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Inferior glenohumeral joint capsule thickness in frozen shoulder via ultrasonography

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Background: The thickening of the inferior glenohumeral joint capsule (IGC) is a characteristic finding in frozen shoulders. However, the relationship between the thickness of the IGC measured using ultrasonography (US) and the range of motion (ROM) remains unclear. This study aimed to investigate a suitable IGC thickness measurement site that can reflect the ROM of frozen shoulders.

Methods: The participants were 29 patients with frozen shoulder and 20 healthy shoulders of 10 healthy adult. US measurements of the IGC were performed at 80° elevation in the scapular plane, with thickness was measured at 3 levels in both groups: just above the surgical neck, just above the anatomical neck, and at the parenchymal level. The relationship between thickness and ROM at the 3 levels was also assessed. The thickness of the IGC was evaluated using magnetic resonance imaging and US, as well as the validity of US evaluation.

Results: There was a positive correlation (r = 0.72) between magnetic resonance imaging–measured and US-measured IGC thickness. The IGC was thicker in the frozen shoulder group than in the control group at all 3 levels ($P < .001$). The thickness of the IGC at the parenchymal level showed a significant negative correlation with all ROMs: flexion (r = −0.63), abduction (r = −0.60), external rotation (r = −0.50), and internal rotation (r = −0.52).

Conclusion: The thickness of the IGC at the parenchymal level is negatively correlated with the ROM. The evaluation of the IGC in this study will be helpful in selecting treatment options for frozen shoulders.

There are reports of residual pain and range-of-motion limitation more than 5 years after frozen shoulder onset, although the condition is believed to heal spontaneously.[16,5] In addition, persistent shoulder pain may cause functional disabilities, sleep disturbances, depression, and decreased social participation.[11] The first-line treatment for frozen shoulder is conservative management with physical therapy and injections. However, in difficult cases, arthroscopic capsular release (ACR) has been reported, and appropriate treatment should be selected according to the pathophysiology of the patient.[14,17,18]

As the pathology progresses in frozen shoulders, tissue fibrosis occurs due to the action of fibroblasts and other factors, and thickening of the capsule is observed.[9] The expression of inflammatory cytokines and collagen-related genes is highest in the inferior glenohumeral joint capsule (IGC).[10] Therefore, it is important to accurately identify the pathological changes in the IGC to select suitable treatments for frozen shoulders.

Magnetic resonance imaging (MRI) is used to evaluate the pathogenesis of frozen shoulder and thickening of the IGC is considered a characteristic finding.[1,6] However, there is no unified view on the relationship between MRI-measured thickness of the IGC and range of motion (ROM).[2,3,15] This may be because MRI is performed with the upper limb in the shoulder at a 0° flexion position, which causes deflection of the IGC and prevents an accurate

This study was approved by the Ethics Committee of the Morinomiya University of Medical Sciences (authorization number: 2022-047), and informed consent was obtained from all participants.

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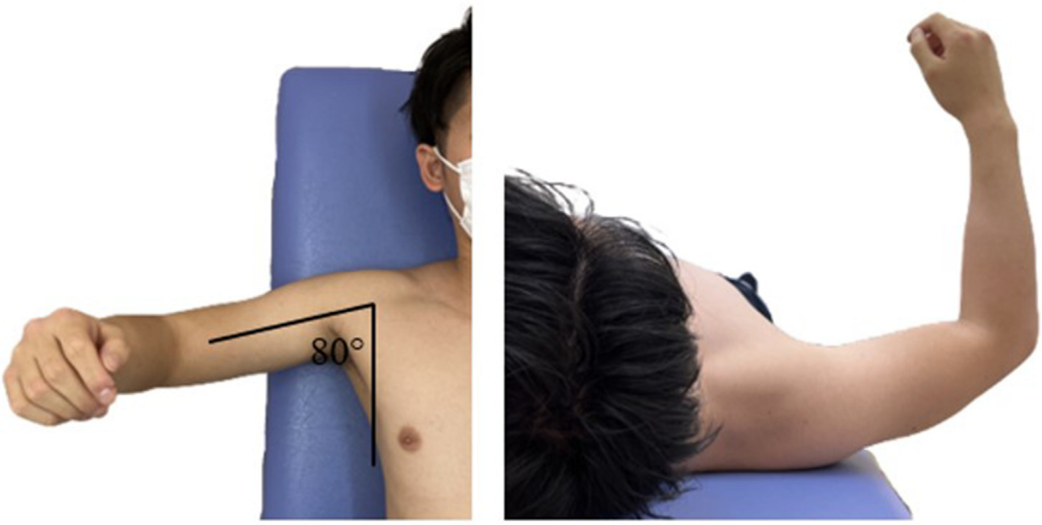

Figure 1 Measurement position of the inferior glenohumeral joint capsule in ultrasonography.

assessment of its thickness. In recent years, ultrasonography (US) has been used to assess the IGC in the abducted position of the shoulder, and attempts have been made to measure it in the extended position of the capsule.[8,12] An accurate assessment of the thickness of the IGC using US would be useful in determining the treatment strategy. However, the relationship between the thickness of the IGC using US and the ROM remains unclear.[4,7,13]

Conventional measurement of the thickness of the IGC is based on the distance between the humeral surgical neck and the capsule.[4,7,8,12,13] Measurement at the surgical neck level measures not only the insertion site of the capsule but also the folds of the capsule and synovium, which may not be an accurate assessment of the thickness of the capsule. We hypothesized that measuring the IGC at an elevated shoulder position and measuring the IGC thickness at a suitable area would clarify the relationship with the ROM. Therefore, this study aimed to investigate a suitable IGC thickness measurement site that can reflect the ROM in frozen shoulders.

Materials and methods

Participants

Twenty-nine patients with frozen shoulder who consented to participate in the study were included. The frozen shoulder group was defined as patients who visited an orthopedic clinic between June 2022 and December 2022 were diagnosed with frozen shoulder and had shoulder joint pain and active and passive range-of-motion limitations for at least 1 month.

The exclusion criteria were rotator cuff tears, osteoarthritis of the shoulder, calcific tendonitis, and a history of shoulder trauma or surgery. Forty healthy shoulders of 20 healthy adult volunteers participated in the control group. Of the 20 participants, 20 healthy shoulders of 10 healthy adult volunteers matched for age with the frozen shoulder group were included in the control group. The remaining 20 healthy shoulders of 10 healthy young volunteers participated in this study. The inclusion criteria for the control group include no history of upper extremity orthopedic disease, shoulder pain, or limited ROM. This study was approved by the Ethics Committee of the Morinomiya University of Medical Sciences (authorization number: 2022-047), and informed consent was obtained from all participants.

Ultrasonography evaluation

The thickness of the IGC was assessed by a single physical therapist with 7 years of US experience, who had previously practiced imaging in more than 20 inferior glenohumeral capsules. The US image was captured in B-mode using a 3-11 MHz linear transducer (SONIMAGE HS1, Konica Minolta, Tokyo, Japan). The subject was placed in the supine position with 80° elevation in the scapular plane and the elbow flexed at 90° (Fig. 1).

To image the IGC, the transducer was placed on the humerus along the short axis, and the IGC was identified in the deep layer of the teres major muscle. The transducer was then rotated along the long axis of the humerus to clearly image the bony contours of the surgical and anatomical neck. After confirming the continuity of the IGC, a long-axis image of the IGC was obtained (Fig. 2). From the obtained images, the thickness of the IGC was measured at 3 levels using ImageJ software (National Institutes of Health, Bethesda, MD, USA) in the following 3 levels. The surgical neck level was defined as the distance from the surgical neck to the IGC,[12] the anatomical neck level as the distance from the anatomical neck to the IGC, and the parenchymal level as the vertical distance from the point of contact between the surgical and anatomical necks, connected by a straight line, to the IGC (Fig. 3). The thickness was assessed 3 times at each of the 3 levels, and the average value was calculated.

Range-of-motion evaluation

The shoulder motion was assessed in the sitting position, and the ROM of flexion, abduction, external rotation, and internal rotation was assessed by the same examiner using a goniometer. Flexion was defined as the angle between the upper arm and trunk when the upper arm was raised in the sagittal plane. Abduction was defined as the angle between the upper arm and trunk when the upper arm was raised in the frontal plane. External rotation was defined as the angle of external rotation with the elbow joint flexed at 90° in the supinated position. Internal rotation was measured at the vertebral level reached by the tip of the thumb with the hand behind the back. For statistical analysis, the values were quantified as follows: buttock = 1, sacrum = 2, fifth to first lumbar vertebrae = 3-7, 12th to seventh thoracic vertebrae, and above = 8-13. Range-of-motion measurements were performed without trunk or scapular trick motions.

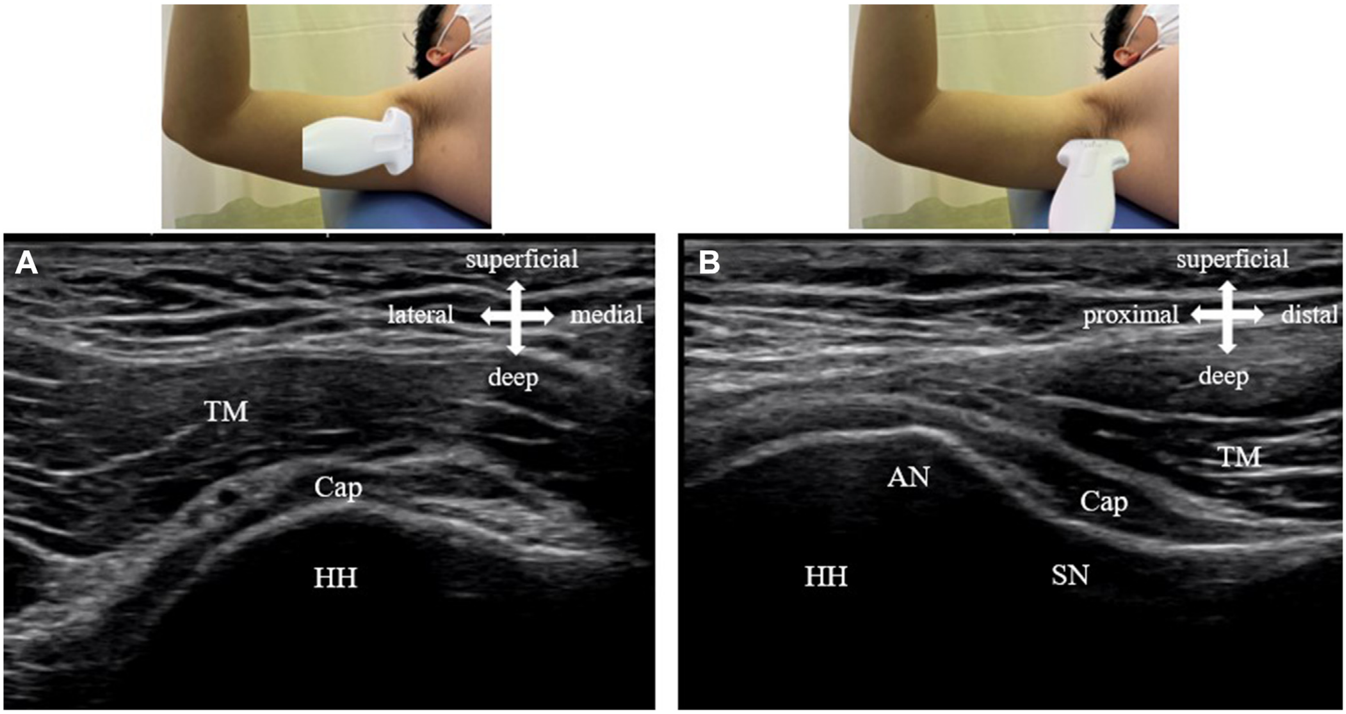

Figure 2 Methods of imaging the inferior glenohumeral joint capsule in ultrasonography. Short axis view (**A**) and long axis view (**B**). *HH*, humeral head; *AN*, anatomical neck; *SN*, surgical neck; *cap*, capsule; *TM*, teres major.

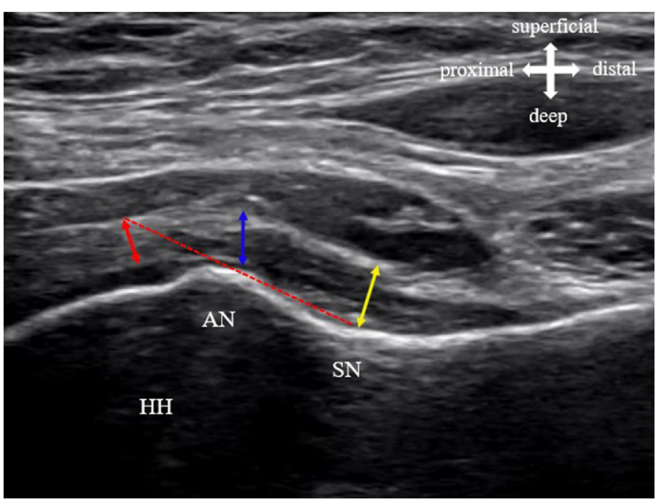

Figure 3 Measurement site for inferior glenohumeral joint capsule thickness in ultrasonography. The surgical neck level (*yellow arrow*), the anatomical neck level (*blue arrow*), and the parenchymal level (*red arrow*). *HH*, humeral head; *AN*, anatomical neck; *SN*, surgical neck.

Validity of US assessment of inferior glenohumeral joint capsule thickness

The subjects were 10 healthy adults with 20 shoulders (mean age 24.8 ± 1.6 years, 5 males and 5 females); US was measured in B-mode using a 4-15 MHz linear transducer (LOGIQ P10; GE Healthcare, Tokyo, Japan). The thickness of the IGC was measured using the same method as in experiment 1.

MRI of the glenohumeral joint capsule in the same position as the US image was captured using a 1.5 T MRI (Oval; HITACHI, Chiba, Japan). Images were obtained in the oblique coronal view.[11] The imaging conditions were as follows: field of view 180 mm, repetition time 1942 ms, echo time 40.0 ms, and slice thickness 3.0 mm. MRI thickness measurements were performed at a site where the thickness could be clearly measured at the level of the anatomical neck from the center of the joint capsule (Fig. 4).

Statistical analysis

The intrarater reliability of the assessment of the thickness of the IGC using US was preliminarily examined in 2 sessions with 1-hour intervals from 10 healthy volunteers in the control group. Intrarater reliability was defined as poor (<0.5), moderate (0.5-0.75), good (0.75-0.9), and excellent (>0.9). The intraclass correlation coefficient (1, 3), 95% confidence interval (95% CI), standard error of the mean (SEM), and 95% confidence interval for Minimal Detectable Change (MDC95) were calculated. The Pearson product-moment correlation coefficient was calculated to examine the relationship between US and MRI IGC thicknesses. The Mann-Whitney U test was used to compare the thickness of the IGC between the groups which are frozen shoulder and control groups. Spearman's rank correlation coefficient was calculated to examine the relationship between the thickness of the IGC and the ROM in the frozen shoulder group. Statistical analysis was performed using SPSS Statistics (version 27.0; IBM Corp., Armonk, NY, USA), and statistical significance was set at $P < .05$.

Results

Intrarater reliability of US assessment of inferior glenohumeral joint capsule thickness

The intrarater reliability was 0.95 (95% CI, 0.88-0.98) at the surgical neck level, 0.97 (95% CI, 0.92-0.99) at the anatomic neck

Figure 4 Measurement site for inferior glenohumeral capsule thickness in MRI.

Table I
Intrarater reliability of the inferior glenohumeral joint capsule thickness.

	ICC	95% CI	SEM	MDC95
Surgical neck	0.95	0.88-0.98	0.15	0.43
Anatomical neck	0.97	0.92-0.99	0.05	0.14
Parenchymal	0.94	0.86-0.98	0.06	0.17

CI, confidence interval; *ICC*, intraclass correlation coefficient; *SEM*, standard error of the mean; *MDC95*, 95% confidence interval for Minimal Detectable Change.

level, and 0.94 (95% CI, 0.86-0.98) at the parenchymal level, demonstrating high repeatability in 3 sites. SEM and MDC95 for intrarater reliability were SEM = 0.15 mm and MDC95 = 0.43 mm at the surgical neck level, SEM = 0.05 mm and MDC95 = 0.14 mm at the anatomical neck level, and SEM = 0.06 mm and MDC95 = 0.17 mm at the parenchymal level (Table I).

Validity of US assessment of inferior glenohumeral capsule thickness

The thickness of the IGC was 2.3 ± 0.6 mm on MRI and 1.3 ± 0.2 mm on US, indicating a positive correlation (r = 0.72) between MRI-measured and US-measured inferior glenohumeral capsule thickness (Fig. 5).

Characteristics of the control group and the frozen shoulder

The control group included 10 patients with 20 shoulders (male: n = 3, female: n = 7, mean age 57.1 ± 9.8 years) and the groups with frozen shoulders included 29 patients with 29 shoulders (male: n = 9, female: n = 20, mean age: 58.2 ± 9.3 years). Age, height, weight, and body mass index were not significantly different between the 2 groups. The ROM of the frozen shoulder group was significantly lower than that of the control group (Table II).

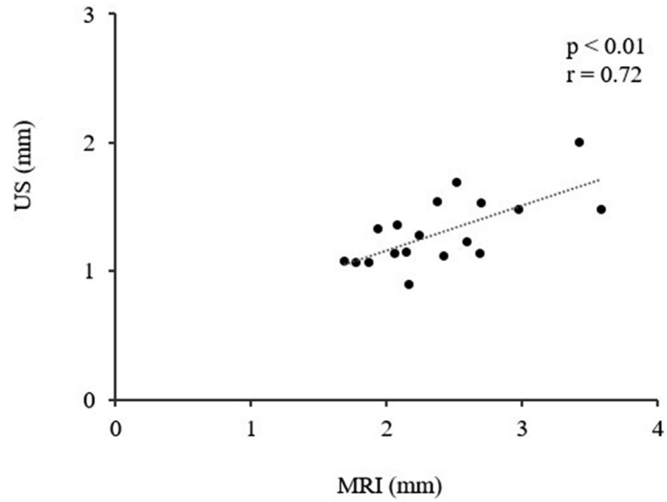

Figure 5 Relationship between MRI and US inferior glenohumeral joint capsule thickness. *MRI*, magnetic resonance imaging; *US*, ultrasonography.

Table II
Demographics of participants.

	Control	Frozen shoulder	*P* value
n/shoulder	10/20	29/29	
Sex (male/female)	3/7	9/20	
Age (yr)	57.1 ± 9.8	58.2 ± 9.3	.67
Height (cm)	161.3 ± 10.8	163.4 ± 6.7	.41
Weight (kg)	58.0 ± 9.7	60.7 ± 10.1	.14
BMI (kg/m^2)	22.4 ± 3.0	22.7 ± 3.0	.60
Range of motion			
Flexion (°)	171.3 ± 2.8	122.8 ± 24.0	<.001*
Abduction (°)	170.8 ± 3.8	86.0 ± 31.2	<.001*
External rotation (°)	67.4 ± 6.5	19.8 ± 19.1	<.001*
Internal rotation	11.1 ± 1.6	2.4 ± 3.1	<.001*

BMI, body mass index.
*P < .01.

Table III
Comparison of inferior glenohumeral joint capsule thickness between the control group and the frozen shoulder.

	Control	Frozen shoulder	Effect size	*P* value
Surgical neck (mm)	2.3 ± 0.4	3.8 ± 1.4	r = 0.6	<.001*
Anatomical neck (mm)	1.3 ± 0.3	2.3 ± 0.8	r = 0.6	<.001*
Parenchymal (mm)	1.1 ± 0.2	2.3 ± 0.8	r = 0.7	<.001*

*P < .01.

Comparison of the thickness of the inferior glenohumeral joint capsule between 2 groups

The thickness of the IGC in the control and frozen shoulder groups were calculated as follows: surgical neck level (2.2 ± 0.3 and 3.8 ± 1.4 mm, respectively), anatomical neck level (1.3 ± 0.3 and 2.3 ± 0.8 mm, respectively), and parenchymal level (1.1 ± 0.2 and 2.3 ± 0.8 mm, respectively) with the frozen shoulder group exhibiting a significantly thicker IGC than that in the control group at all 3 levels (Table III).

Relationship between the thickness of the inferior glenohumeral capsule and the range of motion

The thickness of the IGC at the level of the surgical neck showed a significant negative correlation with the ROM in flexion

Table IV
Relationship between inferior glenohumeral joint capsule thickness and range of motion.

	Surgical neck		Anatomical neck		Parenchymal	
	r	*P* value	r	*P* value	r	*P* value
Flexion (°)	- 0.50	<.01†	- 0.41	.029*	- 0.63	<.001†
Abduction (°)	- 0.47	<.01†	- 0.41	.027*	- 0.60	<.001†
External rotation (°)	- 0.36	.058	- 0.40	.032*	- 0.50	<.01†
Internal rotation	- 0.45	.014*	- 0.36	.053	- 0.52	<.01†

*$P < .05$.
†$P < .01$.

(r = −0.50), abduction (r = −0.47), and internal rotation (r = −0.45). The thickness of the IGC at the level of anatomical neck level showed a significantly negative correlation with the range-of-motion flexion (r = −0.41), abduction (r = −0.41), and external rotation (r = −0.40). The thickness of the IGC at the level of the parenchymal level showed a significant negative correlation with all ranges of motion: flexion (r = −0.63), abduction (r = −0.60), external rotation (r = −0.50), and internal rotation (r = −0.52). Among the 3 levels, the strongest negative correlation was found between the thickness of the IGC at the parenchymal level and the ROM (Table IV).

Discussion

In this study, the thickness of the IGC in the frozen shoulder group was greater than that in the control group and negatively correlated with the joint ROM in all 3 areas. In addition, parenchymal-level thickness negatively correlated with joint ROM in all directions. Therefore, we suggest that the thickness of the IGC, measured using US imaging, can be reflected in the ROM of the frozen shoulder.

In this study, the thickness of the IGC was measured and validated using both MRI and US in the 80° scapular plane elevated arm position, and a positive correlation was found between the MRI and US inferior glenohumeral capsule thickness. Ticker et al[19] reported that the thickness at the center of the IGC in fresh-frozen cadavers was 1.85 ± 0.56 mm. Kim et al[7] reported that the thickness of the IGC using US had a significant correlation with that using MRI; however, the thickness of it using US and MRI were 4.4 ± 1.1 mm and 8.9 ± 1.9 mm, respectively. Thus, this is likely an overestimation. In contrast, our method approximates the results of Ticker et al with 2.3 ± 0.6 mm for MRI and 1.3 ± 0.2 mm for US.[19]

Previous studies have reported that the thickening of the IGC is a feature of frozen shoulders.[1,4,6,7,13] However, these methods do not reflect shoulder joint function, particularly the range of shoulder motion.[1,2,6,10,12] In previous studies, the thickness of the inferior glenohumeral capsule was measured at the level of the surgical neck. However, it is possible that the thickness of the attachment area, in addition to the capsular parenchyma, was measured because of the folded structure of the humeral attachment and capsule (Fig. 6). In addition, there were cases of frozen shoulder in which intra-articular edema was observed on US (Fig. 7). In such cases, measurements at the surgical neck level may overestimate the thickness of the IGC because the shape of the capsule is altered. Therefore, this is the first study to suggest assessment methods for the thickness of the parenchymal level of the IGC at 80° scapular plane elevation using US, which can demonstrate high reliability and validity and reflect the range of shoulder motion.

The assessment of the IGC in this study provides a basis for reconsidering the traditional algorithm for performing ACR in individuals with frozen shoulders. Accurate identification of pathological changes in the IGC is important for selecting the appropriate treatment for frozen shoulders.[9] When the ROM is limited by the thickening of the IGC, improvement with conservative therapies, such as physical therapy and injections, may be minimal and ineffective. Traditionally, ACR has been performed in patients with severe range-of-motion limitation who were refractory to conservative therapies for at least 3 months.[14,17,18] Therefore, any IGC contracture is an indication for ACR, which should be performed earlier and more aggressively.

This study has several limitations. First, the assessment of inferior glenohumeral capsule thickness was performed by a single examiner who was not blinded. Second, although the ROM in the frozen shoulder group was measured with great care to avoid pain, limitations due to pain could not be completely excluded. Finally, it was not possible to determine how the ROM changes with subsequent changes in inferior glenohumeral capsule thickness due to the cross-sectional study nature of the study, and a prospective study is needed.

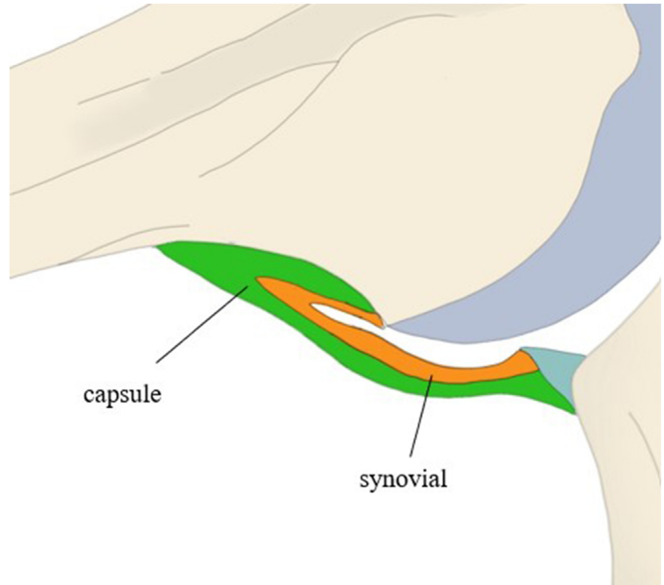

Figure 6 Folding back of the inferior glenohumeral joint capsule.

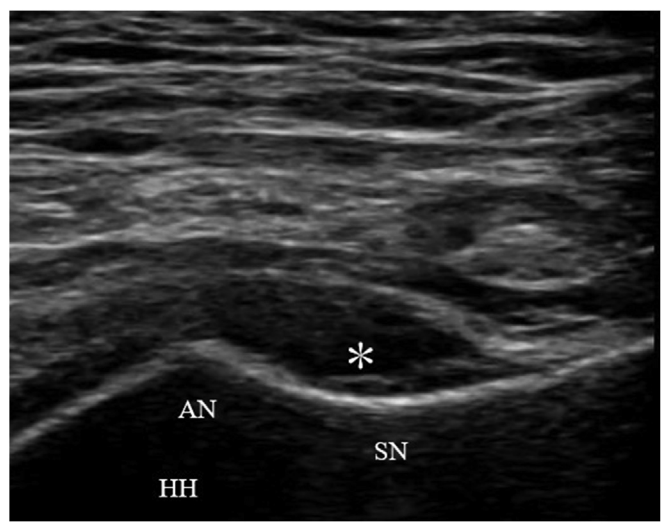

Figure 7 Intra-articular edema. *HH*, humeral head; *AN*, anatomical neck; *SN*, surgical neck; *, edema.

Conclusion

The thickness of the IGC in the 80° scapular plane elevated arm position used in this study was shown to be a highly reliable and valid method. The IGC of the frozen shoulder was thickened, and parenchymal-level thickness was negatively correlated with joint ROM in all directions. Therefore, it is suggested that the assessment of inferior glenohumeral capsule thickness using US in this study reflects the range of shoulder motion in frozen shoulder and may be helpful in selecting treatment options according to the pathophysiology of frozen shoulder.

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