MRI Versus Radiography of Acromioclavicular Joint Dislocation

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OBJECTIVE. Acromioclavicular joint injuries are usually diagnosed by clinical and radiographic assessment with the Rockwood classification, which is crucial for treatment planning. In view of the implementation of MRI for visualization of the acromioclavicular joint, the purpose of this study was to describe the MRI findings of acromioclavicular joint dislocation in comparison with the radiographic findings.

SUBJECTS AND METHODS. Forty-four patients with suspected unilateral acromioclavicular joint dislocation after acute trauma were enrolled in this prospective study. All patients underwent digital radiography and 1-T MRI with a surface phased-array coil. MRI included coronal proton density–weighted turbo spin-echo and coronal 3D T1-weighted fast field-echo water-selective sequences. The Rockwood classification was used to assess acromioclavicular joint injuries at radiography and MRI. An adapted Rockwood classification was used for MRI evaluation of the acromioclavicular joint ligaments. The classifications of acromioclavicular joint dislocations diagnosed with radiography and MRI were compared.

RESULTS. Among 44 patients with Rockwood type I–IV injuries on radiographs, classification on radiographs and MR images was concordant in 23 (52.2%) patients. At MRI, the injury was reclassified to a less severe type in 16 (36.4%) patients and to a more severe type in five (11.4%) patients. Compared with the findings according to the original Rockwood system, with the adapted system that included MRI findings, additional ligamentous lesions were found in 11 (25%) patients.

CONCLUSION. In a considerable number of patients, the MRI findings change the Rockwood type determined with radiography. In addition to clinical assessment and radiography, MRI may yield important findings on ligaments that may influence management.

Keywords: acromioclavicular joint dislocation, MRI, radiography, Rockwood classification

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Disruption of the acromioclavicular joint accounts for approximately 10% of all shoulder injuries and is frequently encountered in sports medicine and traumatology, having a male predominance [1, 2]. Clinical evaluation [2–4] and conventional radiography are usually used to assess instability [1, 2, 5]. Diagnosis and classification of acromioclavicular joint injuries are performed according to the well-established Rockwood system [6, 7].

Treatment planning requires exact classification of acromioclavicular joint lesions [1, 2, 8], which can be difficult clinically [3]. The radiographic findings can be confounded because the acromioclavicular joint widens in traumatic conditions but also with aging, as a normal variant [9], and in diseases such as rheumatoid arthritis [10]. Moreover, type II injuries can be difficult to differentiate from type III injuries on conventional radiographs [11, 12].

The diagnostic limitations of radiography and clinical evaluation prompted implementation of MRI for visualization of the acromioclavicular joint [12–14]. Unlike radiography, which relies on joint distance measurements, MRI allows direct evaluation of the joint-supporting structures. The purposes of this study were to describe assessment of acromioclavicular joint dislocation with MRI and to compare the radiographic and MRI findings in determining the Rockwood type of injury, which is important for treatment planning.

Subjects and Methods

The protocol for this prospective study was approved by our institutional review board, and the procedure was performed in accordance with the

Declaration of Helsinki. Written informed consent was obtained from all patients.

Study Sample

Within a 6-month period, we prospectively enrolled 47 patients (17 women, 30 men; age range, 18–52 years; mean, 29 years), who were referred from the department of trauma surgery because of suspected unilateral acromioclavicular joint dislocation after acute trauma. All patients underwent an initial physical examination by an experienced shoulder surgeon that included acromioclavicular joint compression and shear tests, cross-body adduction tests, and testing for a painful arc. Patients with rheumatoid arthritis, connective tissue disease, or chronic acromioclavicular joint pain were not included in the study.

Imaging Techniques

Digital radiography—Digital radiographs (Super 80 CP system, Philips Healthcare) of the injured shoulder were obtained with a standard protocol (55 kV, 9 mAs). The projections included anteroposterior non–weight-bearing views at 10–15° cephalic angulation (Zanca view) in which the clavicle was projected off the spine of the scapula [15] and axial projections for suspected type IV injuries.

MRI—Within 3 weeks after trauma, MRI was performed with a 1-T unit (T10-NT, Philips Healthcare) and a surface phased-array coil with an external diameter of 11 cm. With the patient supine, an unenhanced MR image of the injured acromioclavicular joint was acquired in the coronal oblique plane parallel to the distal clavicle. The study protocol consisted of the following sequences for imaging the acromioclavicular joint: a coronal proton density–weighted turbo spin-echo sequence (TR/TE, 1500/25; turbo spin-echo factor, 5; FOV: 90 × 90 mm; matrix size, 512 × 512; slice thickness, 2 mm; number of slices, 16; flip angle, 90°; reconstructed voxel size, 0.18/0.18/2 mm; acquisition duration, 5 minutes 12 seconds) and a coronal 3D T1-weighted fast field-echo water-selective sequence (TR/TE, 24/11.95; turbo spin-echo factor, 5; FOV, 150 × 150 mm; matrix size, 512 × 512; slice thickness, 2 mm; number of slices, 40; flip angle, 50°; reconstructed voxel size, 0.29/0.29/1.00 mm; acquisition duration, 3 minutes 56 seconds).

Evaluation

With a PACS, identifying information was eliminated from the radiographs and MR images, and the images were randomly presented to the readers. The images were evaluated in consensus by two MRI specialists (a musculoskeletal radiologist with 10 years of experience and a trauma surgeon with 10 years of experience), who were not aware of patient data. These images were imported into the PACS for reading and interpretation.

Radiographic and MRI measurements of the acromioclavicular joint interspace (pathologic width > 7 mm) and the coracoclavicular distance (pathologic width ≥ 12 mm) of the injured shoulder were obtained [1, 8, 12]. Displacement of the clavicle also was assessed (pathologic dislocation ≥ 50%). The acromioclavicular (superior and inferior portions), coracoclavicular (conoid and trapezoid portions) and coracoacromial ligaments; trapezoid and deltoid muscles; and the articulating osseous structures were evaluated on proton density–weighted images. The ligaments were rated according to established criteria for assessing normal status and partial and complete tears on MR images [16, 17]. Acromioclavicular joint fluid and possible bone marrow edema were evaluated on the T1-weighted fast field-echo water-selective images. The rotator cuff was not considered in this study approach.

On the basis of the findings at radiography and MRI, the injuries were assigned a type according to the Rockwood classification [7]. In addition, the Rockwood classification (0–VI) was adapted to integrate the MRI findings, and the injuries were also assigned a type according to this system. Rockwood type 0 indicates no ligamentous lesions on MRI (aRO). Table 1 summarizes the ligamentous lesions.

Rockwood type I—Rockwood type I is normal radiographic findings. In the adapted system, MRI shows partial tear of the acromioclavicular ligament (type aRI) and additional partial tear of the coracoclavicular ligament (type aRI+).

Rockwood type II—On radiographs, Rockwood type II injuries exhibit acromioclavicular joint space widening, a normal or slightly widened coracoclavicular interspace, and 50% superior clavicular displacement. MRI images show complete tear of the acromioclavicular ligament (type aRII–) and partial tear of the coracoclavicular (type aRII) and coracoacromial (type aRII+) ligaments.

Rockwood type III—On radiographs, Rockwood type III injuries exhibit acromioclavicular joint space widening, increased (25–100%) coracoclavicular interspace, and 100% superior clavicular displacement. MR images show complete tear of the acromioclavicular and coracoclavicular ligaments, detachment of the trapezoid and deltoid muscles from the distal part of the clavicle (aRIII), and additional partial rupture of the coracoacromial ligament (aRIII+).

Rockwood type IV—On radiographs, Rockwood type IV injuries exhibit posterior displacement of the distal clavicle into the trapezius (anterior edge of the distal clavicle not in line with the anterior border of the acromion); the acromioclavicular and coracoclavicular distances may be normal. MR images show rupture of all three ligaments (acromioclavicular, coracoclavicular, and coracoacromial) and detachment of the trapezoid and deltoid muscles from the distal part of the clavicle.

Rockwood types V and VI—In Rockwood type V injuries, the distal clavicle is displaced superiorly, and in type VI injuries, the distal clavicle is displaced inferiorly beneath the acromion or coracoid process.

Statistical Analysis

A statistician using standard statistical software (SPSS version 17.0 for Microsoft Windows, SPSS) performed the statistical analysis for this study. Bland-Altmann plotting and a dependent Student *t* test were used to compare the acromioclavicular joint interspace measurements obtained from the radiographs and MR images. Cross tabulation was used to describe and correlate the frequencies of the Rockwood types of injuries depicted on radiographs and MR images. A chi-square test was used to assess

TABLE 1: Ligamentous Lesions According to Rockwood Classification Adapted for MRI

Injury Type	Acromioclavicular Ligament	Coracoclavicular Ligament	Coracoacromial Ligament	Trapezoid and Deltoid Muscles
I	Partial tear	No tear	No tear	No tear
I+	Partial tear	Partial tear	No tear	No tear
II–	Complete tear	No tear	No tear	No tear
II	Complete tear	Partial tear	No tear	No tear
II+	Complete tear	Partial tear	Partial tear	No tear
III	Complete tear	Complete tear	No tear	Detachment from distal part of clavicle
III+	Complete tear	Complete tear	Partial tear	Detachment from distal part of clavicle
IV	Complete tear	Complete tear	Complete tear	Detachment from distal part of clavicle

the distribution of changes of Rockwood types of injuries based on MRI findings. A value of $p \leq 0.05$ was considered statistically significant.

Results

Three patients were excluded from the study because of impairment of MR image quality due to motion artifacts. Forty-four of the 47 patients underwent sufficient examinations, and their findings were evaluated. Twenty-four of the 44 (54.5%) patients had right-sided injuries, and 20 (45.5%) had left-sided injuries.

Rockwood Classification of Injuries at Radiography

Twelve of the 44 (27.3%) patients had normal findings, and the injuries were judged Rockwood type I. Twenty-six of the 44 (59.1%) had Rockwood type II injuries. Thirteen of the 26 patients had a normal acromioclavicular distance but superior clavicular displacement, and 10 patients had a widened acromioclavicular distance. The injuries in the other three patients with normal findings were judged Rockwood type II because of positive results of acromioclavicular compression testing. Four of the 44 (9.1%) patients were found to have Rockwood type III lesions, and all of these patients had a widened acromioclavicular distance and superior clavicular displacement. Two of the 44 (4.5%) patients had Rockwood type IV injuries. One of these patients had a normal acromioclavicular distance and posterior clavicular displacement, and the other had a widened acromioclavicular distance and posterior clavicular displacement.

The acromioclavicular joint interspaces were abnormal (minimum, 7.1 mm; maximum, 16.6 mm; mean, 9.8 mm) in 15 of the 44 (34.1%) patients (10 with Rockwood type II, four with Rockwood type III, and one with a Rockwood type IV injury). The comparison of the acromioclavicular joint interspaces (including normal and abnormal measurements; radiographic mean, 5.83 mm; MRI mean, 4.62 mm) obtained from radiographs and MR images showed a significant difference ($p = 0.005$). The coracoclavicular distance was abnormal (minimum, 14.1 mm; maximum, 22.9 mm; mean, 17.8 mm) in 5 of 44 (11.4%) patients (four with Rockwood type III injuries, one with a Rockwood type IV injury).

In 20 of the 26 patients with Rockwood type II injuries, 50% superior clavicular displacement was found. The four patients with Rockwood type III injuries had 100% superior clavicular displacement. The two patients with Rockwood type IV injuries had posterior clavicular displacement.

Results of Radiographic Versus MRI Classification

Overall, according to the original Rockwood scheme, radiographic and MRI classifications were concordant in 23 of the 44 (52.2%) patients. The injury was reclassified to a less severe type in 16 (36.4%) patients and to a more severe type in five (11.4%) patients. Chi-square analysis showed a statistically significant distribution of classification changes based on MRI findings ($p < 0.004$). Among 12 Rockwood type I injuries, the MRI and radiographic types were concordant in five cases; the injuries were reclassified to a less severe type in four cases and to a more severe type in three cases. Among 26 Rockwood type II injures, the MRI and radiographic types were concordant in 14 cases (Fig. 1); the injury was reclassified to a less severe type in 10 cases (Fig. 2) and to a more severe type in two cases (Fig. 3). Among four Rockwood type III injuries, the MRI and radiographic types were concordant in three cases, and the injury was reclassified to a less severe type in one case. In the

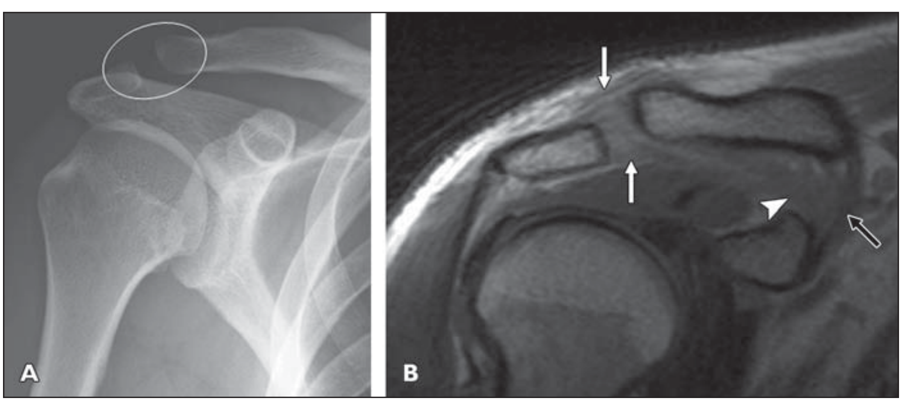

Fig. 1—21-year-old man after right-sided acromioclavicular joint trauma with suspected radiographic Rockwood type II injury confirmed at MRI.
A, Anteroposterior radiograph shows widening of acromioclavicular interspace (*ellipse*) without clavicular displacement.
B, Coronal proton density–weighted image (TR/TE, 1500/25) shows complete disruption of acromioclavicular ligaments (*white arrows*) and partial disruption of coracoclavicular ligaments with abnormal shape and signal intensity of trapezoid portion (*arrowhead*) and thickening of conoid portion (*black arrow*).

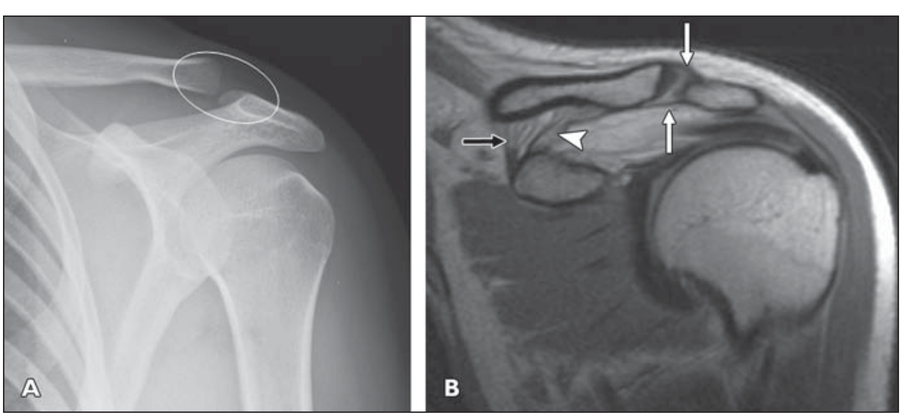

Fig. 2—18-year-old woman after left-sided acromioclavicular joint trauma with suspected radiographic Rockwood type II injury reclassified adapted Rockwood type 0 at MRI.
A, Anteroposterior radiograph apparently shows 50% superior clavicular displacement, but acromioclavicular joint interspace (*ellipse*) appears to be normal.
B, Coronal proton density–weighted image (TR/TE, 1500/25) shows normal condition of superior and inferior acromioclavicular ligaments (*white arrows*) and conoid (*black arrow*) and trapezoid (*arrowhead*) portions of coracoclavicular ligament.

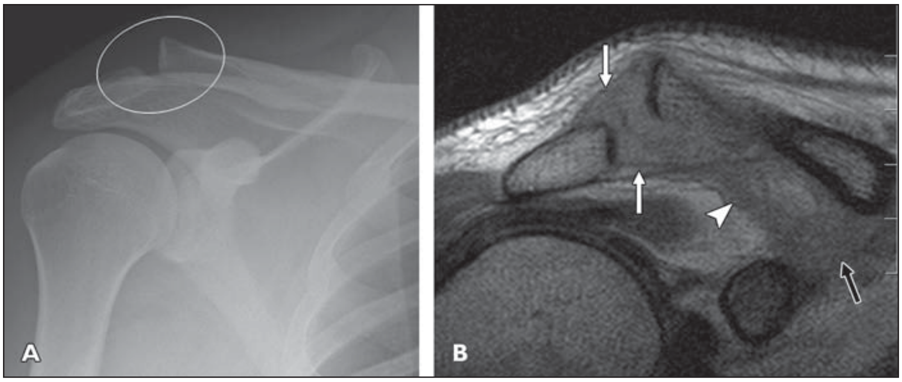

Fig. 3—29-year-old man after right-sided acromioclavicular joint injury with suspected radiographic Rockwood type II injury reclassified Rockwood type IV at MRI.
A, Anteroposterior radiograph shows 60% superior displacement of clavicle and accentuated acromioclavicular interspace (*ellipse*).
B, Coronal proton density–weighted image (TR/TE, 1500/25) shows disruption of acromioclavicular ligaments (*white arrows*), coracoclavicular ligaments (*black arrow*), and coracoacromial ligament (*arrowhead*) with diffuse subclavicular soft-tissue swelling. Normal ligamentous anatomy is abolished. Continuity of clavicle is not fully visible.

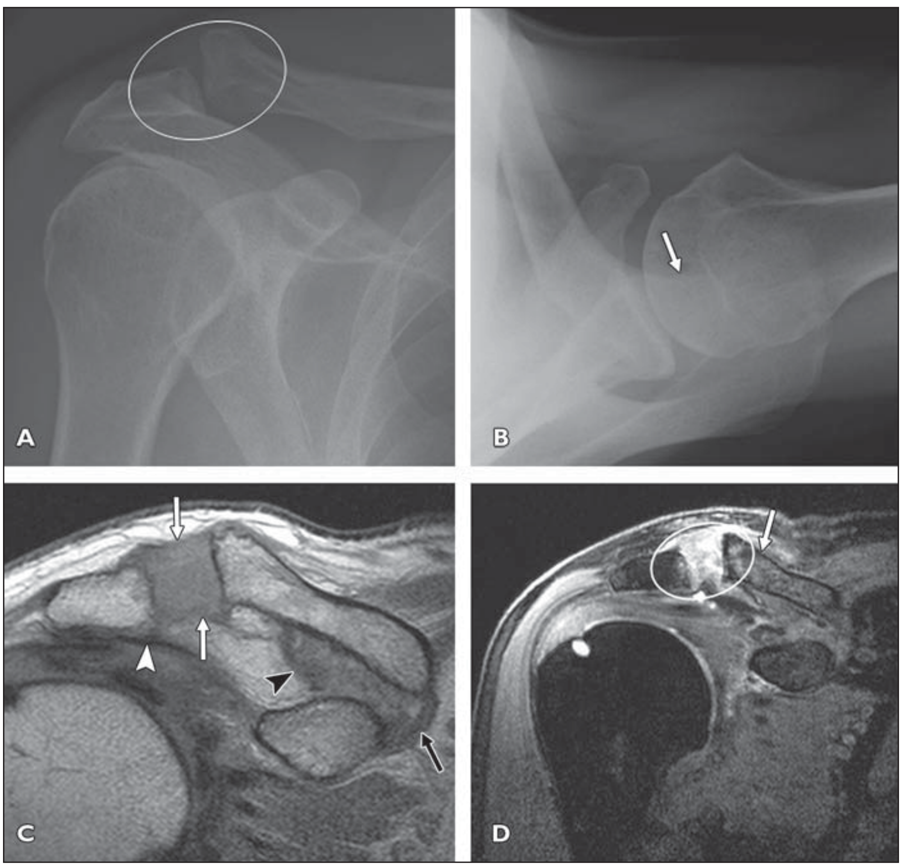

Fig. 4—52-year-old man after right-sided acromioclavicular joint injury with suspected radiographic Rockwood type IV injury reclassified Rockwood type III at MRI.
A, Anteroposterior radiograph shows 50% superior displacement of clavicle (*ellipse*).
B, Radiograph in axial shoulder projection shows apparent posterior displacement of clavicle (*arrow*).
C, Coronal proton density–weighted image (TR/TE, 1500/25) shows disruption of superior and inferior acromioclavicular (*white arrows*), conoid (*black arrowhead*), and trapezoid (*black arrow*) ligaments, diffuse abnormal changes in signal intensity, and ligamentous soft-tissue swelling. Undisrupted coracoacromial ligament is below this plane and only partially visible (*white arrowhead*).
D, Coronal T1-weighted water-selective MR image shows bone bruise of distal clavicle (*arrow*) and diffuse acromioclavicular joint edema (*ellipse*).

two cases of Rockwood type IV injuries, the MRI and radiographic types were concordant in one case, and the injury was reclassified to a less severe type in one case (Fig. 4). No Rockwood type V or VI lesions were diagnosed with either radiography or MRI. Table 2 shows the diagnoses according to Rockwood type at radiography and MRI.

Results With the Rockwood Classification Adapted for MRI

Table 3 shows the results with the adapted Rockwood classification. Compared with use of the original Rockwood system, use of MRI and the adapted classification yielded additional findings on the joint ligaments, by means of new MR categories, in 11 of 44 (25%) patients (Fig. 5).

Additional Findings at MRI

At MRI, acromioclavicular joint effusion was present in 28 of 44 (63.6%) patients, and bone marrow edema of the acromioclavicular joint was found in 18 (40.9%) patients (Fig. 4D). No osseous fractures were identified in any patient at radiography or MRI. Detachment of the deltoid and trapezoid muscles was found in all patients with type III and type IV injuries.

Discussion

To our knowledge, this study included the largest cohort of patients to date to undergo classification of acromioclavicular injuries with MRI compared with radiographic findings. The use of proton density–weighted imaging allowed exact visualization of acute ligamentous lesions, as has been found in other investigations [12–14]. The coronal oblique plane, parallel to the coracoclavicular ligament, has been found to be the optimum orientation [12–14]. In the era of 3-T MRI, use of the standard field strength (1 T) with a dedicated MRI protocol continues to yield valuable results. The use of a surface coil affords a high signal-to-noise ratio, which allows a small FOV and large matrix size and, thus, high spatial resolution for visualizing the vital joint structures [18–20]. As expected, the supine patient position for MRI reduces the amount of gravity-assisted acromioclavicular displacement, resulting in acromioclavicular interspace measurements markedly different from those obtained on radiographs.

Posttraumatic findings in the coracoclavicular ligament, as a central factor in acromioclavicular joint stability [21], serve as crucial criteria for determining a course of

TABLE 2: Rockwood Injuries Detected With Radiography and MRI

Radiography	MRI 0	MRI I	MRI II	MRI III	MRI IV	Total
I	4	5	3	0	0	12
II	2	8	14	1	1	26
III	0	0	1	3	0	4
IV	0	0	0	1	1	2
Total	6	13	18	5	2	44

Note—Values are numbers of patients.

TABLE 3: MRI Findings According to Adapted Rockwood Classification

Radiography	MRI 0	MRI I	MRI I+	MRI II–	MRI II	MRI II+	MRI III	MRI III+	MRI IV	Total
I	4	3	2	1	2	0	0	0	0	12
II	2	4	4	1	12	1	1	0	1	26
III	0	0	0	0	0	1	2	1	0	4
IV	0	0	0	0	0	0	1	0	1	2
Total	6	7	6	2	14	2	4	1	2	44

Note—Values are numbers of patients.

operative or nonoperative therapy. Rockwood types I and II injuries are treated conservatively [22]. Types IV–VI injuries necessitate surgical therapy that includes a number of techniques [8, 23]. The management of type III injuries remains controversial [24] and is usually evaluated case by case with a trend toward nonoperative treatment [25]. In our study, the MRI findings helped to define the dividing line between conservative and surgical treatment through reclassification of radiographic type II injuries to a more severe type in two patients and a radiographic type III lesion to a less severe type in one patient. Thus MRI helps to identify type III injuries, which may not be well evaluated on radiographs, even with weighted-bearing views [11].

Because most acromioclavicular injuries are managed on the basis of clinical and radiographic findings, the role of MRI as a diagnostic modality can be questioned. However, because of the additional ligamentous findings, our data suggest the value of MRI in visualizing acromioclavicular joint lesions. MRI may be useful for excluding higher-grade injuries and differentiating low-grade injuries from normal variations. Six patients found to have radiographic types I and II lesions had normal MRI findings. Otherwise, in five cases overall, our MRI results caused reclassification as more severe the clinical or radiographic grade of acromioclavicular joint dislocation.

By introducing an adapted MRI Rockwood classification, we also found exact delineation of ligamentous injuries compared with results with the classic grading system. Previous authors have noted that acromioclavicular abnormalities discerned with radiography [26, 27] and physical examination [28] did not correlate with the MRI findings. Barnes et al. [27] concluded that refinement in the classification might be necessary. Following up the latter investigation, our scheme yields, in addition to the traditional classification, advanced assessment of the joint ligaments, which may aid in determining extent of injury and the most appropriate treatment in each case. Insights into joint biomechanics underscore the variable individual articular anatomy and support the issue of individualized reconstruction of the ligaments, which can be delineated with MRI [8]. Precise individualized reconstruction may be important to restore the joint and to reduce the extent of secondary degeneration. Patients with high-grade injuries may benefit from the additional information obtained with MRI [23], particularly when there is a choice between arthroscopic and open surgical treatment [13]. Compared with radiography, MRI also showed joint effusion and bone marrow edema as sequelae of injury. Although we did not detect any osseous fractures, MRI may help to identify nondisplaced fissures of the osseous constituents.

The intraarticular fibrocartilaginous structures and the surgical considerations have been the subject of MRI studies [18, 29]. Since an investigation of cadaveric specimens showed a complete disk in only 1 of 53 cases [30], the actual function of the disk has been found questionable [8]. In view of previous imaging results, disk assessment was not included in our study.

Critical aspects of our study should be addressed. Radiographic comparison views can be useful for determining the presence of normal joint variations. Overall, most reports in the literature that describe MRI of acromioclavicular joint injuries entail experience with a limited number of patients, as did our study. Our study therefore was limited in showing surgical correlation for high-grade Rockwood

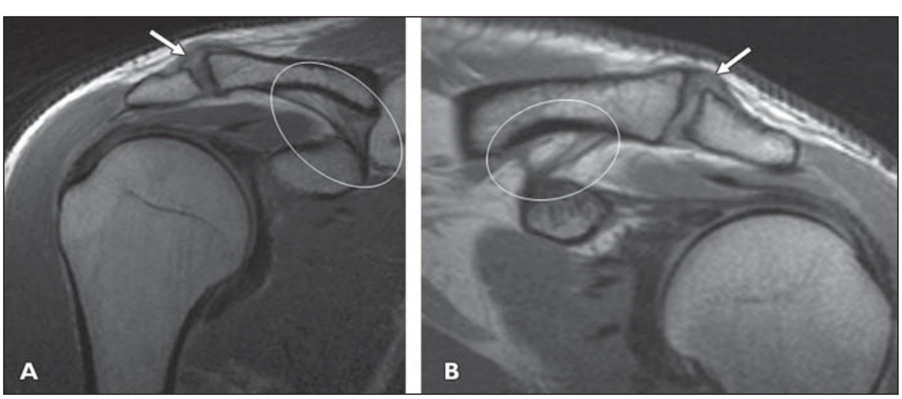

Fig. 5—Comparison of Rockwood type I and MRI-adapted Rockwood I+ injuries.
A, 27-year-old man after right-sided acromioclavicular joint trauma with Rockwood type I injury. Coronal proton density–weighted image (TR/TE, 1500/25) shows partial tear of superior portion of acromioclavicular ligament (*arrow*) and normal coracoclavicular ligaments (*ellipse*).
B, 25-year-old man after left-sided acromioclavicular joint trauma with adapted Rockwood type I+ injury. Coronal proton density–weighted image (TR/TE, 1500/25) shows partial tear of superior portion of acromioclavicular ligament (*arrow*) and partial disruption of coracoclavicular ligaments (*ellipse*) with attenuated fibers of trapezoid and conoid portions.

injuries (type III and more severe). Because of our encouraging results, our MRI facility is about to reconsider the subject of evaluating acromioclavicular joint injuries with 3-T MRI.

Conclusion

We found that MRI findings change the Rockwood classification based on radiographic findings in a considerable number of patients with acromioclavicular joint dislocation. In addition to the traditional Rockwood classification of assessment of increased joint distances on radiographs, our adapted MRI classification entails exact visualization of each ligament, and the findings may influence therapeutic decisions. In particular, MRI findings account for differentiation of type II and type III injuries. Our results indicate that MRI is a useful adjunct to clinical examination and radiography in selected cases.

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