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Extensibility of the supraspinatus muscle with a rotator cuff tear evaluated by magnetic resonance imaging

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Abstract An estimate of the extensibility of the supraspinatus muscle after a rotator cuff tear is useful in selecting the most appropriate operative procedure and the prognosis after surgery. We studied the relationship between the morphological findings of the supraspinatus muscle on magnetic resonance imaging and its elongation length. Twenty-one shoulders of 20 patients with massive rotator cuff tears were scanned parallel to the long axis of the supraspinatus muscle. The ratio of the largest width of the supraspinatus muscle belly to the distance from the greater tuberosity to the proximal end of the supraspinatus muscle was termed the supraspinatus muscle belly ratio. The appearance of linear bands and the degree of retraction of the tendon of the supraspinatus muscle were analyzed. The extensibility of the supraspinatus muscle decreased when the degree of retracted tendon was high, while no correlation was found with the length of the rotator cuff defect, the supraspinatus muscle belly ratio, or the appearance of linear bands.

Key words Extensibility · Supraspinatus muscle · Tendon fiber · Rotator cuff tear · Magnetic resonance imaging

Introduction

The incidence of severe muscle atrophy is very high in patients with large rotator cuff tears.[1–3] An estimation of the extensibility of an atrophic supraspinatus muscle with a torn cuff is useful in selecting the most appropriate operative procedure for repairing the torn cuff and for giving a prognosis after surgery. However, there are no quantitative analyses in the literature comparing the morphological changes of a supraspinatus muscle belly demonstrated by magnetic resonance imaging (MRI) with its extensibility. In the present study, the morphological and volumetric changes in the supraspinatus muscle belly were preoperatively analyzed using MRI and compared with its elongation length at surgery.

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Materials and methods

Twenty-one shoulders of 20 patients with massive rotator cuff tears (tear length ≧4 cm) requiring surgical repair were imaged preoperatively using MR scans. The patients were 11 men and 9 women, ranging in age from 49 to 84 years (mean 66.4 years). Preoperative symptoms were present for a mean period of 11 months (range 1 month to 8 years). They had neither glenohumeral arthritis nor neurological deficits. Patients were scanned preoperatively using a 20-cm circular surface coil with a 0.5 Tesla unit (MRT-50A/2, Toshiba Medical System, Tokyo, Japan). The patients were examined in the supine position, with their arms kept in neutral rotation. Imaging in all patients was performed in the oblique coronal plane, parallel to the long axis of the supraspinatus muscle belly. T1-weighted sequences (spin echo method TR/TE = 450/20) and T2*-weighted sequences (gradient field echo method, TR/TE = 500/22, flip angle = 30°) were obtained. The thickness of the sections was 5 mm, with a 1-mm gap between sections. The field of view was 250 mm and the number of signals averaged two. The matrix size was 256 × 512.

The morphological changes in the supraspinatus muscle belly were analyzed. A T1-weighted image was used to evaluate fatty degenerative changes. The appearance of linear bands (indicative of fatty replacement[3]) were classified into three grades. Grade 1 represented the absence of a

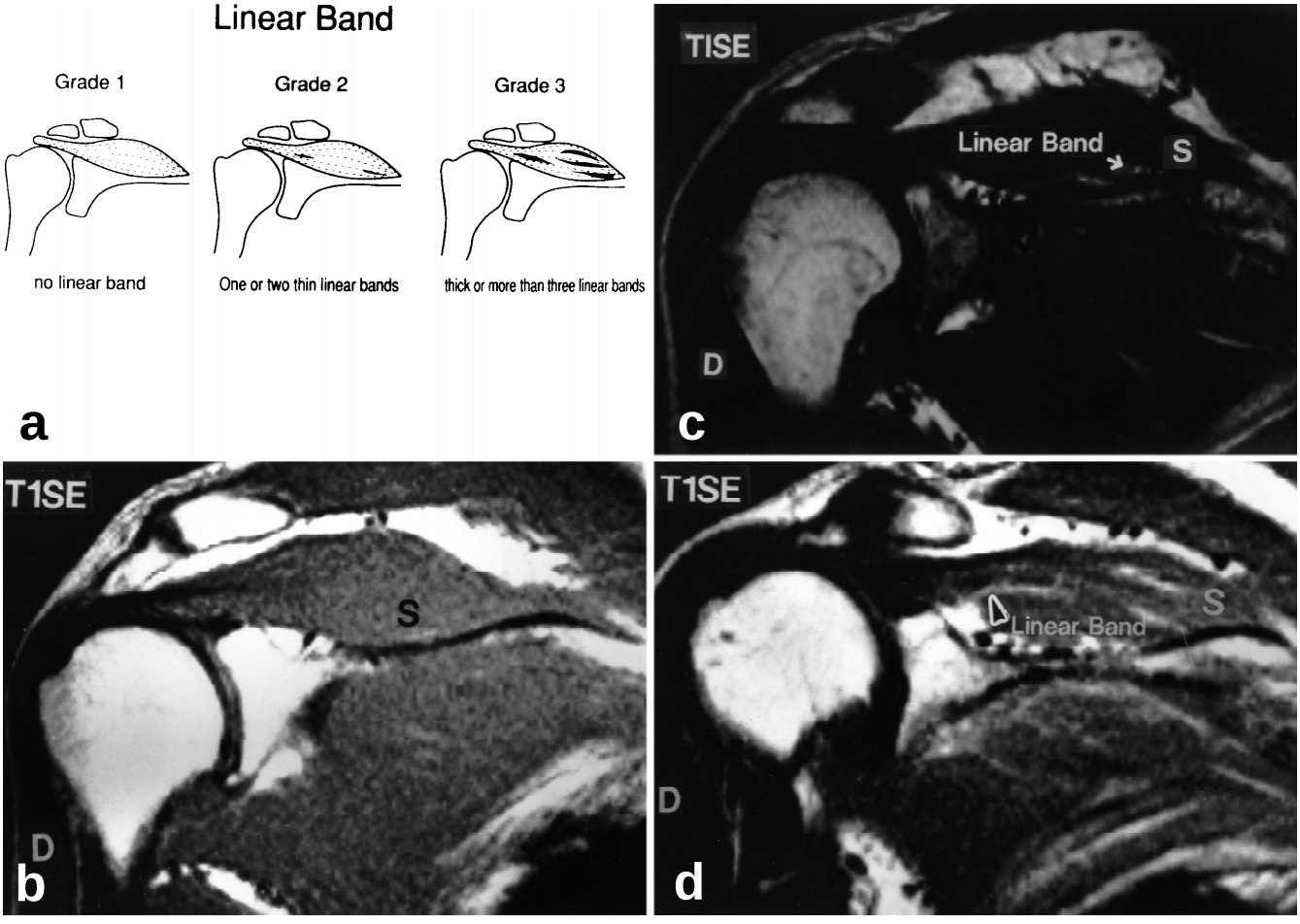

Fig. 1. Classification of linear bands: T1-weighted image. *S*, supraspinatus muscle; *D*, deltoid muscle. **a** Grades of linear band appearance: Grade 1, no linear band; Grade 2, presence of 1 or 2 narrow linear bands; Grade 3, presence of 3 or more narrow linear bands, or 1 or 2 thick linear bands. **b** Grade 1 (normal). **c** Grade 2. **d** Grade 3

linear band in the supraspinatus muscle belly. In Grade 2, one or two narrow linear bands were identified. In Grade 3, three or more narrow linear bands or one or two thick linear bands were identified (Fig. 1).[4,5]

A T2*-weighted image was used to recognize the retracted anterior thick tendon. The supraspinatus muscle belly between the glenoid edge and the proximal end of the supraspinatus fossa was divided into three parts of equal length. The degree of retraction of the tendons was also classified into three grades. In Grade 1, the retracted tendon fiber remained in the distal part. In Grade 2, it remained in the middle part. In Grade 3, the tendon fiber was retracted into the proximal part (Fig. 2).

The image slice showing the greatest distance from the greater tuberosity to the proximal end of the supraspinatus muscle was selected for evaluation. The ratio of the greatest width of the supraspinatus muscle belly to the distance from the greater tuberosity to the proximal end of the supraspinatus muscle on a T1-weighted sequence was calculated, and was defined as the "supraspinatus muscle belly ratio" (SMBR) (Fig. 3), which was the index of the volumetric change of the supraspinatus muscle.

Surgery was performed on all shoulders approximately 1 month after MRI scanning. A supraspinatus tendon tear was present in each rotator cuff tear. A measurement of the distance from the superior facet of the greater tuberosity to the supraspinatus muscle edge was taken with the arm at the side in neutral rotation, and was termed the length of the rotator cuff defect. All shoulders had a rotator cuff defect exceeding 4 cm. This distance was measured later after resecting the coracohumeral ligament and the subacromial bursa, removing the adhesion between the rotator cuff and the deltoid muscle, and pulling out the cuff. The difference between the two measured distances was termed the elongation length of the supraspinatus muscle, which was compared with the length of the rotator cuff defect and the supraspinatus muscle belly ratio using Peason's correlation coefficient. A correlation was considered to be statistically significant when the absolute value was greater than 0.5. The elongation length of each of the morphologic grades of the supraspinatus muscle was compared by one-way analysis of variance and Duncan's multiple range test. The level of significance was set at 0.05.

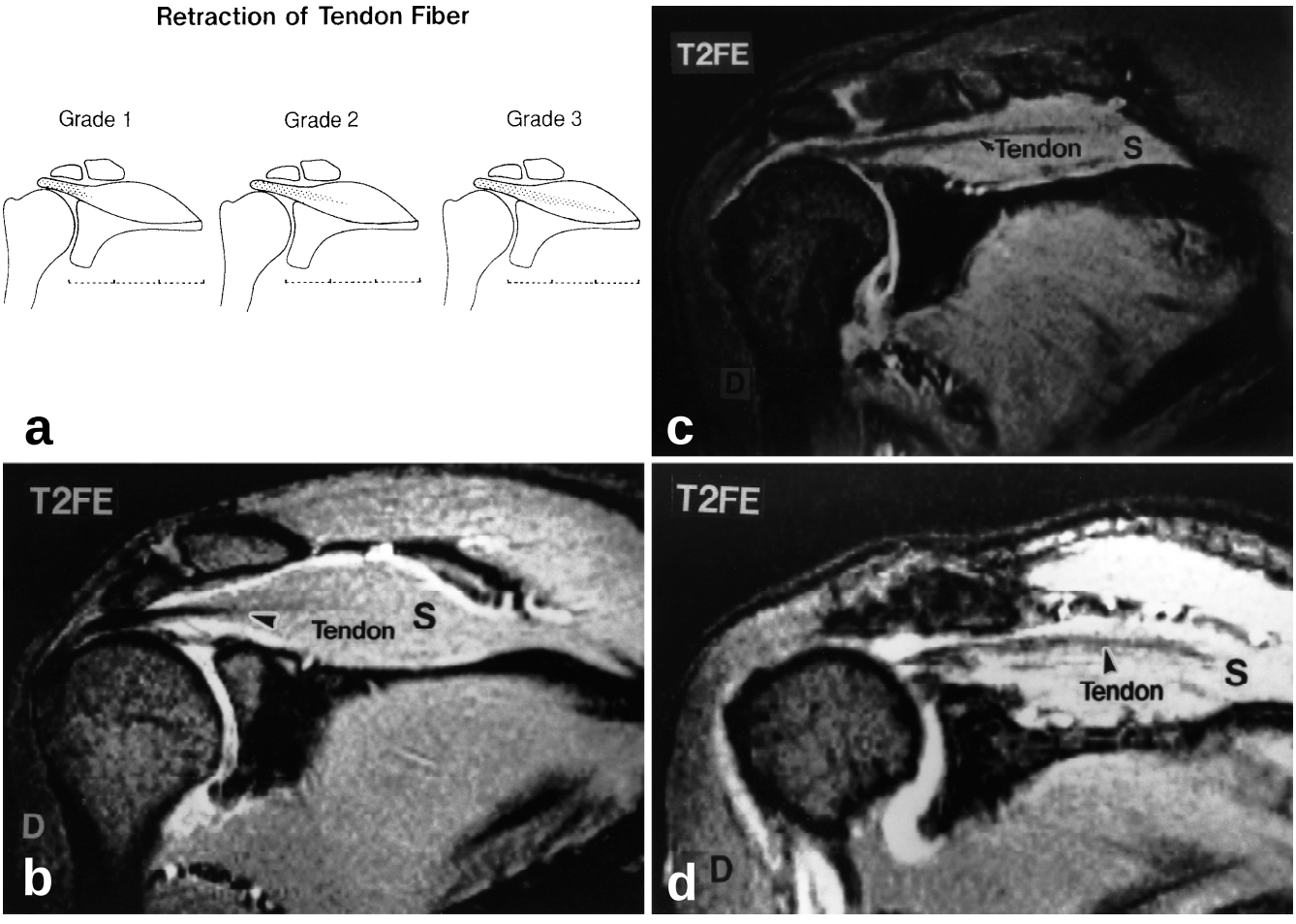

Fig. 2. Classification of the retraction of the tendon fiber: T2*-weighted image. *S*, supraspinatus muscle; *D*, deltoid muscle. **a** Grades of retracted tendon fiber: Grade 1, visible only in the distal part; Grade 2, visible in the middle part; Grade 3, visible in the proximal part of the supraspinatus fossa. **b** Grade 1 (normal). **c** Grade 2. **d** Grade 3

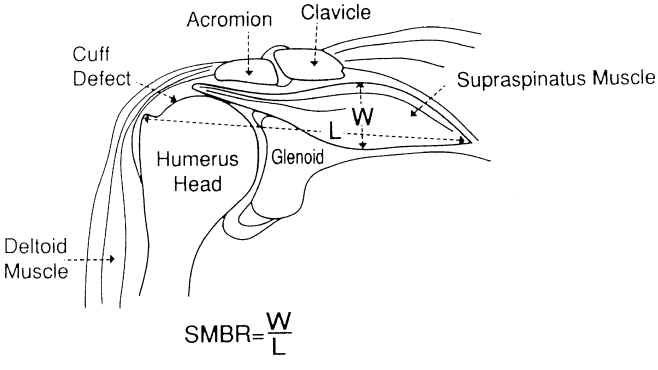

Fig. 3. Calculation of the supraspinatus muscle belly ratio (SMBR)

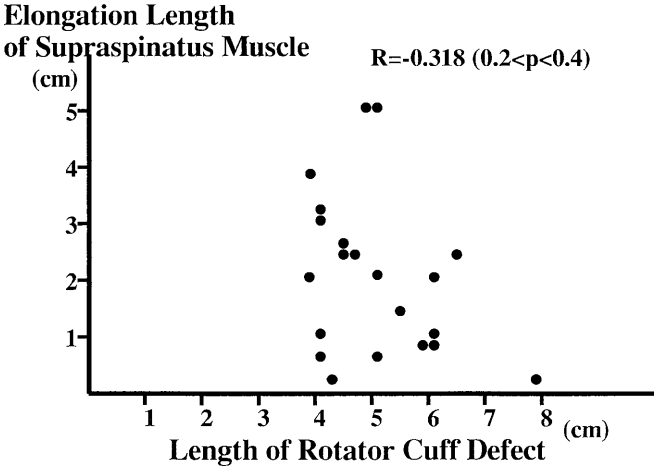

Fig. 4. Relationship between the length of the rotator cuff defect and the elongation length of the supraspinatus muscle

Results

There was no correlation between the length of the rotator cuff defect and the elongation length of the supraspinatus muscle (correlation coefficient -0.318, $0.2 < P < 0.4$) (Fig. 4). There was also no correlation between the supraspinatus muscle belly ratio and the elongation length of the rotator cuff defect (correlation coefficient 0.138, $0.6 < P < 1$) (Fig. 5). All the linear band appearances were Grade 2 or Grade 3, and did not correlate with the elongation length (Fig. 6a).

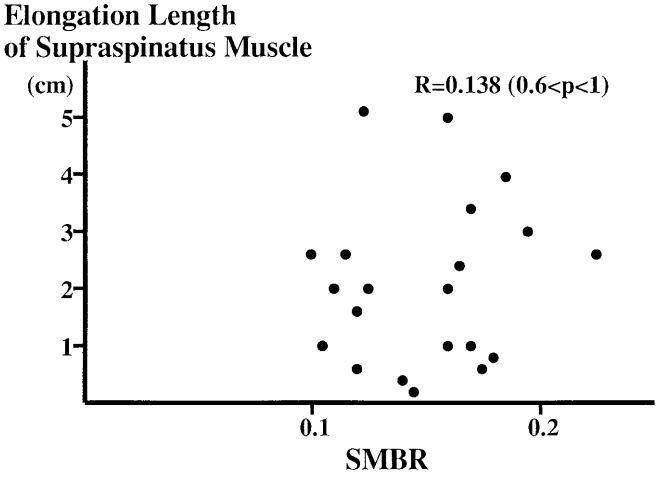

Fig. 5. Relationship between the supraspinatus muscle belly ratio and the elongation length of the supraspinatus muscle

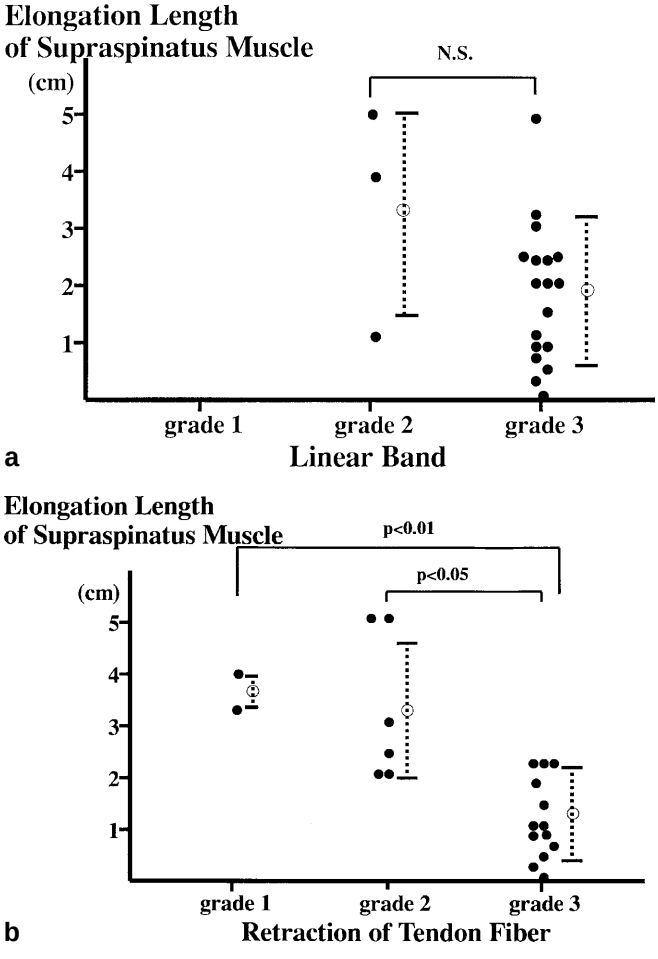

Fig. 6. Relationship between the grade of the morphological changes in the supraspinatus muscle belly and the elongation length of the supraspinatus muscle. **a** Relationship between the grade of the appearance of the linear bands of the supraspinatus muscle belly and the elongation length of the supraspinatus muscle. **b** Relationship between the grade of retraction of the tendon fiber in the supraspinatus muscle belly and the elongation length of the supraspinatus muscle

There were distinct differences among the elongation lengths of the supraspinatus muscles in the associated grades of retraction of the tendon. When an increase in the degree of retraction of the tendon was shown with MR images, the elongation length of the supraspinatus muscle decreased (Fig. 6b).

There was no correlation between the elongation length of the supraspinatus muscle and the duration of preoperative symptoms (correlation coefficient -0.0384, $0.6 < P < 1$).

Discussion

We occasionally encounter difficulty in mobilizing the rotator cuff edge to the greater tuberosity in massive tears. The extensibility of a supraspinatus muscle with a massive rotator cuff tear is generally lower than that of a normal supraspinatus muscle. It is difficult to appraise the extensibility of supraspinatus muscles with massively torn rotator cuffs prior to surgery. In the present study, the elongation length of supraspinatus muscles with massive rotator cuff tears was compared with the morphologic changes of the supraspinatus muscles in MR images. The extensibility of a supraspinatus muscle with a massive rotator cuff tear was estimated using MR imaging.

Gagey et al.[6] has reported that the anterior part of the supraspinatus muscle with a fibrous frame had less extensibility than other muscle parts. In our previous anatomical study on cadavers, the supraspinatus muscle belly was connected tightly to the spine of the scapula rather than to the anterior part of the supraspinatus fossa.[7] The anterior part of the supraspinatus muscle is thought to slide easily when the rotator cuff is torn. The anterior thick tendon fiber is expected to be retracted into the supraspinatus muscle. The degree of retraction of the anterior thick tendon fiber was correlated with the length of the rotator cuff defect,[7] and we recognized that the band with a low signal intensity which continued from the rotator cuff in the supraspinatus muscle belly on a T2*-weighted image corresponded to the anterior thick tendon fiber. In our present study, the further the anterior thick tendon fibers of the supraspinatus muscle belly were retracted towards the proximal end of the muscle, the less extensibility of the supraspinatus muscle was obtained.

The length and thickness of the intramuscular tendon fiber of the supraspinatus muscle vary among individuals.[7,8] The extensibility of a muscle is reported to be associated with the number of the sarcomeres in series.[9,10] Muscles with long intramuscular tendon fibers have short muscle fiber parts, and these muscles have fewer sarcomeres than those with short intramuscular tendon fibers even in the same kind of muscles. Also, the excursion of muscles with long intramuscular tendon fibers is lower than that of muscles with short fibers. Thus, we believe that the extensibility of supraspinatus muscles with long intramuscular retracted tendon fibers is decreased. When a rotator cuff is torn, the extensibility of the supraspinatus muscle is thought to

decrease due to a retraction of the anterior thick tendon fiber. The extensibility was not related to the size of the rotator cuff defect, or to volumetric and fatty degenerative changes on MR images. We believe that the muscle activity is not associated with the extensibility of the muscle belly. Even a muscle with no activity can be stretched, but a muscle with a retracted tendon can hardly be stretched at all without breaking its muscle structure. The preoperative symptom period and the elongation length of the supraspinatus muscle did not correlate with each other. This may be because many patients had little or no pain for a long period of time, despite the presence of a rotator cuff tear, which delayed the diagnosis.

If a tendon is ruptured, isometric contractions cannot occur. Thus, a chronic tendon rupture gives rise to muscle atrophy by disuse. Similarly, we believe that chronic rotator cuff tears cause muscle atrophy by disuse. Some previous papers reported on the fatty degeneration of the supraspinatus muscle. Björkenheim[11] reported that the supraspinatus muscle in rabbits in which tendinous parts have been removed had decreased contractile activity and increased development of fatty degeneration. Goutallier et al.[12] reported that muscular fatty degeneration of the rotator cuff seen on computed tomography scans implies a tear of the corresponding tendon. Seeger et al.[13] reported that MR images depict the extent of muscle retraction in patients who have complete ruptures of their supraspinatus tendons. Muscular atrophy is characterized by bands of bright signals within the muscle belly, indicative of fatty replacement on T1-weighted images. In dissecting cadaveric shoulders, we recognized fatty degeneration around the tendon fibers which continued into the torn cuff tendon in the atrophic supraspinatus muscle belly (Fig. 7).[8] The linear bands in the supraspinatus muscle belly seen on MR images are thought to be the result of fatty degeneration around the tendon fibers in the muscle.

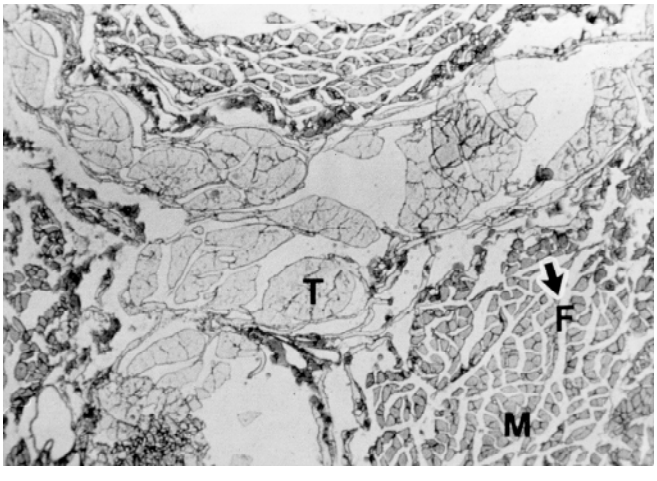

Fig. 7. Transverse section from a cadaver of the supraspinatus muscle associated with a rotator cuff tear. *F*, fatty degeneration tissue; *M*, muscle fiber; *T*, tendon fiber. Fatty degeneration near the tendon fiber is shown (Sudan three stain, ×20)

Conclusions

By analyzing MR images of morphological changes in a supraspinatus muscle with a massive torn rotator cuff, it is possible to evaluate the extensibility of the supraspinatus muscle and select the most appropriate operative procedure, for example using a cuff substitute or muscle transfer, and predict the postoperative outcome. When the anterior thick tendon fibers of the supraspinatus muscle belly were retracted towards the proximal one-third of the muscle on MRI, the extensibility of the supraspinatus muscle was much decreased. In such a case we should use a cuff substitute or transfer the muscle.

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