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Characteristics of post-traumatic shoulder stiffness on dynamic magnetic resonance imaging: preliminary case reports

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Shoulder stiffness is a common condition managed by orthopedic surgeons. It is divided into 2 types: primary and secondary shoulder stiffness. Whereas primary shoulder stiffness is not associated with trauma or any specific shoulder diseases, secondary shoulder stiffness has a known cause such as trauma or surgery.[1]

Dynamic magnetic resonance imaging (MRI) is an examination in which MRI is performed over time after a bolus intravenous injection of gadolinium-chelated contrast material; specifically, MRI is performed every 9 s for a total of 3 min. Compared with MRI or contrast MRI, dynamic MRI enables clinicians to assess the change in blood flow over time. Three dynamic MRI studies have revealed findings associated with shoulder stiffness. First, a dynamic MRI study of frozen shoulder showed an abnormal cluster of blood flow and dispersion of contrast medium around the rotator interval and axillary pouch from the early phase to the late phase.[4] Second, in an imaging study of symptomatic rotator cuff tear, all patients who had shoulder stiffness associated with a rotator cuff tear had abnormal enhancement at the rotator interval and axillary pouch.[5] Third, abnormal blood flow at the rotator interval and axillary pouch was detected by dynamic MRI in patients who had shoulder stiffness with chronic calcifying tendinitis.[3] Regardless of the presence of primary or secondary shoulder stiffness in these 3 studies, all patients with shoulder stiffness had abnormal enhancement at the rotator interval and axillary pouch on dynamic MRI.

Among cases of secondary shoulder stiffness, post-traumatic shoulder stiffness is not rare. However, no study has been performed to investigate the dynamic MRI findings of post-traumatic shoulder stiffness. We experienced 5 cases of post-traumatic shoulder stiffness and performed dynamic MRI studies. Therefore, the current preliminary study was performed to investigate the dynamic MRI findings in patients with post-traumatic shoulder stiffness.

Materials and methods

Data of patients with post-traumatic shoulder stiffness from January 2019 to December 2020 were retrospectively analyzed using our electronic medical database. The inclusion criteria were (1) shoulder pain with limited active and passive range of shoulder motion in at least 3 directions (forward flexion $\leq$ 100 degrees, external rotation at the side $\leq$ 10 degrees, and internal rotation $\leq$ L5), (2) assessment with dynamic MRI, and (3) history of trauma. The exclusion criteria were (1) rotator cuff tear, (2) calcifying tendinitis, (3) osteoarthritis, and (4) previous shoulder surgery. During the study period, we identified 8 patients with post-traumatic shoulder stiffness. After excluding 3 patients who had not undergone dynamic MRI, 5 patients were enrolled in this study.

The assessed items included the patients' baseline characteristics such as age, sex, illness duration, fracture site, fracture treatment, and active range of shoulder motion (anterior elevation, external rotation at side, and internal rotation of thumb vertebral level), and pain score using a numerical rating scale. Abnormal

This study was approved by the Jichi Medical University Institutional Review Board (protocol number: 20-012). All participants provided consent to participate in this study.

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Table I
Patients' baseline characteristics.

Case	Age (y)	Sex	Side	Fracture site	Treatment	Duration from injury to dynamic MRI (mos)
1	57	M	L	Middle clavicle	ORIF	5
2	62	M	L	Middle clavicle	ORIF	11
3	68	F	R	Greater tubercle	Conservative	5
4	57	F	L	Greater tubercle	Conservative	3
5	49	F	L	Greater tubercle	Conservative	2

M, male; *F*, female; *L*, left; *R*, right; *ORIF*, open reduction and internal fixation; *MRI*, magnetic resonance imaging.

enhancement on dynamic MRI in the late phase was also investigated.

All patients underwent 3.0T MRI (Skyra; Siemens Medical Systems, Erlangen, Germany). After bolus intravenous injection of gadolinium-chelated contrast material, 3D fast low-angle images (repetition time, 3.1 ms; echo time, 1.26 ms) were obtained in the oblique coronal plane every 9 s for a total of 3 min. The late phase was defined as 153 s after the initiation of imaging.

Results

The 5 patients comprised 2 men and 3 women, and their mean age was 58.6 ± 6.3 years (range, 49–68 years). The mean duration of shoulder stiffness was 5.8 ± 1.3 months (range, 4–8 months). The patients' baseline characteristics are summarized in Table I. All patients with post-traumatic shoulder stiffness had abnormal enhancement in the rotator interval and axillary pouch (Table II). Two patients with greater tubercle fractures had abnormal enhancement at the fracture site.

Case presentations

Case 1

A 57-year-old man sustained a left middle clavicle fracture due to a bike accident. Because the displacement at the fracture site was severe, open reduction and internal fixation was performed 4 days after injury (Fig. 1, *A* and *B*). The pendulum exercise was started soon after surgery. At 1 week after surgery, passive and active range of motion (ROM) exercise was started, although anterior elevation and abduction was limited to 90 degrees until 4 weeks postoperatively. From 4 weeks postoperatively, active ROM exercise without limitation was continued. However, the patient developed gradually worsening shoulder stiffness, and his active range of shoulder motion was as follows at 5 months after surgery: anterior elevation, 90 degrees; external rotation at side, 10 degrees; and internal rotation, buttock. His pain scores were 6 points during motion, 3 points during rest, and 3 points at night. Dynamic MRI at 153 s (late phase) showed strong enhancement at the rotator interval and axillary pouch after intravenous gadolinium injection (Fig. 1*C*).

Case 5

A 49-year-old woman sustained a greater tubercle fracture due to a fall. Because the displacement at the fracture site was small, conservative therapy was started (Fig. 2*A*). The pendulum exercise was started soon after injury. At 2 weeks after injury, passive ROM exercise was started. Active-assisted ROM exercise was started at 4 weeks after injury, and active ROM exercise was started at 6 weeks after injury. Rotator cuff strength exercise was started at 12 weeks after injury. However, the patient developed gradually worsening shoulder stiffness, and her active range of shoulder motion was as follows at 6 months after injury despite bone union (Fig. 2*B*): anterior elevation, 90 degrees; external rotation at side, 0 degrees; and internal rotation, fifth lumbar spine. Her pain scores were 5 points during motion, 3 points during rest, and 0 points at night. Dynamic MRI at 153 s (late phase) showed strong enhancement at the rotator interval, axillary pouch, and fracture site after intravenous gadolinium injection (Fig. 2*C*).

Discussion

This study provides the first case reports demonstrating the dynamic MRI findings of post-traumatic shoulder stiffness. All patients had abnormal enhancement at the rotator interval and axillary pouch.

Although no previous studies have investigated the dynamic MRI findings in patients with post-traumatic shoulder stiffness, 3 studies examined the dynamic MRI findings of shoulder stiffness in patients with frozen shoulder, rotator cuff tear, and calcifying tendinitis.[3–5] All patients in these studies had abnormal enhancement at the rotator interval and axillary pouch. Further, these findings were similar to the dynamic MRI findings in patients with post-traumatic shoulder stiffness. Abnormal blood flow at the rotator interval and axillary pouch may be one pathologic finding of post-traumatic shoulder stiffness.

One study showed that the arthroscopic findings of shoulder stiffness were associated with a variety of etiologies including idiopathic frozen shoulder, diabetes, impingement, surgery, and trauma.[2] Regardless of the etiology, most patients showed qualitatively remarkably similar glenohumeral pathology. Arthroscopy revealed gelatinous, red, synovitic proliferative material around the long head of the biceps tendon and down the anterior capsule. This synovitic proliferative material is considered abnormal enhancement on dynamic MRI. These findings raise the possibility that the pathology of shoulder stiffness is quite similar regardless of the etiology of the shoulder stiffness.

Two patients with greater tubercle fractures had strong enhancement at the fracture site on dynamic MRI. In these 2 patients, the period from fracture to dynamic MRI was short (3 and 2 months, respectively). Therefore, strong enhancement of the fracture site is considered to reflect the increased blood flow in the process of bone union.

This was a preliminary study of several case reports, and further studies with more patients are needed to confirm the current findings.

Table II
Patients' clinical data and dynamic MRI findings.

Case	ROM			Pain (NRS score)			Location of enhancement on dynamic MRI		
	AE	ER	IR	Motion	Rest	Night	RI	AP	Fracture site
1	90°	10°	B	6	3	3	+	+	−
2	85°	0°	L5	5	0	0	+	+	−
3	90°	0°	B	5	5	5	+	+	−
4	80°	10°	L5	8	8	9	+	+	+
5	90°	0°	L5	5	3	0	+	+	+

ROM, range of motion; *AE*, anterior elevation; *ER*, external rotation; *IR*, internal rotation; *B*, buttock; *L5*, fifth lumbar vertebra; *MRI*, magnetic resonance imaging; *RI*, rotator interval; *AP*, axillary pouch.

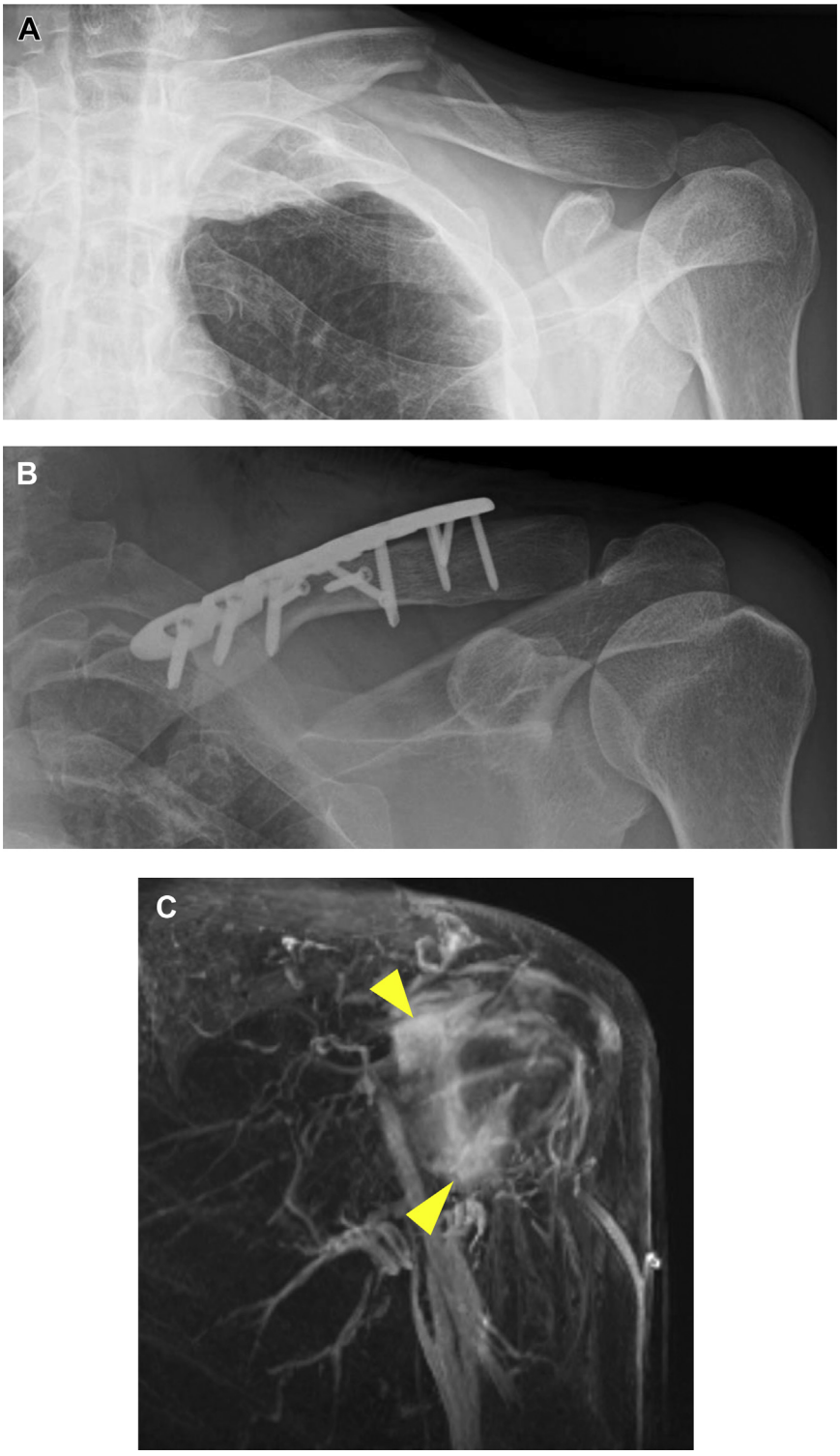

Figure 1 Case 1: A 57-year-old man with a left middle clavicle fracture. (**A**) Initial radiograph showing a displaced middle clavicle fracture. (**B**) Postoperative radiograph showing open reduction and internal fixation. (**C**) Dynamic magnetic resonance imaging findings at 153 s (late phase) show strong enhancement at the rotator interval and axillary pouch (*arrowheads*).

Conclusion

This study presents the first case reports of the dynamic MRI findings in patients with post-traumatic shoulder stiffness. All patients had abnormal enhancement at the rotator interval and axillary pouch.

Conflicts of interest

All authors, their immediate family, and any research foundation with which they are affiliated did not receive any financial payments or other benefits from any commercial entity related to the subject of this article.

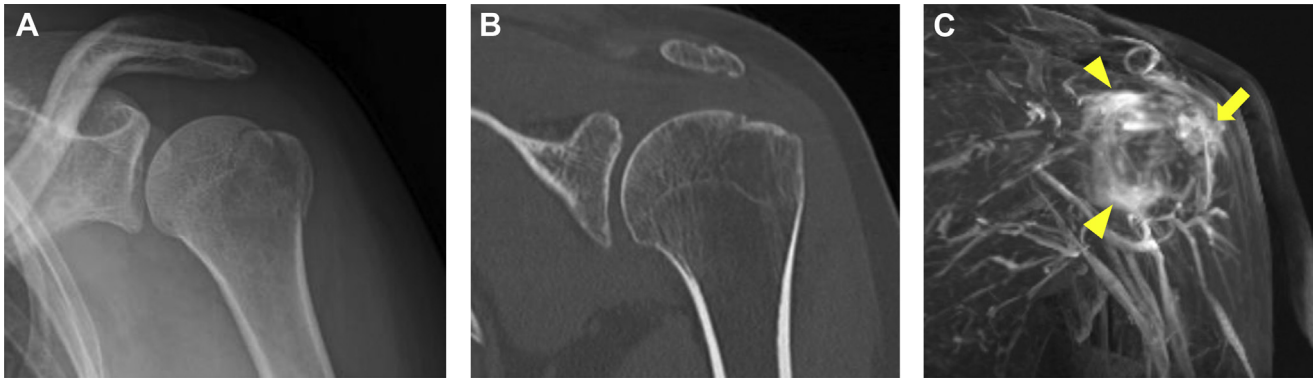

Figure 2 Case 5: A 49-year-old woman with a minimally displaced greater tubercle fracture. (**A**) Initial radiograph showing a minimally displaced greater tubercle fracture. (**B**) Computed tomography showing bone union 5 months after the injury. (**C**) Dynamic magnetic resonance imaging findings at 153 s (late phase) show strong enhancement in the rotator interval, axillary pouch, greater tubercle (*arrowheads*), and fracture site (*arrow*).

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Patient consent

Obtained.

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