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Hypertrophic changes of the teres minor muscle in rotator cuff tears: quantitative evaluation by magnetic resonance imaging

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Background: Few reports have assessed the teres minor (TM) muscle in rotator cuff tears. This study aimed to quantitatively analyze the morphologic changes of the TM muscle in patients with or without rotator cuff tears by magnetic resonance imaging (MRI).
Methods: This retrospective study consisted of 279 subjects classified on the basis of interpretations of conventional MRI observations into 6 groups: no cuff tear; partial-thickness supraspinatus (SSP) tear; full-thickness SSP tear; SSP and subscapularis tears; SSP and infraspinatus (ISP) tears; and SSP, ISP, and subscapularis tears. With use of ImageJ software (National Institutes of Health, Bethesda, MD, USA) for oblique sagittal MRI, we measured the areas of ISP, TM, and anatomic external rotation (ISP + TM) muscles on the most lateral side in which the scapular spine was in contact with the scapular body. The occupational ratios of the TM muscle area to the anatomic external rotation muscle area were calculated. Ratios above the maximum of the 95% confidence intervals of the occupational ratio in the no-tear group were defined as hypertrophy of the TM muscle.
Results: Occupational ratios of the TM muscle in the no-tear group followed a normal distribution, and ratios >0.288 were defined as hypertrophic. Hypertrophic changes of the TM muscle were confirmed in rotator cuff tears involving the ISP tendon. A negative correlation was found between the occupational ratios of TM and ISP ($P < .001$).
Conclusion: The TM muscle appeared hypertrophic in rotator cuff tears involving the ISP, and the progression of ISP muscle atrophy seemed to induce the development of this compensatory hypertrophy.
Level of evidence: Basic Science, Anatomy, Imaging.

Keywords: Teres minor muscle; hypertrophic change; rotator cuff tear; MRI evaluation; infraspinatus muscle; atrophy

This study was approved by the Institutional Review Board.

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Table I Demographic data of each group

Group	Tear pattern	No. of subjects (male, female)	Age (mean ± SD), years	No. of dominant sides	Duration of symptoms (mean ± SD), months	No. of traumas
N	No tear	86 (45, 41)	50.5 ± 17.1	48 (56%)	8.1 ± 14.1	33 (38%)
A	Partial-thickness SSP tear	31 (20, 11)	62.5 ± 9.7	19 (61%)	6.0 ± 6.9	11 (35%)
B	Full-thickness SSP tear	66 (34, 32)	65.0 ± 8.8	36 (55%)	10.6 ± 33.9	36 (55%)
C	Full-thickness SSP and Subsc tears	17 (15, 2)	65.1 ± 8.6	5 (29%)	7.5 ± 15.0	13 (76%)
D	Full-thickness SSP and ISP tears	50 (23, 27)	69.2 ± 7.8	33 (66%)	12.7 ± 35.7	29 (58%)
E	Full-thickness SSP, ISP, and Subsc tears	29 (18, 11)	72.2 ± 7.9	21 (72%)	11.3 ± 25.1	15 (52%)

SSP, supraspinatus; *ISP*, infraspinatus; *Subsc*, subscapularis.

The teres minor (TM) muscle provides 20% to 45% of the external rotation power to the glenohumeral joint[8,10] and retains the power in large and massive tears involving the infraspinatus (ISP) tendon. Tears of the TM tendon are rare, and the tendon usually remains intact even in large or massive rotator cuff tears. In reverse total shoulder arthroplasty with severe atrophy or fatty infiltration of ruptured rotator cuff muscles, integrity of the TM was shown to be a prognostic factor postoperatively.[4,18,19] Recently, reverse total shoulder arthroplasty with latissimus dorsi transfer to restore elevation and external rotation in cases of severe atrophy or fatty infiltration of ISP and TM muscles that were observed preoperatively has been reported.[3,5,11] Understanding of the preoperative integrity of the TM should provide valuable prognostic information for achieving successful clinical results.

Muscle atrophy and fatty infiltration of the torn rotator cuff have previously been analyzed on oblique sagittal magnetic resonance imaging (MRI) with use of image software.[12,17,22] These studies have focused on the supraspinatus (SSP), the ISP, and the subscapularis (Subsc) muscles, but to the best of our knowledge, there have hardly been any reports that assessed the TM muscle. Although Walch et al[21] introduced a morphologic classification system of the TM muscle based on the arthroscopic tenotomy of the long head of the biceps in the treatment of rotator cuff tears, there have been no quantitative evaluations of the TM muscle. The purpose of this study, therefore, was to quantitatively investigate morphologic changes of the TM muscle on the basis of MRI of patients with or without rotator cuff tears. We hypothesized that the TM muscle would appear hypertrophic in rotator cuff tears involving the ISP tendon.

Materials and methods

The Institutional Review Board and ethics committee approved this retrospective study of diagnostic MRI of 331 patients (331 shoulders) with or without rotator cuff tears at our institution between April 2010 and March 2013. Twenty-two shoulders with previous surgical treatment, fractures, dislocation, infection, rheumatoid arthritis, cervical neuropathy, axillary nerve palsy, or previous physical therapy on the affected side were excluded. Twenty-four shoulders in which the ISP and TM muscles could not be divided correctly on oblique sagittal plane MRI were also excluded. Four shoulders with no TM muscles visible on MRI were excluded. Two isolated Subsc tendon tears were also excluded because the numbers were too small to evaluate. Thus, a total of 279 subjects (155 males, 124 females; age, 10–88 years; average age, 61.2 years) were included in this study.

MRI evaluation

MRI was performed on a 1.5T system (Siemens, Germany). T2-weighted spin-echo images (2500–5000/120, with a 3-mm section thickness) were obtained in the oblique coronal plane, parallel to the SSP muscle; in the axial plane; and in the oblique sagittal plane, parallel to the joint surface of the glenoid. According to the standard findings of these 3 MRI planes, subjects were divided into the following 6 groups: no-tear (N) group; partial-thickness SSP tear (A) group; full-thickness SSP tear (B) group; full-thickness SSP and Subsc tears (C) group; full-thickness SSP and ISP tears (D) group; and SSP, ISP, and Subsc tears (E) group. Demographic data including numbers, ages, dominant side, traumas, and duration of symptoms of the patients in each group are shown in Table I. There were 31 incomplete tears, 26 small tears, 46 medium tears, 37 large tears, and 53 massive tears according to Cofield's classification.[7]

Occupational ratio of TM muscle

With use of ImageJ software (National Institutes of Health, Bethesda, MD, USA), the areas of ISP muscle, TM muscle, and anatomic external rotation (a-ER) muscle were measured on the most lateral oblique sagittal image in which the scapular spine was in contact with the scapular body; the area of the a-ER muscle, including the areas of ISP and TM muscles, was traced on the lateral margin of the scapula, the inferior margin of the TM muscle, and the medial margin of the deltoid (Fig. 1). The occupational ratios of TM and ISP muscles were then calculated: occupational ratio of TM muscle = area of TM muscle/area of a-ER muscle; and occupational ratio of ISP muscle = area of ISP muscle/area of a-ER muscle. A random sample of 60 muscles (ISP, TM, a-ER muscles) from 30 subjects was reviewed by an orthopedic surgeon (K.K.) twice to quantify intraobserver reliability and by a second orthopedic surgeon (M.M.) to quantify interobserver reliability.[6]

Definition of hypertrophy of the TM muscle

To define hypertrophy of the TM muscle, the distribution of the occupational ratios of the TM muscle of the N group was