Reduction of abnormal blood flow in frozen shoulder after shoulder manipulation under ultrasound-guided cervical nerve root block: semiquantitative analysis using dynamic magnetic resonance imaging

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**Level of evidence:** Level IV; Case Series; Treatment Study

**Background:** We previously reported a characteristic dynamic magnetic resonance imaging (MRI) change in patients with frozen shoulder (FS) and named this abnormal blood flow pattern the “burning sign”. In this study, a semiquantitative method was used to evaluate changes in this abnormal blood flow pattern on dynamic MRI after shoulder manipulation under ultrasound-guided cervical nerve root block (MUC) in patients with FS.

**Methods:** Nineteen patients with FS underwent MUC, with dynamic MRI performed before and after. We used dynamic MRI to semiquantitatively assess changes in the burning sign at the axillary pouch (AP) and rotator interval (RI) by examining the enhancement rate in the signal intensity and the enhancement velocity. Functional assessments included a numeric rating scale score, the range of shoulder motion, the American Shoulder and Elbow Surgeons score, and the Constant score.

**Results:** The burning sign in the AP and RI was observed with dynamic MRI in all patients before MUC. The average interval from MUC until dynamic MRI was 8.2 months (range, 6-12). Clinical results for all patients improved after MUC. The before and after MUC enhancement rates (%) were 217 ± 51 and 85 ± 36 in the AP and 233 ± 61 and 73 ± 40 in the RI, respectively (both \( P < .001 \)). The before and after MUC enhancement velocities (ms/s) were 902 ± 335 and 203 ± 125 in the AP and 1249 ± 634 and 213 ± 146 in the RI, respectively (both \( P < .001 \)).

**Conclusion:** Dynamic MRI semiquantitatively demonstrated a reduction in abnormal blood flow and improvement in clinical results after MUC in patients with FS.

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Frozen shoulder (FS) is a common disease characterized by limited range of motion (ROM) of the glenohumeral joint and severe shoulder pain. This condition was first described by Codman in 1934,\textsuperscript{5} and the prevalence of FS is reported to be 2%-5% of the total population.\textsuperscript{6,8} Although the clinical symptoms are relatively easy to appreciate, the ability to diagnose this disease based on imaging characteristics is considered poor. We previously found a characteristic change on dynamic 3-dimensional magnetic resonance imaging (3D MRI) in patients with idiopathic severe FS, which we termed the “burning sign”.\textsuperscript{17} The burning sign represents an abnormally high blood flow from the acromial arterial network and the branches of the humeral circumflex arteries into the axillary pouch (AP) and the rotator interval (RI).

There are many conservative treatment options for FS including complete rest, medication, local steroid injection, physiotherapy, and hydrodistension.\textsuperscript{9,13,14,22} If these are not effective, then more invasive procedures are necessary, including manipulation under general anesthesia or arthroscopic capsular release.\textsuperscript{4,6,17} Recent studies have described shoulder manipulation under ultrasound-guided cervical nerve root block (MUC) as a treatment for FS.\textsuperscript{2} We have previously described the effective and safe use of MUC over the short term.\textsuperscript{15,16} We also previously reported articular MRI findings after MUC and the disappearance of...
iatrogenic capsular tears, bone bruises, and labral tears six months later as observed by plain MRI. To our knowledge, a change in the abnormal blood flow that is characteristic of FS after MUC has not yet been reported. In the field of breast cancer diagnosis, dynamic MRI has been used to distinguish malignant breast cancer from benign lesions by evaluating the slope of the washout curve of the lesion and evaluating the kinetic curve quantitatively. We partially referred to these methods when using dynamic MRI to evaluate changes in FS after MUC.

The purpose of this study was to use dynamic MRI to semiquantitatively assess the reduction in abnormal blood flow after MUC in patients with FS.

Methods

Patients

This study was approved by the Jichi Medical University Institutional Review Board (A13-113). We retrospectively reviewed patients’ records and MRI images. Between January 2015 and January 2017, MUC was performed for thirty-four patients in diagnosis of idiopathic FS. In this study, 19 patients who could undergo nonenhanced and dynamic enhanced MRI of the shoulder joint before and after MUC were recruited. The average age was 55.3 (range, 41-67) years, and there were 16 women and three men. Patients were diagnosed with idiopathic FS if they had limited ROM in all directions (<100° in forward flexion [FF], <0° in external rotation at the side [ER], and internal rotation [IR] ≤ L5) and did not respond to a combination of intra-articular steroid injections and physical therapy administered for at least 3 months. The mean time from the onset of shoulder pain to MUC was 5.2 (range, 3-12) months. Before the procedure, all patients underwent radiography of the affected shoulder in addition to dynamic MRI to exclude other shoulder-related diseases. Patients who had any of the following were excluded: rotator cuff tear, shoulder osteoarthritis, rheumatoid arthritis, calcified tendinitis, history of shoulder joint fracture, history of shoulder joint surgery, long head biceps tendon injury, diabetic stiff shoulder, or cervical spine disease.

MRI examination

All patients underwent enhanced dynamic MRI (Skyra; Siemens Medical Systems, Erlangen, Germany) preoperatively and postoperatively. Postoperative MRI was performed greater than 6 months after MUC. Before the dynamic MRI series was performed, our routine series of nonenhanced MRI was performed. After a bolus intravenous injection of the gadolinium-chelated contrast material, 3D fast low-angle shot images (repetition time, 3.1 ms; echo time, 1.26 ms) were obtained in the oblique coronal plane every 9 seconds for a total period of 3 minutes. During the final phase, we obtained four T1-weighted images at each slice level (in-phase T1-weighted image, opposed phase image, water-only image [fat suppression image], and fat-only image). All the images were recovered from a digital database.

Semiquantitative measurement in dynamic MRI

Two shoulder surgeons (Y.I. and H.S.) and one radiologist (H.S.), each with more than 15 years’ experience, independently evaluated the presence or absence of the burning sign at the AP and RI before MUC with 3D dynamic MRI. When there was disagreement over the diagnosis, the final diagnosis was determined based on consensus. If the burning sign was noted, we assessed the burning sign at the AP and RI semiquantiatively by measuring the T1 signal intensity (SI) on dynamic MRI.

As assessment items, the enhancement rate of the SI and the enhancement velocity were measured at the AP and RI. Setting a 0.3-cm² region of interest (ROI) in the area of AP and RI on the contrast-enhanced T1-weighted image, the dynamic MRI kinetic curve of the enhancement was showed graphically (Fig. 1, Fig. 2). The enhancement rate was calculated as per the following enhancement formula:

\[
\text{enhancement rate} = \left( \frac{\text{SI post} - \text{SI pre}}{\text{SI pre}} \right) \times 100 \%
\]

Because comparison of absolute values of T1 between cases is not appropriate, we elected to assess the enhancement rate of the T1 value instead; this was, therefore, a semiquantitative rather than fully quantitative analysis. These tasks were performed using a PACS workstation (SYNAPSE-Fujiﬁlm, Tokyo, Japan) by a single shoulder surgeon (Y.I.). Mean values were determined after three measurements were performed.

Clinical evaluation

Clinical evaluations were recorded at the point of the initial and second dynamic MRI. The items assessed were a numeric rating scale (NRS) at motion, active shoulder ROM (FF, ER, and IR), the American Shoulder and Elbow Surgeons (ASES) score, and the Constant score.

Surgical procedures

Procedures were performed by two shoulder surgeons (Y.I. and H.S.) in an outpatient setting. The cervical nerve roots (C5-C6) were identified using ultrasonographic examination (Noblus; Hitachi ALOKA Medical, Tokyo, Japan); then, injection of 10 mL of 0.75% ropivacaine and 10 mL of 1% lidocaine was performed around them. Manipulation was first performed by moving the shoulder into 90° of abduction with gradual ER. After 90° of abduction and 90° of ER were obtained, the arm was maximally abducted until the patient’s upper arm touched his or her ear. Progression to maximum adduction was then performed, followed by IR while in maximum adduction. Progression to maximum ER with the arm at the patient’s side was followed by progression to maximum ER with the patient’s arm at 45° of abduction. Finally, IR was performed until the vertebral height that could be reached by the dominant thumb was equal to that of the nondominant thumb.

After MUC, vital signs and the swelling of the cervical block site 1 hour after anesthesia were measured for all patients to rule out pneumothorax or vascular injury. We also performed radiography and ultrasonography to detect humeral fractures, shoulder dislocations, or rotator cuff tears.

Postoperative treatment

All patients underwent a standard rehabilitation protocol including shoulder passive and active ROM exercises and stretching of the periscapular muscles by a physical therapist the day after the procedure. They continued to receive rehabilitation under the supervision of a physical therapist for 3 months. All patients successfully completed this program.
Data were expressed as means ± standard deviation. The Wilcoxon signed-rank test was used for comparison. Differences with values of $P < .05$ were considered statistically significant. Calculations were performed with SPSS 20 software (IBM, Armonk, NY, USA).

Results

Table I shows the patient demographics and clinical characteristics. The burning sign in both AP and RI was detected in all 19 cases using 3D dynamic MRI. The clinical results (NRS score at motion, shoulder ROM, Constant score, and ASES score) of all patients improved after MUC. The NRS improved significantly from $6.1 \pm 2.4$ preoperatively to $1.1 \pm 1.6$ at the time of the second dynamic MRI ($P < .001$). Before MUC compared with after MUC, the average values improved for FF from $84^\circ \pm 10^\circ$ to $153^\circ \pm 18^\circ$, for ER from $0^\circ \pm 4^\circ$ to $55^\circ \pm 17^\circ$, and for IR from L5 to T10 (all $P < .001$). The preoperative and postoperative ASES score and Constant score were $35 \pm 14$ and $90 \pm 14$ and $27 \pm 4$ and $78 \pm 6$, respectively (both $P < .001$) (Table II).

The before and after MUC enhancement rate (%) in dynamic MRI SI was $217 \pm 51$ and $85 \pm 36$ in the AP and $233 \pm 61$ and $73 \pm 40$ in the RI, respectively (both $P < .001$). The before and after MUC enhancement velocities (ms/s) were $902 \pm 335$ and $203 \pm 125$ in the AP and $1249 \pm 634$ and $213 \pm 146$ in the RI, respectively (both $P < .001$) (Table III).
Data are presented as means ± standard deviation.

**Table II**
Clinical results before and after MUC.

| Variables                                      | Before MUC | After MUC | P value |
|------------------------------------------------|------------|-----------|---------|
| NRS score at motion                            | 6.1 ± 2.4  | 1.1 ± 1.6 | <.001   |
| Range of motion (degrees)                      |            |           |         |
| Forward flexion                                | 84 ± 10 (50-95) | 153 ± 18 (110-180) | <.001   |
| External rotation at side                      | 0 ± 4 (-10 to 10) | 55 ± 17 (20 to 80) | <.001   |
| Internal rotation                              | 15 (5-15)  | T10 (5-15) | <.001   |
| ASES score                                     | 35 ± 14    | 90 ± 14   | <.001   |
| Constant score                                 | 27 ± 4     | 78 ± 6    | <.001   |

MUC, manipulation under ultrasound-guided cervical nerve root block; NRS, numeric rating scale; ASES, American Shoulder and Elbow Surgeons. Data are presented as means ± standard deviation.

**Table III**
Semiquantitative evaluation with dynamic MRI before and after MUC.

| Variables (n = 19)                          | Before MUC | After MUC | P value |
|---------------------------------------------|------------|-----------|---------|
| Increase rate of T1 values (%)              |            |           |         |
| AP                                          | 217 ± 51   | 85 ± 36   | <.001   |
| RI                                          | 233 ± 51   | 73 ± 40   | <.001   |
| Enhancement velocity (ms/s)                 |            |           |         |
| AP                                          | 902 ± 335  | 203 ± 125 | <.001   |
| RI                                          | 1249 ± 634 | 213 ± 146 | <.001   |

MRI, magnetic resonance imaging; MUC, manipulation under ultrasound-guided cervical nerve root block; AP, axillary pouch; RI, rotator interval. Data are presented as means ± standard deviation.

**Figure 3** A 54-year-old female patient with idiopathic frozen shoulder of the *Left* side. (A) Dynamic 3D MRI shows abnormal enhancement (burning sign) at the AP (arrow head) and RI (arrow) before MUC. (B) Dynamic 3D MRI shows the same patient six months after MUC. The burning sign disappeared. Both images are at 90 seconds after the gadolinium intravenous injection (Middle phase). 3D, 3-dimensional; MRI, magnetic resonance imaging; MUC, manipulation under ultrasound-guided cervical nerve root block; AP, axillary pouch; RI, rotator interval.

**Discussion**

This study demonstrates the use of dynamic MRI to semiquantitatively evaluate the reduction in abnormal blood flow in patients with FS before and after MUC via examining the enhancement rate of the SI and the enhancement velocity. To our knowledge, this is the first study to use dynamic MRI semiquantitatively to assess the relationship between improvement of the images and clinical outcome in FS after MUC.

We have previously reported the safety and efficacy of MUC in the treatment of FS. The clear benefit of this method is improvement in pain and shoulder ROM as early as 1 week after the procedure. Regarding complications associated with MUC, Horner’s syndrome was reported in one patient in our previous study. However, the symptoms of mild miosis and ptosis resolved after several hours, and the patient returned home on the same day. In this study, no complications, such as fracture, rotator cuff tear, vascular injury, neurological disorder, or pneumothorax, were noted. MRI findings 6 months or more after MUC also did not exhibit any iatrogenic capsular tears, bone bruises, labral tears, or rotator cuff tears.

Sasanuma et al evaluated 3D dynamic MRI findings in patients with FS and found that FS was associated with an abnormal cluster of blood flow and dispersion of contrast medium around the RI and AP. This phenomenon was termed the “burning sign”, and the correlation between this burning sign in the RI and pain score was described. This study demonstrated that the burning sign was a
clear finding on imaging that was likely to be beneficial for the diagnosis of FS.

Tamao et al reported an increase in SI in the glenohumeral joint synovium in patients with FS compared with those of healthy volunteers or patients with subacromial impingement on dynamic MRI. They showed that the increased SI observed in the FS volunteers or patients with subacromial impingement was helpful to diagnose FS. They immediately diminished after the procedure. Martinez et al also reported that the AP and RI have the highest uptake of contrast medium successfully with 3D dynamic MRI and to measure the change of the SI there at a pin point by setting ROIs.

In a study of abnormal blood flow in FS, Okuno et al performed angiography on patients with FS to treat the abnormal vessels by transcatheter arterial embolization. They reported the genesis of neovessels around the AP and RI, and nocturnal pain was immediately diminished after the procedure. Martinez et al also described the effects of transcatheter arterial embolization for 40 patients with FS who were resistant to conservative treatment.

In addition to using dynamic MRI and angiography, previous studies have reported that specific patterns in positron emission tomography using fluorine-18-fluorodeoxyglucose and technetium-99m sulfur colloid in idiopathic FS can be helpful to diagnose FS. Won et al reported that the AP and RI may be the main pathologic sites of idiopathic FS based on research using fluorine-18-fluorodeoxyglucose positron emission tomography/computed tomography.

These studies suggest that the pathology of FS is closely related to the presence of the AP and RI and that treatment of the AP and RI may also attenuate the clinical symptoms in patients after MUC. This method of using dynamic MRI to evaluate FS may help to diagnose FS and evaluate the effects of therapy. Furthermore, our findings suggest that there is an association between the burning sign and the pathology of FS.

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