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Abstract

A preliminary study was conducted to evaluate the superior and inferior glenoid labra with abductive movement using an open-type MR unit in asymptomatic healthy volunteers. Both fast low angle shot (FLASH) and turbo spin echo (TSE) images were obtained to evaluate the shapes of both the superior and inferior labra, as well as to assess changes in signal at these sites. As the abduction angle was increased, the shape of the superior labrum changed from round or triangular to crescentic and a higher signal was frequently seen. At an abduction angle of 150 degrees, an increase in signal was seen in one-half of the superior labra; this increase was noted more frequently in volunteers over 40 years of age. In some of the superior labra, the increase in signal seen at 150 degrees abduction disappeared on subsequent images obtained at 0 degrees abduction. Hence, the increase in signal was considered to be a reversible change. The shape of the inferior labrum tended to change from crescentic to triangular or round. An increase in signal in the inferior labrum was unrelated to the abduction angle. Abductive kinematic studies using an open-type MR unit provides information about the morphology of the superior and inferior labra, as well as information about signal changes occurring at these sites.

KEYWORDS: shoulder, kinematic magnetic resonance imaging(MRI), glenoid labrum, open-type MRI

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Original Article

Kinematic Magnetic Resonance Imaging (MRI) of the Normal Shoulder: Assessment of the Shapes and Signals of the Superior and Inferior Labra with Abductive Movement Using an Open-type Imager

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A preliminary study was conducted to evaluate the superior and inferior glenoid labra with abductive movement using an open-type MR unit in asymptomatic healthy volunteers. Both fast low angle shot (FLASH) and turbo spin echo (TSE) images were obtained to evaluate the shapes of both the superior and inferior labra, as well as to assess changes in signal at these sites. As the abduction angle was increased, the shape of the superior labrum changed from round or triangular to crescentic and a higher signal was frequently seen. At an abduction angle of 150°, an increase in signal was seen in one-half of the superior labra; this increase was noted more frequently in volunteers over 40 years of age. In some of the superior labra, the increase in signal seen at 150° abduction disappeared on subsequent images obtained at 0° abduction. Hence, the increase in signal was considered to be a reversible change. The shape of the inferior labrum tended to change from crescentic to triangular or round. An increase in signal in the inferior labrum was unrelated to the abduction angle. Abductive kinematic studies using an open-type MR unit provides information about the morphology of the superior and inferior labra, as well as information about signal changes occurring at these sites.

Key words: shoulder, kinematic magnetic resonance imaging (MRI), glenoid labrum, open-type MRI

Kinematic magnetic resonance imaging (MRI) has made it possible to evaluate joint structures during movement. This imaging technique has generally been limited to the study of the joints of the knee, wrist, and cervical spine.

Only a few studies have been dedicated to examination of the shoulder by kinematic MRI. Previous studies discussing kinematic MRI of the shoulder were performed for the most part with traditional cylindrical-type MRI machines [1-3]. Those studies were limited to internal or external rotation, and only the anterior and posterior glenoid labra could be assessed. To our knowledge, there has been only one report concerning abductive movement in the shoulder [4].

Open-type MR units can be used to show abductive movement on kinematic MR images. Such units are expected to aid clinical evaluation of the superior and inferior glenoid labra. The accurate assessment of abnor-

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mal superior labral MR findings is clinically important in the evaluation of injuries such as superior labral anterior posterior (SLAP) lesions [5] often observed in athletes such as baseball players and tennis players.

In the present study, we performed detailed evaluations of labral shape and signal intensity to determine the normal patterns of the glenohumeral joint during abductive movement, as shown on kinematic MR images. The superior and inferior glenoid labra were evaluated in asymptomatic healthy volunteers. The purpose of our study was to determine the prevalence of abnormalities with respect to sex, age, side, and dominant arm in detail.

Materials and Methods

Twenty-five asymptomatic healthy volunteers (18 men and 7 women; age range, 23-55 years; average age, 33.9 years) with no history of shoulder joint disease were examined by MR imaging from 1997 to 1999. Informed consent was obtained from all of the volunteers prior to participation in the study. The study group was divided into 10-year age ranges as follows: 20-29 years of age, 12 subjects; 30-39, 7 subjects; and > 40, 6 subjects. Each subjects underwent 2 separate MRI sessions on different days; the first session was dedicated to one shoulder, and the second session was dedicated to the contralateral shoulder.

Imaging was performed with a 0.2-T open-type MR imager (Magnetom OPEN, Siemens Medical Systems, Erlangen, Germany). This machine is open on 3 sides due to its C-shaped design. A multipurpose-large coil was used. The subject was asked to elevate his or her arm in 30° increments using a dedicated device with external abduction in the supine position (Fig. 1).

Both T2*-weighted gradient echo (FLASH: fast low angle shot) sequences and T2-weighted turbo spin echo (TSE) sequences were employed. Imaging parameters for the FLASH sequence were a repetition time (TR)/echo time (TE) of 500 ms/17 ms, a flip angle of 25°, 3 acquisitions, and a scanning time of 7 min 9 sec. Imaging parameters for the TSE sequence were a TR/TE of 4,500 ms/102 ms, an echo train length of 7, 2 acquisitions, and a scanning time of 6 min 6 sec. For both sequences, the field of view was 220 × 165 mm, the matrix size was 256 × 142, and 11 slices with a slice thickness of 4 mm were acquired without interslice gaps.

Oblique coronal sections along the scapular axis were obtained in 6 different positions (at abduction angles of 0, 30, 60, 90, 120, and 150°). Examination was indicated at 0°, and the angle was increased in a stepwise manner up to 150°. Subjects who showed an increase in signal in the superior labrum at 150° abduction were examined again at 0° abduction.

The shape and signal changes of the glenoid labrum were visually evaluated in a blinded fashion by 2 radiologists. Disagreements between the reviewers were resolved by consensus. Shape was classified as one of the following: round, triangular, or crescentic on the FLASH images, as classified by Sans N, *et al* [3]. The signal intensities of the superior and inferior glenoid labra were evaluated on TSE images as either positive or negative. The shape of the labrum as well as its signal intensity were evaluated in relation to the abduction angle. The increase in signal was evaluated to identify correlations with sex, age, side, dominant arm, and shape of the labrum. Statistical analysis was performed using a chi-square test. A P value less than .05 was considered to indicate a statistically significant difference.

Results

At an abduction angle of 0°, the shape of the superior labrum was round in 24% (12 of 50) of the shoulders, triangular in 68% (34 of 50), and crescentic in 8% (4 of 50). As the abduction angle increased, the shape changed from round or triangular to crescentic (Fig. 2). At an

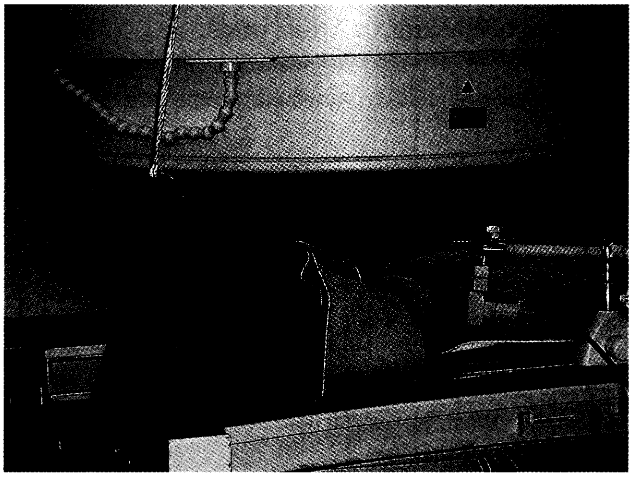

Fig. 1 Appearance of a 0.2-T open-type MR imager. A subject elevates his arm in 30° increments using a dedicated device with 150° external abduction in the supine position.

abduction angle of 150 °, the shape of the superior labrum was crescentic in all of the shoulders (Fig. 4). A positive signal was seen in 24% (12 of 50) of the shoulders at an abduction angle of 0 °. As the abduction angle increased, a positive signal was more frequently seen. At an abduction angle of 150 °, 52% (26 of 50) of the shoulders showed a positive signal in the superior labrum (Figs. 3 and 6). A positive signal was more often seen in volunteers over 40 years of age ($P = 0.0003$) (Table 2). No correlation was seen between the increase in signal and sex, side, or dominant arm (Tables 1, 3, and 4). A positive signal was more often seen in association with a crescentic shape ($P = 0.02$) (Table 5). In superior labra that showed a negative signal at 0 ° abduction and a positive signal at 150 ° abduction, the increase in signal disappeared on subsequent images obtained at 0 ° abduction. The observed increase in signal was therefore considered to be a reversible change.

On the other hand, the shape of the inferior labrum was triangular in 4% (2 of 50) of the shoulders and crescentic in 96% (48 of 50) at an abduction angle of 0 °. The shape of the inferior labrum tended to change from crescentic to triangular with abduction (Fig. 5). A positive signal was seen in 54% (27 of 50) of the shoulders at an abduction angle of 0 ° in the inferior labrum of the shoulders; this signal was unrelated to the abduction angle, sex, side, dominant arm, or shape of the labrum (Fig. 7, Tables 1 and 3-5). A significant correlation was seen between the increase in signal and age ($P = 0.006$) (Table 2).

Discussion

The usefulness of MRI in evaluating the glenoid

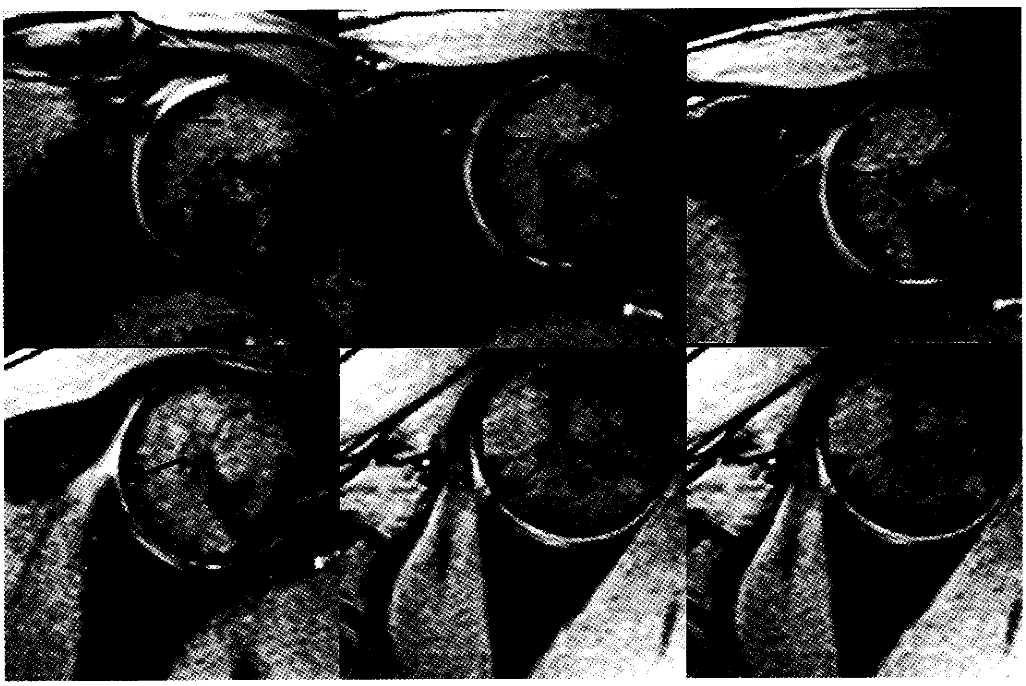

Fig. 2 FLASH images of the left shoulder at each abduction angle in a healthy volunteer (40-y.o. male)

a	b	c
d	e	f

a, 0°; b, 30°; c, 60°; d, 90°; e, 120°; f, 150°.
The bone marrow of the scapla is demonstrated as having a low signal intensity, whereas that of the humeral head is slightly high. The signals of the muscles are as high as that of the humeral head. Articular cartilages are high and curvilinear. The superior labrum (arrow) is triangular at 0 °, 30 °, and 60 ° and it is crescentic at 90 °, 120 °, and 150 °.

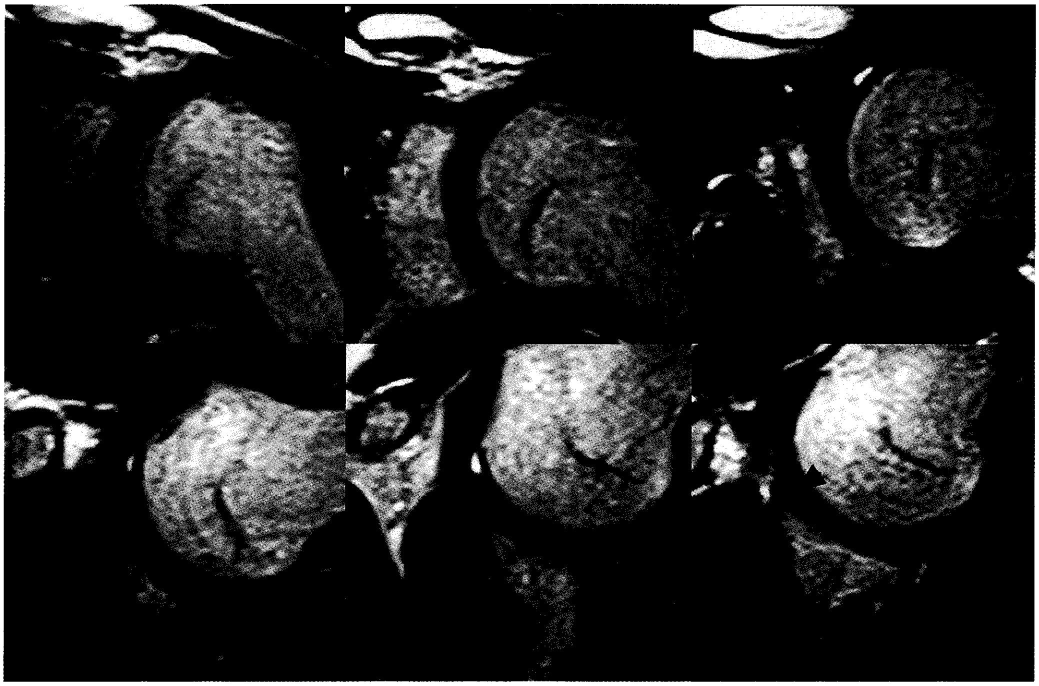

Fig. 3 TSE images of the left shoulder at each abduction angle in a healthy volunteer (40-y.o. male)

a	b	c
d	e	f

a, 0°; b, 30°; c, 60°; d, 90°; e, 120°; f, 150°.
The bone marrow is demonstrated as having a high signal intensity, and that of the muscle is low. The signals of the articular cartilages are lower than those achieved in the FLASH images. A positive signal is seen at an abduction angle of 150° (arrowhead).

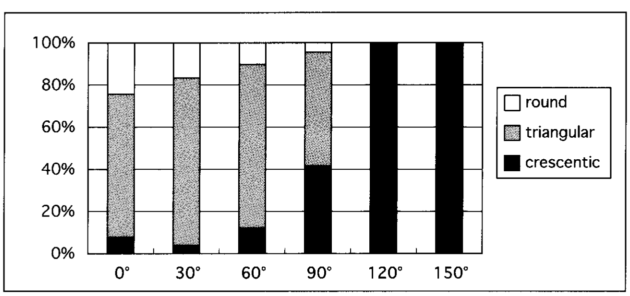

Fig. 4 Relation between abduction angle and shape of the superior labrum. As the abduction angle is increased, the shape of the superior labrum changes from round or triangular to crescentic.

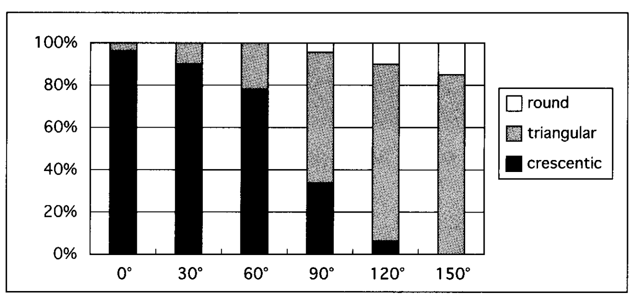

Fig. 5 Relation between abduction angle and shape of the inferior labrum. As the abduction angle is increased, the shape of the inferior labrum changes from crescentic to triangular.

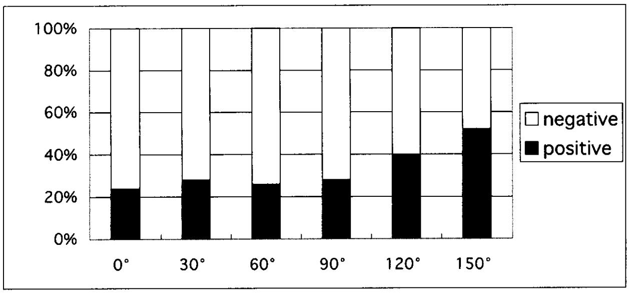

Fig. 6 Relation between abduction angle and signal in the superior labrum. As the abduction angle is increased, a positive signal is more frequently seen in the superior labrum.

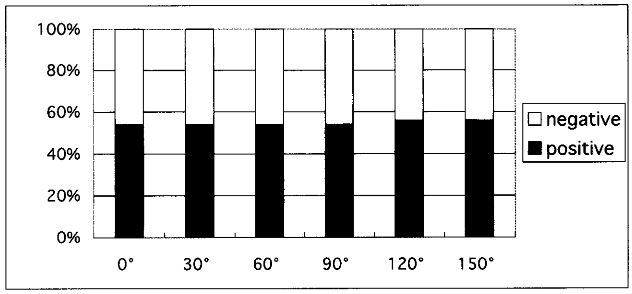

Fig. 7 Relation between abduction angle and signal in the inferior labrum. A positive signal was unrelated to the abduction angle in the inferior labrum.

Table 1 Relation between sex and signal

Sex	Superior labrum Positive	Superior labrum Negative	Inferior labrum Positive	Inferior labrum Negative
Men	21	15	21	15
Women	5	9	6	8
		(*n.s.*)		(*n.s.*)

No correlation is seen in either the superior or inferior labrum.

Table 2 Relation between age and signal

Age	Superior labrum Positive	Superior labrum Negative	Inferior labrum Positive	Inferior labrum Negative
21-30	7	17	10	14
31-40	7	7	6	8
40<	12	0	11	1
		($P = 0.0003$)		($P = 0.006$)

A significant correlation is seen in both the superior and inferior labrum.

Table 3 Relation between side and signal

Side	Superior labrum Positive	Superior labrum Negative	Inferior labrum Positive	Inferior labrum Negative
Right	15	10	13	12
Left	11	14	14	11
		(*n.s.*)		(*n.s.*)

No correlation is seen in either the superior or inferior labrum.

Table 4 Relation between dominant arm and signal

Dominant arm	Superior labrum Positive	Superior labrum Negative	Inferior labrum Positive	Inferior labrum Negative
Dominant	15	10	12	13
Non-dominant	11	14	15	10
		(*n.s.*)		(*n.s.*)

No correlation is seen in either the superior or inferior labrum.

Table 5 Relation between shape of labrum and signal

Shape	Superior labrum Positive	Superior labrum Negative	Inferior labrum Positive	Inferior labrum Negative
Round	6	21	6	8
Triangular	38	102	74	60
Crescentic	55	78	84	68
		($P = 0.02$)		(*n.s.*)

A positive signal is more often seen in association with a crescentic shape in the superior labrum, whereas no correlation is seen in the inferior labrum.

labrum has previously been reported [6–9]. It is important to evaluate the superior labrum in sports injuries such as SLAP lesions [5]. In the case of type 1 SLAP lesions, MR findings reveal an irregularity of the labral contour and a slight increase in signal intensity. In the early stages, clinical symptoms often appear in the abducted position. Therefore, kinematic MRI has been proposed as a useful method for early detection of SLAP lesions. However, only one report has been published thus far concerning abductive movement in the shoulder, as observed by kinematic MRI. In that report, instability and impingement were evaluated with abductive movement. The present study is the first to use kinematic MRI in order to evaluate the superior and inferior labra. It is essential to establish patterns of variation in healthy individuals before attempting to evaluate abductive movement in symptomatic patients.

In the present study, we used an open-type MR machine that permitted abductive motion. However, the field strength (0.2 tesla) and signal-to-noise ratio of this machine are low. It is necessary to maintain good spatial resolution in order to assess the glenoid labrum. Therefore, the selection of a suitable pulse sequence is crucial. The glenoid labrum has been evaluated with T2/T2*-weighted images; gradient echo (FLASH) and TSE sequences have also been described [10-12]. In our study, we employed both FLASH and TSE sequences and compared the images obtained. Due to the high signal intensity in surrounding tissues such as cartilage, the ability of the FLASH sequence to allow for visualization of the glenoid labrum was superior to that of the TSE sequence. The increase in signal intensity of the glenoid labrum seen with the TSE sequence was not observed with the FLASH sequence. Therefore, we consider the FLASH sequence to be unsuitable for the detection of SLAP injuries. We attempted to increase the echo time in the FLASH sequence to obtain a heavily T2*-weighted image, but the signal-to-noise ratio was insufficient to permit evaluation. Both FLASH and TSE sequences are necessary to evaluate the glenoid labrum using this machine. A total study time of 100 to 120 min, including positioning and prescanning, was required to complete this protocol. Since additional sequences, including transverse images or T1-weighted images, are required for the evaluation of patients, it is impossible in the clinical setting to obtain all of the sequences used in this protocol. Based on our results, imaging at 0° and 150° is sufficient for evaluation.

Using a dedicated device, the subject's humerus was elevated to 30° in all of the abducted positions, as the axis of the arm should be concordant with the scapular axis. The humerus was rotated externally to position the long head of the biceps and the superior labrum in the same plane.

A previous study involving cadaveric shoulder specimens demonstrated that an increase in signal is due to the presence of histologically fibrovascular tissue, mucoid or eosinophilic degeneration, calcification, ossification, synovial tissue, or a combination of these factors [13]. However, these findings were obtained in cadaveric shoulders and were presumed to be irreversible changes. The results of our study, on the other hand, suggest that changes in the glenoid labrum, especially an increase in signal, are related to compression by the humeral head. Some increases in signal in the superior glenoid labrum were reversible, indicative of edema. Other increases in signal were seen at all abduction angles, including 0°, and represented degeneration. This finding suggests that a reversible increase in signal can progress to an irreversible increase. The detection of a reversible increase in signal may make it possible to prevent subsequent irreversible changes.

With regard to the inferior labrum, the increase in signal did not vary with the abduction angle. This finding may indicate that the inferior labrum is usually compressed by the humeral head, and that an increase in signal reflects degeneration.

Our results clarify the normal patterns for the superior and inferior glenoid labrum in abductive kinematic MRI studies in healthy volunteers. This method is expected to provide useful information for the accurate and early detection of superior or inferior labral injuries, as it provides baseline data for healthy subjects.

In conclusion, abductive kinematic studies using an open-type MR unit that permits dynamic evaluation of the superior and inferior glenoid labra are expected to be useful for the evaluation of patients with various sports injuries.

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