

- **MASSIVE TEARS**

MASSIVE CUFF TEAR

J Bone Joint Surg Am.

2010;92:1894-1908.

Repair of massive rotator cuff tears is technically difficult but often feasible.

1. inelastic poor-quality tendon tissue,

2. Scarring, muscle atrophy,

3. Fatty infiltration.

Fatty infiltration of the involved rotator cuff muscles has been identified as an important negative prognostic factor for the outcome after repair of massive rotator cuff tears.

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Tendon transfer is a good option for young patients and manual laborers with an irreparable massive rotator cuff tear.

Arthroplasty can be considered for the treatment of symptomatic massive rotator cuff tears in patients who have glenohumeral arthritis.

Cofield et al.¹⁷ defined a massive tear as a tear with a diameter of ≥ 5 cm, while Zumstein et al.¹⁸ defined a tear as massive if there was complete detachment of two or more tendons.

Burkhart proposed a classification of rotator cuff tears based on the tear pattern and the mobility of the tear margins.

Crescent-shaped tears are the classic standard type, and they have excellent medial-to-lateral mobility. These tears can be repaired directly to bone with minimal tension.

In contrast, **u-shaped tears extend** much farther medially, with the apex of the tear being adjacent to or medial to the glenoid rim.

Signs of irreparability include

The prevalence of massive tears reported in the literature has ranged from 10% to 40% of all rotator cuff tears.

Massive anterosuperior tear configurations involving the supraspinatus and subscapularis tendons are less common, ranging from approximately 5% to 20% of all rotator cuff tear patterns

It is critical to recognize that massive rotator cuff tears are not necessarily synonymous with irreparable tears

An acute traumatic tear or an avulsion injury may be >5 cm in dimension but have a good-quality elastic tendon stump and be anatomically reducible without placing excessive tension on the repair.

Signs of irreparability include 1. Static superior migration of the humeral head,
2. A narrowed or absent acromiohumeral interval,
3. Fatty infiltration affecting ≥50% of the

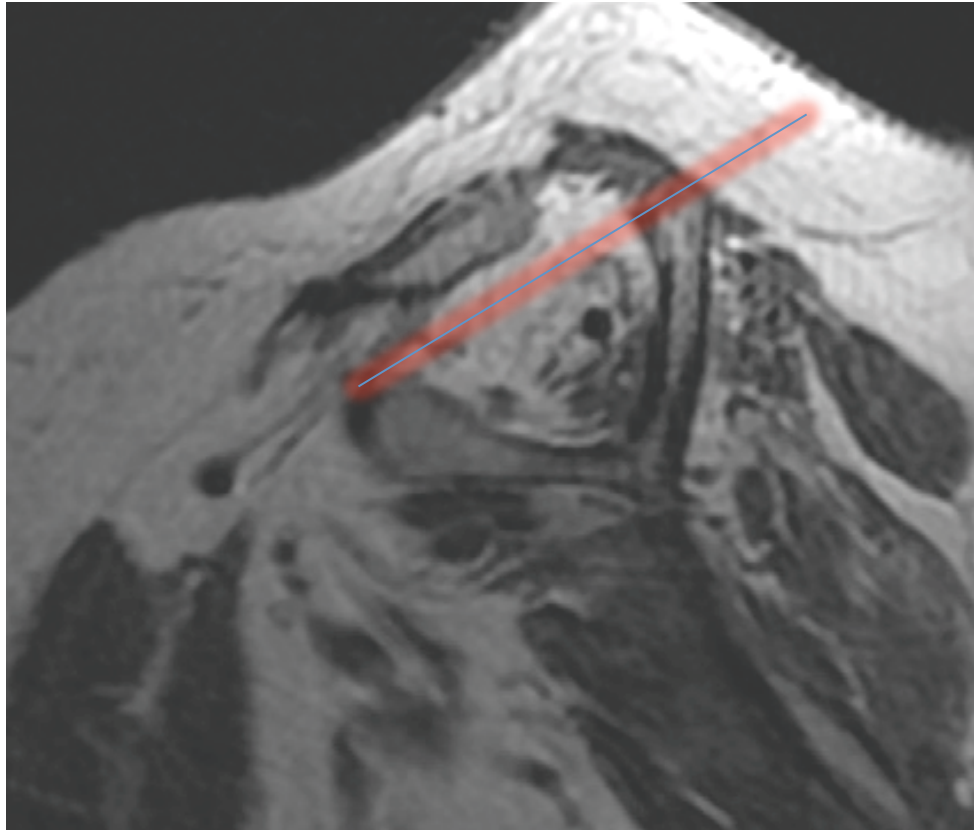
Biomechanics of Massive Cuff Tears

- The deltoid and rotator cuff muscles work synergistically to maintain a balanced force couple for the glenohumeral joint . “Force couple”
- In this capacity, the rotator cuff muscles function as primary dynamic stabilizers to maintain a concentric reduction during rotation of the humeral head on the Glenoid
- **Massive cuff tears can disrupt this force couple** and ultimately compromise the fulcrum that is necessary for normal glenohumeral mechanics.

Clinical

- Frequently painful, particularly at night and during activities of daily living.
- Patients may report varying degrees of weakness and varying losses of the range of motion.
- On physical examination, patients with a long-standing tear may have visible atrophy of the supraspinatus and/or infraspinatus muscles.
- **Lag sign**
- Complete loss of external rotation strength
- A positive hornblower sign—i.e., they may be unable to externally rotate the shoulder (the motion required for a hornblower to get the horn to the lips with the arm at the side).
- An inability to complete this action without abducting the arm to avoid active external rotation reflects deficiency of teres minor function. Walch et al. found this sign to be 100% sensitive and 93% specific in terms of identifying irreparable tears of the teres minor
- Positive belly-press and lift-off tests

1. A decreased acromiohumeral distance can provide evidence
2. Magnetic resonance imaging and ultrasonography are the most common imaging modalities used to diagnose
3. Limitations of ultrasonography as compared with MRI include difficulty with defining complex
 - tear patterns, with grading of the severity of fatty infiltration of muscle, and with identifying coexistent intra-articular pathological involvement of the labrum or biceps tendon
 - In recent studies, magnetic resonance imaging has been shown to be 100% sensitive in terms of diagnosing rotator cuff tears, and it can be used accurately to estimate tear size, retraction, and fatty infiltration.

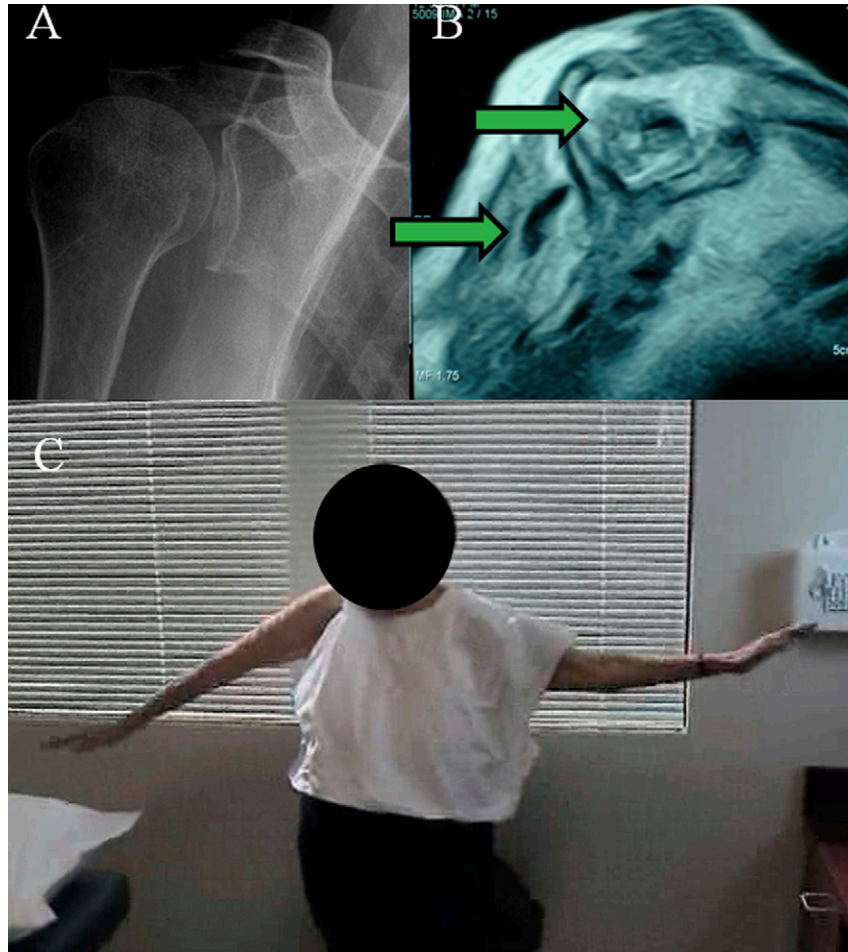


- T1-weighted sagittal image of a massive rotator cuff tear with extensive fatty atrophy of both the supraspinatus and the infraspinatus muscle belly.
- Note that only the central tendon slip (black dot) is visible within the supraspinatus fossa, while the remaining space has been replaced with fat.

TABLE I Grades of Recommendations for Treatment of Massive Rotator Cuff Tears

Grade of Recommendation*	
Nonoperative treatment	B
Debridement and subacromial decompression	C
Biceps tenotomy	B
Partial repair	I
Complete repair	A
Repair with scaffold or tissue augmentation	C
Tendon transfer	B
Hemiarthroplasty	B
Reverse shoulder arthroplasty	B
<p>*A = good evidence (Level-I studies with consistent findings) for or against recommending intervention, B = fair evidence (Level-II or III studies with consistent findings) for or against recommending intervention, C = poor-quality evidence (Level-IV or V studies with consistent findings) for or against recommending intervention, and I = there is insufficient or conflicting evidence not allowing a recommendation for or against intervention.</p>	

Scenerio 1: Pseudoparalysis in Massive cuff tear



- Preoperative anteroposterior radiograph of the right shoulder demonstrates no evidence of escape of the humeral head (A), but magnetic resonance imaging demonstrates severe atrophy of the supraspinatus and infraspinatus muscles (arrows in B)
- The patient has pseudoparalysis of the right shoulder (C) on clinical examination.

93-A d NUMBER 10 :576

- Scenario 1.
- An elderly patient with comorbidities (e.g., smoking or diabetes) predictive of poor healing of the rotator cuff
- Presents after an acute on- chronic rotator cuff tear.
- The patient has pseudoparalysis (forward elevation of $<90^\circ$) and pain, and, although there is no anterior-superior escape of the humeral head, magnetic resonance imaging reveals rotator cuff atrophy.
- In this scenario, a reverse shoulder arthroplasty offers the potential for reliable return of function and relief of pain with a decreased risk of reoperation compared with attempted rotator cuff repair.

Nonoperative Treatment

- Hansen et al. demonstrated that stable glenohumeral abduction without excessive superior humeral head translation could be maintained in the setting of a massive tear but requires the generation of higher forces in the deltoid and the remaining intact portion of the rotator cuff .
- Some individuals with a massive tear, can maintain active shoulder abduction and good function with low-demand daily activities.
- One hypothesis is that contraction of the deltoid muscle superiorly translates the humeral head underneath the coracoacromial arch and allows pivoting around this abnormally superior center of rotation
- Bokor et al. noted improvement in 50% to 85% of 53% patients after nonoperative treatment of a full-thickness rotator cuff tear.
- Recent biomechanical studies that have demonstrated an important role for the anterior deltoid muscle in preventing superior humeral head migration and compressing the glenohumeral joint in the presence of a large cuff tear
- The risk of rotator cuff arthropathy and irreversible fatty infiltration of muscle may limit future treatment options and must be considered when counseling patients.

Debridement and Subacromial Decompression

- Have satisfactory short-term outcomes is primarily indicated for elderly, low-demand patients with pain but good preservation of active motion
- Shoulder strength does not improve after this intervention, function is usually enhanced because of relief from pain
- Preoperative relief from a subacromial injection is a favorable prognostic finding for improvement after this operation.
- It is critical that the coracoacromial ligament be preserved
- Rockwood reported decreased pain and improvement of function and strength in forty-four (88%) of fifty patients after tear debridement and decompression
- Zvijac reported deterioration of function and strength over time

Biceps Tenotomy

- The function of the long head of the biceps tendon, particularly in the setting of a massive rotator cuff tear, is controversial.
- Recent electromyographic studies have shown the long head of the biceps to be quiescent in patients with a massive cuff tear during active abduction, suggesting that its stabilizing role is likely more passive than active
- There is evidence suggesting that the long head of the biceps tendon may be a source of pain and contribute to the discomfort associated with symptomatic massive cuff tears.
- Walch et al. reported the outcomes after biceps tenotomy in patients with an irreparable massive rotator cuff tear.
- Fatty infiltration of the rotator cuff, however, had a negative influence on both functional and radiographic outcomes.

Partial Repair

- Partial repair has been shown to yield a good outcome in some patients should be considered in the setting of good tissue quality.
- Often, isolated repair of the infraspinatus tendon to bone can significantly improve external rotation strength and functional outcomes
- It is important for the treating surgeon to recognize that complete closure of the defect is less important than restoration of a stable fulcrum of the glenohumeral joint
- Good-to excellent results were achieved in 67% of the patients and 92% were satisfied with the result.

Complete Repair

- Technically difficult, with a retear rate
- Operative Technique
- Subacromial and subdeltoid adhesions should be released and bursal tissue should be excised first to clearly visualize the tear pattern
- Occasionally, capsular releases may also be required to address particularly contracted or immobile tendons in massive tears.
- Bigliani described an open anterior interval release of the coracohumeral ligament to the base of the coracoid process,
- Performing a double-row repair has been advocated by several authors, who have cited
- superior biomechanical characteristics and an increased tendon bone
- Snyder et al. advocated performing a medialized repair with a single row of sutures placed at the articular margin.

Outcomes

- Zumstein [N 27] had undergone an open, transosseous repair; 3 yrs
- All of these patients reported a good-to-excellent result despite a re tear rate of 37%.
- Lam and Mok [N =74] at 4 years
- 84% of the patients were satisfied and 93% had pain relief.
- Jost et al. found that the clinical outcomes of patients with rerupture after a massive rotator cuff repair correlated significantly with the size of the recurrent defect and the extent of fatty degeneration of the infraspinatus and supraspinatus muscles

Recent advances with Massive RCT J Shoulder

Elbow Surg (2012) 21, 164-

1. SSN denervation: On a molecular level, denervation of skeletal muscle leads to increased expression of NF-kB, FOXO1, and atrogin-1 and subsequent increased muscle atrophy.
2. Poor functional outcomes in patients undergoing a rotator cuff repair are correlated to the atrophy and fatty infiltration of the supraspinatus and infraspinatus muscles.^{42,62,77}
3. MMPs have been found to be involved in increasing atrophy in a rat and rabbit model of muscle atrophy.^{4,19,49}
4. The myocyte is a multinucleate cell that often contains over 100 nuclei in its mature state. Myocytes sit within an extracellular matrix of myofibrils, which are long chains of sarcomeres, to form myocyte contractile units
5. During the development of muscle atrophy, there is significant remodeling of the ECM that includes increased collagenous connective tissue (fibrosis). A matrix metalloproteinases (MMPs), is believed to play an important role of ECM remodeling in skeletal muscle.

Repair with Scaffolds or Tissue Augmentation

- The high failure rate associated with repairs of massive tears has prompted investigation of scaffolds and other tissue augments to substitute for deficient tissue and achieve a tension-free Repair
- Scaffolds provide mechanical support and have biological properties that may favorably influence cell proliferation and differentiation, hopefully improving tendonto-bone healing.
- Currently, scaffolds derived from dermis, small intestinal submucosa, skin, fascia lata, and pericardium have been processed and marketed for augmentation in the repair of massive tears.
- Flaps of the deltoid and autogenous biceps tendon have also been utilized to bridge a residual defect during massive cuff tear repair

Tendon Transfers

- Viable surgical option for patients with a weakness, pain, and impaired active motion; who does not have glenohumeral arthritis; Manual laborers with a massive irreparable tear
- The operation and associated rehabilitation are often extensive.

Latissimus Dorsi Transfer

- Proposed by Gerber
- The subscapularis tendon and deltoid muscle origin must be intact for the transfer to establish balanced coronal and transverse force couples about the glenohumeral joint
- Warner reported a 73% overall patient satisfaction rate.
- Iannotti et al. reported a 64% rate of satisfactory results

Pectoralis subcoracoid transfer for irreparable tear.

International Orthopaedics (SICOT) (2010) 34:689–694

- Massive ruptures are characterised by a poor quality of the rotator cuff that does not allow for a direct tendon-to-bone reconstruction.
- Between 2000 and 2006, 15 patients were treated using a deltopectoral approach and transfer of the clavicular part of the pectoralis major to the lesser tuberosity and to the anterior part of the greater tuberosity. After an average follow-up (follow-up rate 100%) of 37 months the average functional rating using the Constant and Murley score (CS) increased from 51.73 ± 16.18 to 68.17 ± 8.84 points ($p = 0.005$). Age: Mean 61 +/- 6 years
- Nine patients (70%) had an intact transferred pectoralis major muscle, two (15%) had one that was thin but intact and two patients a rupture (one complete).
- The good results confirm that pectoralis major transfer is a reliable treatment option for irreparable anterosuperior rotator cuff injuries with significant improvement in pain and function.

Hemiarthroplasty

- Neer: Hemiarthroplasty is a treatment option
- F
- However, static anterosuperior escape, in which the humeral head is no longer contained by the coracoacromial arch, is a contraindication.
- The reported clinical outcomes after hemiarthroplasty for cuff tear arthropathy have been mixed.
- Overall, a successful result was reported in 67%
- The mean active forward flexion and external rotation improved rarely

Reverse Shoulder Arthroplasty

- A treatment for glenohumeral arthritis in the setting of advanced rotator cuff arthropathy.
- These designs shifted the axis of rotation laterally relative to its native position and increased the lever arm across the glenoid, resulting in loosening and failure of the glenoid component.
- With the reverse shoulder replacement, Grammont et al. modified these designs and increased the efficiency of the deltoid by (1) medializing the center of rotation and thereby
- decreasing shear forces on the glenoid, and (2) tensioning the deltoid by effectively lengthening the arm
- While short-term results have been encouraging, reverse total shoulder arthroplasty is associated with a substantial complication rate and the long-term results remain to be defined.
- In a multicenter study : The prosthetic survival rate was 91% at five years and 75% at seven years but declined substantially, to 30%, at eight years. re132.

- Frankle
- 35 patients; 3 years
- The complication rate was 17%, with revision surgery required in 12% of the patients.
- The clinical results of reverse shoulder arthroplasty are inferior when there is dysfunction of the posterior aspect of the rotator cuff, specifically the teres minor
- Guery et al. Found worse clinical results in patients who had had deficient external rotation and a positive hornblower sign preoperatively.
- Despite favorable short-term clinical results, the high rate of complications associated with this operation is a substantial concern.

- The most common complications were dislocation (7.5%) and infection (4%). Glenoid fractures, humeral fractures, pain associated with implants, radial nerve palsy, and loosening of the glenosphere or baseplate occurred in five or fewer cases each.
- Importantly, the risk of complications in the setting of revision surgery was more than double that observed with primary surgery (37% and 13%, respectively).
- Loosening: related to impingement of the medial aspect of the humeral cup on the scapular neck in adduction. The clinical implications of notching are controversial. Guery et al. noted small notching to be inconsequential
- Boileau no adverse effect of notching regardless of size¹³⁴.
- Notching is clearly related to the surgical technique and can be decreased with inferior baseplate positioning and superior tilting of the glenosphere

- **FAT ATROPHY**

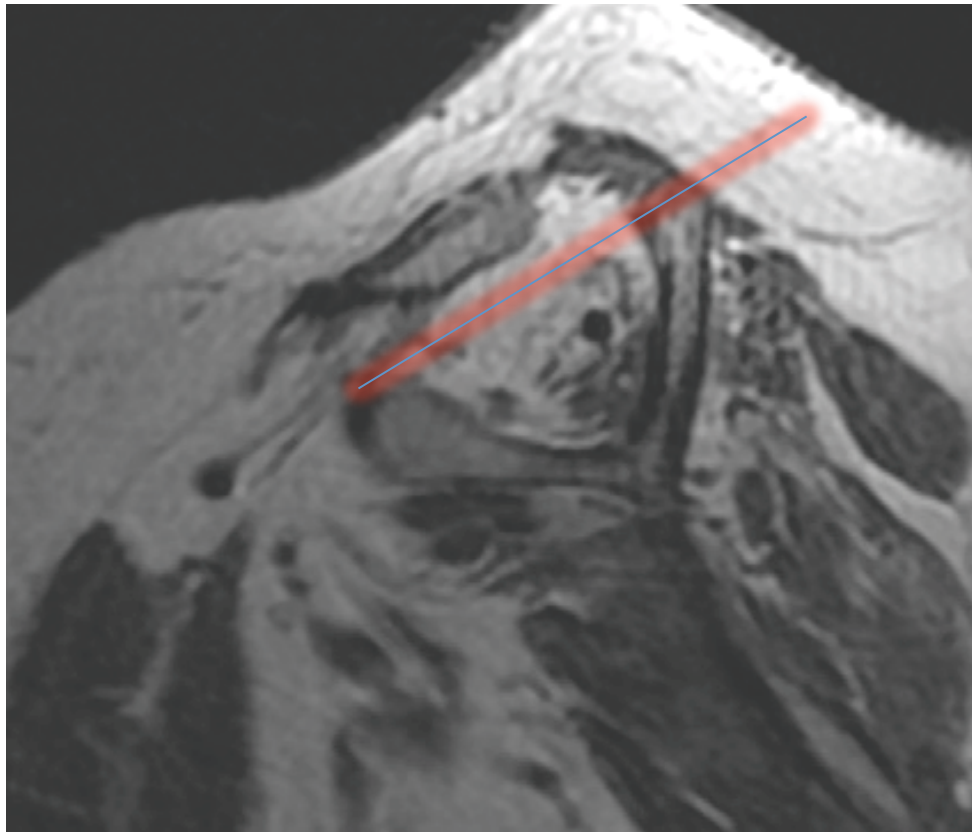
Natural History

Clin Orthop Relat Res (2010) 468:1498–1505

- Walsch, Boston
- Relationship of fatty infiltration and atrophy and prognosis of cuff repair
- Study to determine the speed of appearance and progression of this phenomenon, and to correlate fatty infiltration with muscular atrophy.
- We did not measure rotator cuff tear size or tendon retraction as there is not a reliable
- However, as demonstrated by Yamaguchi et al., asymptomatic tears are usually small, becoming symptomatic as their size increases .
- Retraction of the torn rotator cuff tendon may be a factor in the development of supraspinatus fatty infiltration.

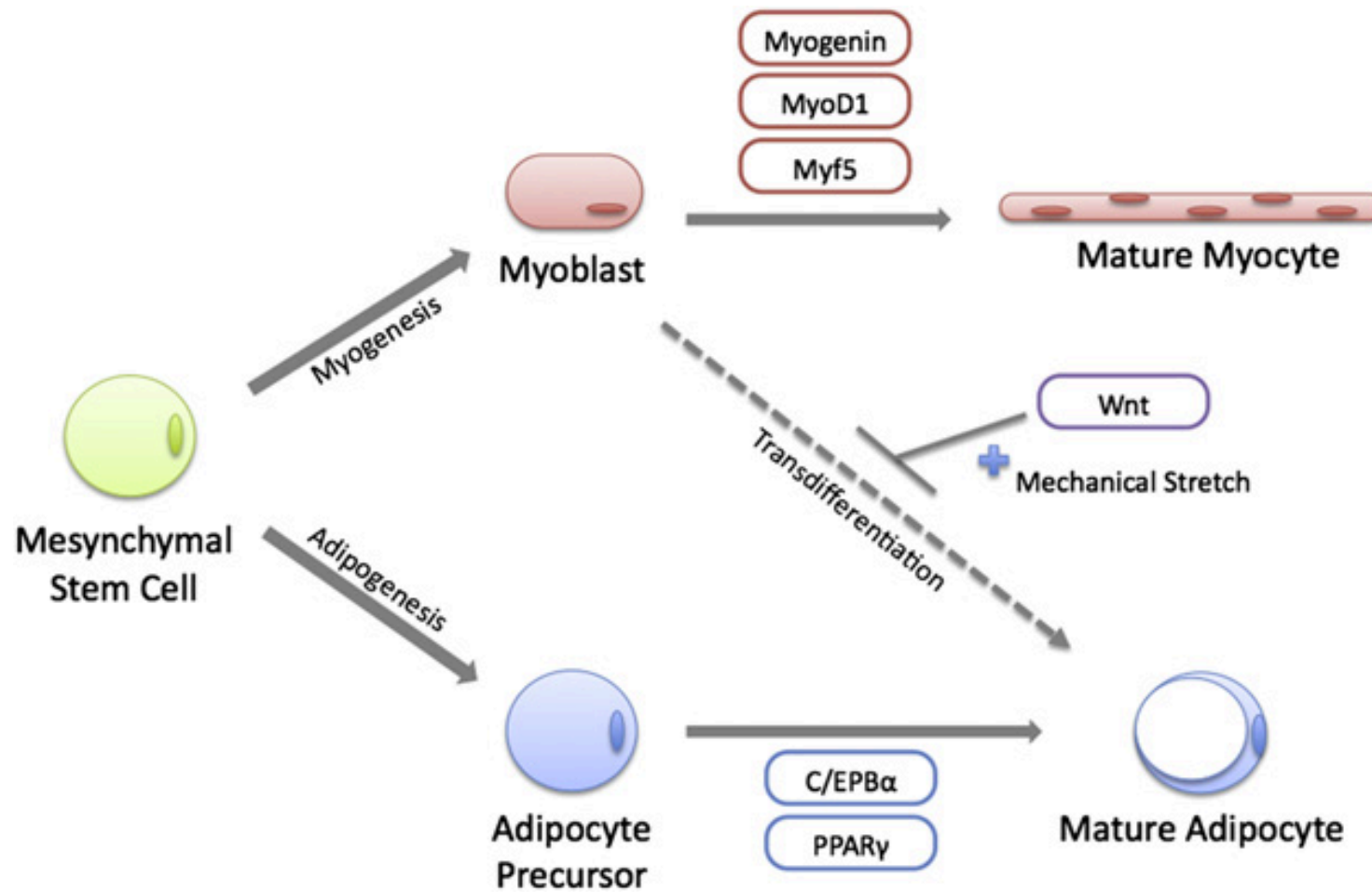
- Degenerative muscular changes associated with rotator cuff tears include fatty infiltration and atrophy .
- Both of these changes influence healing and clinical outcome of rotator cuff repairs
- Several studies have associated these changes with poor clinical outcome
- The natural history of fatty infiltration is described as irreversible and, usually, progressive.
- Indeed, fatty infiltration graded as Stage 2 or higher is associated with a definitive loss of muscular function and, increases the rate of repair failure
- . Although the changes may be irreversible, repair seems to halt atrophy because in patients with a retear there was more atrophy compared to patients with a healed supraspinatus repair
- Increasing patient age correlated with the presence and severity of supraspinatus

- 1. The onset of fatty infiltration is earlier, and its progression is faster in patients with more than one tear.
- 2. The time between the onset of rotator cuff symptoms and diagnosis of rotator cuff tear plays a major role in the development of muscular changes.
- 3. For traumatic tears, the time of onset of symptoms is easier to determine than in others types (degenerative or mixed).
- 4. We observed that the fatty infiltration was minimal (stage 0 or 1) in small tears: if fatty infiltration is minimal in small symptomatic tears, we can presume that it is minimal or absent in asymptomatic small tears.
- 5. Greater supraspinatus fatty infiltration was observed with longer delay between symptom onset and the diagnosis of rotator cuff tear on imaging studies.



- T1-weighted sagittal image of a massive rotator cuff tear with extensive fatty atrophy of both the supraspinatus and the infraspinatus muscle belly.
- Note that only the central tendon slip (black dot) is visible within the supraspinatus fossa, while the remaining space has been replaced with fat.

Pathogenesis



- Transcription factors regulating the differentiation of myoblasts into mature muscle cells include myogenin, MyoD1, and Myf5. In addition, the Wnt signaling pathway has been identified as a key regulator of adipogenesis of MSCs.
- Another study established that mechanical stretch in muscle directly activates Wnt signaling to inhibit myoblast differentiation into adipocytes.¹ These studies suggest that the loss of mechanical stretch initiates adipogenic pathways of pluripotent stem cell

Time of tear and fatty atrophy

- With all rotator cuff tear types in this study, moderate (Stage 2) fatty infiltration developed at an average of 4 years (45.7 months \pm 61.8 months) after the onset of symptoms.
- Severe fatty infiltration appeared at an average of 6 years after the onset of symptoms.
- Nevertheless for patients who experienced traumatic rotator cuff tears, moderate (Stage 2) fatty infiltration appeared at an average of 3 years after the initial incident onset of symptoms. Severe fatty infiltration (stage 3 or 4) developed at an average of 5 years after the initial incident/onset of symptoms.
- We used the **tangent sign** as an indirect measure of muscle atrophy, observing a positive tangent sign more frequently in cases where more rotator cuff tendons were torn. Atrophy in the supraspinatus was associated with a concomitant infraspinatus tear, but not a subscapularis tear.

Time interval Vs Tangent sign

- The development of a tangent sign also correlated with the time interval between onset of symptoms and diagnosis of rotator cuff tear. **With all tear types under consideration in this study, a negative tangent sign occurred at a mean of 2.5 years** (30.2 months \pm 47.1 months) and a positive tangent sign at 4.5 years (55 months \pm 63.5 months) after the onset of symptoms (Table 6).
- The data suggest the tangent sign is negative when there is minimal fatty infiltration.
- The progression of fatty infiltration is faster in rotator cuff tears that are traumatic and/or involve more than one tendon with moderate (Stage 2) fatty infiltration appearing at an average of 3 years after onset of symptoms.
- **Based on the findings in this study, rotator cuff repair should be performed before the appearance of fatty infiltration (Stage 2) and atrophy (positive tangent sign)** and as soon as possible in older patients when the tear involves multiple tendons.

Tangent sign

- Indirectly using the tangent sign on the most lateral cut of the sagittal plane where the spine appears in contact with the scapula on the MRI/CT as described by Zanetti
- A healthy supraspinatus should cross a line drawn for the superior border of the coracoid process to the superior border of the scapular spine; this line is called the “tangent.”
- Failure of the supraspinatus to cross the tangent is considered a “tangent sign”

- Because the distribution of fatty infiltration through a muscle belly is variable and random, the final stage of supraspinatus fatty infiltration was determined by grading the muscle in an entire set of three imaging planes (coronal, axial, and sagittal)
- The average of these values was defined as the final stage of fatty infiltration for the supraspinatus muscle.

Animal Study Fatty atrophy J Bone Joint Surg Am.

2010;92:2270-2278●

- Methods: New Zealand white rabbits were divided into three groups: (1) partial rotator cuff tear without retraction of the muscle, (2) complete rotator cuff tear with retraction of the muscle, and (3) nerve transection of the subscapular nerve.
- Conclusions: This study establishes the rabbit subscapularis muscle as a valid model to study the muscular changes associated with rotator cuff tears.

Our data suggest that the muscular changes associated with complete tenotomy are comparable with those seen with denervation of the muscle and suggest that chronic rotator cuff tears may induce a neurologic injury.

- Clinical Relevance: Chronic rotator cuff injuries are associated with neuronal injury of the affected muscle. As such, neuronal injury may explain the histopathologic changes that have been observed following chronic rotator cuff tears.

- 1. The increase in fat exhibited a spatial pattern, with higher fat accumulation distally (closer to the tendon attachment as compared with proximally).
- 2. Denervated muscle showed a similar fat accumulation pattern, both temporally and spatially.
- 3. Fat in the subscapularis muscle is directly related to the extent of tendon injury, which is consistent with findings in humans.
- 4. Complete tenotomy with retraction of the muscle resulted in extensive fat accumulation and a decrease in weight.

Goutallier Type: CORR (2010) 468:1558–1564

Table 1. Criteria for grading fatty degeneration of rotator cuff muscles

Grade (Goutallier et al. [8])	Proportion of the muscle	Stage (Fuchs et al. [6])
0	No fatty deposits	Normal muscle
1	Some fatty streaks	
2	Muscle > fat	Moderately pathologic muscle
3	Muscle = fat	Advanced degeneration
4	Muscle < fat	

Fatty degeneration.

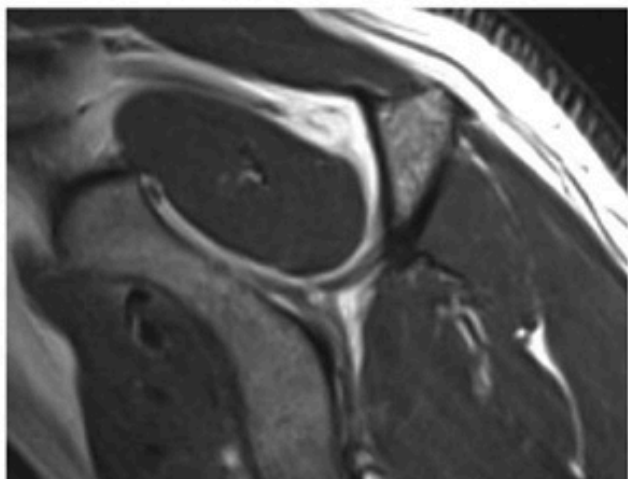
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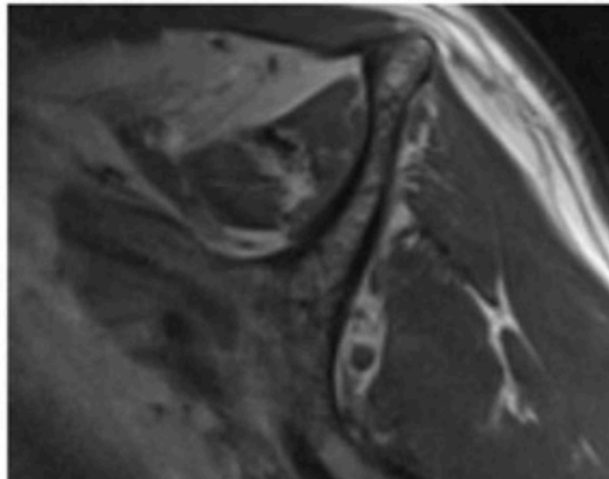
Goutallier Stage (CT)	Degree of Fatty Change	Fuchs Stage (MRI)
0	Normal muscle (no fatty deposits)	I
I	Some fatty streaks present	
II	More muscle than fat	II
III	Equal muscle and fat	III
IV	More fat than muscle	

B

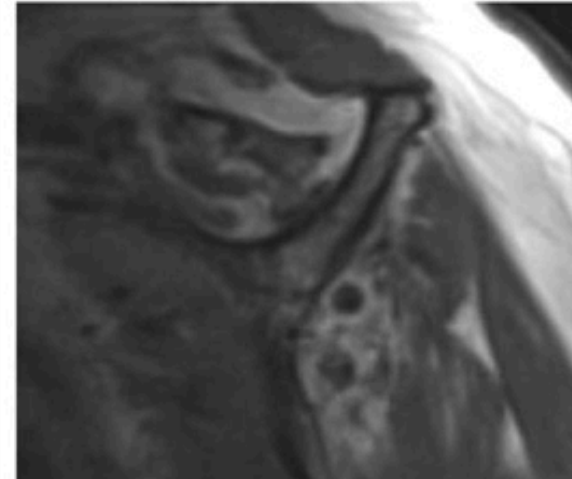
Fuchs Stage I



Fuchs Stage II



Fuchs Stage III



Drawbacks

1. The FD of each cuff muscle usually is measured at one cross-sectional image rather than the whole muscle belly. Relatively distally located evaluation points may not well represent the condition of the entire muscle.

Rotator cuff tear with fatty infiltration is a progressive and infiltrative process that increases with time and fatty infiltration progresses from the musculotendinous junction

The cross-sectional areas of the muscle may be highly and directly influenced by retraction of the musculotendinous junction of the torn rotator cuff

JBJS . 92-A d NUMBER 13:2276, 2010

- The complete, chronically detached subscapularis muscle in this rabbit model changes significantly, with a decrease in muscle mass, a decreased cross-sectional area, and an increase in fat content.
- The muscle fiber type was not changed as compared with that of the control groups. In addition, we showed that the increase in fat exhibited a spatial pattern, with higher fat accumulation distally (closer to the tendon attachment as compared with proximally).
- Denervated muscle showed a similar fat accumulation pattern, both temporally and spatially. Furthermore, the nerve specimens from the rabbits that underwent complete tenotomy revealed evidence of neuronal injury, as did the nerve specimens from animals in which the nerve was transected.
- Rotator cuff pathology is associated with progressive and likely irreversible degenerative changes of the rotator cuff muscles. The amount of atrophy and fatty degeneration influences several clinical parameters, such as strength and loss of function, and may affect the results of rotator cuff repair^{2,10}, Clin Orthop Relat Res. 1997;344:275-83., J Shoulder Elbow Surg. 1999;8:599-605.; J Bone Joint Surg Am. 2005;87:2662-70., J Bone Joint Surg Am. 2000;82:505-15..
- Despite the importance of these factors, there are few studies that address the quantitative changes present in the muscle following rotator cuff injury, and there is limited understanding of the mechanisms behind these processes^{22,23}.
- Gerber et al.²⁶ and Coleman et al.²⁷ reported significant fat infiltration of the detached infraspinatus muscle in sheep models but showed differing outcomes with regard to reversal of the fatty degeneration process. In studies in which the effects of early and delayed reattachment of torn rotator cuff tendons in rabbits were evaluated, it was found that the reattachment of the tendon at either time point reversed the atrophy or fat accumulation^{12,16}.

- We found a significant increase in fat content in chronically detached (tenotomy) muscles at six weeks after injury, with minimal fat accumulation at two weeks after injury. The fat accumulation exhibited a distinct spatial variation. Distal to the origin of the subscapularis muscle, there was a higher accumulation of fat than there was proximally, demonstrating a nonuniform pattern.
- Another study of chronically detached rabbit supraspinatus muscles showed an increase in fat content from 1.3% in normal muscle to 5.4% in the detached muscle at twenty-four weeks after injury, although minimal changes were noted at twelve weeks after injury¹².
- Furthermore, the present magnetic resonance imaging method of evaluating fatty atrophy
- in the supraspinatus muscle involves a single image obtained just medial to the scapular spine and may not be sufficient to assess this important biologic parameter. The experimental data have shown a spatial pattern of fat accumulation in the affected muscle, with a higher percentage of fat accumulation in the distal aspects and a milder accumulation proximally; therefore, an analysis of a limited region of the muscle may inaccurately measure the amount of accumulation within the supraspinatus. The data from this study

- The data from this study also support the concept that **the amount of infiltration of fat in the subscapularis muscle is directly related to the extent of tendon injury**, which is consistent with findings in humans.
- In computed tomography studies performed in humans, the closer the tendon stump is to the glenoid fossa, the higher is the percentage of fat accumulation
- Furthermore, more severe fatty degeneration is noted with larger tears that extend into the infraspinatus from the supraspinatus.
- The use of the term fatty degeneration has been called into question by investigators who have sought to understand the spatial location and source of the fatty tissue.
- Gerber et al. used electron microscopy to document that the process is not fatty degeneration but rather a fatty infiltration, with the remaining muscle fibers atrophied but still capable of recovery²⁶. In that study, the histology showed both extrafascicular and interfascicular fat accumulation, with the greatest amount of fat being found between the fascicles in all groups.

- Cadaver studies have shown a **significant increase in tension of the suprascapular nerve at the notch with associated tendon retraction**. Additionally, electromyographic studies of the suprascapular nerve have shown slowing of conduction and the F-wave action potential in complete rotator cuff tears, suggesting an injury to the neuromuscular axis
- Thus, findings of atrophy, cross-sectional area loss, and increased fat in the muscles of animals with a tenotomy may in part be explained by neuronal injury and are consistent with
- the hypothesis that a rotator cuff tear, and the associated myotendinous retraction, may induce an injury to the primary motor nerve unit.
- This neural injury may contribute to the irreversibility of the muscle injury and delayed healing after primary rotator cuff repair. Degenerative changes in tenotomy models are less severe when there is interruption of either the afferent pathways or sensory outflow

Epidemiology:

• Clin Orthop Relat Res (2010) 468:1498–1505

Table 1. Type of rotator cuff tears and epidemiology

Variable	Partial thickness SS tears	Full thickness SS tears	Isolated SScap tears	SS + Sscap tears	SS + IS ± TM tears	SS + IS + Sscap tears	Total
n	232	577	115	353	246	165	1688
%	13.7%	34.2%	6.8%	20.9%	14.6%	9.7%	100%
Age at imaging (years)	51.7	56.8	52.1	58.5	59.9	63.1	57.2
Male	62.1%	52.9%	80.9%	62%	58.9%	60%	59.2%
Dominant side	62.1%	69%	75.7%	78.2%	71.1%	78.2%	71.6%
Traumatic onset	33.5%	35.8%	46%	45.1%	43.6%	39%	39.6%
Degenerative onset	62.5%	56.5%	49.6%	48.6%	44%	58.5%	53.5%
Mixed onset	4%	7.7%	4.4%	6.3%	12.4%	2.5%	6.9%

SS = supraspinatus; Sscap = subscapularis; IS = infraspinatus; TM = teres minor.

Age and fatty infiltration

Table 3. Fatty infiltration (FI) stages according to age class
($p < 0.0005$)

Supraspinatus fatty infiltration	Age		
	50 years or younger	Between 50 and 60 years old	60 years or older
Minimal	90%	73%	47%
Moderate	9%	24%	41%
Severe	1%	3%	12%

Onset of symptoms and MRI

Table 4. Delay between the symptoms onset and the imaging studies for the different fatty infiltration stages (variation observed according to the onset.)

Supraspinatus fatty infiltration	Delay onset – imaging studies (months)		
	Total	Traumatic onset	Progressive onset
Minimal	23.6 ± 36.8	19.4 ± 37.3	29.5 ± 37.5
Moderate	45.7 ± 61.8	34.8 ± 55.7	54.1 ± 66.7
Severe	70.3 ± 74.2	57.7 ± 66.7	83.9 ± 80.2

Between minimal and moderate and between minimal and severe:
 $P < 0.0005$.

- On average, moderate (Stage 2) fatty infiltration appeared **at a mean of 4** years after the onset of symptoms
- severe fatty infiltration appeared at an average of 6 years after the onset of symptoms.
- In traumatic tears, where the delay can be precisely determined, moderate (Stage 2) fatty infiltration appeared at an average of 3 years
- **The prevalence of muscle atrophy** increased with the number of torn tendons; in other words, we observed a positive tangent sign less frequently in partial tears of the supraspinatus and more commonly in massive rotator cuff tears involving supraspinatus, infraspinatus, and subscapularis

- 1. The influence of fatty infiltration and atrophy on healing and outcome
- 2. The onset of fatty infiltration is earlier, and its progression is faster in patients with more than one tear.
- 3. The time between the onset of rotator cuff symptoms and diagnosis of rotator cuff tear plays a major role in the development of muscular changes.
- 4. For traumatic tears, the time of onset of symptoms is easier to determine than in others types (degenerative or mixed).
- 5. Greater supraspinatus fatty infiltration was observed with longer delay between symptom onset and the diagnosis of rotator cuff tear on imaging studies.
- 6. Atrophy in the supraspinatus was associated with a concomitant infraspinatus tear, but not a subscapularis tear.
- 7. Based on the findings in this study, rotator cuff repair should be performed before the appearance of fatty infiltration (Stage 2) and atrophy (positive tangent sign) and as soon as possible in older patients when the tear involves multiple tendons.

Fatty atrophy and muscle atrophy

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The primary goal of this study was to explore the relationship between fatty infiltration, atrophic muscle changes, and tears of the supraspinatus tendon.

This study was unable to prove the hypothesis that fatty infiltration and atrophy are 2 distinct and independent pathologic processes resulting from tears in the supraspinatus.

In this study,

- Multivariate modeling demonstrated that significant independent predictors of fatty infiltration of supraspinatus include age, sex, tear severity, and the relative size of the muscle itself (atrophy).
- Older women with severe rotator cuff tears and atrophic muscles were more likely to show substantial fatty infiltration. When factors that

- We found that with increasing age, the prevalence of muscle atrophy and fatty infiltration both increase in patients without rotator cuff tears.
- This finding is supported by previous muscle studies demonstrating the aging process can result in a loss of muscle mass with subsequent replacement with fat and connective tissue.

Pathologic evidence of

degeneration as a primary cause of rotator cuff tear. Clin Orthop Relat 2003;415:111-20.

- Although fatty degeneration and atrophy are clearly seen in the pathologic rotator cuff, it is still unclear exactly how these changes occur, what causes them, and whether the processes are interrelated or two completely separate injury responses.

Prognosis

- **Muscle atrophy too has been found to be a poor prognosticator after rotator cuff repair.**

- Am J Sports Med 2007;35:719-28.

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