane and internal rotation. (**b**) The full-can test is performed with the arm in 90° of abduction in the scapular plane and external rotation

Fig. 43.3 Positive belly-press test on the right side. Note that the hand must be kept flat in contact with the abdomen

rotator muscles in terms of an unbalanced transverse force couple [5].

As an alternative the bear-hug test can be used [2]. The palm of the involved side is placed on the opposite shoulder with the fingers extended, and the elbow is positioned anterior to the body. The patient tries to hold the starting position by means of resisted internal rotation as the examiner tries to pull the patient's hand from the shoulder with an external rotation force applied perpendicular to the forearm. A positive bear-hug test results when the patient cannot hold the hand against the shoulder as the examiner applies an external rotation force. Hereby, a 90° flexion position addresses more the inferior subscapularis, whereas a 45° flexion position involves both, the superior and inferior aspects. Thus, the latter is recommended for routine clinical use.

A positive lift-off test indicates a complete subscapularis tear. The arm is in internal rotation positioned with the backhand to the middle part of the lumbar spine. The patient is asked to lift off the hand from the back. Inability indicates subscapularis insufficiency. Elbow extension and/or deviation of the hand from the mid-part of the lumbar spine render the test positive, as well.

Finally, using the internal rotation lag sign, the function of the subscapularis can be tested in maximal internal rotation. The arm is brought in maximal internal position with the elbow flexed and the backhand with a submaximal distance from the lower lumbar spine. The patient is asked to keep this position. The extent of the lag correlates to the tear size, and especially partial tears

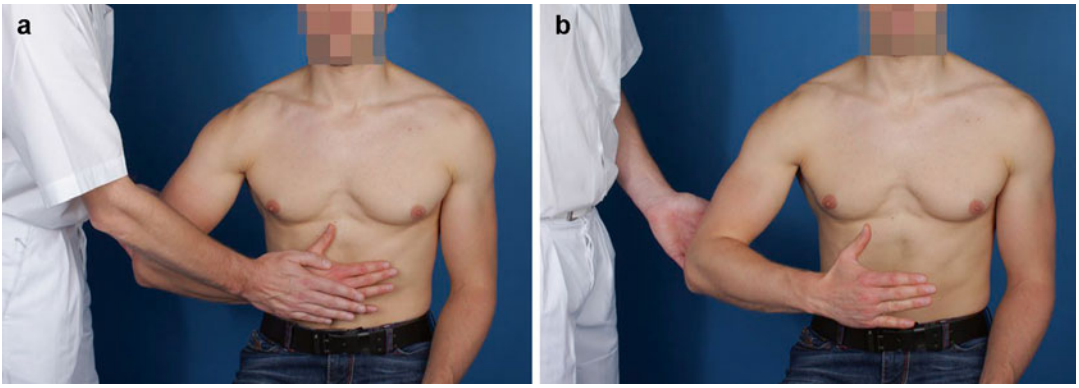

Fig. 43.4 Positive belly-off sign. The patient with subscapularis deficiency is not able to hold his hand at the abdomen due to rotational imbalance in favour of external rotators

of the upper subscapularis tendon can be diagnosed in the presence of a subtle lag. Be aware that passive restrictions of the shoulder can falsify this test.

43.2 Exploration: Instrumented and Radiological

To evaluate a suspected RCT, various imaging modalities can be used. Routinely, plain radiographs in three planes should be performed including a true AP view, an outlet and an axillary view. Even though conventional radiography does not visualize soft tissues, several associated and prognostic relevant factors can be seen allowing for further therapeutic decisions. Concomitant radiologic changes as glenohumeral or acromioclavicular osteoarthritis, calcifying tendinitis or osteolysis can be detected. Several radiologic parameters have been described as risk factors for development of RCT including a lateral acromion angle below 70°, a large lateral extension of the acromion in terms of the acromiohumeral index and the critical shoulder angle [1, 27, 34, 35]. The configuration of the acromion in the parasagittal plane according to Bigliani does not show any significant correlation [28]. Another important information which can be got from the native X-ray relates to humeral head centering. Superior migration of the humeral head indicates loss of function of the RC and appears with a longstanding two-tendon tear. The normal acromiohumeral distance (AHD) measures from 9 to 10 mm with a range from 7 to 14 mm [38]. It has been suggested that an AHD <7 mm is consistent with an RCT [8, 11] and fatty degeneration [33, 48, 51] and that a space <5 mm indicates a massive RCT [15, 50]. Another way to determine superior head migration is the assessment of the normal "Gothic arch" [24] or so called Maloney's line which is interrupted in patients with RC failure or dysfunction.

In cuff tear arthropathies based on chronic massive RCT characteristic radiologic changes can be observed with joint space narrowing, superior migration of the head, rounding of the greater tuberosity, concave erosion of the acromial undersurface (acetabularization), superomedial glenoid wear and finally humeral head collapse [20].

43.2.1 Ultrasound

Ultrasound examination allows for accurate diagnosis of RCT. Every shoulder surgeon should be familiar with this everywhere and cost-efficient imaging tool. It allows quick and reliable diagnostics focusing on RC tendon integrity [44]. With high-resolution probes up to 12.5 MHz, even partial RCT can be detected. In addition, pathologic changes of the long head of the biceps tendon (LHBT), including peritendinitis or subluxation/gross instability, can be diagnosed. Furthermore, intratendinous calcium deposits and perihumeral fluid accumulation in terms of subcoracoid, subacromial or subdeltoid bursitis can be seen. Compared to MRI, dynamic testing is a clear advantage when RCT are evaluated. However, the grade of tendon retraction and secondary alterations as muscle atrophy and fatty infiltration cannot be determined. Also intraarticular structural pathologies as labral tears, SLAP lesions or cartilage lesions cannot be detected by ultrasound [45]. Obviously, the reliability is strongly dependent from the observer's experience. Another advantage of ultrasound is offered during the postoperative course evaluating RC integrity after repair or the presence of intra- or periarticular effusion due to postoperative inflammatory processes.

43.2.2 Magnetic Resonance Imaging (MRI)

MRI represents the most accurate imaging tool to evaluate RCT. In addition to the structural lesion itself, prognostic and therapeutic decision influencing factors including muscle atrophy [46], tendon retraction [37] and fatty infiltration [13, 17] can precisely diagnosed. The classification system of muscle atrophy, tendon retraction and fatty infiltration are presented in Chap. 1.3. Certain principles have to be respected, i.e. that parasagittal slices are extended beyond the coracoid process in order to assess adequately the grade of muscle atrophy and slice thickness should not exceed 3 mm.

43.3 Rating: International Classification

The classification of RCT is of utmost importance within the setting of the preoperative staging for surgical planning. In order to achieve an excellent surgical result, a preoperative pathology-related therapeutic planning has to be performed. This includes the functional demands of the patient and his motivation and compliance regarding the long-lasting rehabilitation period, as well. Parameters providing all required information include tendon tear size and retraction, muscle atrophy and fatty infiltration.

43.3.1 Articular-Sided Partial Tears

The first established classification of articular-sided partial tears was described by Ellman [9].

Classification of partial tears according to Ellman [9]	
Grade 1	Diameter <¼ or >3 mm
Grade 2	Diameter <½ or 3–6 mm
Grade 3	Diameter >6 mm

However, due to its mono-dimensional approach considering the medial-to-lateral extension alone, it does not fulfil the criteria required for a complete classification.

Habermeyer et al. introduced in 2008 a new classification for partial supraspinatus tendon tears considering two dimensions [18]. In the parasagittal plane, three zones are defined:

- Zone A includes the lateral pulley sling.
- Zone B includes the crescent zone.
- Zone C is a combination of both.

In the paracoronal plane, another three zones are distinguished similar to the classification according to Ellman:

- Type 1 refers to the articular-sided area directly close to the osteochondral transition zone.
- Type 2 extends to the middle third of the footprint.
- Type 3 involves the lateral third in terms of a subtotal lesion.

43.3.2 Bursal-Sided Partial Tears

The classification according to Ellman for partial tears can be applied for bursal-sided tendon lesions as well. However, the more detailed classification according to Snyder [42] is preferred by the author.

Classification of bursal-sided partial tears according to Snyder [42]	
Grade 0	Normal
Grade 1	Minimal superficial bursal or synovial irritation or slight capsular fraying over a small area
Grade 2	Fraying and failure of some rotator cuff fibres in addition to synovial bursal or capsular injury. More severe rotator cuff injury fraying and fragmentation of tendon fibres often involving the whole of a cuff tendon, usually <3 cm
Grade 3	Very severe partial rotator cuff tear that contains a sizeable flap tear and more than one tendon

A special kind of partial RCT is represented by intratendinous tears located between both tendon sheets: the bursal- and articular-sided layers are intact [14]. The diagnosis is difficult and is possible by MRI.

43.3.3 Partial Subscapularis Tendon Tears

Subscapularis tendon tears can be either of traumatic or atraumatic origin. The pathomorphological mechanism for atraumatic lesion is caused by pulley lesions in terms of instability of the long head of the biceps tendon. Chronic antero-medial subluxation out of the bicipital groove leads to tendon damage at its insertion area at the lesser tuberosity and stepwise tendon avulsion. Two classification systems are established for tears of the subscapularis tendon, whereas that according to Lafosse [25] takes imaging-verified muscle atrophy into account, as well.

Classification of SSC tendon tears according to Fox and Romeo [12]	
Type 1	Partial thickness tear
Type 2	Complete tear of upper 25 % of SSC tendon
Type 3	Complete tear of upper 50 % of SSC tendon
Type 4	Complete rupture of SSC tendon

Classification of SSC tendon tears according to Lafosse [25]	
Type 1	Partial lesion of superior one-third
Type 2	Complete lesion of superior one-third
Type 3	Complete lesion of superior two-thirds
Type 4	Complete lesion of tendon but head centred and fatty degeneration classified as less than or equal to Goutallier stage III
Type 5	Complete lesion of tendon but eccentric head with coracoid impingement and fatty degeneration classified as more than or equal to Goutallier stage III

43.3.4 Tear Size

Before sizing an RCT, the two-dimensional character of RCT has to be taken into account. This means that the size has to be related to the parasagittal extension from anterior to posterior and to the paracoronal extension from lateral to medial which corresponds to the grade of retraction. Obviously, depending from the number of tendons involved, the tear size increases. An internationally well-accepted classification system for full-thickness tears was introduced by Bateman et al. in 1984 [4].

Complete cuff tears: Bateman classification	
Grade 1	Tear <1 cm after debridement
Grade 2	Tear 1–3 cm after debridement
Grade 3	3–5 cm
Grade 4	Global tear, no cuff left

In combination with the topographic classification of rotator cuff tears in the sagittal plane according to Habermeyer [19], the RCT can be sized precisely in the parasagittal plane regarding tear extension as distance measurement and the region with the according tendons involved.

- Sector A: Anterior lesions – subscapularis tendon, rotator interval and LHB tendon
- Sector B: Central superior lesions – supraspinatus tendon
- Sector C: Posterior lesions – infraspinatus and teres minor lesions

For example, a posterosuperior RCT tear involving the infra- and supraspinatus tendons is classified as Bateman 3 BC.

43.3.5 Tear Configuration

Depending from the direction of retraction, different tear configurations can evolve. For reconstruction purposes it is important to analyse the tear pattern in order to achieve anatomical reduction of the RC and a tension-free refixation of the tendon at the footprint. A widely accepted classification was presented by Ellman in 1993, which covers most of the cases [10].

Tear configuration according to Ellman and Gartsman [10]	
Transverse	Tear at the insertion site
Crescent cable	Transverse tears with deformation due to SSC/ISP tension
L shaped	Transverse tear with extension into the interval between SSP and ISP
Reversed L shaped	Transverse tears with extension into the rotator interval
Trapezoidal	L shaped + reversed L shaped
Massive RCT	Extension into TM or anterior SSC

43.3.6 Tendon Retraction

Once the tendon shows a complete tear, a certain trend towards retraction of the stump following the muscle tension in a medial direction is present. The course over time is unpredictable. However, the grade of retraction is of prognostic value in regards to RC repair feasibility and success [16]. The classification according to Patte has been established to grade tendon retraction [37]. Note that the grade of tendon retraction does not provide any information regarding tendon's elasticity and thus the feasibility of tendon reconstruction.

Classification of tendon retraction according to Patte [37]	
Grade 1	Proximal stump close to bony insertion
Grade 2	Proximal stump at level of humeral head
Grade 3	Proximal stump at glenoid level

43.3.7 Muscle Atrophy

In chronic RCT degenerative changes evolve over time and lead to functional impairment. A nonworking muscle due to the interruption of its myo-tendino-osseous function chain loses its contractility and atrophies. This means that muscle volume reduces, and the surrounding perimuscular space is replaced by fibrous and/or fat tissue. For classification purposes the occupational ratio between the entire space of the fossa supraspinata and the SSP muscle belly itself is calculated [46]. Measurements are performed on the scapular cut in the parasagittal plane at level of the medial border of spine of scapula (first cut of scapular Y shape, Fig. 43.5).

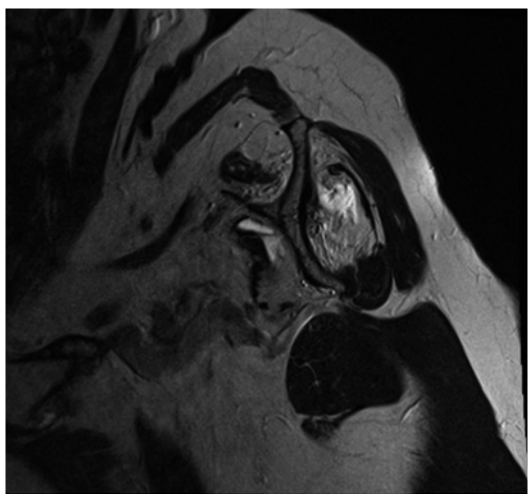

Fig. 43.5 Parasagittal plane of a left shoulder showing advanced muscle atrophy and fatty infiltration in a massive global cuff tear. Only the teres minor is at least in part viable

Classification of muscle atrophy according to Thomazeau [46]	
Stage 1	Normal/slight atrophy occupation ratio (1.00–0.60)
Stage 2	Moderate atrophy occupation ratio (0.60–0.40)
Stage 3	Severe atrophy occupation ratio (<0.40)

Basically, degenerative changes are reversible until a certain critical "point of no return". For SSP muscle atrophy this critical point is achieved when the muscle belly is below a tangent line drawn from the top of the coracoid base to the scapular spine (= tangent sign according to Zanetti [52]). The risk for RC irreparability or RC retear is directly correlated to the grade of muscle atrophy. Again, speed of atrophy progression varies, but is directly correlated to the number of tendons torn. The subscapularis as the strongest RC muscle tends to atrophy more quickly. It could be shown that over a 4-year follow-up period in patients with massive RCT refusing surgery, both muscle atrophy and fatty infiltration together with osteoarthritic changes increased [53]. Whereas shoulder function was stable, four out of eight patients with a primary reconstructable RCT showed an irreparable situation at the final follow-up.

Moosmayer et al. [29] observed clinical deterioration of 36 % of initially asymptomatic full-thickness tears within 3 years. Progression of tear size, muscle atrophy and fatty infiltration were correlated directly with the presence of symptoms.

43.3.8 Fatty Infiltration

Over time, muscle atrophy is accompanied by fatty infiltration of the muscle tissue. It could be shown that the localization of the fatty infiltration is not the muscle cell itself, but the intercellular space [43]. The first description and classification of fatty infiltration of the RC was performed on CT scans by Goutallier et al. in 1994 [17]. Fuchs adapted this classification to MRI, which nowadays represents the primary imaging modality in evaluation of the RC [13]. However, fatty infiltration is a negative prognostic value and irreversible when stage 3 or 4 according to Goutallier is achieved.

Classification of fatty infiltration		
Goutallier [17] stage (CT)	Degree of fatty change	Fuchs [13] stage (MRI)
0	Normal muscle	1
1	Some fatty streaks present	
2	More muscle than fat	2
3	Equal muscle and fat	3
4	More fat than muscle	

References

1. Banas MP, Miller RJ, Totterman S. Relationship between the lateral acromion angle and rotator cuff disease. J Should Elb Surg. 1995;4(6):454–61.
2. Barth JR, Burkhart SS, De Beer JF. The bear-hug test: a new and sensitive test for diagnosing a subscapularis tear. Arthroscopy. 2006;22(10):1076–84.
3. Bartsch M, Greiner S, Haas NP, Scheibel M. Diagnostic values of clinical tests for subscapularis lesions. Knee Surg Sports Traumatol Arthrosc. 2010;18(12):1712–7.
4. Bayne O, Bateman J. Long-term results of surgical repair of full-thickness rotator cuff tears. In: Bateman JE, Welsh R, editors. Surgery of the shoulder. Philadelphia: CV Mosby; 1984. p. 167–71.
5. Burkhart SS. Arthroscopic treatment of massive rotator cuff tears. Clinical results and biomechanical rationale. Clin Orthop Relat Res. 1991;267:45–56.
6. Calis M, Akgun K, Birtane M, Karacan I, Calis H, Tuzun F. Diagnostic values of clinical diagnostic tests in subacromial impingement syndrome. Ann Rheum Dis. 2000;59(1):44–7.
7. Castoldi F, Blonna D, Hertel R. External rotation lag sign revisited: accuracy for diagnosis of full thickness supraspinatus tear. J Should Elb Surg. 2009;18(4):529–34.
8. Cotton RE, Rideout DF. Tears of the humeral rotator cuff; a radiological and pathological necropsy survey. J Bone Joint Surg (Br). 1964;46:314–28.
9. Ellman H. Arthroscopic subacromial decompression: analysis of one- to three-year results. Arthroscopy. 1987;3(3):173–81.

10. Ellman H. Rotator cuff disorders. In: Ellman H, Gartsman GM, editors. Arthroscopic shoulder surgery and related disorders. Philadelphia: Lea and Febiger; 1993. p. 98–119.
11. Ellman H, Hanker G, Bayer M. Repair of the rotator cuff. End-result study of factors influencing reconstruction. J Bone Joint Surg Am. 1986;68(8):1136–44.
12. Fox JA, Noerdlinger MA, Romeo AA. Arthroscopic subscapularis repair. Tech Should Elb Surg. 2003;4:154–68.
13. Fuchs B, Weishaupt D, Zanetti M, Hodler J, Gerber C. Fatty degeneration of the muscles of the rotator cuff: assessment by computed tomography versus magnetic resonance imaging. J Should Elb Surg. 1999;8(6):599–605.
14. Fukuda H, Hamada K, Nakajima T, Tomonaga A. Pathology and pathogenesis of the intratendinous tearing of the rotator cuff viewed from en bloc histologic sections. Clin Orthop Relat Res. 1994;304:60–7.
15. Gerber C, Fuchs B, Hodler J. The results of repair of massive tears of the rotator cuff. J Bone Joint Surg Am. 2000;82(4):505–15.
16. Gohlke F, Rolf O, Bohm D. Open reconstruction of the rotator cuff. Orthopade. 2007;36(9):834–47.
17. Goutallier D, Postel JM, Bernageau J, Lavau L, Voisin MC. Fatty muscle degeneration in cuff ruptures. Pre- and postoperative evaluation by CT scan. Clin Orthop Relat Res. 1994;304:78–83.
18. Habermeyer P, Krieter C, Tang KL, Lichtenberg S, Magosch P. A new arthroscopic classification of articular-sided supraspinatus footprint lesions: a prospective comparison with Snyder's and Ellman's classification. J Should Elb Surg. 2008;17(6):909–13.
19. Habermeyer P, Schiller K, Schweiberer L. Rotatorenmanschette. In: Habermeyer P, Krueger P, Schweiberer L, editors. Schulterchirurgie, vol. 1. Muenchen: Urban & Schwarzenberg; 1990. p. 149–67.
20. Hamada K, Fukuda H, Mikasa M, Kobayashi Y. Roentgenographic findings in massive rotator cuff tears. A long-term observation. Clin Orthop Relat Res. 1990;254:92–6.
21. Hertel R, Ballmer FT, Lombert SM, Gerber C. Lag signs in the diagnosis of rotator cuff rupture. J Should Elb Surg. 1996;5(4):307–13.
22. Itoi E, Kido T, Sano A, Urayama M, Sato K. Which is more useful, the "full can test" or the "empty can test," in detecting the torn supraspinatus tendon? Am J Sports Med. 1999;27(1):65–8.
23. Jobe FW, Moynes DR. Delineation of diagnostic criteria and a rehabilitation program for rotator cuff injuries. Am J Sports Med. 1982;10(6):336–9.
24. Krishnan SG, Bennion PW, Reineck JR, Burkhead WZ. Hemiarthroplasty for proximal humeral fracture: restoration of the Gothic arch. Orthop Clin N Am. 2008;39(4):441–50. vi.
25. Lafosse L, Jost B, Reiland Y, Audebert S, Toussaint B, Gobezie R. Structural integrity and clinical outcomes after arthroscopic repair of isolated subscapularis tears. J Bone Joint Surg Am. 2007;89(6):1184–93.
26. Medical Research Council. Aids to the examination of the peripheral nervous system. Memorandum No. 45. HMSO, London; 1996.
27. Moor BK, Bouaicha S, Rothenfluh DA, Sukthankar A, Gerber C. Is there an association between the individual anatomy of the scapula and the development of rotator cuff tears or osteoarthritis of the glenohumeral joint?: A radiological study of the critical shoulder angle. Bone Joint J. 2013;95-B(7):935–41.
28. Moor BK, Wieser K, Slankamenac K, Gerber C, Bouaicha S. Relationship of individual scapular anatomy and degenerative rotator cuff tears. J Should Elb Surg. 2014;23(4):536–41.
29. Moosmayer S, Tariq R, Stiris M, Smith HJ. The natural history of asymptomatic rotator cuff tears: a three-year follow-up of fifty cases. J Bone Joint Surg Am. 2013;95(14):1249–55.
30. Neer CS, 2nd. Impingement lesions. Clin Orthop Relat Res. 1983(173):70–7.
31. Neviaser JS. Ruptures of the rotator cuff of the shoulder. New concepts in the diagnosis and operative treatment of chronic ruptures. Arch Surg. 1971;102(5):483–5.
32. Noel E, Walch G, Bochu M. Jobe's maneuver. Apropos of 227 cases. Rev Rhum Mal Osteoartic. 1989;56(12):803–4.
33. Nove-Josserand L, Edwards TB, O'Connor DP, Walch G. The acromiohumeral and coracohumeral intervals are abnormal in rotator cuff tears with muscular fatty degeneration. Clin Orthop Relat Res. 2005;433:90–6.
34. Nyffeler RW, Werner CM, Sukthankar A, Schmid MR, Gerber C. Association of a large lateral extension of the acromion with rotator cuff tears. J Bone Joint Surg Am. 2006;88(4):800–5.
35. Ozaki J, Fujimoto S, Nakagawa Y, Masuhara K, Tamai S. Tears of the rotator cuff of the shoulder associated with pathological changes in the acromion. A study in cadavera. J Bone Joint Surg Am. 1988;70(8):1224–30.
36. Park HB, Yokota A, Gill HS, El Rassi G, McFarland EG. Diagnostic accuracy of clinical tests for the different degrees of subacromial impingement syndrome. J Bone Joint Surg Am. 2005;87(7):1446–55.
37. Patte D. Classification of rotator cuff lesions. Clin Orthop Relat Res. 1990;254:81–6.
38. Petersson CJ, Redlund-Johnell I. The subacromial space in normal shoulder radiographs. Acta Orthop Scand. 1984;55(1):57–8.
39. Scheibel M, Magosch P, Pritsch M, Lichtenberg S, Habermeyer P. The belly-off sign: a new clinical diagnostic sign for subscapularis lesions. Arthroscopy. 2005;21(10):1229–35.
40. Scheibel M, Tsynman A, Magosch P, Schroeder RJ, Habermeyer P. Postoperative subscapularis muscle insufficiency after primary and revision open shoulder stabilization. Am J Sports Med. 2006;34(10):1586–93.
41. Silva L, Andreu JL, Munoz P, et al. Accuracy of physical examination in subacromial impingement syndrome. Rheumatology (Oxford). 2008;47(5):679–83.

42. Snyder SJ, Pachelli AF, Del Pizzo W, Friedman MJ, Ferkel RD, Pattee G. Partial thickness rotator cuff tears: results of arthroscopic treatment. Arthroscopy. 1991;7(1):1–7.
43. Steinbacher P, Tauber M, Kogler S, Stoiber W, Resch H, Sanger AM. Effects of rotator cuff ruptures on the cellular and intracellular composition of the human supraspinatus muscle. Tissue Cell. 2010;42(1):37–41.
44. Teefey SA, Hasan SA, Middleton WD, Patel M, Wright RW, Yamaguchi K. Ultrasonography of the rotator cuff. A comparison of ultrasonographic and arthroscopic findings in one hundred consecutive cases. J Bone Joint Surg Am. 2000;82(4):498–504.
45. Teefey SA, Rubin DA, Middleton WD, Hildebolt CF, Leibold RA, Yamaguchi K. Detection and quantification of rotator cuff tears. Comparison of ultrasonographic, magnetic resonance imaging, and arthroscopic findings in seventy-one consecutive cases. J Bone Joint Surg Am. 2004;86-A(4):708–16.
46. Thomazeau H, Rolland Y, Lucas C, Duval JM, Langlais F. Atrophy of the supraspinatus belly. Assessment by MRI in 55 patients with rotator cuff pathology. Acta Orthop Scand. 1996;67(3):264–8.
47. Tokish JM, Decker MJ, Ellis HB, Torry MR, Hawkins RJ. The belly-press test for the physical examination of the subscapularis muscle: electromyographic validation and comparison to the lift-off test. J Should Elb Surg. 2003;12(5):427–30.
48. van de Sande MA, Rozing PM. Proximal migration can be measured accurately on standardized anteroposterior shoulder radiographs. Clin Orthop Relat Res. 2006;443:260–5.
49. Walch G, Boulahia A, Calderone S, Robinson AH. The ‘dropping’ and ‘hornblower’s’ signs in evaluation of rotator-cuff tears. J Bone Joint Surg (Br). 1998;80(4):624–8.
50. Walch G, Marechal E, Maupas J, Liotard JP. Surgical treatment of rotator cuff rupture. Prognostic factors. Rev Chir Orthop Reparatrice Appar Mot. 1992;78(6):379–88.
51. Werner CM, Conrad SJ, Meyer DC, Keller A, Hodler J, Gerber C. Intermethod agreement and interobserver correlation of radiologic acromiohumeral distance measurements. J Should Elb Surg. 2008;17(2):237–40.
52. Zanetti M, Gerber C, Hodler J. Quantitative assessment of the muscles of the rotator cuff with magnetic resonance imaging. Invest Radiol. 1998;33(3):163–70.
53. Zingg PO, Jost B, Sukthankar A, Buhler M, Pfirrmann CW, Gerber C. Clinical and structural outcomes of nonoperative management of massive rotator cuff tears. J Bone Joint Surg Am. 2007;89(9):1928–34.