

Rotator Cuff Lesions in Patients with Stiff Shoulders

A Prospective Analysis of 379 Shoulders

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Background: Idiopathic adhesive capsulitis is defined as a frozen shoulder with severe and global range-of-motion loss of unknown etiology. The purpose of our study was to clarify the prevalence of rotator cuff lesions according to patterns and severity of range-of-motion loss in a large cohort of patients with stiff shoulders.

Methods: Rotator cuff pathology was prospectively investigated with use of magnetic resonance imaging (MRI) or ultrasonography in a series of 379 stiff shoulders; patients with traumatic etiology, diabetes, or radiographic abnormalities were excluded. Eighty-nine shoulders demonstrated severe and global loss of passive motion ($\leq 100^\circ$ of forward flexion, $\leq 10^\circ$ of external rotation with the arm at the side, and internal rotation not more cephalad than the L5 level) and were classified as having severe and global loss of motion (Group 1). The remaining 290 shoulders were divided into two groups: those with severe but not global loss (Group 2; 111 shoulders) and mild to moderate limitation (Group 3; 179 shoulders).

Results: Among all shoulders, imaging demonstrated an intact rotator cuff in 51%, a full-thickness tear in 35%, and a partial-thickness tear in 15%. In Group 1, 91% had an intact rotator cuff and 9% had a partial-thickness rotator cuff tear. No patient in this group demonstrated a full-thickness tear. In Group 2 and Group 3, respectively, 44% and 35% of the shoulders were intact, 17% and 16% had a partial-thickness tear, and 39% and 50% had a full-thickness tear.

Conclusions: Shoulder stiffness with severe and global loss of passive range of motion is not associated with full-thickness rotator cuff tears, although some patients may have a partial-thickness tear. Shoulders with severe and global loss of range of motion at a first visit are likely to be cases of idiopathic adhesive capsulitis and may not require further imaging studies.

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The term “periartthritis” was first used in 1872 to refer to shoulders that had limited active and passive shoulder motion¹. The term “frozen shoulder” was introduced by Codman in 1934². Idiopathic adhesive capsulitis is now more narrowly defined as a frozen shoulder with severe and global loss of range of motion (ROM) with unknown etiology³⁻⁵.

Despite this definition and understanding, several authors recently reported that rotator cuff lesions are strongly associated with frozen shoulder, and some have even stated that the rotator

cuff lesion can be a cause of frozen shoulder⁵⁻⁸. However, because of the ambiguity of the definition of a frozen shoulder, the degree of ROM deficit often varies according to investigators^{5,7-10}. Robinson et al. defined frozen shoulder as $\leq 90^\circ$ of abduction and some limitation of internal and external rotation⁵. Yoo et al. defined stage-2 adhesive capsulitis as $\leq 100^\circ$ of forward flexion, $\leq 10^\circ$ of external rotation, and internal rotation not more cephalad than the T12 level⁷. Furthermore, Watson et al. defined frozen shoulder as $\leq 120^\circ$ of abduction and $\leq 50\%$ of

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TABLE 1 Range of Motion and Prevalence of Rotator Cuff Lesions by Group

Group	Severity of Motion Loss*			Shoulders (no.)	Male (no.)	Female (no.)	Age§ (yr)
	FF	ER	IR				
Group 1 (severe and global loss)	S	S	S	89	26	63	57 (35-80)
Group 2 (severe but not global loss)#				111	56	55	60 (38-83)
	S	S	M	4	3	1	58 (41-76)
	S	M	S	12	6	6	56 (43-70)
	M	S	S	12	10	2	57 (44-77)
	S	M	M	7	1	6	66 (53-78)
	M	M	S	66	32	34	61 (38-83)
	M	S	M	10	4	6	61 (45-77)
Group 3 (mild to moderate limitation)#	M	M	M	179	82	97	63 (35-83)

*FF = forward flexion, ER = external rotation with arm at side, IR = internal rotation, S = severe limitation ($\leq 100^\circ$ of FF, $\leq 10^\circ$ of ER, and L5-level IR), and M = mild to moderate limitation ($\geq 101^\circ$ of FF, $\geq 11^\circ$ of ER, and L4-level IR). †Values are given as the mean with the range in parentheses. IR is indicated by the spine level reachable by the thumb; S = sacrum, B = buttock, and GT = greater trochanter. ‡Values are given as the percentage with the number of shoulders in parentheses. PTT = partial-thickness tear, and FTT = full-thickness tear. §Values are given as the mean with the range in parentheses. #A significant difference in the prevalence of rotator cuff lesions compared with Group 1 was observed ($p < 0.01$, Steel-Dwass test).

external rotation relative to the contralateral shoulder⁸. Thus, a consensus on definition is necessary when the pathology and etiology of frozen shoulder are considered.

In a previous study, we investigated the characteristics of the ROM deficit in 155 patients with a full-thickness rotator cuff tear who underwent surgical repair and found that their ROM deficit was relatively mild compared with the group of patients with frozen shoulder who underwent arthroscopic capsular release for refractory severe and global loss of motion¹¹. Furthermore, although approximately one-third of patients with a full-thickness rotator cuff tear demonstrated global loss of motion, there were no patients with severe loss of motion, which was defined as $\leq 100^\circ$ of forward flexion, $\leq 10^\circ$ of external rotation with the arm at the side, and internal rotation not more cephalad than the L5 level¹¹.

In the present study, we hypothesized that there would be no full-thickness rotator cuff tears in stiff shoulders with severe and global loss of passive ROM. The purpose of this study was to investigate in a prospective fashion, using magnetic resonance imaging (MRI) or ultrasonography, the prevalence of rotator cuff lesions in patients with stiff shoulders, excluding patients with a traumatic etiology, diabetes, or radiographic abnormalities.

Materials and Methods

We received institutional review board approval prior to initiating this study and obtained informed consent from all participating patients prior to imaging.

Patient Selection and ROM Measurement

Between June 2012 and July 2013, 2052 consecutive patients (2185 shoulders) thirty-five years of age or older visited our institution with shoulder pain associated with ROM deficit. Passive forward flexion, external rotation with the arm at the side, and internal rotation (the highest vertebral level reached by the thumb) were

measured for both shoulders in all patients. Patients with unilateral involvement who had a loss of $\geq 10^\circ$ of forward flexion, a loss of $\geq 10^\circ$ of external rotation with the arm at the side, and a loss of internal rotation of more than two spinal levels compared with the contralateral side were included in this study. In addition, patients with bilateral shoulder pain and stiffness were also included. Patients who had a history of diabetes mellitus or who had experienced a traumatic event involving the shoulder were excluded. Patients with radiographic evidence of a calcified deposit or osteoarthritic change were also excluded. Consequently, the study cohort consisted of 379 shoulders in 367 patients (162 male and 205 female) with a mean age of sixty-one years (range, thirty-five to eighty-three years).

Passive ROM was measured first with the patient in the standing position. However, we also measured forward flexion and external rotation with the patient in the supine position in order to minimize the influence of pain. In the supine position, the scapula can be stabilized, and it is easier to maintain the humeral head in an optimal position relative to the glenoid cavity by holding the patient's arm. Pain can therefore be reduced or eliminated because muscle tone around the shoulder girdle is reduced. Consequently, more precise measurement with less pain is possible compared with measurement when the patient is in the standing position (Figs. 1 and 2).

Patterns and Severity of ROM Limitation

The patients were divided into three groups according to the severity and patterns of shoulder stiffness. Group 1 had severe and global loss, with severe limitation of passive ROM in all three measured directions corresponding with adhesive capsulitis: $\leq 100^\circ$ of forward flexion, $\leq 10^\circ$ of external rotation, and internal rotation not more cephalad than the L5 level. We used the same definition in a previous study¹¹. Group 2 had severe limitation in at least one direction but not global loss of motion. For example, this would include a patient with 90° of forward flexion, 40° of external rotation, and L5-level internal rotation. Group 3 included the remaining shoulders and was defined as those having mild to moderate limitation.

Imaging Studies

Three hundred and sixty-five shoulders (355 patients) underwent plain MRI with a 1.5-T imager (Intera 1.5T; Philips, Amsterdam, the Netherlands) with a phased-array surface coil. Patients were positioned with the humerus in a neutral position. T2-weighted MRI scans using an echo-train length of 10 were obtained in axial, oblique coronal (parallel to the long axis of the supraspinatus

TABLE 1 (continued)

Range of Motion† (deg)			Rotator Cuff Lesions‡		
FF	ER	IR	Intact	PTT	FTT
88 (70-100)	1 (-15-10)	B (GT-L5)	91% (81)	9% (8)	0% (0)
130 (80-170)	31 (-5-80)	L5 (GT-T7)	44% (49)	17% (19)	39% (43)
93 (80-100)	0 (-5-5)	L4 (L4-L4)	25% (1)	25% (1)	50% (2)
95 (90-100)	27 (15-45)	S (GT-L5)	42% (5)	25% (3)	33% (4)
120 (105-160)	3 (0-10)	S (B-L5)	100% (12)	0% (0)	0% (0)
96 (85-100)	41 (20-70)	L1 (L4-T7)	29% (2)	0% (0)	71% (5)
142 (105-170)	41 (15-80)	S (B-L5)	38% (25)	21% (14)	41% (27)
144 (110-170)	7 (0-10)	T12 (L4-T8)	40% (4)	10% (1)	50% (5)
154 (105-180)	49 (20-90)	T12 (L4-T6)	35% (62)	16% (28)	50% (89)

tendon), and oblique sagittal (perpendicular to the long axis of the supraspinatus tendon) planes using a 3.5-mm slice thickness with a 1-mm gap between the slices. The MRI parameters of the T2 coronal scans were as follows: repetition time (TR), 5000 ms; echo time (TE), 100 ms; field of view (FOV), 160 mm; and matrix, 512 × 800. For the T2 sagittal scans, parameters were TR, 4147 ms; TE, 100 ms; FOV, 160 mm; and matrix, 384 × 720. For the T2 axial scans, they were TR, 4000 ms; TE, 100 ms; FOV, 160 mm; and matrix, 400 × 720. In addition, T1-weighted oblique sagittal images (TR, 400 ms; TE, 10.5 ms; FOV, 160 mm; and

matrix, 400 × 720) were routinely obtained in order to assess rotator cuff muscle atrophy.

The remaining fourteen shoulders (twelve patients), which did not undergo MRI because of cost issues, claustrophobia, or other reasons, underwent high-resolution ultrasonography (EUB-7500; Hitachi Medical, Tokyo, Japan) performed by experienced radiographic technicians with use of a high-frequency transducer (14 MHz). The examination was performed with the patient seated on a stool, with the examiner standing behind the patient. Images



Fig. 1



Fig. 2

Fig. 1 Measuring external rotation in the standing position. Many patients complain of pain during range-of-motion measurement, especially during external rotation with the arm at the side. This often forces examiners to underestimate the range of motion. **Fig. 2** Measuring external rotation in the supine position. In this position, the scapula can be stabilized and the pain can be reduced or eliminated during measurement. As a result, a more accurate measurement may be possible.

of the supraspinatus tendon were obtained with 20° of shoulder extension with neutral rotation. The transducer was oriented parallel to the tendon (approximately 45° between the coronal and sagittal planes). The transducer was rotated 90° in order to examine the tendons in the transverse plane.

Two physicians (one musculoskeletal radiologist and one shoulder surgeon), who were unaware of the patients' information, such as symptoms and ROM, investigated rotator cuff lesions using the T2-weighted MRI or ultrasonography images. The final diagnosis on ultrasonography was made by these two physicians on the basis of reports by the experienced radiology technicians. Reports regarding rotator cuff pathology were reviewed, and any divergent findings were reevaluated until the two physicians reached consensus.

Statistical Analysis

We used the Kruskal-Wallis test for a comparison of the groups. The Steel-Dwass test was used for post-hoc analysis when the difference was significant. A one-way analysis of variance (ANOVA) and a post-hoc test (Tukey-Kramer test) were also used for a comparison of age among the groups. The level of significance was set at $p < 0.05$. All analyses were conducted with use of Statcel software (version 3; OMS Institute, Tokyo, Japan).

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No external funding was received in support of this study.

Results

Group Characteristics

Group 1 consisted of eighty-nine shoulders in eighty-five patients (twenty-six male and fifty-nine female). The mean age was fifty-seven years (range, thirty-five to eighty years). Group 2 consisted of 111 shoulders in 109 patients (fifty-five male and fifty-four female). The mean age was sixty years (range, thirty-eight to eighty-three years). Group 3 consisted of 179 shoulders in 173 patients (eighty-one male and ninety-two female). The mean age was sixty-three years (range, thirty-five to eighty-three years). One-way ANOVA and the post-hoc test found that Group 1 was significantly younger than Group 3 ($p < 0.01$). Group 1 included a significantly higher percentage of female patients than Group 2 and Group 3 ($p < 0.05$).

ROM by Group

In Group 1 (severe and global loss), mean ROM measurements were 88° of forward flexion (range, 70° to 100°), 1° of external rotation with the arm at the side (range, -15° to 10°), and buttock-level internal rotation (range, greater trochanter to L5) (Table I). In Group 2 (severe but not global loss), mean ROM measurements were 130° of forward flexion (range, 80° to 170°), 31° of external rotation with the arm at the side (range, -5° to 80°), and L5-level internal rotation (range, greater trochanter to T7). In Group 3 (mild to moderate limitation), mean ROM measurements were 154° of forward flexion (range, 105° to 180°), 49° of external rotation with the arm at the side (range, 20° to 90°), and T12-level internal rotation (range, L4 to T6).

Rotator Cuff Lesions

Imaging studies revealed that, in Group 1, eighty-one (91%) of the shoulders had an intact cuff and eight (9%) had a partial-thickness tear (Table I). No patient in this group had a full-thickness rotator cuff tear. In Group 2, forty-nine (44%) of the shoulders were intact, nineteen (17%) had a partial-thickness

tear, and forty-three (39%) had a full-thickness tear. In Group 3, sixty-two (35%) of the shoulders were intact, twenty-eight (16%) had a partial-thickness tear, and eighty-nine (50%) had a full-thickness tear.

Statistical analysis found a significant difference among the groups in the prevalence of rotator cuff lesions ($p < 0.001$). The post-hoc test revealed that Group 1 differed significantly from both Group 2 and Group 3 ($p < 0.01$ for each).

Discussion

There is some controversy about the relationship between shoulder stiffness, loss of motion, and rotator cuff tearing. This study clearly demonstrated that severe global loss of motion, which is consistent with idiopathic adhesive capsulitis, is not associated with full-thickness rotator cuff tearing. In contrast, shoulders with a rotator cuff tear may have stiffness, although it is not usually severe with global loss of motion. The most prominent finding in this study was that rotator cuff lesions were rare in the severe and global stiffness group (Group 1); no shoulders had a full-thickness rotator cuff tear. In Group 2 and Group 3, we found that 39% and 50% of the shoulders, respectively, had a full-thickness rotator cuff tear.

Because advanced imaging studies such as MRI or ultrasonography are not typically warranted in the early evaluation of frozen shoulder¹²⁻¹⁴, our results may obviate the use of advanced imaging studies for patients who demonstrate severe and global loss of motion. Clinical examination, including accurate measurement of ROM, and proper treatment according to symptoms are much more important than rushing into advanced imaging studies for these patients¹⁵. In contrast, patients presenting with less severe shoulder stiffness and loss of motion may have early or late/recovering adhesive capsulitis, or the stiffness they are experiencing might be secondary to rotator cuff disease. Therefore, advanced imaging studies in an early stage of a patients' visit can help physicians make a proper diagnosis for these patients.

Our criteria for classifying severe and global loss of ROM may have potential weaknesses because we used specific ranges that are somewhat arbitrary. However, in our experience, a typical patient with frozen shoulder usually demonstrates around 80° to 90° of forward flexion, 0° of external rotation, and buttock-level internal rotation. In fact, a standardized definition of frozen shoulder based on ROM does not exist and may not be appropriate. Therefore, we believe that our criteria are appropriate when compared with those of other authors^{5,7,8}.

The main strength of this study is that a broad spectrum of subjects with variable limitation of motion was included, and that enabled us to perform a meaningful statistical analysis of the relationship between shoulder stiffness and rotator cuff tearing. Another strength is that two physicians reviewed the imaging studies in a blinded fashion, and the rotator cuff lesions were diagnosed through the consensus of these two physicians. In addition, ROM was evaluated carefully while also minimizing the effect of pain during measurement.

There were several limitations of this study. First, we did not take disease duration into account for the analyses, despite

the fact that this might relate to the degree of stiffness. Second, we did not evaluate muscle strength. However, this may have little effect on the results of this study, as weakness is not a typical finding of adhesive capsulitis and patients with rotator cuff tears who are weak generally have larger tears. Third, we did not use intra-articular injections of anesthetics to completely eliminate pain when we examined passive ROM. Finally, we used both MRI and ultrasonography to evaluate rotator cuff lesions. Although sensitivity for the diagnosis of rotator cuff lesions can be different between MRI and ultrasonography, we had to use ultrasonography for some patients, for reasons including claustrophobia. At least one review article has demonstrated no significant differences in either sensitivity or specificity between MRI and ultrasonography in the diagnosis of partial or full-thickness rotator cuff tears¹⁶.

In conclusion, we found that shoulder stiffness with severe and global loss of passive ROM is not associated with a full-thickness rotator cuff tear, although some patients may demonstrate a partial-thickness tear. Shoulders with severe and global loss of ROM at the first visit are likely to be cases of idiopathic

adhesive capsulitis and may have less necessity for further imaging studies. In contrast, because the patients with less severe stiffness may have a higher risk of rotator cuff disease, further imaging can help determine the proper treatment strategy. ■

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