MRI Findings of Rotator Cuff Myotendinous Junction Injury

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OBJECTIVE. The purpose of this article is to describe the MRI features of rotator cuff myotendinous junction injuries.

MATERIALS AND METHODS. We retrospectively identified MRI cases with myotendinous junction injury of the rotator cuff muscles and reviewed clinical, imaging, and surgical records. MR images were reviewed independently by two musculoskeletal radiologists to grade myotendinous junction injuries (strain, partial tear, or complete tear) and to assess for concurrent tendon tears (partial or full thickness) and bone changes (fracture or contusion).

RESULTS. The final study group comprised 16 subjects. The mean age was 38 years, with a majority of men (56%). The left shoulder was affected in 56% of subjects, with the dominant upper limb affected in 50%. The mean time between symptoms and MRI was 19 days. Subjects reported heavy lifting (19%), landing on the arm after a fall (19%), or prior shoulder therapeutic injection (25%). Myotendinous junction injuries affected the infraspinatus muscle (50%), followed by the supraspinatus (31%), subscapularis (25%), and teres minor (19%) muscles. About one fifth of subjects presented with more than one muscle affected, and 94% did not present with tears of the corresponding tendons. Most myotendinous junction injuries were strains (80%), followed by partial tears (20%). No complete tears were identified. There was no correlation between myotendinous junction injury and the presence of bone changes or the presence of tendon tears ($p > 0.05$).

CONCLUSION. Rotator cuff myotendinous junction injuries affect mostly the infraspinatus and supraspinatus muscles, usually in a strain pattern and without tear of the corresponding tendon attachment.

Keywords: MRI, myotendinous junction, rotator cuff, strain, tear

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The myotendinous junction is the weakest point of a myotendinous unit, because it is less capable of absorbing energy than either muscle or tendon and it allows injuries along a wider range of trauma [1, 2]. Myotendinous junction injuries are graded as strains that heal without adverse sequelae (grade 1), partial tears (grade 2), and complete tears (grade 3) [2, 3]. Although myotendinous junction injuries are generally well recognized in the literature, there are limited data regarding such injuries in rotator cuff muscles. Prior studies have focused on myotendinous junction injury of individual muscles (supraspinatus or infraspinatus) without assessing concurrent involvement of other components of the rotator cuff [1, 3–6]. Furthermore, to our knowledge, no studies have described the features of subscapularis and teres minor myotendinous junction injuries.

Rotator cuff myotendinous junction injuries are distinct from rotator cuff tendon tears on the basis of anatomic location, epidemiology, imaging characteristics, progression, treatment, and outcome [5]. For example, although rotator cuff tendon tears occur within a 2-cm zone surrounding their insertion [7, 8], rotator cuff myotendinous junction injuries are located several centimeters medially, frequently with intact tendon attachments and acute severe edema [3–5]. Importantly, rotator cuff myotendinous junction injuries may evolve with high-grade fatty infiltration [3–5].

The goal of this study is to describe the clinical and MRI features of rotator cuff myotendinous junction injury in a cohort of subjects imaged at a tertiary academic institution. We sought to determine the clinical profile of affected subjects, major symptoms and clinical examination findings, and therapeutic approach. We also evaluated the distribution and grade of myotendinous junction injuries, as well as the presence of tendon tears involving all components of the rotator cuff, bone abnormalities, and tendon calcifications.

Materials and Methods

Subject Selection and Clinical Information

This study was approved by the institutional review board of Partners HealthCare and complied with HIPAA guidelines, with exemption status for individual informed consent. A retrospective search was performed in a database of reports generated for shoulder MRI obtained at our institution from July 1994 to May 2013. Among shoulder MRI studies performed in this period, we selected cases by searching for a combination of terms in the impression field, including “myotendinous or musculotendinous,” “edema, strain, tear, or rupture,” and the name of each rotator cuff muscle (supraspinatus, infraspinatus, subscapularis, and teres minor). Exclusion criteria included subjects with more than 60 days between symptom onset and MRI examination [9–11], the absence of myotendinous junction injury on MRI despite positive report, edema not surrounding the myotendinous junction, suboptimal MRI examination (characterized by motion artifacts or incomplete study), evidence of prior shoulder surgery, muscle inflammatory or infectious process, tumors, and findings suggestive of nerve disorder affecting the shoulder.

For every case, we reviewed medical records, radiology reports, and surgical notes when available. Clinical data included age, sex, dominant upper limb, mechanism of injury, symptoms and physical examination of affected shoulder, time between onset of pain and MRI examination, previous therapeutic injections, and management.

Imaging Studies

MRI examinations of the shoulder were performed according to a departmental protocol in the supine position (with the extended alongside of the body) using a phased-array dedicated coil, on 1.5- or 3-T scanners. Most of the examinations used the following sequences: axial multiplanar gradient recalled (TR/TE, 600/18; number of excitations, 1; matrix, 320 × 256; thickness, 3 mm; FOV, 14 cm), coronal proton density–weighted (TR/TE, 2366/28; number of excitations, 1; matrix, 448 × 320; thickness, 3 mm; FOV, 16 cm), coronal T2-weighted fat-suppressed (TR/TE, 3000/52; number of excitations, 1; matrix, 320 × 256; thickness, 3 mm; FOV, 16 cm), sagittal T1-weighted (TR/TE, 500/15; number of excitations, 1; matrix, 448 × 320; thickness, 4 mm; FOV, 14 cm), and sagittal T2-weighted fat-suppressed (TR/TE, 3133/47; number of excitations, 1; matrix, 320 × 256; thickness, 4 mm; FOV, 14 cm) or STIR (TR/TE, 5000/43; number of excitations, 1; matrix, 256 × 192; thickness, 4 mm; FOV, 16 cm). Shoulder radiographs were assessed when available (anteroposterior in neutral rotation, anteroposterior in external rotation, and axillary view).

Reading Technique and Qualitative Parameters

All MRI examinations were evaluated independently for myotendinous, tendon, and bone abnormalities using all imaging planes on a PACS by two fellowship-trained musculoskeletal radiologists with 4 years (reader 1) and 33 years (reader 2) of experience.

The rotator cuff muscles were examined for myotendinous junction injuries and were graded as normal, strain (edema surrounding the myotendinous junction), partial tear (fluidlike signal intensity [SI] partially involving the myotendinous junction), or complete tear (fluidlike discontinuity SI transecting the myotendinous junction). In muscles with multiple myotendinous junctions (e.g., subscapularis), the highest grade lesion was considered.

Shoulder bones (humerus, scapula, acromion, and clavicle) were classified as normal, contusion (traumatic pattern of marrow edema), or fracture (cortical discontinuity). Rotator cuff tendon tears, if present, were classified as partial or full-thickness tear. Both readers examined available shoulder radiographs independently regarding calcifications at attachment sites of rotator cuff tendons [4, 5].

Attention was paid to an increased SI due to the magic angle effect at the medial portion of rotator cuff tendons, especially regarding the supraspinatus tendon [12]. To avoid overcalling myotendinous junction injury because of this pitfall, both readers carefully evaluated T2-weighted images with attention to the cuff surface, and they determined whether the SI abnormality was present in different planes [12]. Minor SI changes at the medial portion of the supraspinatus tendon were ignored. In addition, we carefully analyzed images to differentiate myotendinous junction injuries from dissecting intramuscular cysts resulting from delaminating rotator cuff tendon tears [13].

Statistical Analyses

The weighted kappa statistic was used to determine interobserver agreement on graded scales of abnormalities of bone, tendon, and myotendinous junction. The Fisher exact test two-tail statistical analysis was performed to evaluate differences between groups. All statistics were calculated using JMP (version 5.0.1, SAS Institute) and MedCalc software (version 12.3.0.0, MedCalc).

Values for $p < 0.05$ were considered statistically significant. A kappa value of 0–0.20 indicated poor agreement, 0.21–0.40 indicated fair agreement, 0.41–0.60 indicated moderate agreement, 0.61–0.80 indicated good agreement (significant), and 0.81–1.00 indicated very good agreement (almost perfect). Data analyses were performed using interpretations from the more experienced reader (reader 2); interpretations from reader 1 were used only to assess interobserver agreement.

Results

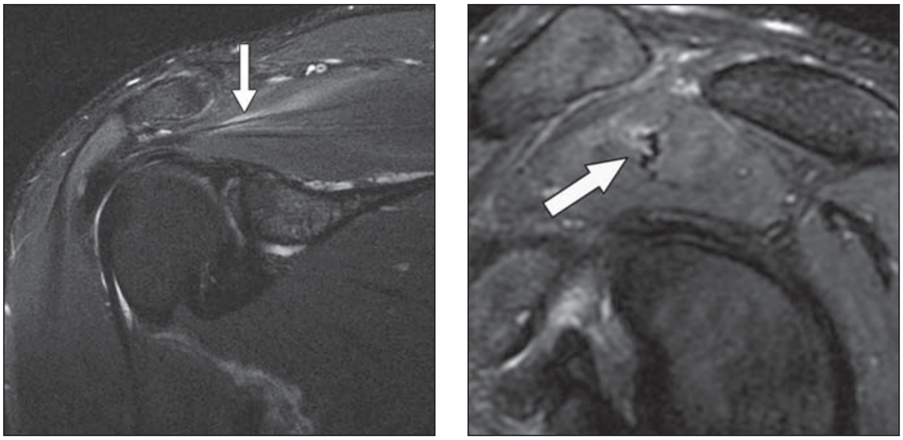
Subject Selection

We identified 32 subjects with positive reports for rotator cuff myotendinous injuries who underwent shoulder MRI at our institution from July 1994 to May 2013. Sixteen subjects were excluded as follows: four subjects because the time between symptom onset and MRI examination was longer than 60 days, two subjects because of the absence of myotendinous junction injury on MRI despite a positive report, two subjects because of evidence of prior shoulder surgery, two subjects because of infectious process affecting muscles of the rotator cuff, four subjects because of patchy edema involving muscle belly suggesting a denervation pattern, and two subjects because of minor SI abnormality identified next to the medial supraspinatus tendon. The final study group comprised 16 subjects.

Clinical Information and Imaging Studies

Most MRI scans were performed on a 1.5-T scanner (94% [15/16]), with 6% (1/16) obtained on a 3-T scanner. The mean age was 38 years (range, 12–57 years). There were 56% men (9/16) and 44% women (7/16). The left shoulder was affected in 56% (9/16) and the right shoulder was affected in 44% (7/16) of subjects. In subjects for whom upper limb dominance information was available, there was equal distribution between dominant (50% [5/10]) and nondominant limbs affected (50% [5/10]). In subjects for whom a specific date of injury was available (81% [13/16]), the mean time between onset of symptoms and MRI examination was 19 days (range, 1–60 days).

Analyzing the mechanism of injury, 19% (3/16) of subjects reported heavy lifting for work or at the gym, 19% (3/16) of subjects landed on the shoulder or arm after a ground-level fall, 12% (2/16) of subjects experienced direct trauma during a motor-vehicle crash (one subject) or fall from a ladder (one subject), 6% (1/16) of subjects had a sudden



A

B

Fig. 1—29-year-old man with painful left shoulder after performing pull-ups and push-ups at gym 2 days earlier.
A and **B,** Coronal (**A**) and sagittal (**B**) T2-weighted fat-suppressed MR images show strain of myotendinous junction of supraspinatus muscle (*arrow*). Corresponding tendon attachment was intact (not shown).

shoulder pain during a wrestling match but did not recall a specific movement, and 6% (1/16) presented with shoulder dislocation. In six subjects (38%), there was no information or clear mechanism of injury available.

Before MRI examination, four patients (25%) received a single-site steroid shoulder injection. These injections were performed at the clinician's office, without imaging guidance, and included three subjects with subacromial injection and one subject for whom the injection site was not specified. The approach for the injections was not described in the clinical notes. The mean time between injection and the onset of symptoms was 42 days (range, 40–46 days). All four subjects presented with myotendinous junction injury of the infraspinatus muscle, including a strain in two subjects and a partial tear in one subject, and strain of both supraspinatus and infraspinatus muscles in the last subject.

Major symptoms at initial presentation were pain (81% [13/16]), weakness (19% [3/16]), stiffness (19% [3/16]), swelling over the shoulder (12% [2/16]), and subluxation symptoms, clicking or snapping, and numbness (6% [1/16] for each symptom). Physical examination showed that 44% (7/16) of subjects had rotator cuff muscle focal tenderness, 31% (5/16) had painful limited range of movement, 12% (2/16) had weakness, 6% (1/16) had swelling, and 6% (1/16) had ecchymosis. Clinical information about symptoms was unavailable for 12% (2/16) of subjects, and physical examination information was unavailable for 19% (3/16) of subjects.

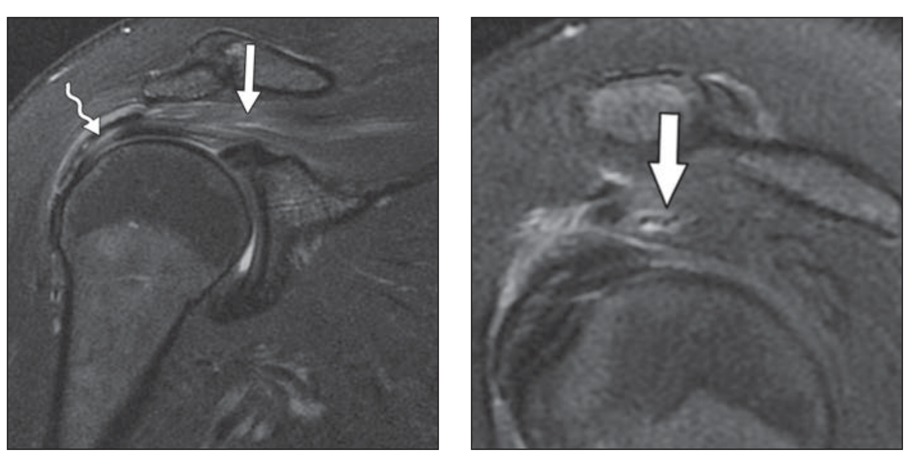
Regarding follow-up, 56% (9/16) of subjects underwent successful conservative treatment, with variable combinations of analgesics and nonsteroidal antiinflammatory drugs, slings, or physical therapy. One subject (6%) underwent arthroscopic surgery for labral repair. There was no surgery specifically for myotendinous injuries. Information on treatment was not available for 38% (6/16) of subjects

Myotendinous Junction Injury Overall

In an evaluation of all muscles from 16 subjects, myotendinous junction injuries were found in 20 muscles, with 80% (16/20) showing strains and 20% (4/20) showing partial tears. No complete myotendinous junction tear was identified. In 19% (3/16) of subjects, myotendinous junction injury affected more than one muscle, with the following distribution: supraspinatus and infraspinatus (12% [2/16]), and supraspinatus, infraspinatus, and teres minor (6% [1/16]).

Myotendinous Junction Injury by Muscle

Supraspinatus myotendinous junction injury was present in 31% (5/16) of subjects, with all cases showing strain edema (Figs. 1 and 2). Infraspinatus myotendinous junction injury was present in 50% (8/16) of subjects, graded as strain in 38% (6/16) and as partial tear in 12% (2/16) of subjects (Fig. 3). Subscapularis myotendinous junction injury was present in 25% (4/16) of subjects, graded as strain in 19% (3/16) and as partial tear in 6% (1/16) of subjects (Fig. 4). Teres minor myotendinous junction injury was present in 19% (3/16) of subjects, graded as strain in two subjects (Fig. 5) and as partial tear in



A

B

Fig. 2—39-year-old woman with painful right shoulder 12 days after injury from motor-vehicle crash.
A and **B,** Coronal (**A**) and sagittal (**B**) T2-weighted fat-suppressed MR images show strain of myotendinous junction of supraspinatus muscle (*straight arrow*, **A** and **B**), with partial tear of corresponding tendon attachment (*wavy arrow*, **A**).

one subject. The prevalence and distribution of myotendinous junction injuries are outlined in Table 1 and illustrated in Figure 6.

Myotendinous Junction Injury: Presence of Rotator Cuff Tendon Tear

Supraspinatus tendon tear was present in 25% (4/16) of cases, graded as partial in two subjects and as full-thickness in two subjects. Readers did not identify infraspinatus, subscapularis, or teres minor tendon tears.

Overall, 94% (15/16) of cases showed myotendinous junction injury with an intact corresponding tendon attachment. Only one subject presented with myotendinous junction injury with tear of the corresponding tendon in which strain of supraspinatus myotendinous junction was seen concurrently with partial tear of the tendon attachment (Fig. 2).

Interobserver agreement for myotendinous junction injuries and tendon tears is outlined in Table 2. Interobserver agreement was good for the detection of bone changes (κ = 0.7), which were present in 31% (5/16) of subjects; 19% (3/16) were contusions and 12% (2/16) were fractures. Interobserver agreement was perfect for the detection of tendon calcification (κ = 1.0). Radiographs of the shoulder were available in nine cases, with only one subject (11%) showing calcifications at the tendon attachment site on greater tuberosity.

There was no correlation between myotendinous junction injuries and the presence of bone changes (supraspinatus, $p = 0.55$; infraspinatus, $p = 0.73$; subscapularis, $p = 0.08$; teres minor, $p = 0.21$), or between myotendinous junction injuries and corresponding tendon tear (supraspinatus, $p = 1.00$; analyses were not performed for the infraspinatus, subscapularis, and teres minor muscles because no tendon tears were present).

TABLE 1: Prevalence of Myotendinous Junction Injuries in 16 Subjects

Structure	Strain	Partial Tear	Complete Tear	Total
Supraspinatus	31	0	0	31
Infraspinatus	38	12	0	50
Subscapularis	19	6	0	25
Teres minor	13	6	0	19

Note—Data are percentages.

Discussion

Our study shows that myotendinous junction injuries of the rotator cuff detected by MRI were present in 16 subjects over a 19-year span at an academic tertiary hospital. The mean age of our subjects was 38 years, close to previously described ranges of 41 years in supraspinatus myotendinous junction injuries [3] and 48–49 years for infraspinatus myotendinous junction injuries [4–6]. This finding supports the notion that myotendinous junction injuries occur in a younger population when compared with subjects with rotator cuff tendon tears [3, 5]. The dominant limb was injured in half of our subjects, which is within the reported rate ranging from 20% to 63% [3, 4, 6]. The average time between symptom onset and MRI examination in our study was 19 days, shorter than the range reported in previous studies (2.5–4.5 months) [3–6]. We did not have any subjects with bilateral shoulder involvement. Such presentation was reported previously by Lipford et al. [14], affecting the infraspinatus muscle after bilateral shoulder steroid injections.

Most of our subjects reported heavy lifting activities (19%) or landing on the shoulder after a ground-level fall (19%), with pain and limited range of movement being dominant findings on initial physical examination. Similar clinical presentation was reported by other studies [3–5], showing that 22–60% of subjects had some sort of trauma with special note of torsional movements. In our study, one subject reported being injured during a wrestling match. Despite sharing a similar profile of affected subjects with previous studies, our study is the first, to our knowledge, to show a complete panel of imaging characteristics from acute myotendinous junction injuries involving all rotator cuff components, as well as myotendinous junction injuries of the subscapularis and teres minor muscles, which have not been previously reported.

We found no correlation between myotendinous junction injuries and bone trauma or be-

TABLE 2: Interobserver Agreement

Structure	Myotendinous Injury	Tendon Tear
Supraspinatus	0.5	0.7
Infraspinatus	0.9	—
Subscapularis	1.0	—
Teres minor	0.6	—

Note—Data are weighted kappa values. Infraspinatus, subscapularis, and teres minor tendon tears were not identified (dashes).

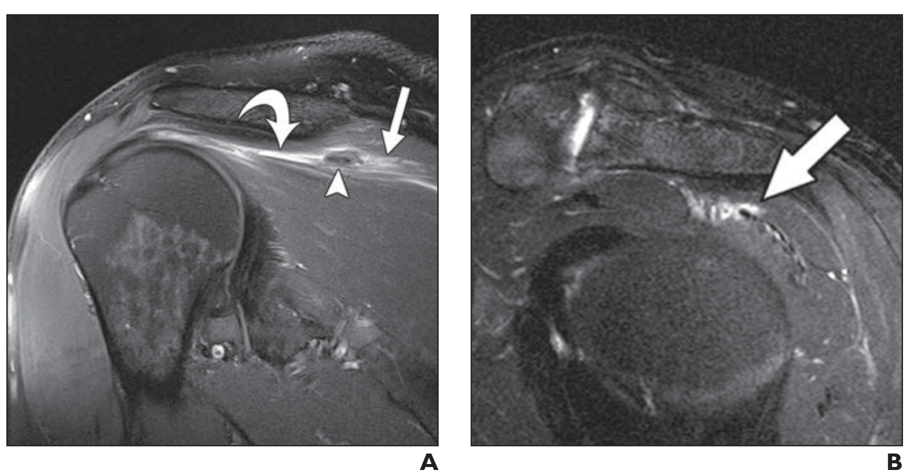


Fig. 3—50-year-old man with history of sudden pain at anterior aspect of left shoulder while heavy overhead lifting for work purposes 1 month earlier. **A** and **B**, Coronal (**A**) and sagittal (**B**) T2-weighted fat-suppressed MR images show partial tear of myotendinous junction of infraspinatus muscle (*straight arrow*, **A** and **B**), with focal retraction of fibers (*arrowhead*, **A**), and adjacent fluid (*curved arrow*, **A**). Corresponding tendon attachment was intact (not shown).

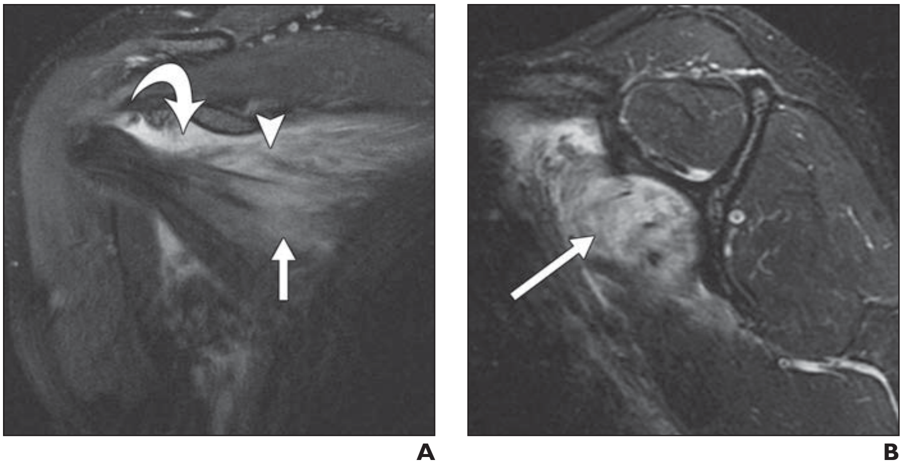


Fig. 4—41-year-old woman with pain and stiffness of left shoulder 1 day after landing on arm because of mechanical fall.
A and **B,** Coronal (**A**) and sagittal (**B**) T2-weighted fat-suppressed MR images show partial tear of superior myotendinous junction of subscapularis muscle (*straight arrow*, **A**), with focal retraction of fibers (*arrowhead*, **A**), adjacent fluid (*curved arrow*, **A**), and extensive edema throughout muscle belly (*arrow*, **B**). Corresponding tendon attachment was intact (not shown).

tween myotendinous junction injuries and tendon tears. Moreover, the fact that some patients did not present with a clear history of trauma suggests that there are multifactorial causes for myotendinous junction injury, including various contributions of anatomic components, intrinsic degeneration, and extrinsic factors, such as structural weakness caused by steroid injections. Rather than being only a consequence of direct trauma, the different mechanisms of injury presented suggest a role of sudden muscular contractions or contraction against resistance during maximum lengthening, which is worsened by muscle fatigue [5].

Four subjects (25%) underwent steroid injection (mostly subacromial) at a mean of 42 days before symptoms onset. Steroid injections before the onset of symptoms of rotator cuff myotendinous junction injury have been previously reported. Lunn et al. [4] described that 95% (18/19) of subjects had prior shoulder steroid injections, with five of them showing subsequent worsening of symptoms (glenohumeral joint or bursal injection in two subjects, and needle aspiration of calcific tendinitis in three subjects). Walch et al. [5] reported that 95% of subjects had received steroid injections and that 20% underwent dry needle placements (without specifying location). Tavernier et al. [6] found that 68% (17/25) of subjects had previous shoulder injections, without specific mention of the injection location. Animal studies have shown that steroid injections can weaken normal tendons, and intratendinous steroid injections are known to cause tendon rupture [4, 15–18]. It is possible that injections may play a role by weakening the myotendinous junction as an effect of the steroid or because of mechanical needle injury, or both [4, 5]. The temporal relationship between injections and symptom onset suggests a possible relationship both in the available literature [4, 14] and in our study.

In contrast to previous reports [3–5], none of our subjects underwent specific myotendinous injury repair, which may be because of the absence of complete tears. Nonetheless, myotendinous injury repairs provide only partial functional restoration and also increased, or did not prevent, subsequent severe fatty infiltration of the corresponding muscle belly [4, 5]. On the other hand, early repair of tendon injuries at the attachment site restores muscle tension and may prevent progression and functional loss [5]. The optimal treatment of myotendinous injuries is still debated.

As seen in our study, acute myotendinous injuries mainly show intense edema of the muscle. Most cases of acute myotendinous injuries are reported to show a strain pattern by MRI [3]. We found this pattern in 80% of injuries, presenting as edema at the myotendinous junction, without discontinuity of fibers. For subjects with a partial tear, focal retraction of fibers was seen. Most of the myotendinous junction injuries occurred in isolation (94%), rather than in association with tears of the corresponding tendon (6%). These results are similar to those previously reported by Walch et al. [5] in a study limited to acute infraspinatus myotendinous injuries that found associated tendon tears in only 21% of subjects. Concomitant tendon calcification was found at a lower rate within our cohort (11% [1/9]), similar to results presented by Lädermann et al. [3], where no calcific tendinitis was seen. Conversely, higher rates of calcific tendinitis have been reported in other studies, ranging from 61% to 68% of subjects [4, 5].

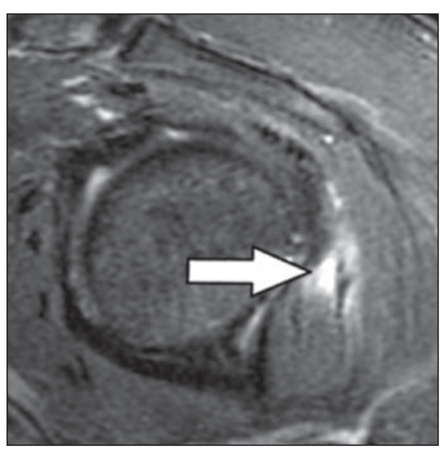


Fig. 5—31-year-old woman who presented with pain and weakness of left shoulder for 1 month, with posterior tenderness over palpation and internal rotation. Sagittal T2-weighted fat-suppressed MR image shows strain of myotendinous junction of teres minor muscle (*arrow*). Corresponding tendon attachment was intact (not shown).

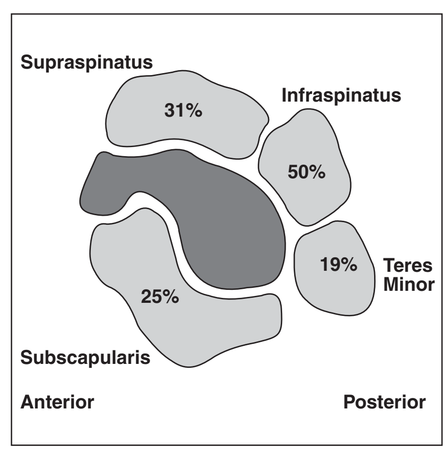


Fig. 6—Illustration of distribution of myotendinous junction injuries in 16 shoulders. (Drawing by Torriani M)

Edema of rotator cuff muscles with an intact tendon-bone insertion is infrequent, but it has been described in a wide variety of conditions, such as direct trauma, myositis, infection, sickle cell disease, Graves disease, tumors, denervation, and Parsonage-Turner syndrome [3, 4]. MRI is helpful to accurately identify myotendinous junction injury, where the SI abnormality and fiber discontinuity are centered around the myotendinous junction, rather than patchy edema (as in neuropathies) [19, 20] or affecting the tendon attachment (as in tendon tears) [7, 8]. Another distinguishing feature from tendon tears is the rapid progression of myotendinous junction injuries to severe muscle fatty infiltration in less than 1 year, sometimes in association with ossifications [5]. One of our subjects presented with myotendinous junction injury of the infraspinatus muscle and concurrent suprascapular neuropathy on an electrophysiological study. Because partial tear of the myotendinous junction with focal retraction of fibers was clearly present on MRI, it seems reasonable to speculate that neuropathy could have played a role in predisposing such injury or, alternatively, that local edema or hemorrhage could have affected nerve conduction.

Our study has limitations, mainly because of its retrospective design. Follow-up MRI studies were not performed, allowing assessment only of acute presentations rather than chronic progression. Clinical notes were not available for all subjects, such as dominant arm side information, mechanism of injury, or orthopedic physical examination. Because of the grade of tears seen in our cases, no surgery was performed and intraoperative confirmation of imaging findings was lacking.

It is important to explore rotator cuff myotendinous junction injuries because they may be overlooked arthroscopically as a result of their extraarticular nature. The combination of shoulder pain, limited movement, and weakness, along with compatible MRI findings, are diagnostic for this type of injury [4]. In summary, we present comprehensive clinical and MRI features of myotendinous junction injury involving rotator cuff muscles. Our results suggest that this entity affects mostly the infraspinatus and supraspinatus muscles, usually in a strain pattern and without corresponding tendon tear.

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