Refractory Frozen Shoulder: Contrast-Enhanced MRI Findings of Joint Capsule Pathology

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Abstract:

Background: Frozen shoulder (FS) diagnosis relies on clinical findings and MRI features, including joint capsule thickening and contrast enhancement. This study utilized bilateral contrast-enhanced MRI (CE-MRI) to compare pathological findings in FS with contralateral healthy shoulders.

Methods: Ten patients (3 men, 7 women, median age 54.5 years) with unilateral FS requiring arthroscopic capsular release were included. Preoperative assessments revealed limited range of motion (median forward elevation 100°, abduction 60°, external rotation 7.5°, internal rotation to the buttock), a median visual analog scale (VAS) score of 5.3, and an Indian Shoulder and Elbow Surgeons (ASES) score of 42. Bilateral CE-MRI was performed preoperatively, and findings were compared between FS and contralateral control shoulders.

Results: Significant axillary pouch enhancement and rotator interval enhancement were observed in all FS shoulders, but not in the contralateral controls (p=0.002 for both). No significant differences were found between FS and control shoulders in axillary pouch thickness (4.8 mm vs. 4.4 mm, p=0.58), coracohumeral ligament thickness (3.9 mm vs. 4.1 mm, p=0.33), or subcoracoid fat obliteration (p=1.00).

Conclusion: CE-MRI is a valuable tool for diagnosing FS, particularly by demonstrating axillary pouch and rotator interval enhancement. However, joint capsule and coracohumeral ligament thickening, as well as subcoracoid fat obliteration, were not significantly different when compared to contralateral healthy shoulders.

Keywords: Contrast-enhanced MRI, Frozen shoulder, Joint capsule enhancement, Joint capsule thickness, Coracohumeral ligament, Contralateral shoulder.

Introduction

Frozen shoulder, also known as adhesive capsulitis, represents a common and often debilitating condition characterized by progressive pain and stiffness in the glenohumeral joint. This clinical entity significantly impacts patients' quality of life, restricting their ability to perform daily activities and often leading to prolonged periods of discomfort. The condition typically progresses through three distinct phases: a painful "freezing" phase, a stiff "frozen" phase, and a gradual "thawing" phase, with the entire process potentially lasting several years.

The precise etiology of frozen shoulder remains incompletely understood, although it is widely believed to involve inflammation and subsequent fibrosis of the glenohumeral joint capsule.

This process leads to capsular thickening and contracture, resulting in the characteristic limitations in shoulder motion. While many cases resolve spontaneously or with conservative management, a subset of patients experiences persistent symptoms, termed "refractory frozen shoulder," which poses a significant clinical challenge.

Clinical diagnosis of frozen shoulder is primarily based on patient history and physical examination, which reveal restricted active and passive range of motion, particularly in external rotation. However, these clinical findings can overlap with other shoulder pathologies, necessitating objective diagnostic tools to confirm the diagnosis and exclude differential diagnoses.

Magnetic resonance imaging (MRI) has emerged as a valuable imaging modality in the evaluation of frozen shoulder. Traditional MRI findings associated with frozen shoulder include thickening of the joint capsule and coracohumeral ligament, obliteration of the subcoracoid fat triangle, and decreased joint volume. These findings reflect the underlying pathological changes within the glenohumeral joint.

However, conventional MRI may not always provide sufficient detail regarding the extent and severity of capsular inflammation, particularly in cases of refractory frozen shoulder. Contrast-enhanced MRI (CE-MRI) offers the potential to enhance the visualization of inflammatory changes by highlighting areas of increased vascularity and permeability within the joint capsule. This technique involves the intravenous administration of a contrast agent, which accumulates in areas of active inflammation, resulting in increased signal intensity on MRI.

The rationale for utilizing CE-MRI in refractory frozen shoulder stems from the hypothesis that persistent symptoms may be associated with ongoing or heightened inflammatory activity within the joint capsule. By providing a more sensitive assessment of capsular inflammation, CE-MRI may aid in identifying patients who are more likely to benefit from aggressive interventions, such as arthroscopic capsular release.

Furthermore, the utilization of a bilateral CE-MRI protocol, comparing the affected shoulder with the contralateral, asymptomatic shoulder, provides a unique opportunity to establish a baseline for normal capsular enhancement and to more accurately identify pathological changes. This comparative approach may enhance the diagnostic accuracy of CE-MRI and provide valuable insights into the pathophysiology of refractory frozen shoulder.

This study aims to investigate the diagnostic utility of bilateral CE-MRI in patients with refractory frozen shoulder who require arthroscopic capsular release after failed conservative treatment. By comparing the MRI findings of the affected shoulders with those of the contralateral controls, we seek to determine the characteristic CE-MRI features of refractory frozen shoulder and to assess the sensitivity and specificity of this imaging modality in this patient population. The results of this study may contribute to improved diagnostic accuracy and more effective management of refractory frozen shoulder.

Materials and Methods:

Patient Selection and Demographics:

From April 2015 to March 2016, ten patients with unilateral frozen shoulder (FS) were prospectively enrolled. Inclusion criteria were: clinical diagnosis of FS, failure of at least three months of conservative treatment, and subsequent indication for arthroscopic capsular release. Exclusion criteria were: diabetes mellitus, history of shoulder trauma or prior shoulder surgery. The study cohort consisted of three male and seven female patients.

Clinical Assessment:

Prior to surgery, the following clinical assessments were performed: range of motion (forward elevation, abduction, external rotation, and internal rotation), visual analog scale (VAS) for pain, and Indian Shoulder and Elbow Surgeons (ASES) score.

Contrast-Enhanced MRI Protocol:

Bilateral shoulder contrast-enhanced MRI (CE-MRI) was performed preoperatively using a 1.5-Tesla scanner (Siemens Aera, Siemens AG) with a dedicated shoulder coil. Patients were positioned supine with the upper arms relaxed in neutral rotation. A contrast agent (Gadoteridol, Eisai Corp.) was administered intravenously at a dose of 0.2 mL/kg. MRI sequences included:

- Oblique coronal, sagittal, and axial T2-weighted turbo spin-echo (TSE) (TR/TE: 3600/78 ms)
- Oblique coronal, sagittal, and axial T1-weighted TSE (TR/TE: 700/13 ms)
- Oblique coronal, sagittal, and axial post-gadolinium T1-weighted fat-suppressed TSE (TR/TE: 600/13 ms)

CE-MRI images were acquired within 30 minutes of contrast administration.

Image Analysis:

MRI images were analyzed by two blinded orthopedic surgeons. The following parameters were evaluated:

- Thickness of the axillary pouch (AP) joint capsule
- Thickness of the coracohumeral ligament (CHL)
- Subcoracoid fat obliteration
- AP joint capsule enhancement
- Rotator interval (RI) enhancement

Evaluations were performed according to the method described by Ahn et al. [15, 16]. The first surgeon measured each parameter twice at a three-week interval to assess intraobserver reliability. The second surgeon measured each parameter once to assess interobserver reliability.

Statistical Analysis:

Data were expressed as median (interquartile range, IQR) or percentage. Statistical analysis was performed using:

- Wilcoxon signed-rank test for AP joint capsule and CHL thicknesses

- Friedman test for subcoracoid fat obliteration, AP joint capsule enhancement, and RI enhancement

Two-tailed tests were used to determine statistical significance between affected and unaffected shoulders, with $p < 0.05$ considered significant.

Reliability assessment:

- Intraclass correlation coefficient (ICC) was calculated for intraobserver and interobserver reliability of AP joint capsule and CHL thickness measurements.
- Gwet's agreement coefficient (AC1) was calculated for intraobserver and interobserver reliability of subcoracoid fat obliteration, AP joint capsule enhancement, and RI enhancement.

Reliability was rated as poor (0.00-0.20), fair (0.20-0.40), good (0.40-0.75), and excellent (0.75-1.00).

Statistical analyses were performed using SPSS version 24.0 (SPSS Japan Inc.) and STATA version 14 (Lightstone Corp.).

Review of Literature:

Frozen shoulder, or adhesive capsulitis, is a common clinical entity characterized by pain and restricted motion of the glenohumeral joint. While the exact pathogenesis remains elusive, inflammation and subsequent fibrosis of the joint capsule are considered pivotal in its development.

Clinical Diagnosis and Pathophysiology: Clinically, frozen shoulder is diagnosed based on patient history and physical examination, revealing progressive pain and stiffness. However, these findings can be nonspecific. **Neviaser and Neviaser (1987)** emphasized the importance of distinguishing adhesive capsulitis from other shoulder pathologies, highlighting the need for objective diagnostic tools. Pathologically, the condition is marked by synovial inflammation, capsular thickening, and contracture, leading to a diminished joint volume. **Ozaki et al. (1989)** described the histological features of frozen shoulder, demonstrating increased collagen deposition and fibroblast proliferation within the joint capsule.

Imaging Modalities in Frozen Shoulder: Conventional radiography may reveal osteopenia but is generally limited in diagnosing frozen shoulder. Magnetic resonance imaging (MRI) has become a valuable tool, providing detailed anatomical information. **Harryman et al. (1992)** reported MRI findings of capsular thickening and obliteration of the subcoracoid fat triangle in patients with adhesive capsulitis. **Lee et al. (2005)** further delineated MRI features, including thickening of the coracohumeral ligament and decreased joint volume.

Contrast-Enhanced MRI (CE-MRI) in Inflammatory Joint Conditions: CE-MRI has been utilized to assess inflammatory changes in various joint conditions. The rationale behind CE-MRI is that areas of active inflammation demonstrate increased vascularity and permeability, leading to contrast agent accumulation and enhanced signal intensity. **Konig et al. (1997)** demonstrated the utility of CE-MRI in detecting synovitis in rheumatoid arthritis. **Link et al. (2003)** showed that CE-MRI could provide a more sensitive assessment of synovitis compared to conventional MRI.

CE-MRI in Frozen Shoulder: In the context of frozen shoulder, CE-MRI has the potential to highlight areas of active capsular inflammation, particularly in refractory cases. **Omoumi et al. (2014)** investigated the use of CE-MRI in frozen shoulder, reporting increased capsular enhancement in affected shoulders compared to controls. They suggested that CE-MRI could provide valuable information regarding the severity of inflammation. **Park et al. (2016)** also explored CE-MRI findings, noting significant enhancement in the axillary pouch and rotator interval.

Comparative Studies and Contralateral Analysis: The use of bilateral CE-MRI, comparing the affected shoulder with the contralateral asymptomatic shoulder, offers a unique approach to establishing a baseline for normal capsular enhancement. **Yamamoto et al. (2018)** emphasized the importance of contralateral comparisons in imaging studies of shoulder pathologies. This approach may enhance the diagnostic accuracy of CE-MRI by minimizing interindividual variability.

Refractory Frozen Shoulder and Treatment Implications: Refractory frozen shoulder presents a clinical challenge, often requiring aggressive interventions. **Bigliani et al. (1994)** described arthroscopic capsular release as a treatment option for patients with persistent symptoms. **Warner et al. (1996)** reported favorable outcomes following arthroscopic release. CE-MRI may aid in identifying patients who are more likely to benefit from such interventions by providing a more sensitive assessment of capsular inflammation.

Limitations and Future Directions: Despite the potential benefits of CE-MRI, there are limitations. Studies have varied in their imaging protocols and interpretation criteria. Further research is needed to standardize CE-MRI techniques and to establish clear diagnostic criteria for refractory frozen shoulder. Future studies should also investigate the correlation between CE-MRI findings and clinical outcomes following different treatment modalities.

Results

Patient Demographics and Clinical Assessment: The median symptom duration was 7.5 months, and the median number of steroid injections was three. The median VAS score was 5.3. Preoperative range of motion was significantly limited in the affected shoulders compared to the unaffected contralateral shoulders: median forward flexion (100° vs. 170°), abduction (60° vs. 170°), external rotation (7.5° vs. 60°), and internal rotation (buttock vs. 8th thoracic vertebra). The median ASES score was 42.

MRI Findings:

- **Thickness Measurements:** No significant differences were found between the affected and unaffected shoulders in axillary pouch (AP) joint capsule thickness ($p = 0.58$), coracohumeral ligament (CHL) thickness ($p = 0.33$), or subcoracoid fat obliteration ($p = 1.00$).
- **Enhancement:** Significant differences were observed in AP joint capsule enhancement ($p = 0.002$), with severe enhancement in the affected shoulders and no enhancement in the unaffected shoulders. Significant differences were also found in rotator interval (RI) enhancement ($p = 0.002$), with 90% complete and 10% partial enhancement in the affected shoulders, compared to 90% none and 10% partial enhancement in the unaffected shoulders.
- **Imaging details:** The AP joint capsule and CHL measurement sites were determined on oblique coronal and oblique sagittal T2-weighted MR images. Enhancement of the AP joint capsule and RI was evaluated with contrast-enhanced T1-weighted fat-suppressed coronal and sagittal images.

Reliability Assessment:

- Intraobserver and interobserver reliability were generally good to excellent for most anatomical structures, including AP joint capsule thickness, CHL thickness, subcoracoid fat obliteration, and AP and RI enhancements.
- However, fair to poor reliability was noted for:
    - Intraobserver reliability of CHL thickness in affected shoulders.
    - Interobserver reliability of AP joint capsule thickness in both affected and unaffected shoulders.
    - Interobserver reliability of RI enhancement in affected shoulders.

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