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Effects of joint capsular release on range of motion in patients with frozen shoulder

Yoshihiro Hagiwara, MD, PhD[a,*], Kenji Kanazawa, MD, PhD[b], Akira Ando, MD, PhD[c], Takuya Sekiguchi, MD, PhD[d], Masashi Koide, MD, PhD[c], Yutaka Yabe, MD, PhD[a], Kazuaki Suzuki, MD, PhD[a], Eiji Itoi, MD, PhD[a]

[a]*Department of Orthopaedic Surgery, Tohoku University School of Medicine, Sendai, Japan*
[b]*Department of Orthopaedic Surgery, South Miyagi Medical Center, Ōgawara, Japan*
[c]*Department of Orthopaedic Surgery, Matsuda Hospital, Sendai, Japan*
[d]*Department of Orthopaedic Surgery, Iwate Prefectural Central Hospital, Morioka, Japan*

Background: A thickened joint capsule is believed to be one of the most specific manifestations of and the primary restraint against range of motion (ROM) in frozen shoulders. The purpose of this study was to evaluate the relationship among ROMs under general anesthesia before surgery and the effects of each joint capsular release on ROM.
Methods: ROM was measured using a goniometer with scapular fixation. Arthroscopic pan-capsular release was performed with the patient in the beach-chair position in the following order: (1) rotator interval, (2) coracohumeral ligament, (3) superior capsule, (4) middle glenohumeral ligament, (5) anterior inferior glenohumeral ligament, and (6) posterior inferior glenohumeral ligament. ROMs in forward flexion (FF), lateral elevation (LE), external rotation with the arm at the side (ER1), external rotation at 90° of LE (ER2), internal rotation at 90° of LE (IR2), horizontal flexion, external rotation at 90° of FF (ER3), and internal rotation at 90° of FF (IR3) were evaluated before and after each release.
Results: A total of 32 consecutive shoulders were included. After each capsular release, the ROM recovered; the final ROM was significantly greater on the affected side than on the unaffected side. Significant correlations were found between FF and LE, FF and ER1, ER1 and ER2, ER1 and ER3, ER2 and ER3, and IR2 and IR3 on both sides, regardless of surgery.
Conclusion: Each segment of the joint capsule affected ROM in all directions, supporting the need for whole-joint capsular release; ROM was significantly greater on the affected side than on the unaffected side after surgery.
Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Frozen shoulder; arthroscopic capsular release; range of motion; coracohumeral ligament; joint capsule; beach-chair position; goniometer

"Frozen shoulder" (FS), another term for "idiopathic stiff shoulder," develops without any trauma or specific shoulder disease.[13] It is characterized by restriction in range of motion (ROM) and is not influenced by pain.[13] Although FS has been considered a self-limiting condition on the basis of the natural history,[6] some patients show little or no improvement, with residual limited ROM and continuing symptoms, even after a few years of conservative

Institutional Review Board approval was received from Tohoku University School of Medicine (approval no. 2015-1-483). All procedures in this study were performed in accordance with the ethical standards of the institutional and/or national research committee and with the Declaration of Helsinki. Written informed consent was obtained from all participants.

*Reprint requests: Yoshihiro Hagiwara, MD, PhD, Department of Orthopaedic Surgery, Tohoku University Graduate School of Medicine, 2-1 Seiryo-machi, Aoba-ku, Sendai 980-8574, Japan.

E-mail address: hagi@med.tohoku.ac.jp (Y. Hagiwara).

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treatment.[11,19] For such cases, surgical interventions using manipulation under anesthesia[7,16] and arthroscopic capsular release[10] are potential treatment options. These surgical interventions mainly target the release of the thickened joint capsule, as it connects the humerus and glenoid.

The shoulder joint complex includes 4 bony segments that show articular relationships with one another: humerus, scapula, clavicle, and thorax. Muscles around the shoulder girdle also connect the bones and may impact their motion and posture.[2] Evaluating shoulder ROM has been accepted as a means of summarizing ROM. However, to evaluate true glenohumeral motion, the scapula must be fixed by an examiner with one hand so that the scapula is immobile, and ROM should be measured to exclude scapular-thoracic motion with the patient under general anesthesia.[8] This procedure can only evaluate true glenohumeral motion, which depends on the joint capsule pathology.

A thickened coracohumeral ligament (CHL)—which forms the anterosuperior part of the joint capsule—at the rotator interval (RI) is considered by some researchers to be the most specific manifestation of FS[12] and the primary restraint against external rotation (ER) in FS.[14,17,18] However, during true glenohumeral ROM evaluation, the CHL restricted the ROM in lateral elevation (LE), ER with the arm at the side (ER1), ER at 90° of forward flexion (ER3), and internal rotation at 90° of forward flexion (IR3).[9] Considering that the CHL originates from the base and horizontal limb of the coracoid process and encloses the subscapularis, supraspinatus, and infraspinatus tendons,[5] it is reasonable to hypothesize that it affects ROM in various directions, other than ER. For recurrent anterior shoulder instability, the obliteration of the subcoracoid fat triangle and the thickness of the CHL were positively correlated with ROM restriction (forward flexion [FF],[3] ER, and hand behind the back[15]). The CHL is able to limit ROM, similarly to limited ROM in other shoulder disorders.

There are no published data regarding the degree of ROM restriction for each part of the joint capsule, except for the CHL and ROM relationships among different parts of the joint capsule. The purpose of this study was to evaluate the relationship among ROMs under general anesthesia and the effects of each joint capsule (RI, CHL, superior capsule, middle glenohumeral ligament [MGHL], anterior inferior glenohumeral ligament [AIGHL], and posterior inferior glenohumeral ligament [PIGHL]) on ROM during arthroscopic surgery in patients with FS.

Materials and methods

Patients and inclusion and exclusion criteria

Between October 2014 and June 2015, patients who underwent arthroscopic pan-capsular release for severe shoulder stiffness with discomfort in activities of daily living were included in this prospective comparative study. They were treated using physiotherapy and steroid injections to relieve pain. FS was diagnosed based on (1) a history of shoulder pain and stiffness longer than 1 month; (2) limited passive shoulder motion of 100° of FF or less, 20° of ER1 or less, and the fifth lumbar vertebra or less during hand-behind-the-back testing, which was measured by asking patients to place the thumb on the highest spinal vertebra they could possibly reach; and (3) a normal radiologic appearance of the shoulder.[1,9,19] Patients were excluded based on radiographic evidence of abnormalities indicating glenohumeral osteoarthritis, calcific tendinitis, a superiorly migrated humeral head, osteonecrosis of the humeral head, or rotator cuff tears visualized on magnetic resonance imaging. Patients with a history of fractures around the shoulder, shoulder dislocation, thyroid disorders, diabetes mellitus, and post-traumatic FS were also excluded.

Preoperative treatment

A mixture of 4 mg of dexamethasone and 10 mL of 1% lidocaine was injected using ultrasonography until symptoms were relieved (in total, $\leq$2 times, 1 time/week). Stretching of the muscles around the shoulder girdle, thorax, spine, trunk, and hip joints was performed.[8] If limited ROM remained after at least 3 months of physiotherapy and patients had some discomfort, arthroscopic pan-capsular release was recommended.[8,9]

Intraoperative ROM measurements

A total of 32 consecutive shoulders in 32 patients were included in this study. To evaluate the true glenohumeral ROM and exclude scapulothoracic motion, the scapula was first fixed by an examiner with one hand (without palpating scapular motion) and the following motions were measured with a goniometer with the patient under general anesthesia in the beach-chair position[8]: passive ROM of FF, LE, ER1, ER at 90° of LE (ER2), internal rotation at 90° of LE (IR2), horizontal flexion (HF) and ER3, and IR3 (Supplementary Video S1). The surgical bed was set up in a horizontal fashion, and the angle between the trunk of the patient and the surgical bed was measured with a goniometer before draping. The reliability and validation of the goniometer measurement methods were not evaluated to save surgical time.

Surgical procedure

After draping, the axis of the trunk was re-created with a surgical pen before the operation began. The joint capsule was released in a sequential order: (1) RI, (2) CHL, (3) superior capsule, (4) MGHL, (5) AIGHL, and (6) PIGHL.[8,9] Each ROM for each procedure was measured after arthroscope removal. In cases with difficulty achieving 90° of FF and LE, the ROM was evaluated at the maximum degrees of FF and LE.[9] No complications occurred during or after the operations, and rotator cuff abnormalities were not found in any cases. A single surgeon (Y.H.) performed all surgical procedures and ROM measurements without subacromial decompression.

Table I Changes in ROM after each segmental capsular release

Postoperative ROM at each component of joint capsule	Affected							Unaffected
	Initial preoperative evaluation of ROM performed under anesthesia	RI	CHL	SCap	MGHL	AIGHL	PIGHL	
FF, °	70 (15)	84 (9)	88 (7)	91 (6)	92 (6)	100 (12)	162 (15)	141 (31)
P value vs. former value		<.001	<.001	.011	.08	<.001	<.001	
P value vs. unaffected side	<.001	<.001	<.001	<.001	<.001	<.001	.001	
LE, °	64 (21)	77 (17)	83 (13)	86 (12)	88 (12)	99 (19)	170 (9)	150 (31)
P value vs. former value		<.001	.001	.003	.009	<.001	<.001	
P value vs. unaffected side	<.001	<.001	<.001	<.001	<.001	<.001	<.001	
ER1, °	−20 (23)	18 (17)	30 (14)	36 (13)	39 (12)	46 (11)	59 (13)	43 (11)
P value vs. former value		<.001	<.001	<.001	<.001	<.001	<.001	
P value vs. unaffected side	<.001	<.001	<.001	.019	.173	.093	<.001	
ER2, °	51(11)	68 (13)	74 (12)	78 (12)	80 (11)	91 (13)	104 (13)	86 (10)
P value vs. former value		<.001	.002	<.001	.003	<.001	<.001	
P value vs. unaffected side	<.001	<.001	.001	.012	.033	.108	<.001	
IR2, °	−36 (12)	−37 (18)	−31 (21)	−27 (22)	−24 (22)	−6 (20)	12 (11)	4 (17)
P value vs. former value		.402	.001	.019	.026	<.001	<.001	
P value vs. unaffected side	<.001	<.001	<.001	<.001	<.001	.067	.018	
HF, °	64 (18)	100 (21)	112 (15)	120 (13)	123 (12)	127 (10)	130 (8)	102 (19)
P value vs. former value		<.001	<.001	<.001	<.001	<.001	.001	
P value vs. unaffected side	<.001	.608	.043	<.001	<.001	<.001	<.001	
ER3, °	61 (12)	81 (11)	84 (14)	87 (13)	89 (7)	92 (8)	98 (9)	88 (9)
P value vs. former value		<.001	.004	.003	.109	<.001	<.001	
P value vs. unaffected side	<.001	.012	.213	.85	.624	.013	<.001	
IR3, °	−47 (8)	−44 (8)	−40 (9)	−37(11)	−29 (23)	−20 (21)	2 (4)	−8 (24)
P value vs. former value		.004	<.001	<.001	.012	<.001	<.001	
P value vs. unaffected side	<.001	<.001	<.001	<.001	<.001	.006	.025	

ROM, range of motion; *RI*, rotator interval; *CHL*, coracohumeral ligament; *SCap*, superior capsule; *MGHL*, middle glenohumeral ligament; *AIGHL*, anterior inferior glenohumeral ligament; *PIGHL*, posterior inferior glenohumeral ligament; *FF*, forward flexion; *LE*, lateral elevation; *ER1*, external rotation with arm at side; *ER2*, external rotation at 90° of lateral elevation; *IR2*, internal rotation at 90° of lateral elevation; *HF*, horizontal flexion; *ER3*, external rotation at 90° of forward flexion; *IR3*, internal rotation at 90° of forward flexion. Data are presented as mean (standard deviation).

Table II Regained range of motion after capsular release

	RI vs. initial	CHL vs. RI	SCap vs. CHL	MGHL vs. SCap	AIGHL vs. MGHL	PIGHL vs. AIGHL
FF, °	15 (13)	4 (5)	3 (6)	1 (3)	8 (9)	63 (18)
LE, °	13 (13)	8 (13)	3 (6)	2 (3)	11 (15)	71 (21)
ER1, °	38 (20)	11 (9)	6 (5)	3 (4)	7 (5)	13 (10)
ER2, °	18 (11)	6 (10)	4 (6)	2 (3)	11 (7)	13 (8)
IR2, °	0 (13)	6 (10)	4 (8)	3 (7)	18 (13)	18 (19)
HF, °	37 (26)	12(10)	8 (6)	3 (5)	3 (5)	3 (5)
ER3, °	20 (10)	3 (12)	3 (4)	2 (10)	4 (4)	6 (7)
IR3, °	3 (6)	4 (5)	3 (4)	7 (22)	10 (10)	22 (20)

RI, rotator interval; *CHL*, coracohumeral ligament; *SCap*, superior capsule; *MGHL*, middle glenohumeral ligament; *AIGHL*, anterior inferior glenohumeral ligament; *PIGHL*, posterior inferior glenohumeral ligament; *FF*, forward flexion; *LE*, lateral elevation; *ER1*, external rotation with arm at side; *ER2*, external rotation at 90° of lateral elevation; *IR2*, internal rotation at 90° of lateral elevation; *HF*, horizontal flexion; *ER3*, external rotation at 90° of forward flexion; *IR3*, internal rotation at 90° of forward flexion. Data are presented as mean (standard deviation).

Statistical analyses

Continuous variables are presented as mean ± standard deviation. Because most values were not normally distributed, nonparametric procedures were performed for analysis. The Wilcoxon signed rank test was used to compare ROM (FF, LE, ER1, ER2, IR2, HF, ER3, and IR3) before and after resection. Spearman rank correlation coefficients were calculated to evaluate the association between each ROM and the other ROMs. All statistical analyses were performed using SPSS software (version 24.0; SPSS Japan, Tokyo, Japan). All tests were 2-tailed, and $P < .05$ was considered statistically significant.

Results

A significant recovery in ROM was noted for each section of the joint capsule following release, except the RI in IR2 and the MGHL in FF and ER3 (Table I). Compared with the unaffected side, the affected side showed significant increases, except for the MGHL and AIGHL in ER1, the AIGHL in ER2 and IR2, the RI in HF, and the CHL, superior capsule, and MGHL in ER3 (Table I). Regained ROM after each capsular release is shown in Table II. Significant correlations were found between FF and LE, FF and ER1, ER1 and ER2, ER1 and ER3, ER2 and ER3, and IR2 and IR3 on the affected side, regardless of surgery, as well as on the unaffected side (Tables III-V). In addition, on the affected side before surgery, significant correlations were noted between FF and HF, FF and ER3, LE and ER3, ER1 and HF, ER2 and IR2, ER2 and IR3, IR2 and ER3, and ER3 and IR3 (Table III). On the affected side after surgery, significant correlations were found between FF and IR2, FF and ER3, LE and ER1, LE and IR2, LE and ER3, ER1 and IR2, ER2 and HF, IR2 and ER3, HF and ER3, and ER3 and

Table III Correlation coefficients among ranges of motion before surgery on affected side

	FF	LE	ER1	ER2	IR2	HF	ER3	IR3
FF	1.000	0.583	0.501	0.299	0.092	0.371	0.455	0.009
P value		<.001	.004	.096	.617	.037	.009	.963
LE		1.000	0.328	0.324	−0.086	0.135	0.523	−0.308
P value			.067	.070	.639	.462	.002	.086
ER1			1.000	0.360	−0.025	0.722	0.558	−0.188
P value				.043	.894	<.001	.001	.303
ER2				1.000	−0.663	0.150	0.723	−0.419
P value					<.001	.414	<.001	.017
IR2					1.000	0.120	−0.423	0.525
P value						.514	.016	.002
HF						1.000	0.144	0.050
P value							.433	.784
ER3							1.000	−0.596
P value								<.001
IR3								1.000

FF, forward flexion; *LE*, lateral elevation; *ER1*, external rotation with arm at side; *ER2*, external rotation at 90° of lateral elevation; *IR2*, internal rotation at 90° of lateral elevation; *HF*, horizontal flexion; *ER3*, external rotation at 90° of forward flexion; *IR3*, internal rotation at 90° of forward flexion.

Table IV Correlation coefficients among ranges of motion after surgery on affected side

	FF	LE	ER1	ER2	IR2	HF	ER3	IR3
FF	1.000	0.935	0.499	0.200	0.610	0.259	0.581	0.326
P value		<.001	.004	.272	<.001	.152	<.001	.068
LE		1.000	0.466	0.227	0.625	0.196	0.629	0.345
P value			.007	.212	<.001	.282	<.001	.053
ER1			1.000	0.632	0.637	0.324	0.509	0.349
P value				<.001	<.001	.071	.003	.050
ER2				1.000	0.319	0.455	0.515	0.136
P value					.075	.009	.003	.460
IR2					1.000	−0.064	0.624	0.382
P value						.726	<.001	.031
HF						1.000	0.363	0.218
P value							.041	.230
ER3							1.000	0.399
P value								.024
IR3								1.000

FF, forward flexion; *LE*, lateral elevation; *ER1*, external rotation with arm at side; *ER2*, external rotation at 90° of lateral elevation; *IR2*, internal rotation at 90° of lateral elevation; *HF*, horizontal flexion; *ER3*, external rotation at 90° of forward flexion; *IR3*, internal rotation at 90° of forward flexion.

IR3 (Table IV). On the unaffected side, significant correlations were observed between FF and IR2, LE and IR2, ER2 and HF, and HF and IR3 (Table V).

Discussion

The most important finding of this study was that each segment of the joint capsule had some effect on ROM in all directions; in addition, ROM on the affected side was significantly greater than that on the unaffected side after surgery. Furthermore, significant correlations were found between FF and LE, FF and ER1, ER1 and ER2, ER1 and ER3, ER2 and ER3, and IR2 and IR3 on the affected side, regardless of surgery, and on the unaffected side for true glenohumeral motion.

A thickened CHL has been reported as one of the most specific clinical manifestations of[12] and the primary restraint against ER for FS.[14,17,18] However, after releasing of the remained CHL during arthroscopic capsular release in patients with FS, LE, ER3, and IR3 recovered to normal range.[9] In this study, each segment of the joint capsule had some restoration in ROM of all directions, and all the ROMs on the affected side were significantly greater than those on the unaffected side after the final release.[4] For FS, the necessity to release the PIGHL remains controversial. No significant difference in function and ROM after 6 months was found in FS patients with or without PIGHL

Table V Correlation coefficients among ranges of motion on unaffected side

	FF	LE	ER1	ER2	IR2	HF	ER3	IR3
FF	1.000	0.839	0.383	−0.117	0.444	−0.119	0.179	0.088
P value		<.001	.031	.524	.011	.515	.328	.632
LE		1.000	0.224	−0.282	0.462	−0.262	0.097	0.246
P value			.218	.118	.008	.148	.599	.175
ER1			1.000	0.552	0.240	0.129	0.427	0.231
P value				.001	.186	.481	.015	.204
ER2				1.000	−0.135	0.558	0.567	−0.079
P value					.462	.001	.001	.666
IR2					1.000	−0.276	0.158	0.532
P value						.127	.387	.002
HF						1.000	0.327	−0.469
P value							.067	.007
ER3							1.000	0.196
P value								.281
IR3								1.000

FF, forward flexion; *LE*, lateral elevation; *ER1*, external rotation with arm at side; *ER2*, external rotation at 90° of lateral elevation; *IR2*, internal rotation at 90° of lateral elevation; *HF*, horizontal flexion; *ER3*, external rotation at 90° of forward flexion; *IR3*, internal rotation at 90° of forward flexion.

release, but rapid recovery was obtained within the first 3 months in the PIGHL release group.[4] Although short-term results were similar to the results of our study, scapular kinematics would compensate for shoulder ROM 6 months after surgery. In our study, it was difficult to conclude whether PIGHL release was necessary because the ROM evaluation and follow-up period differed from those in previous research.[4] Further studies are needed to determine the necessity.

Significant correlations were found between FF and LE, FF and ER1, ER1 and ER2, ER1 and ER3, ER2 and ER3, and IR2 and IR3 on the affected and unaffected sides in this study, both before and after surgery. These 6 correlations were quite important for evaluating true ROM under general anesthesia. In other words, evaluating these true ROMs made it easier to identify capsular restriction in the glenohumeral joint in patients with FS. Evaluating true ROM is beneficial for revealing faint changes in the joint capsule.[9]

This study has some limitations. First, surgery and ROM were evaluated by a single surgeon, and the degree of tissue expansion during surgery was not estimated. Additional research should include reliability tests such as inter-rater reliability assessment. Second, preoperative and postoperative evaluations of ROM performed in the outpatient clinic were not included, and randomization was not adopted. Third, the order of the releasing area might have affected the results. Fourth, the long-term clinical outcomes of the entire arthroscopic capsular release and evaluation of true ROM in the glenohumeral joint were not evaluated. Larger studies that include reliability tests, preoperative and postoperative ROM evaluations, and evaluation of long-term clinical outcomes are necessary in the future.

Conclusion

Each segment of the joint capsule has some effect on ROM in all directions, and ROM on the affected side was significantly greater than that on the unaffected side after surgery. Furthermore, significant correlations were found between FF and LE, FF and ER1, ER1 and ER2, ER1 and ER3, ER2 and ER3, and IR2 and IR3 on the affected and unaffected sides, regardless of surgery, for true glenohumeral motion. Whole-joint capsular release is required to regain ROM in patients with FS.

Disclaimer

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Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jse.2020.01.085.

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