

5.1 Classifications of rotator cuff tears according to Patte [107]

- 1) Extent of the tear (see Sect. 5.6)
- 2) Topography of the tear in the sagittal plane
- 3) Topography of the tear in the frontal plane
- 4) Trophic quality of the muscle of the torn tendon
- 5) State of the long head of the biceps

Topography of rotator cuff tear in sagittal plane according to Patte [107] (Fig. 7)

- **Segment 1:** subscapularis tear
- **Segment 2:** coracohumeral ligament tear
- **Segment 3:** isolated supraspinatus tear
- **Segment 4:** tear of entire supraspinatus and one-half of infraspinatus
- **Segment 5:** tear of supraspinatus and infraspinatus
- **Segment 6:** tear of subscapularis, supraspinatus, and infraspinatus

This assessment is necessary for anatomic-clinical correlations and for the proper choice of surgical approach and technique. Anteriorly situated defects are more painful, whereas posterior lesions interfere more with function. In a sagittal section viewed from the subscapularis to the infraspinatus, several segments can be distinguished.

Segment 1. Isolated subscapularis tears are seldom exclusively involved in degenerative tears. These tears in general are due to traumatic avulsions often associated with a medial dislocation of the LHB.

Segment 2. Isolate coracohumeral ligament tears are traumatic in nature and do not contribute to the pathology of the cuff.

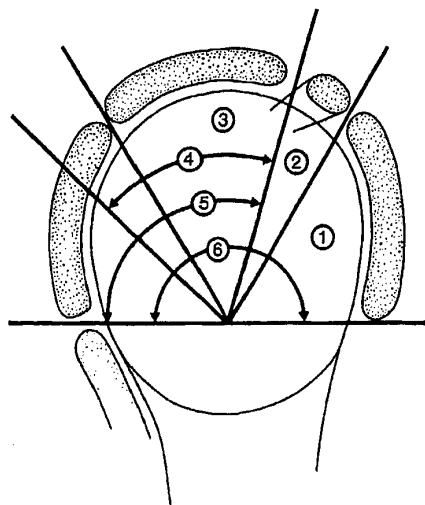


Fig. 7. Topography of tears in the sagittal plane. Location and extent of tears determine their division into six segments: anterosuperior lesions (segments 1–3), superior lesions (segments 2 and 3), posterosuperior lesions (segments 4 and 5), and total-cuff lesions (segment 6)

Segment 3. Isolated supraspinatus tears include only the supraspinatus, but other segments can be involved simultaneously. When associated with a tear of Segment 2, a Segment 3 tear constitutes a superior defect. If Segment 1 is also involved, then the lesion is an anterosuperior defect.

Segments 4 and 5. Segment 4 (supraspinatus and the upper one-half of the infraspinatus) and Segment 5 (supraspinatus and the entire infraspinatus) tears merit special attention, given the inherent difficulties of repair.

Segment 6. Total-cuff tears including the subscapularis, supraspinatus, and infraspinatus. Secondary OA was most common among these patients.

5.2 Topography of rotator cuff tear in the sagittal plane according to Habermeyer [51, 53] (Fig. 8)

- **Sector A:** lesions localized anteriorly
Sector A contains the subscapularis tendon, rotator interval and the long head of the biceps tendon
- **Sector B:** lesions localized central superiorly
Sector B circumscribes the at the apex located central area with the supraspinatus tendon
- **Sector C:** lesions localized posteriorly
Sector C localized the posteriorly located lesions of the infraspinatus and teres minor tendon

The extension of the line of spina scapulae separates sector B from sector C.

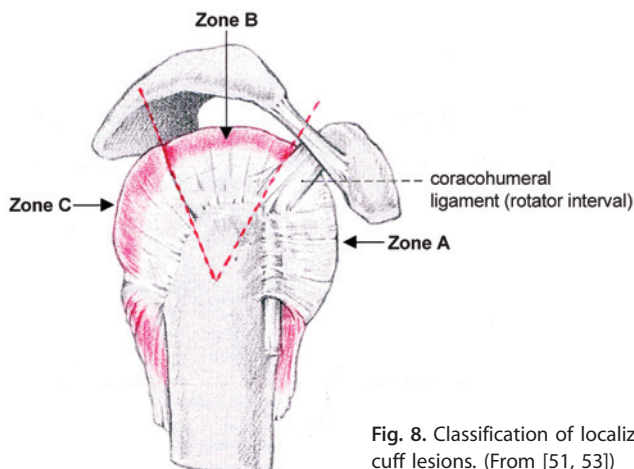


Fig. 8. Classification of localization of rotator cuff lesions. (From [51, 53])

5.3 Arthroscopic classification of partial-thickness rotator cuff tears according to Ellman [32]

The author stated that any tear, whether partial or complete, should be classified as Stage III (impingement according to Neer [97]). The following subclassification of Stage III is proposed to include both partial- and full-thickness rotator cuff tears (Table 1).

The *classification of partial-thickness tears* (Fig. 9 [34]) indicates which surface is involved and grades the severity of the tear according to depth. The normal cuff is considered to be 10–12-mm thick.

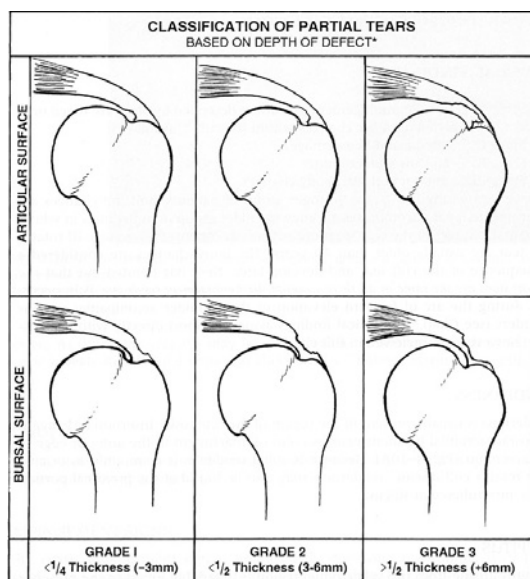
- A **Grade 1** partial tear (less than 3-mm deep) is relatively minor, but definite disruption of the tendinous fibres can be identified. Superficial fraying of the articular capsule does not constitute a cuff tear.
- **Grade 2** lesions (3–6-mm deep) extend well into the substance of the cuff but do not exceed one-half of the thickness of the tendon.
- **Grade 3** lesions are more than 6 mm in depth are significant disruptions of more than one-half the substance of the cuff; continuity appears tenuous.

A small arthroscopic probe with a 3-mm bent arm or a suction shaver of known diameter can be used to measure the tear. In addition to depth, the base of the defect and its width should be measured. This information clearly defines the extent of the tear.

Table 1. Subclassification of stage-III rotator cuff tears

Location	Grade	Area of defect
<i>Partial-thickness tear(P)^a</i>		
A. Articular surface	1: <3 mm deep	Base of tear×maximum retraction=mm ²
B. Bursal surface	2: 3–6 mm deep	
C. Interstitial	3: >6 mm deep	
<i>Full-thickness tear (F)</i>		
A. Supraspinatus	1: Small, <2 cm	Base of tear×maximum retraction=cm ²
B. Infraspinatus	2: Large, 2–4 cm	
C. Teres minor	3: Massive, >5 cm	
D. Subscapularis	4: Cuff arthropathy	

^a Torn muscle(s)



*Indicate **AREA OF DEFECT**: Base of tear \times maximum retraction = mm²

Fig. 9. Ellman classification of partial-thickness rotator cuff tears

Full-thickness tears are described in the traditional fashion with minor variations. Designated grades can be substituted for the adjectives *small* and *large*. A **fourth grade** is added to include cuff arthropathy. As defined by Neer, this includes a massive tear articular irregularity with collapse of the humeral head, chronic synovitis and capsular laxity. Estimates of the total area of defect measured in square millimeters or centimeters are obtained by multiplying the length of the base of the tear by the distance of maximum retraction. Use of the classification defines the location and extent of rotator cuff lesions and facilitates comparison of findings among various studies.

5.4 Arthroscopic classification of rotator cuff lesions according to Snyder (the Southern California Orthopedic Institute (SCOI) rotator cuff classification system) [121]

The Southern California Orthopedic Institute rotator cuff classification system is a simple, descriptive scheme that uses letters and numbers to designate the pathologic conditions of the tendon. The capital letter indicates the side of the cuff where the tear is located: A for articular-side partial tears, B for bursal-side partial injuries, and C for complete-thickness or trans-tendon damage. The degree of tendon damage is classified using a numeric designation of 0 to 4.

Location of tears

- A Articular surface
- B Bursal surface
- C Complete tear, connecting A and B sides

Severity of tear (A and B partial tears)

- 0 Normal cuff, with smooth coverings of synovium and bursa
- I Minimal, superficial bursal or synovial *irritation* or slight capsular fraying in a small, localized area; usually <1 cm
- II Actually *fraying* and failure of some rotator cuff fibres in addition to synovial, bursal, or capsular injury; usually <2 cm
- III More severe rotator cuff injury, including fraying and *fragmentation* of tendon fibres, often involving the whole surface of a cuff tendon (most often the supraspinatus); usually <3 cm
- IV Very severe partial rotator cuff tear that usually contains, in addition to fraying and fragmentation of tendon tissue, a sizable *flap* tear and often encompasses more than a single tendon

(A partial articular supraspinatus tendon avulsion (*PASTA*) is an A-III or A-IV tear.)

Classification of complete (C) rotator cuff tears

- CI A small, complete tear, such as a puncture wound
- CII A moderate tear (usually <2 cm) that still encompasses only one of the rotator cuff tendons with no retraction of the torn ends
- CIII A large, complete tear involving an entire tendon with minimal retraction of the torn edge; usually 3 to 4 cm
- CIV A massive rotator cuff tear involving two or more rotator cuff tendons, frequently with associated retraction and scarring of the remaining tendon ends and often L-shaped tear. The CIV classification can also be modified with the term *irreparable*, indicating that there is no possibility of direct repair

5.5 Classification of complete rotator cuff tears according to Cofield [21]

- Small tears represented fissuring or an isolated avulsion of the supraspinatus
- Medium tears were less than 3 cm in the longest diameter
- Large tears were 3 to 5 cm in diameter
- Massive tears were greater than 5 cm in diameter

5.6 Classification of complete rotator cuff tears according to Bateman [7]

- **Grade 1:** cuff tears of 1 cm or less measured in the longest diameter after debriding of the avascular edges
- **Grade 2:** cuff tears of 1 to 3 cm in diameter after debridement of the avascular edges
- **Grade 3:** cuff tears of 5 cm or less
- **Grade 4:** global cuff tears with little or no cuff left

5.7 Classification of the extent of rotator cuff tears according to Patte [107]

The extent of the lesion is measured in centimetres at the level of the bony insertion. The tears are divided into three groups: *small*, *intermediate*, and *large*. A fourth group, characterized by secondary osteoarthritic (OA) changes in the humeral head (which is usually subluxed), deserves a separate analysis of results.

- **Group I:** partial tears or full-substance tears measuring less than 1 cm in sagittal diameter at bony detachment
 - a. Deep, partial tears
 - b. Superficial tears
 - c. Small, full-substance tears
- **Group II:** full-substance tears of entire supraspinatus
- **Group III:** full-substance tears involving more than one tendon
- **Group IV:** massive tears with secondary OA

Group I: this group includes partial tears and full-substance tears measuring less than 1 cm. The cuff remains watertight in the presence of incomplete tears. However, full-substance tears that do not involve the entire width of a given tendon are of no apparent mechanical consequence. The essential symptom is pain, which may cause loss of function. Lesions of Group I rarely exhibit an operative indication. Physiotherapy aiming to eliminate subacromial impingement usually results in satisfactory pain relief. Surgical repair, when indicated, is easily achieved either by suturing or by reattachment to bone. The necrotic tissue must be resected before repair.

The following three types of lesions are recognized:

- 1) The most commonly observed lesion during surgery is the *distally situated deep tear*, characterized by a detachment at the fibrocartilaginous zone. Trauma preceded 62% of these lesions. When partial tears at the articular side occur at a certain distance from the bony insertion (at the critical zone), they can be diagnosed by arthrography. They are the consequence of degeneration secondary to inadequate vascular supply. These partial tears must be followed closely, since their healing potential is low.

- 2) *Partial superficial tears*, which cannot be detected by arthrography, are diagnosed either by bursoscopy or at the time of surgery. These tears occur less frequently than some surgical statistics tend to indicate. Because of an adequate blood supply, their prognosis is good.
- 3) The third type is the *full-substance tear* of the supraspinatus that measures less than 1 cm in diameter at the bony insertion and thus does not involve the entire width of the tendon.

Group II: this group includes full-substance tears, which are usually limited to the supraspinatus. The sagittal diameter, measured at the bony insertion, is approximately 2 cm. The fascicles of the coracohumeral ligament inserting into the greater tuberosity are included in the tear. The infraspinatus is intact, although an intrasubstance tear secondary to interstitial necrosis developing in the posterior aspect is usually present.

Group III: in this group, defects are large and involve not only the supraspinatus but sometimes the subscapularis and usually the infraspinatus. The sagittal extent of the tear (4 cm or more), combined with a defect in the frontal plane, explains the nearly total absence of the cuff, especially when the necrotic part of the proximal stump is considered part of the defect. As a result, the humeral head migrates cranially and frontally, gradually impinging against the coracoacromial arch. These defects are serious and demand early surgical treatment.

Group IV: lesions in this group are characterized not only by massive tears but also by secondary OA of the humeral head. An acromiohumeral arthrosis develops, as does glenohumeral OA accompanied by narrowing of the joint at the superior glenoid pole and droplike osteophyte formation inferiorly. These lesions often limit the possibility of repair, and an arthroplasty thus becomes necessary.

5.8 Patterns of full-thickness rotator cuff tears according to Ellman and Gartsman [33]

The progressive failure of cuff fibre insertion produces several types of commonly encountered defects. One the tendon separates from its insertion, the torn margin is retracted by the unopposed pull of the torn muscle and its neighbours. An understanding of these patterns of tear facilitates reconstruction.

- **Crescent tear:** tear involves supraspinatus tendon (Fig. 10 a).

Medial retraction presents a crescent-shaped defect beginning near the long head of the biceps tendon and arching medially and posteriorly for 2 to 3 cm.

- **Triangular defect:**

Reverse L: Supraspinatus tear extends medially through rotator cuff interval in line with long head of biceps tendon (Fig. 10 b)

A moderate-sized triangular defect is most commonly produced when a supraspinatus tear extends medially along its anterior border in a line with the long head of the biceps tendon. This limb of the tear is located through the relatively thin fibrocapsular area between the subscapularis and supraspinatus tendon. The long head of the biceps tendon travels below the interval, whereas the coracohumeral ligament joins this interval from above as it courses toward its insertion. The torn surfaces outline a reverse L. The cuff margin retracted medially and posteriorly forms the hypotenuse of the triangular defect.

L-shaped tear: Supraspinatus tear has extend through junction with infraspinatus, thereby producing an anteromedial displacement (Fig. 10 c).

A less commonly observed variation involves a tear of the supraspinatus with extension of the tear medially between the junction of the supra- and the infraspinatus fibres. In this L-shaped tear, the torn end of the infraspinatus has retracted medially and somewhat anteriorly. The pattern of retraction must be appreciated to identify the retracted edge and return it to its origin. Larger L-shaped tears are created as increasing portions of the infraspinatus become involved.

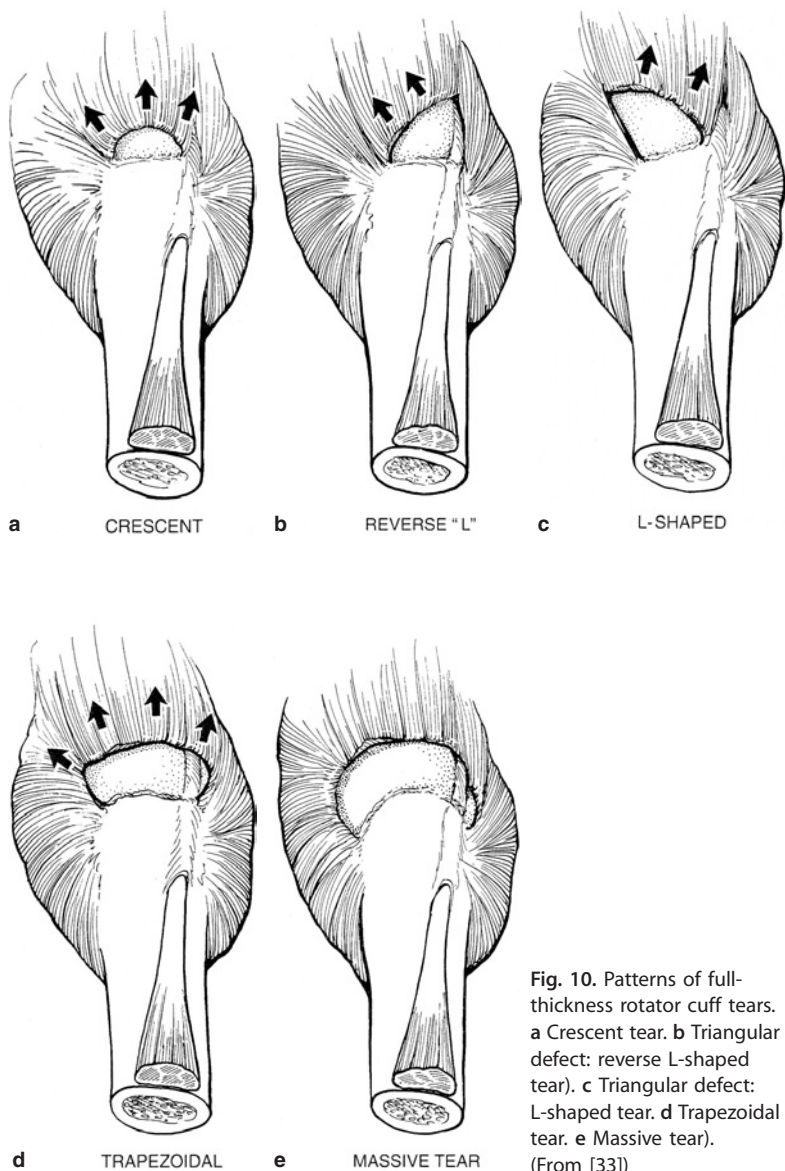


Fig. 10. Patterns of full-thickness rotator cuff tears. a Crescent tear. b Triangular defect: reverse L-shaped tear. c Triangular defect: L-shaped tear. d Trapezoidal tear. e Massive tear. (From [33])

- **Trapezoidal tear:** This tear results when both supraspinatus and infraspinatus are torn. As more of the infraspinatus insertion fails, the trapezoid enlarges (Fig. 10 d).

The trapezoidal tear generally develops when both the supraspinatus and the infraspinatus are torn and the tear extends anteriorly along the rotator interval and posteriorly into the interval between the infraspinatus and teres minor. The torn edges of the supra- and infraspinatus may be retracted medially to the level of the glenoid. In some instances, portions of the tendon and its musculotendinous junction may be literally ground away between the undersurface of the acromion and the humeral head as the head rises superiorly during overhead elevation of the arm. A pebbled and irregular appearance of the humeral head suggests the lengthy presence of the cuff defect. On the other hand, a relatively smooth, glistening dome suggests that the extensive two-muscle tear may be more recent in origin and more likely repairable.

- **Massive tear:** When three muscles are involved, the tear is usually massive. Two-muscle tears should be retracted at least 5 cm to be designated massive (Fig. 10 e).

The long head of the biceps is often displaced in these circumstances.

5.9 Classification of subscapularis tendon tears according to Fox and Romeo [39]

- **Type I:** partial thickness tear
- **Type II:** complete tear of upper 25% of tendon
- **Type III:** complete tear of upper 50% of tendon
- **Type IV:** complete rupture of tendon

5.10 Classification of tendon retraction in the frontal plane according to Patte [107] (Fig. 11)

- Stage 1: proximal stump close to the bony insertion
- Stage 2: proximal stump at level of humeral head
- Stage 3: proximal stump at level of glenoid



Fig. 11. Topography of tears in the frontal plane, in which three stages are easily recognized. In stage 1 the stump shows little retraction, in stage 2, it lies at the level of the humeral head, and in stage 3 it is seen at the level of the glenoid

5.11 Classification of supraspinatus muscle atrophy in MRI according to Thomazeau [128]*

All MRI images were obtained with a 1 Tesla unit. The quantitative analysis was then performed on the spin-echo T1-weighted oblique-sagittal images (TR: 480 ms, TE: 12 ms, FOV: 250×250, matrix: 380×512).

To evaluate the atrophy of the supraspinatus muscle, the occupation ratio (R) of the supraspinatus fossa by the muscle belly is calculated. This analysis was based on the ratio between the surface of the muscle S1 and the surface delineated by the limits of the fossa S2 (Fig. 12). The selected oblique-sagittal image was digitalized in order to use a calculation program. The limits of the surfaces were drawn by hand, and the ratio, $R = S1/S2$ was automatically calculated. The final result was a mean of these values expressed from 0 (empty fossa) to 1 (full fossa).

The measurement was taken at the level, where the scapula is cut through the medial border of the spine, just above the spinoglenoid notch. Moreover, the clavicle partially closes the anterosuperior part of the fossa.

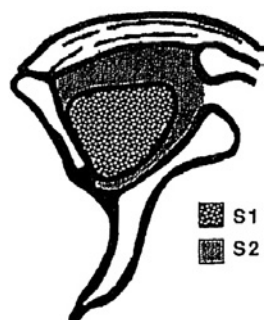


Fig. 12. Calculation of the occupation ratio R on the oblique-sagittal view. $S1$ Surface of the supraspinatus muscle; $S2$ surface of the entire supraspinatus fossa

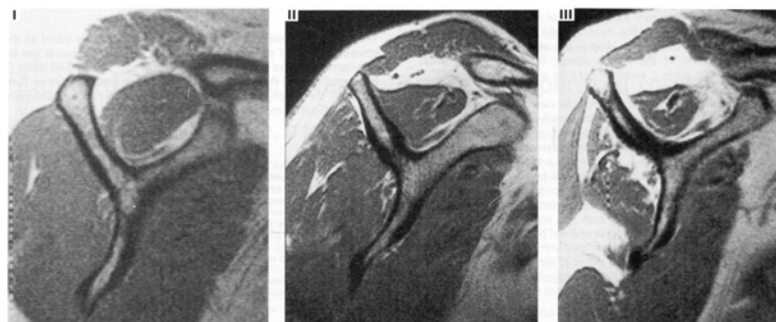


Fig. 13. Three grades of supraspinatus atrophy in MRI

The authors propose a classification of the supraspinatus belly atrophy based on the occupation ratio to the supraspinatus fossa (Fig. 13). In the case of a ratio between 1.00 and 0.60 (**stage I**), the muscle can be considered as *normal or slightly atrophied*. Values between 0.60 and 0.40 (**stage II**) suggest *moderate atrophy*. Values below 0.40 (**stage III**) indicate *serious or severe atrophy* (Table 2).

Table 2. Occupation ratio of the supraspinatus fossa related to grade of supraspinatus tendinopathy

Stage		Occupation ratio
I	Normal or slightly atrophied	1.00–0.60
II	Moderate atrophy	0.60–0.40
III	Serious or severe atrophy	<0.40

5.12 Classification of supraspinatus muscle atrophy in MRI according to Zanetti [142]*

Magnetic resonance imaging was performed on a 1.0-Tesla scanner. A sequence of parasagittal T1-weighted turbo spin-echo MRI images (repetition time [TR]/echo time [TE]: 700/12 ms) parallel to the glenohumeral joint space was obtained.

For quantitative assessment, areas and SIs of the rotator cuff muscle and the area of the fossa supraspinata were measured at the most lateral image on which the scapular spine is in contact with the rest of the scapula (Fig. 14a).

Tangent Sign: Qualitative assessment of atrophy of the supraspinatus muscle: For quick qualitative evaluation of atrophy of the supraspinatus muscle a morphologic sign was introduced. A line (tangent) was drawn through the superior borders of the scapular spine and the superior margin of the coracoid (Fig. 14d). The tangent sign was defined as abnormal (**positive**) (Fig. 14e,f) when the supraspinatus muscle did not cross the tangent. The tangent sign is a qualitative sign of muscle atrophy with a high predictive value. Obviously, its use is limited to the supraspinatus muscle, which is not adequate for all types of tears.

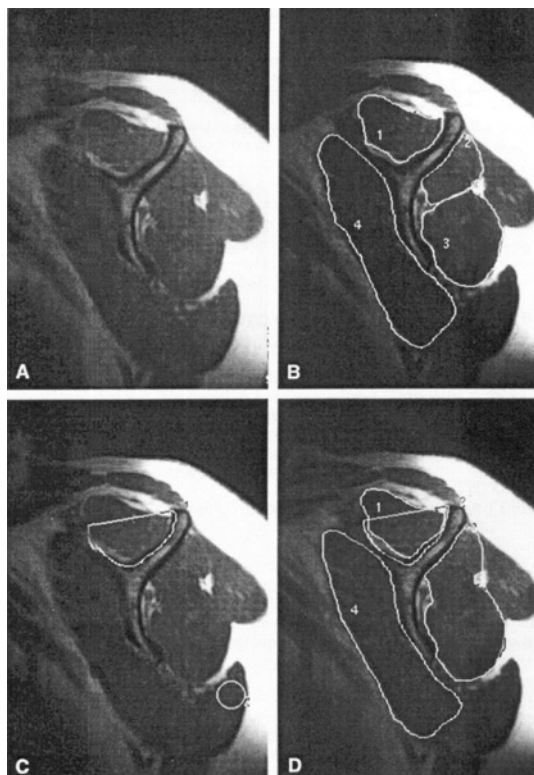


Fig. 14A–F. **A** The most lateral image on which the scapular spine is in contact with the rest of the scapula was chosen as reference section. **B** Areas and mean signal intensities were obtained using regions of interest determined by the contours of the supraspinatus (1), infraspinatus (2); teres minor (3), and subscapularis muscle (4). **C** Measurement of the area of the supraspinatus (1) and the mean signal intensity of the teres major muscle (2). **D** Because the border between the infraspinatus and teres minor muscles cannot reproducibly be measured, these two measurements were combined for the purpose of the investigation. This figure demonstrates all measurements used in this investigation for quantification of the rotator cuff: supraspinatus muscle (1); supraspinatus fossa (2); combined measurement of the infraspinatus and teres minor muscles (3); and subscapularis muscle (4). Note normal (negative) tangent sign: the normal supraspinatus muscle reaches above the line drawn through the superior borders of the coracoid and scapular spine

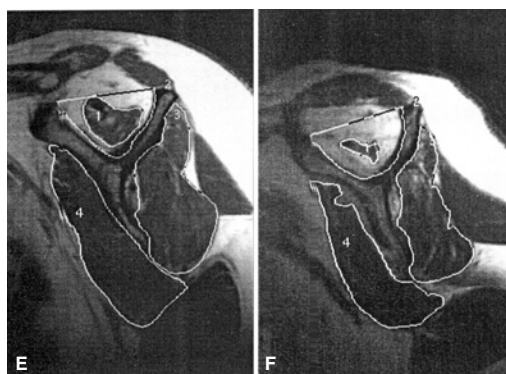


Fig. 14. E A borderline abnormal (positive) tangent sign. F Positive tangent sign

5.13 Classification of fatty muscle degeneration in cuff ruptures using CT-scan according to Goutallier et al. [49] (Fig. 15)*

The areas of muscular hypodensity observed seem to correspond to fat tissue, which does not necessarily mean that there is a muscular atrophy, and CT scan patterns are said to be without specific diagnostic value.



Fig. 15. Classification of muscles according to their degree of fatty infiltration

Measurement of shoulder cuff muscle areas or volumes cannot be reliably or easily performed, particularly with a CT scan, but the assessment of fatty muscular infiltration remains a good tool in clinical practice.

- **Stage 0:** corresponds to a completely normal muscle, without any fatty streak
- **Stage 1:** the muscle contains some fatty streaks
- **Stage 2:** the fatty infiltration is important, but there is still more muscle than fat
- **Stage 3:** there is as much fat as muscle
- **Stage 4:** more fat than muscle is present

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