Fatty infiltration of the shoulder: diagnosis and reversibility

Leonardo Osti[1]
Matteo Buda[2]
Angelo Del Buono[3]

[1] Unit of Arthroscopic and Sports Medicine, Hesperia Hospital, Modena, Italy
[2] Unit of Orthopaedics and Traumatology, University of Ferrara, Italy
[3] Department of Orthopaedic and Trauma Surgery Hospital Antonio Cardarelli, Campobasso, Italy

Corresponding author:
Leonardo Osti
Unit of Arthroscopy and Sports Medicine, Hesperia Hospital
Via Arquà, 80/a
41125 Modena, Italy
E-mail: leonardoosti@yahoo.com

Summary

Fatty degeneration is a degenerative condition of the tendon-muscle unit of rotator cuff muscles, characterized by atrophy of muscle fibers, fibrosis, and fatty accumulation within and around the muscles. Many classification may be useful to stage this pathology, especially on Computed Tomography (CT) and magnetic resonance imaging (Mari) findings. Stem cell-based therapies for repair and regeneration of tendons and muscles may be used to promote healing and to make this condition reversible. Diagnosis and management of this condition is mandatory as in patients undergoing rotator cuff repair, it may influence outcomes, increase the likelihood of re-tearing, and evolve negatively.

KEY WORDS: fatty degeneration, diagnosis, management, outcomes.

Introduction

Originally described by Goutallier, fatty degeneration is a degenerative condition of the tendon-muscle unit of rotator cuff muscles, which incurs after rotator cuff tearing, characterized by atrophy of muscle fibers, fibrosis, and fatty accumulation within and around the muscles[1]. Mostly occurring in elderly patients, it is frequently associated with an aging-related reduction of the regenerative potential of rotator cuff tendons[2]. Given the close proximity between the muscle tendon-unit and rotator cuff tendons, a prompt diagnosis of this condition should be needed to improve outcomes after rotator cuff repair and better understand prognosis and evolution of patients with rotator cuff pathology. This review, arising from current classification systems for fatty infiltration, aims to define the impact of this condition on functional and clinical outcomes of patients with rotator cuff pathology.

Staging and classification

The classification staging system by Goutallier was conceived on Computed Tomography (CT) scanning, on axial images of the infraspinatus and subscapularis muscles to predict clinical outcomes and biomechanical features (repair integrity) after rotator cuff tendon repair (Tab. 1)[3]. Fuchs applied the same classification system on MRI scans (Tab. 2)[4]. The reliability of these system was successively tested, with no evident differences between the CT and MRI methods[5].
Another criterion, called “the tangent sign”, was introduced in 1998 to assess the atrophy of the rotator cuff complex[6]. Specifically, the supraspinatus muscle, when normal, lies always above the tangent line going from the superior aspect of the scapula to the superior portion of the scapular spine. This sign presents good inter-observer reliability, 100% sensitivity, 85% specificity, 67% positive predictive value, 100% negative predictive value[5]. When positive, this sign is highly correlated with the extent of the rotator cuff tear, and may be predictive of the good chances to repair successfully the tear. Rulewicz has found a

Table 1. Goutallier staging system.

Stage	Muscle description
0	Completely normal muscle
I	Some fatty streaks
II	Amount of muscle is greater than fatty infiltration
III	Amount of muscle is equal to fatty infiltration
IV	Amount of fatty infiltration is greater than muscle

Table 2. Fuchs grading system.

Grade	Rotator cuff fat content
Minimal	No fat to minimal fat
Moderate	More muscle than fat
Severe	Amount of fat is equal/greater than fatty infiltration

high correlation between the positivity of the tangent sign (positive) and the presence of a stage 2 or more (Goutallier classification) fatty infiltration[7].
Another method to measure muscle atrophy has been proposed by Thomazeau[8] and Schaeffer[5]: the occupation ratio is used to evaluate the percentage of atrophy of the supraspinatus muscle. The cross-sectional area of the belly of the supraspinatus muscle is placed in relation with the area of the supraspinatus fossa: and when the occupation ratio decreases the size of the tear increases.
Marked architectural changes occur within the muscle tissue after tendon release and musculotendinous retraction: fiber shortening, increased pennation angle, and fatty infiltration[9,10]. All these changes may be appreciated at MRI. When comparing US and MRI for assessment of atrophy and fatty infiltration of the supraspinatus muscle, the two methods provide comparable sensitivity, although it is difficult to distinguish moderate from severe fatty infiltration[11].

Neurological cause of muscle athrophy

Suprascapular nerve (SSN) and rotator cuff function are closely associated. A suprascapular neuropathy should be considered in patients with postero-superior shoulder pain, atrophy or weakness of supraspinatus and infraspinatus muscles without any rotator cuff tear or retraction[12]. Retracted tears of the supraspinatus may be associated with SSN neuropathy, probably as consequence of an increased tension over the suprascapular notch and on the nerve[13]. This neuropathy has been found in 8-27% of patients with massive rotator cuff tears[14]. The main feature of this condition is a slow speed conduction of the fibres of the suprascapular nerve which increases proportionally with the percentage of atrophy[15, 16]. Axillary nerve disorders and cervical radiculopathy have to also considered.
The pattern of fatty infiltration in patients with rotator cuff tear without suprascapular neuropathy is different from that of patients with suprascapular nerve dysfunction without rotator cuff tear[17]. Although chronic rotator cuff tears and suprascapular neuropathy may be both associated with fatty infiltration and atrophy of the rotator cuff muscles, the features of the fatty infiltrations are markedly different.
The suprascapular neuropathy can be assessed by electromyography and nerve conduction velocity. The current evidence is rotator cuff repair may improve electromiographic changes, atrophy, and fatty infiltration[18].

Biological and regenerative approaches

Stem cell-based therapies for repair and regeneration of tendons and muscles may also be used for management of fatty infiltration and muscle atrophy[19].
Specifically, satellite cells or mesenchimal stem cells may promote regeneration in damaged muscles and improve a condition of muscle atrophy[20]. The effect of injections of periosteal progenitor cells and poly ethylene glycol diacrylate tethered with bone morphogenic protein-2 (PPCs-BMP2-hydrogel) in patients with rotator cuff tears is encouraging, promoting the neo-formation of fibro-cartilage, which has an inductive action on tendon and bone, and enhances the tendon-bone healing process.
Locally administered ADSCs may promote the tendon bone healing, and improve fatty infiltration, by inducing electrophysiological, biomechanical, and histological changes[21]. Although the administration of vascular endothelial growth factor (VEGF)[22] the injection of PRP products improve biomechanical properties (tensile strength and stiffness) of repaired Achilles tendons[23], there is no evidence that these products would be used in a condition of fatty infiltration of the shoulder[24].

Fatty infiltration and outcomes after rotator cuff repair

A study on 220 shoulders followed up at an average of 37 months after surgery showed that functional outcomes were positively correlated with the stage of fatty degeneration present at baseline and at the last follow-up[25]. There is evidence of re-tear recurrence in 28% of patients undergoing repair of an isolated tear of the supraspinatus tendon, with little fatty degeneration staged less than 2, and a tendon stump close to the greater tuberosity[26].
The fact that at a significant functional improvement in terms of Constant and UCLA scores was reported at a mean follow-up of 39 months in 84% of patients with massive rotator cuff tears and Goutallier stage 3 or 4 fatty degeneration of the infraspinatus induces to suppose that an advanced fatty infiltration is not an absolute contra-indication to arthroscopic repair of rotator cuff tears[27]. In another study on 29 patients undergoing open repair for massive rotator cuff tears, fatty infiltration had increased postoperatively in infraspinatus, supraspinatus and subscapularis muscles, especially when the tendon of the respective muscle was found to be torn at operation time[28]. Nevertheless, at the last follow-up, the Constant score was significantly improved, pain was decreased, and almost all patients had successfully returned to daily activities ($p < 0.05$).
A study compared outcomes of 38 patients undergoing rotator cuff repair for management of full thickness rotator cuff tears at an average of 62 years: 15 underwent open surgery, 23 underwent arthroscopic repair[29]. At 1 year follow-up, ASES, Constant and Pain scales were significantly improved than at baseline ($p<0.0001$), with evidence of negative association between the quality of the muscle and postoperative outcomes. The tear size was the only parameter predictive of cuff integrity. Both atrophy and fatty infiltration progressed significantly over time, mostly in patients who presented a re-tear[29].
A delayed diagnosis worsen the prognosis, as both the tendon and muscle belly undergo atrophy and degeneration, with significantly better outcomes for patients with low stage fatty infiltration than for those with a severe condition[30].

Another study on patients undergoing arthroscopic repair for isolated tears of the supraspinatus tendon showed that not only fatty infiltration but also older age at surgery were positive predictive features for re-tear[31].
There is no evidence that muscular atrophy decreases significantly after repair of the tendon but, conversely, the condition will progress, regardless of functional scores and pain[26]. Patients undergoing transosseous repair of chronic massive rotator cuff tears were significantly improved at the final follow-up after the surgery[32]. The number of patients in whom muscle atrophy and fatty infiltration were improved was significantly higher than that in whom the condition was worsened, showing a strong association between preoperative grading of muscle atrophy and fatty infiltration and repair integrity[33]. A study on 22 patients who underwent open repair for rotator interval tears showed that the repair is successful and effective when muscle atrophy is limited[34].
A retrospective series of 47 patients (49 shoulders) undergoing open surgery for reinsertion of retracted tears of the supraspinatus tendon showed that none of preoperative MRI parameters had been predictive for re-tearing. The highest functional scores were observed ($p = 0.01$) when the standardized area of the supraspinatus muscle was greater than 0.5[35].
On the other hand, a study on 60 patients undergoing rotator cuff arthroscopic repair showed medial-lateral tear size, tear retraction to the glenoid or beyond, atrophy, high grade fatty infiltration, and increased inferior glenohumeral distance are all negative predictive factors after repair of large or massive rotator cuff tears[36].

Conclusions

We now stress that muscle atrophy and fatty infiltration should be carefully evaluated before surgery in patients candidates to undergo shoulder surgery. Mesenchimal Stem Cells seem to be beneficial to promote healing and to make this condition reversible. After rotator cuff repair, muscle athrophy may influence outcomes, increase the likelihood of re-tearing, and evolve negatively.

References

1. Goutallier D, Postel J, Bernageau J, Lavau L, Voisin M. Fatty muscle degeneration in cuff ruptures. Pre- and postoperative evaluation by CT scan. Clin Orthop Relat Res 1994; 304: 78-83.
2. Gumucio J, Korn M, Saripalli A, et al. Aging-associated exacerbation in fatty degeneration and infiltration after rotator cuff tear. J Shoulder Elbow Surg 2014; 23: 99-108.
3. Williams M, Lädermann A, Melis B, Barthelemy R, Walch G. Fatty infiltration of the supraspinatus: a reliability study. J Shoulder Elbow Surg 2009; 18: 581-587.
4. 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 Shoulder Elbow Surg 1999; 8: 599-605.
5. Schaefer O, Winterer J, Lohrmann C, Laubenberger J, Reichelt A, Langer M. Magnetic resonance imaging for supraspinatus muscle atrophy after cuff repair. Clin Orthop Relat Res 2002; 403: 93-99.
6. Zanetti M, Gerber C, Hodler J. Quantitative assessment of the muscles of the rotator cuff with magnetic resonance imaging. Invest Radiol 1998; 33: 163-170.
7. Rulewicz G, Beaty S, Hawkins R, Kissenberth M. Supraspinatus atrophy as a predictor of rotator cuff tear size: an MRI study utilizing the tangent sign. J Shoulder Elbow Surg 2013; 22: e6-10.
8. Thomazeau H, Boukobza E, Morcet N, Chaperon J, Langlais F. Prediction of rotator cuff repair results by magnetic resonance imaging. Clin Orthop Relat Res 1997; 344: 275-283.
9. Meyer D, Hoppeler H, von Rechenberg B, Gerber C. A pathomechanical concept explains muscle loss and fatty muscular changes following surgical tendon release. J Orthop Res 2004; 22: 1007-1007.
10. Farshad M, Würgler-Hauri C, Kohler T, Gerber C, Rothenfluh D. Effect of age on fatty infiltration of supraspinatus muscle after experimental tendon release in rats. BMC Res Notes 2011; 4: 530.
11. Khoury V, Cardinal E, Brassard P. Atrophy and fatty infiltration of the supraspinatus muscle: sonography versus MRI. AJR Am J Roentgenol 2008; 190: 1105-1111.
12. Shi L, Freehill M, Yannopoulos P, Warner J. Suprascapular nerve: is it important in cuff pathology? Adv Orthop 2012; 2012: 516985.
13. Albritton M, Graham R, Richards R, Basamania C. An anatomic study of the effects on the suprascapular nerve due to retraction of the supraspinatus muscle after a rotator cuff tear. J Shoulder Elbow Surg 2003; 12: 497-500.
14. Boykin R, Friedman D, Higgins L, Warner J. Suprascapular neuropathy. J Bone Joint Surg Am 2010; 92.
15. Mallon W, Wilson R, Basamania C. The association of suprascapular neuropathy with massive rotator cuff tears: a preliminary report. J Shoulder Elbow Surg 2006; 15: 395-398.
16. Vad V, Southern D, Warren R, Altchek D, Dines D. Prevalence of peripheral neurologic injuries in rotator cuff tears with atrophy. J Shoulder Elbow Surg 2003; 12: 333-336.
17. Beeler S, Ek E, Gerber C. A comparative analysis of fatty infiltration and muscle atrophy in patients with chronic rotator cuff tears and suprascapular neuropathy. J Shoulder Elbow Surg 2013; 22: 1537-1546.
18. Gerber C, Meyer D, Schneeberger A, et al. Effect of tendon release and delayed repair on the structure of the muscles of the rotator cuff: an experimental study in sheep. J Bone Joint Surg Am 2004; 86-A: 1973-1982.
19. Uysal A, Mizuno H. Tendon regeneration and repair with adipose derived stem cells. Curr Stem Cell Res Ther 2010; 5: 161-167.
20. Kawiak J, Brzóska E, Grabowska I, et al. Contribution of stem cells to skeletal muscle regeneration. Folia Histochem Cytobiol 2006; 44.
21. Oh J, Chung S, Kim S, Chung J, Kim J. 2013 Neer Award: Effect of the adipose-derived stem cell for the improvement of fatty degeneration and rotator cuff healing in rabbit model. J Shoulder Elbow Surg 2013; S1058-2746: 00398-4.
22. Zhang F, Liu H, Stile F, et al. Effect of vascular endothelial growth factor on rat Achilles tendon healing. Plast Reconstr Surg 2003; 112: 1613-1619.
23. Maffulli N, Del Buono A. Platelet plasma rich products in musculoskeletal medicine: any evidence? Surgeon; 10: 148-50.
24. Del Buono A, Papalia R, Denaro V, Maccauro G, Maffulli N. Platelet rich plasma and tendinopathy: state of the art. Int J Immunopathol Pharmacol; 24: 79-83.
25. Goutallier D, Postel J, Radier C, Bernageau J, Zilber S. Long-term functional and structural outcome in patients with intact repairs 1 year after open transosseous rotator cuff repair. J Shoulder Elbow Surg 2009; 18: 521-528.

26. Fuchs B, Gilbart M, Hodler J, Gerber C. Clinical and structural results of open repair of an isolated one-tendon tear of the rotator cuff. J Bone Joint Surg Am 2006; 88: 309-316.
27. Burkhart S, Barth J, Richards D, Zlatkin M, Larsen M. Arthroscopic repair of massive rotator cuff tears with stage 3 and 4 fatty degeneration. Arthroscopy 2007; 23: 347-354.
28. Gerber C, Fuchs B, Hodler J. The results of repair of massive tears of the rotator cuff. J Bone Joint Surg Am 2000; 82: 505-515.
29. Gladstone J, Bishop J, Lo I, Flatow E. Fatty infiltration and atrophy of the rotator cuff do not improve after rotator cuff repair and correlate with poor functional outcome. Am J Sports Med 2007; 35: 719-728.
30. Warner J, Higgins L, Parsons I, Dowdy P. Diagnosis and treatment of anterosuperior rotator cuff tears. J Shoulder Elbow Surg 2001; 10: 37-46.
31. Liem D, Lichtenberg S, Magosch P, Habermeyer P. Magnetic resonance imaging of arthroscopic supraspinatus tendon repair. J Bone Joint Surg Am 2007; 89: 1770-1776.
32. Yamaguchi H, Suenaga N, Oizumi N, Hosokawa Y, Kanaya F. Will preoperative atrophy and Fatty degeneration of the shoulder muscles improve after rotator cuff repair in patients with massive rotator cuff tears? Adv Orthop 2012; 2012: 195876.
33. Petersen S, Murphy T. The timing of rotator cuff repair for the restoration of function. J Shoulder Elbow Surg 2011; 20: 62-68.
34. Di Schino M, Augereau B, Nich C. Does open repair of anterosuperior rotator cuff tear prevent muscular atrophy and fatty infiltration? Clin Orthop Relat Res 2012; 470: 2776-2784.
35. Nich C, Mütschler C, Vandenbussche E, Augereau B. Long-term clinical and MRI results of open repair of the supraspinatus tendon. Clin Orthop Relat Res 2009; 467: 2613-2622.
36. Dwyer T, Razmjou H, Henry P, Gosselin-Fournier S, Holtby R. Association between pre-operative magnetic resonance imaging and reparability of large and massive rotator cuff tears. Knee Surg Sports Traumatol Arthrosc 2013.