Original Article
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Concomitant Rotator Cuff Tear with Frozen Shoulder: A Contemplation on the Necessity and Legitimacy of Magnetic Resonance Imaging Stratified by Age

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Background: Frozen shoulder (FS) is often accompanied by a rotator cuff tear (RCT), but it can be challenging to diagnose a concomitant RCT without imaging studies. Therefore, having practical criteria to identify patients requiring imaging studies at initial presentation with FS would lead to more cost-effective use of these studies. This study investigated the relationship between RCT and stiffness in patients with FS and whether this relationship was modified by patient age.

Methods: This study included 540 adults with shoulder pain who had ≥ 10° of limited passive range of motion in forward flexion, compared to the contralateral side. Patients were categorized into 2 groups depending on the degree of forward flexion stiffness: overhead stiffness (OHS) group, patients with ≥ 110° forward flexion (n = 349); and non-OHS group, patients with forward flexion < 110° (n = 191). The presence of concomitant RCT was determined by magnetic resonance imaging and compared between groups before and after stratification by age.

Results: The OHS group had increased odds of concomitant RCT, compared to the non-OHS group (odds ratio [OR], 4.99; 95% CI, 3.36–7.42). OHS was also significantly associated with a more severe grade of RCT (no tear, partial-thickness tear, or full-thickness tear) (OR, 4.42; 95% CI, 3.05–6.39). The odds of RCT in the OHS group, compared to the non-OHS group, increased with age (50–59 years: OR, 3.83; 95% CI, 1.96–7.48; 60–69 years: OR, 5.94; 95% CI, 3.14–11.26; and 70–79 years: OR, 7.67; 95% CI, 2.71–21.66).

Conclusions: Patients with FS and forward flexion range of motion ≥ 110° (i.e., OHS) at initial presentation had approximately 5-fold higher odds of concurrent RCT than patients with non-OHS. Moreover, in patients aged 50 years or above, these odds increased up to almost 8-fold. Therefore, we recommend confirming the rotator cuff integrity with magnetic resonance imaging in patients with FS and OHS.

Keywords: *Rotator cuff tear, Frozen shoulder, Magnetic resonance angiography, Aging*

Frozen shoulder (FS) is one of the most common causes of shoulder pain, with a prevalence of approximately 2%–5%.[1-4] Accordingly, FS is frequently encountered by not only shoulder specialists but also by general physicians. When FS occurs alone, with no other systemic or secondary influences, it is generally a self-limiting condition that is relatively easy to cure with conservative treatment, such as steroid injections and range of motion (ROM) exercises.[5] With the absence of osteoarthritis on radiographic exami-

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nation, the diagnosis of FS can be made clinically by confirming global loss of passive and active ROM.[6,7] Various diagnostic criteria for FS in terms of ROM deficit have been published, but no consensus criteria have been established.

FSs are often accompanied by rotator cuff tears (RCTs).[8-13] While FS is known to be self-limiting, untreated RCTs can not only cause pain, but also lead to a progressive loss of shoulder function, including reduced ROM and strength.[14] The functional impairment can greatly affect daily activities and diminish quality of life. Furthermore, it can lead to rotator cuff arthropathy, a type of arthritis that results from chronic RCTs.[15] When these 2 conditions present simultaneously, the diagnosis of a rotator cuff lesion may be missed on clinical examination, justifying the use of imaging examinations, such as ultrasonography or magnetic resonance imaging (MRI), to accurately diagnose RCT.[16] Furthermore, when an accompanying RCT is not identified at initial presentation, the optimal time for RCT treatment may be missed, which may even lead to a medicolegal claim.

Ideally, all patients should undergo additional investigations when appropriate, but imaging studies cannot be performed on every patient with shoulder stiffness because of cost considerations.[17] Patients presenting with shoulder stiffness exhibit wide variations in age and degree of ROM deficit, suggesting that the incidence of concomitant RCT among patients with FS differs according to age and ROM deficit. If this hypothesis is correct, age and ROM deficit may function as practical criteria to identify patients who require imaging studies during their initial presentation with FS, thereby improving the cost-effective use of these investigations.

The objectives of this study were to investigate (1) the relationship between RCTs in patients with FS according to the presence of preserved ROM in forward flexion (only overhead stiffness [OHS]) and (2) the presence of RCT in patients with FS stratified according to age. We hypothesized that individuals with only OHS would be more likely to present with concomitant RCTs and that this relationship would be stronger in the elderly.

METHODS

This study was approved by the Institutional Review Board of Yonsei University Health System, Severance Hospital (IRB No. 4-2023-0193). All experiments were performed in accordance with relevant guidelines and regulations. The informed consent was obtained from all patients or their legal guardians.

Study Population and Assessment

We retrospectively reviewed the data of 584 consecutive patients presenting to our institute between January 2021 and November 2022 with shoulder pain. All patients were aged 40 years or older, had ≥ 10° of limited passive ROM in forward flexion on physical examination (compared to the contralateral side), and underwent MRI (3.0-T MRI unit; MAGNETOM Tim Trio; Siemens). Fat-saturated T1-weighted (T1W) axial, oblique coronal, and oblique sagittal; T2-weighted oblique coronal; and T1W oblique sagittal sequences were obtained. Patients with pseudoparalysis or previous surgery, fracture(s), or neoplasm of the affected shoulder were excluded. A total of 540 patients were enrolled in the study (Fig. 1).

Shoulder ROMs, including forward flexion, abduction, external rotation, and internal rotation were measured using a goniometer with the patient in the standing position. Forward flexion and abduction were evaluated including the scapulohumeral motion. In measuring range of internal rotation, the scratch test was performed recording the vertebral level reached with the tip of the thumb in the sitting position. This level was then converted into a serial number as follows: T1 to T12 into 1 to 12, respectively; L1 to L5 into 13 to 17; sacrum into 18; coccyx into 19; and buttock into 20.[18] According to the severity of forward flexion limitation of motion at initial presentation, patients were divided into 2 groups. We defined the OHS group as patients with passive forward flexion ≥ 110° and the non-OHS group as those with forward flexion < 110°. The presence of concomitant RCT was determined through independent review of MRI scans by 2 fellowship-trained shoulder surgeons (KHL, HA), who were blinded to all radiologic reports and clinical information. Disagreements between

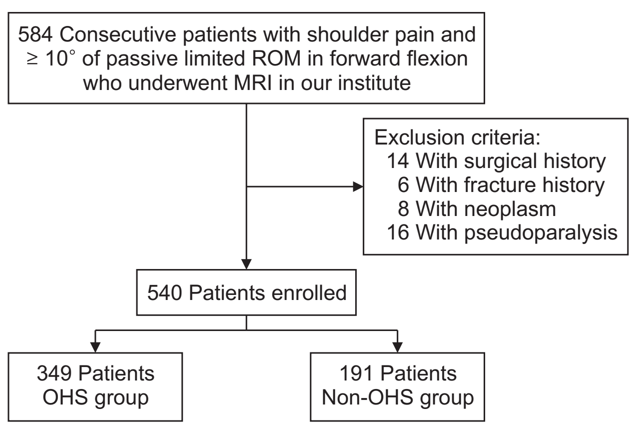

Fig. 1. Flowchart of selection of the study population. ROM: range of motion, MRI: magnetic resonance imaging, OHS: overhead stiffness.

the reviewers were resolved by consensus after discussion.

Statistical Analyses

Statistical differences in demographics between OHS and non-OHS groups were evaluated using the chi-square test for categorical variables and the Student *t*-test for continuous variables. Logistic regression and ordinal logistic regression analyses were performed to evaluate the association between OHS and RCT. We calculated the odds ratio (OR) and corresponding 95% CI for the association between OHS and RCT, using the non-OHS group as the reference. The regression models were adjusted for age, sex, and dominant arm. Logistic regression analyses were also performed after stratification for age (40–49 years, 50–59 years, 60–69 years, and 70–79 years). Interrater reliability was determined by calculating the kappa statistic. A $p < 0.05$ was considered indicative of a statistically significant difference. Statistical analyses were conducted using SPSS version 21.0 (IBM Corp.), with the statistical significance set at $\alpha < 0.05$.

RESULTS

Patient Demographics

The OHS group included 349 patients (148 men and 201 women), and the non-OHS group consisted of 191 patients (64 men and 127 women). There were significantly more men in the OHS group than in the non-OHS group ($p = 0.043$). Individuals in the OHS group were older than those in the non-OHS group ($p < 0.001$). The mean ROM in forward flexion was 126° in the OHS group and 91° in

Table 1. Patient Demographics

Characteristics	OHS* (n = 349)	Non-OHS (n = 191)	*p*-value	Kappa
Initial shoulder ROM (°)†				
Forward flexion	126 ± 11	91 ± 13	< 0.001	
Abduction	81 ± 10	81 ± 10	0.921	
Internal rotation	18.9 ± 1.3	18.8 ± 1.0	0.628	
External rotation	40 ± 11	39 ± 10	0.189	
Rotator cuff tear			< 0.001	0.894
No tear	93 (26.6)	128 (67.0)		
Overall tear	256 (73.4)	63 (33.0)		
Partial-thickness tear	114	36		
Full-thickness tear	142	27		
Sex			0.043	
Male	148 (69.8)	64 (30.2)		
Female	201 (61.3)	127 (38.7)		
Age (yr)			< 0.001	
40–49	18 (39.1)	28 (60.9)		
50–59	114 (64.8)	62 (35.2)		
60–69	125 (62.5)	75 (37.5)		
70–79	92 (78.0)	26 (22.0)		
Dominant arm			0.924	
Yes	197 (64.8)	107 (35.2)		
No	152 (64.4)	84 (35.6)		

Values are presented as mean ± standard deviation or number (%).
OHS: overhead stiffness, ROM: range of motion.
*OHS was defined as ROM in forward flexion ≥ 110°. †ROM was rounded to the nearest decimal point and recorded as a whole number.

the non-OHS group ($p < 0.001$). There were no significant differences in terms of mean ROM in abduction, internal rotation and external rotation. Concomitant RCT was present in 80.3% of patients in the OHS group (n = 256) and 33.0% of patients in the non-OHS group (n = 63). The presence of concomitant RCT was significantly different between the groups ($p < 0.001$) (Table 1).

Association between OHS and Concomitant RCT

Compared to patients in the non-OHS group, those in the OHS group were more likely to have concomitant RCT, with an unadjusted OR of 5.59 (95% CI, 3.81–8.21). After controlling for age, sex, and dominant arm, the adjusted OR for concomitant RCT was 4.99 (95% CI, 3.36–7.42) in the OHS group, compared to the non-OHS group. Increased ROM in forward flexion was likewise associated with increased odds of concomitant RCT (unadjusted OR, 1.04; 95% CI, 1.03–1.05; adjusted OR, 1.04; 95% CI, 1.03–1.05) (Table 2). RCT severity was also associated with OHS. Compared to patients in the non-OHS group, those in the OHS group were more likely to have a higher grade of tear, with an adjusted OR of 4.42 (95% CI, 3.05–6.39) (Table 3). Older age was also associated with concomitant RCT. The adjusted OR for concomitant RCT in patients in the OHS group, compared to those in the non-OHS group, increased with age from 2.2 in the 40–49 years age group to 7.67 in the 70–79 years age group (Table 4).

DISCUSSION

This study examined the relationship between RCT and preserved ROM in forward flexion in patients with FS and the impact of age in modifying the relationship between shoulder ROM and RCT. Overall, we found that patients with OHS had 5 times higher odds of concomitant RCT than those with non-OHS. In addition, the odds of having an RCT tear in patients with OHS (compared to those with non-OHS) increased with age. The odds of RCT were significantly higher in patients with OHS than in those with non-OHS beginning in the 40–49 years age group, with the adjusted OR being highest (7.67) in the oldest age group.

RCT occurs in approximately 7%–15% of the general population, and the prevalence of symptomatic RCTs increases with age.[19,20] Asymptomatic RCTs have also been reported to increase in frequency with increasing age.[21] When RCT is accompanied by FS, the likelihood of undi-

Table 2. Association of Range of Motion and OHS with Concomitant RCT

	Concomitant RCT		OR (95% CI) for concomitant RCT	
	No	Yes	Unadjusted model	Adjusted model*
ROM in forward flexion	221 (40.9)	319 (59.1)	1.04 (1.03–1.05)	1.04 (1.03–1.05)
OHS status				
Non-OHS group	128 (67.0)	63 (33.0)	1.00 (Reference)	1.00 (Reference)
OHS group	93 (26.7)	256 (73.3)	5.59 (3.81–8.21)	4.99 (3.36–7.42)

Values are presented as number (%) unless otherwise indicated.
OHS: overhead stiffness, RCT: rotator cuff tear, OR: odds ratio, ROM: range of motion.
*Adjusted for age, side, and sex.

Table 3. Association between OHS and Severity of Concomitant RCT

	Severity of RCT			OR (95% CI) for concomitant RCT	
	No tear	Partial-thickness	Full-thickness	Unadjusted model	Adjusted model*
OHS status					
Non-OHS group	128 (67.0)	36 (18.9)	27 (14.1)	1.00 (Reference)	1.00 (Reference)
OHS group	93 (26.7)	114 (32.7)	142 (40.7)	5.15 (3.58–7.40)	4.42 (3.05–6.39)

Values are presented as number (%) unless otherwise indicated.
OHS: overhead stiffness, RCT: rotator cuff tear, OR: odds ratio.
*Adjusted for age, side, and sex.

Table 4. Association between OHS and Concomitant RCT Tear According to Age

Age group	Concomitant RCT		OR (95% CI) for concomitant RCT	
	No	Yes	Unadjusted model	Adjusted model*
40–49 yr (n = 46)				
OHS				
No	22 (78.6)	6 (21.4)	1.00 (Reference)	1.00 (Reference)
Yes	12 (66.7)	6 (33.3)	1.83 (0.48–6.95)	2.20 (0.54–8.98)
50–59 yr (n = 176)				
OHS				
No	42 (67.7)	20 (32.3)	1.00 (Reference)	1.00 (Reference)
Yes	40 (35.1)	74 (64.9)	3.89 (2.01–7.49)	3.83 (1.96–7.48)
60–69 yr (n = 200)				
OHS				
No	49 (65.3)	26 (34.7)	1.00 (Reference)	1.00 (Reference)
Yes	29 (23.2)	96 (76.8)	6.24 (3.32–11.73)	5.94 (3.14–11.26)
70–79 yr (n = 118)				
OHS				
No	15 (57.7)	11 (42.3)	1.00 (Reference)	1.00 (Reference)
Yes	12 (13.0)	80 (87.0)	9.09 (3.39–24.38)	7.67 (2.71–21.66)

Values are presented as number (%) unless otherwise indicated.
OHS: overhead stiffness, RCT: rotator cuff tear, OR: odds ratio.
*Adjusted for side and sex.

agnosed RCT increases, and when considering both age and the prevalence of RCT, the probability of RCT occurring with FS is even higher when patients become older. Iwamoto et al. compared ROM deficits in patients with symptomatic unilateral full-thickness RCTs who underwent arthroscopic repair versus patients with FS without RCT who underwent arthroscopic pancapsular release.[22] They found that patients with a full-thickness RCT exhibited relatively mild ROM restriction, compared to patients with FS alone. In another study, Ueda et al.[23] investigated the prevalence of rotator cuff lesions according to ROM deficit in patients with FS. They found a lower rate of concomitant RCT in patients with severe and global reduction in ROM than in patients with severe but not global reduction in ROM and patients with mild to moderate reduction in ROM. Furthermore, no full-thickness tear was observed in patients with severe and global reduction in ROM, whereas full-thickness tears were more frequent than no or partial tears in patients with mild to moderate reduction in ROM. Previous studies have shown that the severity of ROM restriction may be associated with the prevalence of RCT.[24,25] Instead of a global reduction in ROM, we focused on ROM in forward flexion as a reflection of whether stiffness occurred mostly with overhead movements because considering stiffness in terms of overhead movements is more intuitive in clinical practice. In line with the results of previous studies, our results showed that patients with OHS were more likely to have a concomitant RCT and were also more likely to have a severe grade of RCT.

We further analyzed whether the association between RCT and OHS differed between age groups. In patients aged 40–49 years, the presence of OHS was associated with approximately 2-fold increased odds of RCT, although this association did not reach statistical significance. However, among patients aged 50–59 years, the odds of RCT in those with OHS increased almost 4-fold, and the odds increased even further in the oldest age groups. In patients aged 70–79 years, the odds of RCT were almost 8-fold higher in patients with OHS than in those with non-OHS. Thus, in patients with FS who are aged 50 years and older and present with mostly OHS (preserved forward flexion), it is appropriate to evaluate the integrity of the rotator cuff by ultrasonography or MRI.

Further research is necessary to understand the reason behind the increased prevalence of concomitant RCT in patients with non-global shoulder stiffness. It has been hypothesized that limited ROM in patients with FS and non-OHS (i.e., global reduction in ROM) originates from pathophysiologic mechanisms associated with idiopathic primary FS, whereas patients with OHS develop FS secondary to RCT, resulting in less limitation of ROM than typical primary FS. Of course, even in idiopathic primary FS, there could be variations in loss of motion depending on the stage of FS, and primary FS can still develop in patients with RCT. Nonetheless, our results suggest that more extensive (i.e., global) stiffness, such as that seen in our non-OHS group with restricted forward flexion, is usually caused by primary FS, whereas more limited stiffness, such as that seen in our OHS group, is more frequently the consequence of an RCT.

This study has several limitations. First, the presence of concomitant RCT was not confirmed by arthroscopy, and more subtle partial-thickness tears may have been missed on review of the MRI scans. Second, our definition of OHS as forward flexion ≥ 110° in patients with FS was somewhat arbitrary. When we analyzed the odds of concomitant RCT for different OHS-group definitions (≥ 100°, ≥ 110°, or ≥ 120°), the OR was highest using this angle. In addition, we used the term "OHS" instead of "≥ 110° forward flexion" because OHS will likely be more intuitive and understandable for general orthopedic surgeons. Third, we only evaluated the effects of age on the relationship between RCT and OHS in patients with FS. Further studies should be conducted to identify other risk factors that may modify the relationship between RTC and OHS in this patient population.

In conclusion, patients with FS who have a forward flexion ROM ≥ 110° (i.e., OHS) at initial presentation have approximately 5-fold higher odds of concurrent RCT, compared to patients with non-OHS. Moreover, in patients aged 50 years and above, the increased odds were up to 8 times higher in patients with OHS than in those with non-OHS. Therefore, we recommend confirming rotator cuff integrity by MRI in older patients with FS who present with OHS.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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