Original Article

# A preliminary study of contrast-enhanced ultrasound guided capsule-preserving hydrodilatation in shoulder adhesive capsulitis

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**Background:** Capsule-preserving hydrodilatation is a common treatment for adhesive capsulitis (AC), and ultrasound (US) has recently become the most popular adjuvant tool for image-guided glenohumeral joint injection. However, traditional US is hardly adequate to assess extracapsular fluid leakage, which may decide the treatment outcomes. In this study, we explored the value of contrast-enhanced ultrasound (CEUS) guided capsule-preserving hydrodilatation with steroids and ultrasonic contrast agents for treatment of AC.

**Methods:** A total of 40 consecutive patients with AC were prospectively enrolled and received CEUS-guided capsule-preserving hydrodilatation. The number of injection attempts, injection volume, and fluid leakage were recorded, and the correlations with clinical features were analyzed by Pearson or Spearman correlation coefficients. Outcome measures including visual analog scale (VAS) score, passive range of motion (ROM), and shoulder pain and disability index (SPADI) score were evaluated at baseline and 4 weeks after treatment. Comparisons between patients with good and poor clinical outcomes were performed with independent *t*-test, Mann-Whitney U test, and chi-square test. Logistic regression was used to identify predictors of good clinical outcomes. A P value <0.05 defined significance.

**Results:** Access to the glenohumeral joint was successful in 87.5% patients on the first attempt. The infused fluid volume was 21.0±3.40 mL. Longer symptom duration (r=–0.676, P<0.001), greater SPADI (r=–0.148, P=0.007), and decreased ROM in abduction (r=0.38, P=0.016) were associated with a decreased volume of infused fluid. CEUS detected massive fluid leakage in 5 (12.5%) patients, with 4 capsule ruptures confirmed by magnetic resonance imaging (MRI). Longer symptom duration (r=0.485, P=0.001), decreased ROM in the direction of abduction (r=–0.33, P=0.037), and external rotation (r=–0.34, P=0.032) were correlated with an increased incidence of massive fluid leakage. Moreover, patients with good outcomes had significantly shorter symptom duration (5.7±2.09 *vs.* 11.2±3.89 months, P=0.002) and greater initial VAS score (6.9±1.04 *vs.* 6.3±0.50, P=0.022) than those with poor outcomes. Absence of massive fluid leakage was an independent predictor of clinical good outcomes at 4 weeks after treatment [odd ratio (OR) =0.05, 95% confidential interval (CI): 0.003–0.882, P=0.041].

**Conclusions:** CEUS-guided capsule-preserving hydrodilatation allows real-time visualization of capsule dilatation, accurate detection of extracapsular fluid leakage, and identification of risks for capsule rupture. It provides an effective treatment for AC, and is useful to predict patients' clinical outcomes.

**Keywords:** Adhesive capsulitis (AC); contrast-enhanced ultrasound (CEUS); hydrodilatation; glenohumeral joint; capsule rupture

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## Introduction

Adhesive capsulitis (AC), also known as frozen shoulder, is a common, but poorly understood, musculoskeletal disorder, with a prevalence of 2–5% in the general population (1,2). Risk factors include trauma, diabetes mellitus, prolonged immobilization, autoimmune disorders, stroke, and myocardial infarcts (3). It is characterized by progressive shoulder pain with gradual loss of passive and active range of motion (ROM), caused by inflammation of the synovial member of shoulder capsule, capsular contracture, and decreased joint capacity (4). Although AC is considered a self-limiting disease, it often has a prolonged course over 2–3 years, and up to 40% of patients may have persistent symptoms and restricted movement beyond 3 years, with 15% left with permanent disability (3,5).

Common treatments include oral medication, physical therapy, exercise, steroid injection, hydrodilatation, manipulation under anesthesia, and arthroscopic capsular release (6). Hydrodilatation involves expanding a contracted shoulder capsule by infusing a large volume of fluid consisting of saline, steroid, local anesthetic, or contrast agent under fluoroscopic or ultrasound (US) guidance. It is believed to be an effective therapeutic intervention which provides rapid pain relief and ROM improvement (7,8), and a recent study of meta-analyses (9) also indicated that hydrodilatation with steroids provides superior short-term treatment benefit to other general conservative treatments in AC. On the one hand, the injected steroids could reduce synovial inflammation and be useful to reduce pain which is predominant in the initial painful freezing stages (10). On the other hand, the large amount of fluid would distend the contracted capsule and breakdown adhesions that are limiting ROM, thereby decreasing the intra-articular pressure and increasing the shoulder volume capacity (11).

In the past, many researchers believed that infusing fluid until rupturing the capsule applied the strongest force and resulted in clinical improvement (12-14). However, capsule ruptures occurred mostly frequently in the subscapularis recess and sometimes in the long head of biceps tendon sheath (15-17), which was not the tightest but the thinnest and weakest portion of the joint capsule. Recent studies claimed that capsule-preserving hydrodilatation has a superior effect compared with capsule-rupturing hydrodilatation (18,19). Extra-capsular fluid leakage through the ruptured point should result in a rapid drop of intra-articular pressure. Thus, it would be insufficient to stretch and expand the adhered capsule, and as a consequence inflict injury in the normal structure, which would diminish the therapeutic effect (20). Moreover, steroids could be retained within the intraarticular space for a long time without leakage if the capsule is preserved rather than ruptured, thus resulting in better inflammation control and more durable pain relief (18,20).

Recently, US has become the most popular adjuvant tool for image-guided glenohumeral joint injection, owing to the advantages of real-time imaging, absence of radiation, and high soft tissue resolution (21,22). In addition, US-guided capsule-preserving hydrodilatation has been widely utilized in routine management of AC. The presence of extracapsular leakage of the injected fluid into the periarticular soft tissues, or the size of the distended capsule shrink (19,23) have been reported as signs to confirm capsule rupture. However, the vision would be obscured, and it would be time-consuming to monitor capsular dilatation and confirm extracapsular fluid leakage due to its inferior contrast to periarticular soft tissues, especially for less-experienced operators.

Ultrasound contrast agents (UCAs) have been broadly applied to further improve US imaging for intervention (24,25). UCAs can be injected into the bloodstream (intravascular use) or instilled into almost any accessible body cavity, both normal and pathological (intracavitary use). In intracavitary applications, contrast-enhanced US (CEUS) allows identification of needle or catheter position, delineation of any cavity or duct, improved tracking of a fistula, and depiction of potential communications with adjacent structures or organs (24,26-28). In our previous study, UCAs were mixed with normal saline and injected into the glenohumeral joint to perform US arthrography, which provided characteristic findings of filling defects and synovitis-like abnormality for diagnosis of AC (29). Further, additional medication such as an anesthetic or a glucocorticoid can also be injected into the joint space for therapeutic purposes during the arthrography. In this pilot study, we explore the value of intracavitary CEUS-guided capsule-preserving hydrodilatation with steroids and

 

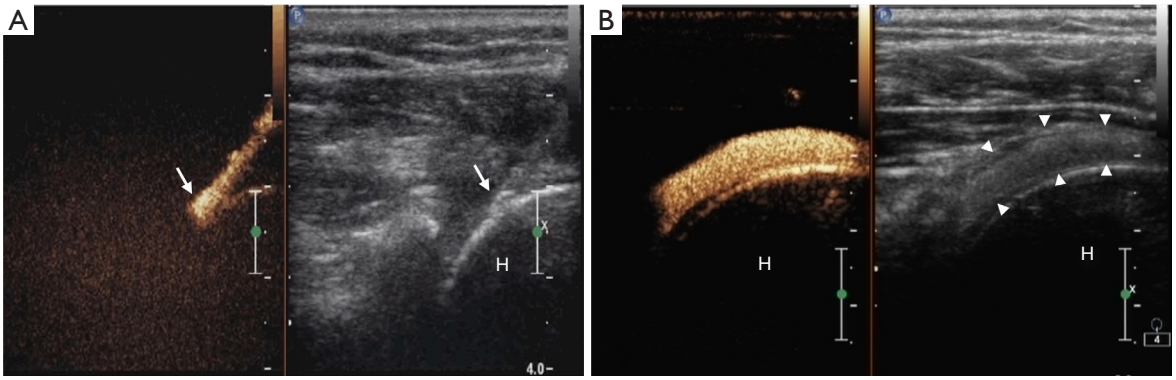


**Figure 1** CEUS-guided capsule-preserving hydrodilatation by the posterior approach. (A) CEUS-guided posterior glenohumeral joint injection. The arrow shows the needle tip. (B) Visualization of capsule dilatation by CEUS. CEUS image shows a distended capsule (arrowheads) without any leakage. H, humeral head; CEUS, contrast-enhanced ultrasound.

UCAs for treatment of AC. We hypothesize that CEUS may be a good approach to confirm the capsule dilatation, monitor the distension process, and to check extracapsular fluid leakage for capsule-preserving hydrodilatation in AC. We present this article in accordance with the STROBE reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-24-39/rc).

## Methods

### *Patients*

This prospective cohort study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and was approved by the Ethics Committee of Sichuan Cancer Hospital (No. SCCHIEC-D-2015126). Informed consent was provided by all individual participants. A total of 56 consecutive patients who had been diagnosed with AC in primary care and referred to shoulder hydrodilatation at Sichuan Cancer Hospital between May 2018 and June 2021 were prospectively included. The diagnosis of AC was made by orthopedists according to the patients' history and physical examination. The inclusion criteria were as follows: (I) shoulder pain for over 4 weeks; (II) nocturnal pain; (III) restriction of active and passive motion in 2 or more planes, >30°. A total of 16 patients were excluded due to: (I) US and/or magnetic resonance imaging (MRI) indicating full-thickness rotator cuff tear (n=6); (II) osteoarthritis, or systemic inflammatory joint disease in the shoulder (n=4); (III) previous fracture or surgery in the shoulder (n=3); (IV) history of shoulder physical therapy or injections in the past 3 months (n=3). Finally, the study group comprised 40 patients.

### *CEUS-guided capsule-preserving hydrodilatation*

All interventional procedures of CEUS-guided capsule-preserving hydrodilatation were performed by a chief physician (M.L., with more than 10 years of experience in musculoskeletal US and intervention) using a Philips EPIQ 7 US device (Philips Healthcare, Amsterdam, Netherlands) with a 3–9 MHz linear array transducer while the patient lay on the examination table in a lateral position with the affected shoulder side up. All the procedures were performed under full sterile and aseptic conditions. The US probe was placed along the long axis of the infraspinatus tendon just below the scapular line. The posterior approach was practiced, and a 22-G needle was inserted in plane from lateral to medial to ensure correct location of the needle tip in the glenohumeral joint space under guidance of contrast/greyscale imaging (side by side, *Figure 1A*). A solution composed of 0.1 mL of SonoVue (Bracco, Milan, Italy) suspension, 1 mL normal saline (9 mg/mL), 1 mL lidocaine (20 mg/mL), and 1 mL triamcinolone acetonide (40 mg/mL) in a 5-mL syringe was injected after reconfirming that the needle tip had been accurately placed in the joint by a test injection. An attempt to inject the joint was defined as the need for repositioning of the needle after unsuccessful test injection. Subsequently, a maximum amount of 20 mL of normal saline mixed with 1 mL of SonoVue solution was instilled to distend the capsule (*Figure 1B*). Both the injection and the distension of the capsule was monitored by CEUS imaging in real-time. The procedure was terminated when the plunger became difficult to push as a result of increased intra-articular pressure, or the patient requested to stop due to pain, in order to avoid capsule rupture. The

 

total amount of injected fluid was recorded.

After termination of the procedure, both the glenohumeral joint and its surrounding muscles and bursae (including supraspinatus, infraspinatus, teres minor muscle and subscapular muscles, and subacromial-subdeltoid bursa) were scanned by CEUS to confirm the capsule dilatation and to determine fluid leakage outside the shoulder capsule. Leakage was graded as no leakage, minimal, and massive leakage. The presence of fluid around the needle insertion point or along the needle tract was defined as minimal leakage. The presence of fluid among the fascial planes or muscle fascicles, or localized fluid collection outside the joint capsule, was defined as massive leakage. If massive fluid leakage was demonstrated by CEUS, a further MRI of the affected shoulder was performed on the same day.

Finally, the patients were told not to move the treated shoulders sharply for at least 30 minutes to avoid rupture. Once the procedure was over, all patients were instructed to take the home exercise programs comprising table-lean passive stretches and wall-climbing exercises with the fingers. Patients were asked to initiate the exercise programs the day after hydrodilatation with a subsequent routine 1-month time for 5–10 repetitions per day.

### *Outcome measurement*

The outcome measures included visual analog scale (VAS) score for pain, passive ROM, and shoulder pain and disability index (SPADI) score of the affected shoulder. All these measurements were performed at baseline and 4 weeks after the treatment by an independent orthopedist. The passive ROM was measured in a supine position in the directions of forward flexion, abduction, and external rotation using a goniometer (30). Shoulder flexion and abduction were examined with the elbow joint extended, and the upper limb movement range was measured in the sagittal and coronal surfaces, respectively. ROM in external rotation was measured with the shoulder maximally abducted and 90° of flexion of the elbow. A clinical good outcome was defined with a measure of ≥50% improvement in the VAS score and ≥20 points improvement in the SPADI score (31). The patients who failed to meet these criteria were considered to have poor outcomes.

### *Statistical analysis*

The demographic data at baseline and the quantitative data were expressed as frequencies and mean ± standard deviation (SD). The Pearson or Spearman correlation co-efficient was used to analyze the correlations of demographic variables and clinical data with injection volume and occurrence of massive fluid leakage. The independent *t*-test or Mann-Whitney U test was used for the comparison of age, symptom duration, injection volume, passive ROM, VAS score, and SPADI score between patients with clinical good outcome and those with poor outcome at 4 weeks. The chi- square test was used to test the differences in gender, affected side, first attempt success rate, and massive fluid leakage rate. Predictors of clinical good outcome at 4 weeks were examined with univariate logistic regression models, and those achieving significance in univariate analysis ($P<0.05$) were used to construct a multivariate logistic regression model to identify independent predictors of clinical good outcome. Statistical significance was accepted on the condition that the P value was less than 0.05 for all tests. All statistical analyses were performed with the software SPSS 13.0 (IBM Corp., Chicago, IL, USA).

## Results

Our cohort consisted of 40 patients (19 male, 21 female) with a mean age of 53.0±8.43 years. The mean symptom duration was 6.9±3.60 months. All participants reported full compliance with the home exercise program. In 22 patients (55.0%), the right shoulder was affected, and in 18 (45.0 %), the left shoulder was affected.

### *Assessment of CEUS-guided capsule-preserving hydrodilatation*

Overall access to the joint was gained on the first attempt in 35 (87.5%) patients and, on the second attempt, in 5 (12.5%) patients. The mean injection volume of fluid was 21.0±3.40 mL (range from 10 to 23 mL), and the overall extravasation rate was 47.5% (19/40), with 14 (35.0%) cases of minimal extravasation and 5 (12.5%) cases of massive extravasation (*Figure 2A*). Among 5 patients with massive extravasation, 4 were confirmed as capsule rupture by MRI (*Figure 2B*). Finally, our procedures of CEUS-guided capsule-preserving hydrodilatation were successfully completed in 90% (36/40) of AC patients, with unexpected capsule rupture occurring in 4 (10%) patients.

From the performance of CEUS-guided hydrodilatation, we analyzed the correlations of injection volume, occurrence of massive fluid leakage with demographic variables and baseline characteristics, including age, gender, dominant

 

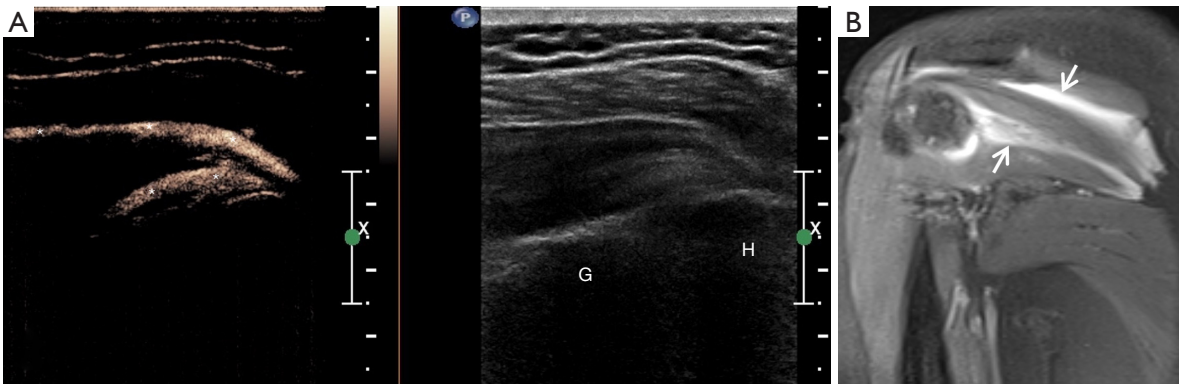


**Figure 2** Glenohumeral joint hydrodilatation with capsular rupture in a 56-year-old female. (A) CEUS image shows the extraarticular fluid (X) extend along infraspinatus muscle fascicle and intermuscular septa clearly, and indicate as massive fluid leakage. (B) T2WI image confirms capsule rupture with extraarticular fluid (arrows) collected at muscle fascicles and intermuscular septa. G, glenoid; H, humeral head; CEUS, contrast-enhanced ultrasound; T2WI, T2 weighted image.

**Table 1** Correlations between the occurrence of massive fluid leakage and clinical data

| Characteristic | Correlation coefficient (r) | P value |
|---|---|---|
| Age (years) | 0.016 | 0.920 |
| Gender (male:female) | 0.149 | 0.358 |
| Sidedness (right:left) | 0.149 | 0.358 |
| Symptom duration (m) | 0.485 | 0.001 |
| Initial VAS score | 0.061 | 0.710 |
| Initial flexion (°) | –0.094 | 0.563 |
| Initial abduction (°) | –0.33 | 0.037 |
| Initial external rotation (°) | –0.34 | 0.032 |
| Initial SPADI | 0.187 | 0.247 |

VAS, visual analog scale; SPADI, shoulder pain and disability index.

shoulder, symptom duration, shoulder VAS, SPADI, and ROM. The Pearson or Spearman correlation coefficient demonstrated that patient age (r=–0.045, P=0.782), gender (r=–0.191, P=0.238), dominant shoulder (r=0.15, P=0.355), VAS (r=0.259, P=0.106), ROM in flexion (r=0.13, P=0.424), or ROM in external rotation (r=0.281, P=0.078) did not correlate with injection volume. Meanwhile, longer symptom duration (r=–0.676, P<0.001), greater SPADI (r=–0.148, P=0.007), and decreased ROM in abduction (r=0.38, P=0.016) were associated with a smaller injection volume. Besides, longer symptom duration (r=0.485, P=0.001), decreased ROM in the direction of abduction (r=–0.33, P=0.037), and external rotation (r=–0.34, P=0.032) were associated with an increased incidence of massive fluid leakage. The correlation coefficients and P values are shown in *Table 1*.

### *Assessment of outcomes*

There were no significant complications, such as bleeding, paraesthesia, mobility restriction, allergic reaction, fever, or infection during the 4 weeks' follow-up. VAS score, passive ROM, and SPADI score improved significantly at 4 weeks after treatment as compared to baseline (all P<0.001, *Table 2*). There were 31 (77.5%) patients who were detected to have ≥50% improvement in the VAS score (decreased from 6.9±1.04 to 3.0±0.52) and ≥20 points improvement in the SPADI score (decreased from 59.5±9.94 to 27.7±10.34), which indicated with good clinical outcomes. The demographics, baseline characteristics, properties of CEUS-guided capsule-preserving hydrodilatation, and outcomes were compared between those patients with good efficacy and the others with poor efficacy, as shown in *Table 3*. Patients with good outcomes had significantly shorter symptom duration (5.7±2.09 *vs.* 11.2±3.89 months, P=0.002) and greater initial VAS score (6.9±1.04 *vs.* 6.3±0.50, P=0.022) than those with poor outcomes.

Predictors of good clinical outcomes at 4 weeks after CEUS-guided capsule-preserving hydrodilatation were examined by logistic regression at a univariate and multivariate level. As shown in *Table 4*, univariate analysis indicated that shorter symptom duration [odd ratio (OR) =0.47, 95% confidential interval (CI): 0.28–0.79, P=0.004],

 

greater injection volumes (OR =1.37, 95% CI: 1.08–1.75, P=0.011), and absence of massive fluid leakage (OR =0.052, 95% CI: 0.007–0.398, P=0.004) were significant predictors of good outcomes (all P<0.05). At multivariate analysis, only absence of massive fluid leakage (OR =0.05, 95% CI: 0.003–0.882, P=0.041) was an independent predictor of good outcomes at 4 weeks after treatment.

**Table 2** VAS, passive ROM, and SPADI of adhesive capsulitis patients at pre- and 4 weeks after CEUS-guided glenohumeral joint hydrodilatation

| Characteristic | Pre-treatment | 4 weeks after treatment | Difference |
|---|---|---|---|
| VAS score | 6.8±0.97 | 3.1±0.56* | 3.7±0.92 |
| SPADI score | 60.9±10.46 | 32.4±13.35* | 28.5±7.93 |
| Flexion (°) | 107.8±10.35 | 124.5±10.01* | 16.8±3.24 |
| Abduction (°) | 61.8±10.94 | 83.3±12.93* | 21.5±5.37 |
| External rotation (°) | 32.5±6.00 | 48.7±7.18* | 16.1±4.25 |

Values represent mean ± standard deviation. *, compared with baseline, P<0.001. VAS, visual analog scale; ROM, range of motion; SPADI, shoulder pain and disability index; CEUS, contrast-enhanced ultrasound.

## Discussion

Capsule-preserving hydrodilatation with corticosteroid provides an effective treatment for AC, which could reduce shoulder pain and improve ROM. In this study, we mixed steroids, anesthetic, and normal saline with UCAs to perform intracavity CEUS guidance of glenohumeral joint capsule-preserving hydrodilatation for treatment of AC. This new technique would allow better visualization of the flow of fluid, monitoring the capsule dilatation in real-time, as well as direct confirmation of massive fluid extravasation. We demonstrated that longer symptom duration, greater SPADI, and decreased ROM in abduction were associated with a decreased volume of infused fluid. Meanwhile,

**Table 3** The difference between patients with good and poor clinical response after treatment of CEUS-guided glenohumeral hydrodilatation

| Characteristic | Variable | Good clinical response (n=31) | Poor clinical response (n=9) | P value |
|---|---|---|---|---|
| Outcomes | Change of VAS score | 3.9±0.87 | 2.9±0.60 | 0.002 |
| | Change of SPADI | 31.8±5.34 | 17.3±4.27 | <0.001 |
| | Change of ROM | | | |
| | - Flexion (°) | 17.0±3.52 | 16.0±1.97 | 0.432 |
| | - Abduction (°) | 22.6±5.39 | 17.5±2.91 | 0.01 |
| | - External rotation (°) | 16.9±4.55 | 13.7±1.2 | 0.048 |
| Baseline data | Age (years) | 53.4±8.04 | 51.9±10.13 | 0.652 |
| | Gender (male:female) | 16:15 | 3:6 | 0.334 |
| | Sidedness (right:left) | 17:14 | 5:4 | 0.97 |
| | Symptom duration (m) | 5.7±2.09 | 11.2±3.89 | 0.002 |
| | Initial VAS score | 6.9±1.04 | 6.3±0.50 | 0.022 |
| | Initial SPADI | 59.5±9.94 | 65.7±11.39 | 0.169 |
| | Initial flexion (°) | 109.2±10.25 | 102.8±9.64 | 0.105 |
| | Initial abduction (°) | 63.6±10.95 | 5.9±9.05 | 0.063 |
| | Initial external rotation (°) | 32.9±5.67 | 30.9±7.21 | 0.394 |
| Intervention | Injection volume (mL) | 21.9±2.03 | 18.0±5.26 | 0.058 |
| | 1st attempt success rate (%) | 90.3% (28/31) | 77.8% (7/9) | 0.316 |
| | Massive fluid leakage rate (%) | 2.6% (1/39) | 44.4% (4/9) | 0.006 |

Values represent mean ± standard deviation. CEUS, contrast-enhanced ultrasound; VAS, visual analog scale; SPADI, shoulder pain and disability index; ROM, range of motion.

**Table 4** Logistic regression analysis of the factors correlated with good clinical outcomes after treatment of CEUS-guided glenohumeral hydrodilatation

| Factors | Univariate | | Multivariate | |
|---|---|---|---|---|
| | OR (95% CI) | P value | OR (95% CI) | P value |
| Age (years) | 1.02 (0.93–1.12) | 0.643 | – | – |
| Gender (male:female) | 2.13 (0.45–10.09) | 0.339 | – | – |
| Sidedness (right:left) | 0.75 (0.17–3.33) | 0.705 | – | – |
| Symptom duration (m) | 0.47 (0.28–0.79) | 0.004 | 0.69 (0.36–1.34) | 0.276 |
| Initial VAS score | 2.26 (0.83–6.18) | 0.112 | – | – |
| Initial flexion (°) | 1.07 (0.99–1.16) | 0.107 | – | – |
| Initial abduction (°) | 1.08 (0.99–1.17) | 0.216 | – | – |
| Initial external rotation (°) | 1.06 (0.93–1.20) | 0.378 | – | – |
| Initial SPADI | 0.94 (0.87–1.02) | 0.129 | – | – |
| Successful 1st attempt | 0.38 (0.05–2.69) | 0.330 | – | – |
| Injection volume (mL) | 1.37 (1.08–1.75) | 0.011 | 1.32 (0.77–2.28) | 0.313 |
| Massive fluid leakage | 0.052 (0.007–0.398) | 0.004 | 0.05 (0.003–0.882) | 0.041 |

CEUS, contrast-enhanced ultrasound; OR, odds ratio; CI, confidential interval; VAS, visual analog scale; SPADI, shoulder pain and disability index.

longer symptom duration, decreased ROM in abduction, and external rotation were correlated with an increased incidence of massive fluid leakage. Moreover, absence of massive fluid leakage was an independent predictor of good outcomes in the short term. To our knowledge, this is the first study to reveal the correlations of technical indicators with patients' demographics, disease severity, and clinical outcomes in capsule-preserving hydrodilatation.

As for capsule-preserving hydrodilatation, a sufficient intraarticular volume of fluid needs to be injected and maintained for as long as possible without rupture the capsule in order to achieve a great treatment effect (18,32). In previous studies, a pressure-volume profile monitoring device was used to measure the intraarticular pressure in real-time, predict the time of capsule rupture, and stop fluid infusion immediately before rupture (20,32,33). The mean injected fluid volume of capsule-preserving hydrodilatation in AC patients was reported to be 25.1±6.9 mL, and the smallest volume for effective capsule-preserving hydrodilatation is suggested to be approximately 18 mL (32). In cases where real-time pressure monitoring is not available, hydrodilatation using a total volume of 18 mL under US guidance is suggested to ensure preservation of the joint capsule (7). However, in fact, a smaller volume injection, even below 10 mL, can cause capsule rupture in frozen shoulder patients (31). The maximum capacity of the glenohumeral joint without rupturing the capsule has been reported to vary from 12.95 mL to more than 38.99 mL among painful stiff shoulder patients (34). In this study, we infused a maximum total volume of 23 mL fluid with a mean volume of about 21 mL (range from 10 to 23 mL) into the glenohumeral joint for stretching without rupturing the capsule in 40 AC patients. However, unexpected capsule ruptures occurred in 10% patients as confirmed by MRI. In addition, we found that patient's symptom duration, SPADI, and ROM in abduction correlated with injection volume for hydrodilatation. That is to say, patients who have longer symptom duration, greater SPADI score, and distinct limitation in abduction tend to tolerate a lesser amount fluid for capsule-preserving dilatation. Therefore, it may not be appropriate to recommend a standardized amount of volume to provide capsule-preserving hydrodilatation for every AC patient.

In capsule-preserving hydrodilatation with real-time pressure monitoring, the appearance of phase III on the pressure-volume curve, or the intraarticular pressure exceeding 500 mmHg was considered as a preruptural sign (18,20). However, there were patients who experience rupture without showing the preruptural sign (34). In Kim et al.'s study, the preruptural sign failed to prevent capsular

 

rupture in about 15% of patients (18). With regard to US-guided capsule-preserving hydrodilatation, the injection was subjectively terminated by the operators when the ultrasonography showed no further expansion of the capsule or resistance was felt through the plunger as a result of increased intra-articular pressure (19,23). The preclusion of capsule rupture is largely dependent on operator experience. Herein, our new technique of CEUS guidance allows superior observation of capsular distension and detection of any amount of extracapsular fluid leakage directly. Among 5 patients detected with massive fluid leakage, 4 cases were confirmed as capsule rupture by MRI. Hence, we interpreted that the presence of massive fluid leakage is a useful sign to confirm capsule rupture for CEUS-guided capsule-preserving hydrodilatation. More importantly, we found that patients with longer duration of symptoms and more severe limitation in abduction and external rotation were susceptible to massive fluid leakage. Similarly, Lee *et al.* measured capsule stiffness ($K_{cap}$) by calculating the slope of the elastic phase in pressure-volume curves, and found that $K_{cap}$ significantly and negatively correlates with ROM in abduction and external rotation (32). They also found that women with AC had significantly stiffer capsules relative to men. However, in this study, patients' age, gender, and sides of the affected shoulder did not correlate with the injected volume and incidence of massive extravasation. In general, capsule-preserving hydrodilatation should be performed more carefully with less fluid volume being infused for those AC patients with longer symptom duration and more severe affected shoulder, in order to avoid capsule rupture.

Accurate intra-articular injection and sufficient preserved distension of the capsule is the key of good clinical outcomes (35,36). On the contrary, inaccurate injections could pose risks, such as soft tissue damage and tendon weakening, with corticosteroid injections. Although the needle visualization in the dual-screen B-mode image is inferior to that in the conventional B-mode, priming the needles with UCA increased the contrast-specific imaging-mode needle visibility (37). Our first attempt success rate was 87.5% for posterior glenohumeral joint injection under CEUS guidance, similar to the reported 92% under US guidance (38). The treatment of capsule-preserving hydrodilatation achieved a significant improvement of VAS, SPADI, and ROM in the short-term in this study. Some 77.5% of patients demonstrated good clinical outcomes and 22.5% of patients indicated poor clinical outcomes. Interestingly, patients with good outcomes had significantly shorter duration of symptoms and greater initial VAS score compared to those with poor outcomes. Regarding technique, patients with poor outcomes showed significantly greater incidence of massive extravasation, and seemed to allow a lower fluid volume to be infused. Moreover, absence of massive fluid leakage was investigated as an independent predictor of good clinical outcomes at 1 month after CEUS-guided hydrodilatation by using multivariate logistic regression analysis. We suspected that a larger volume of injectate retained in the capsule without rupture may result in a better effect of reducing synovial inflammation, disrupting adhesions (scar tissue) and capsular distension, thus achieving a more favorable short-term outcome. Similarly, Bell *et al.* and Pimenta *et al.* also indicated that more severely affected shoulders at baseline show greater improvement of disability following hydrodilatation compared to less severely affected patients (19,39). Additionally, Pimenta *et al.* found that capsule rupture was an independent predictor of impaired functionality at 1, 3, and 6 months after US-guided hydrodilatation (19). Above all, determination of such predictors is of clinical importance as it may aid in individualized management of AC by selecting patients who are most likely to benefit from hydrodilatation.

This study had several limitations. Firstly, it covered only 1 month for follow-up. Middle- or long-term evaluation was not available in this study, because patients would accept the second hydrodilatation and/or the other treatments such as physiotherapy and manipulation under anesthesia if they showed poor clinical outcome at 1 month after CEUS-guided capsule-preserving hydrodilatation. Secondly, a real-time pressure-volume monitoring system was not performed in this study. The procedure of hydrodilatation was terminated subjectively according to the operators' experiences and patients' requests. The results may reflect the experience of 1 musculoskeletal radiologist which may limit the generalization of the findings. Lastly, the patient compliance of the home exercise program may have biased our results, although all participants reported full compliance.

## Conclusions

CEUS-guided capsule-preserving hydrodilatation with steroids and UCAs allows real-time visualization of capsule dilatation, detection of extracapsular fluid leakage, and identification of risks for capsule rupture. It provides an effective treatment for AC, and can be useful to predict patients' clinical outcomes. However, the results of this

 

study did not provide additional practical value in improving the routine practice of utilizing US-guided hydrodilatation, which is more convenient and cost-effective.

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## Footnote

*Reporting Checklist:* The authors have completed the STROBE reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-24-39/rc

*Conflicts of Interest:* All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-24-39/coif). The authors have no conflicts of interest to declare.

*Ethical Statement:* The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of Sichuan Cancer Hospital (No. SCCHIEC-D-2015126) and informed consent was provided by all individual participants.



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