J Shoulder Elbow Surg (2021) 30, 795–805

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

SHOULDER

The ligamentous injury pattern in acute acromioclavicular dislocations and its impact on clinical and radiographic parameters

Marvin Minkus, MD[a,*], Gero Wieners, MD[b], Nina Maziak, MD[a], Fabian Plachel, MD, PhD[a], Markus Scheibel, MD[a,c], Natascha Kraus, MD[a,d]

[a]*Department for Shoulder and Elbow Surgery, Center for Musculoskeletal Surgery, Charité-Universitaetsmedizin Berlin, Berlin, Germany*
[b]*Department of Radiology, Charité-Universitaetsmedizin Berlin, Berlin, Germany*
[c]*Schulthess Clinic, Zürich, Switzerland*
[d]*Department of Orthopedics and Orthopaedic Surgery, University Medicine Greifswald, Greifswald, Germany*

Background: Acromioclavicular (AC) joint dislocations are classified according to the Rockwood (RW) classification, which is based on radiographic findings. Several authors have suggested magnetic resonance imaging (MRI) for visualization of the capsuloligamentous structures stabilizing the AC joint. The aim of this study was to describe the ligamentous injury pattern in acute AC joint dislocations by MRI and investigate associations with clinical and radiographic parameters.

Methods: This prospective study included 45 consecutive patients (5 women and 40 men; mean age, 33.6 years [range, 19-65 years]) with an acute AC joint separation (RW type I in 5, RW type II in 8, RW type III in 18, and RW type V in 14). All patients underwent physical examination of both shoulders, and clinical scores (Subjective Shoulder Value, Constant score, Taft score, and Acromioclavicular Joint Instability Score) were used to evaluate the AC joint clinically as well as radiographically. Post-traumatic radiography included bilateral anteroposterior stress views and bilateral Alexander views to evaluate vertical instability and dynamic posterior translation. MRI was performed for assessment of the AC and coracoclavicular (CC) ligaments and the delto-trapezoidal fascia.

Results: Radiographic and MRI classifications were concordant in 23 of 45 patients (51%), whereas 22 injuries (49%) were misjudged; of these, 6 (13%) were reclassified to a more severe type and 16 (36%), to a less severe type. The integrity of the CC ligaments was found to have a clinical impact on vertical as well as horizontal translation determined by radiographs and on clinical parameters. Among patients with an MRI-confirmed complete disruption of the CC ligaments, 68% showed a radiographic CC difference $>$ 30% and 75% showed complete dynamic posterior translation. Inferior clinical parameters were noted in these patients as compared with patients with intact CC ligaments or partial disruption of the CC ligaments (Constant score of 67 points vs. 49 points [$P <$ .05] and Acromioclavicular Joint Instability Score of 51 points vs. 23 points [$P <$ .05]). The inter-rater and intra-rater reliability for assessment of the ligamentous injury pattern by MRI was fair to substantial ($r = 0.37$-0.66).

Conclusion: The integrity of the CC and AC ligaments found on MRI has an impact on clinical and radiographic parameters.

Level of evidence: Level I; Diagnosis Study

Keywords: Acromioclavicular joint; AC joint instability; ligamentous injury; coracoclavicular ligaments; MRI; AC dislocation

This study was approved by the local ethical committee (no. EA1/298/12).

*Reprint requests: Marvin Minkus, MD, Campus Virchow-Klinikum, Charité-Universitätsmedizin Berlin, Augustenburger Platz 1, 13353 Berlin, Germany.

E-mail address: marvin.minkus@charite.de (M. Minkus).

1058-2746/$ - see front matter
https://doi.org/10.1016/j.jse.2020.10.026

Acromioclavicular (AC) joint dislocations are frequent injuries and account for 4%-12% of shoulder injuries.[7,16] In 1917, Cadenet and Petersson[5] described a sequential injury mechanism of AC joint dislocations affecting the AC ligaments first. With increasing energy impact, the coracoclavicular (CC) ligaments are involved as well. The most severe injury leads to avulsion of the deltoid and trapezoid muscle from the distal clavicle. Although this pattern of injury has never been proved, it is the basis for both the Tossy and Rockwood (RW) classifications of AC joint instability.[17,22] Regarding the affection of the AC and CC ligaments, 3 and 6 types of injury, respectively, can be distinguished. Types I-III are defined in the same way in both classification systems. A type I AC joint dislocation is described as an incomplete AC ligament tear without damage to the CC ligaments. A type II injury is defined as a complete disruption of the AC ligaments and an incomplete CC ligament injury. The Tossy and RW classifications both describe a type III separation as a disruption of both structures stabilizing the AC joint, that is, the AC and CC ligaments. However, the Tossy classification system considers vertical displacement only. In the RW classification, a second plane is taken into account, defining a type IV injury as a static posterior horizontal dislocation. The dynamic component of instability, however, is neglected. Type V describes a more severe type III separation with an increase in the CC distance of >100% compared with the contralateral side. Finally, a type VI injury defines an inferior dislocation of the distal clavicle beneath the coracoid process.

For the evaluation of AC joint instability, various kinds of radiographs can be used. A plain radiograph in the anteroposterior direction at 10°-15° cephalic angulation, the so-called Zanca view, allows projection of the AC joint itself.[23] To evaluate vertical instability, bilateral anteroposterior stress views are recommended.[11] Detecting and measuring an increased CC distance are the basis for grading AC joint dislocations in the RW classification. Lateral Alexander views, with the arm in an adducted horizontal stress position, or functional axillary views, according to Tauber et al,[21] are of particular benefit in evaluating dynamic posterior translation (DPT).[1,14] Because AC joint dislocations are ligamentous injuries, classifying them by conventional radiographic imaging seems to be a paradox. Therefore, several authors have suggested magnetic resonance imaging (MRI) for visualization of the AC and CC ligaments.[2-4,15,18] It has been shown that MRI allows adequate assessment of the ligamentous structures of the AC joint and its results can change the estimated grade of severity determined by radiography and may consequently influence treatment.[2-4,15,18] Barnes et al[4] have found that the RW classification system failed to correlate with the pathoanatomy seen on MRI, and they suggested improvements in the classification of these injuries. Furthermore, DPT is neglected in the current classification system. DPT might cause chronic AC joint instability and, if persisting postoperatively, is associated with poor clinical results.[9,10,19]

To our knowledge, no study comparing MRI findings with clinical and radiologic parameters has been published in the literature. Therefore, the aim of this study was to describe the ligamentous pattern in acute AC joint dislocations with MRI and compare it with clinical and radiologic findings.

Materials and methods

Patient population

From 2010 until 2013, 45 consecutive patients (5 women and 40 men; mean age, 33.6 years [range, 19-65 years]) with an acute AC joint separation were included in this prospective study. All patients underwent MRI, clinical, and radiographic evaluation during the first 2 weeks after trauma. According to the RW classification based on radiographic findings, the patient population showed the following distribution: 5 patients (11.1%) received a diagnosis of an acute RW type I AC joint injury, and 8 patients (17.8%), RW type II. The majority of patients (n = 32, 71.1%) had high-grade injuries: RW type III in 18 (40%) and RW type V in 14 (31.1%). No type IV or VI separations were encountered during this period. The dominant side was affected in 22 patients (48.9%) and the nondominant side, in 23 (51.1%).

Clinical evaluation

All patients underwent an initial physical examination of both shoulders, including clinical tests for AC joint disorders (tenderness to palpation, cross-body test, and resisted AC joint compression test). Signs of AC joint dislocation, such as hematoma or abrasion over the superolateral aspect of the shoulder, as well as visible asymmetry between the 2 distal clavicle ends, were noted. We used the Subjective Shoulder Value, Constant score (CS), and Taft score, as well as the Acromioclavicular Joint Instability Score (ACJI), for additional clinical and radiologic evaluation.[6,8,19,20] Strength measurements to determine the CS and ACJI were performed with the arm in 90° of abduction in the scapular plane by using an isometric dynamometer (Isobex; Medical Device Solutions, Burgdorf, Switzerland).

Radiographic evaluation

Post-traumatic radiography included bilateral anteroposterior stress views with a 10-kg axial load and bilateral stress views according to Alexander.[1] The CC distances were measured and compared with the contralateral side, resulting in the CC difference (CCD). The CC distance is the interspace between the inferior cortex of the clavicle and the highest part of the coracoid, measured parallel to the spine. According to the RW classification,

the diagnosis of type I was established when 0% to <10% superior displacement of the distal clavicle was found. If the affected side differed by 10% to ≤25%, RW type II was present. An RW type III dislocation was defined as a CCD of >25% to ≤100%. A CCD of >100% compared with the contralateral side indicated an RW type V separation. According to a new classification of AC joint instability that has recently been published, 2 groups that reached the widest and most significant difference in all clinical scoring systems were defined by setting the cutoff at a 30% difference in the CCD compared with the contralateral side.[12] Group 1, with a CCD ≤ 30%, included all RW type I, type II, and borderline low-grade type III patients (n = 4, 22.2%). Group 2, defined as having a CCD > 30%, represented the high-grade AC joint dislocations, including all RW type V patients and the majority of the RW type III patients (n = 14, 77.8%). DPT was evaluated on bilateral Alexander views, a modification of the lateral view with the arm in adduction in a shoulder-forward position, bringing stress on the AC joint.[1,14] In cases of AC joint ligament disruption, the distal clavicle was displaced posterosuperiorly and overlapping with the acromion was less or nullified. Horizontal translation was graded as none, partial translation, or complete translation. No horizontal translation was defined as a clavicle that was in line with the acromion. In cases with clavicle displacement to the acromion of <1 clavicle shaft width, DPT was rated as partial. Lost contact between the joint surfaces with displacement ≥ 1 shaft width indicated complete DPT. The unaffected contralateral side served as a control for all evaluations.

MRI performance and evaluation

Within 2 weeks after trauma, MRI was performed with a 1.5-T imaging unit (Signa Twin Speed; General Electric, Fairfield, CT, USA) using a dedicated shoulder coil. Sequences and orientations of the planes were performed following the well-established and comprehensive protocol of Alyas et al.[2] The coronal oblique plane parallel to the distal clavicle has been shown to be reproducible and practical because it allows assessment of the AC and CC ligaments owing to its in-plane orientation to these structures.[2,3,15] The coronal plane is planned on axial images parallel to a line drawn from the anterior tip of the coracoid process to the lesser tuberosity. Therefore, imaging in the axial plane was performed first in a proton density–weighted fat-suppressed sequence. Two sequences in the coronal orientation were performed: both proton density weighted, with and without fat suppression. Finally, parasagittal proton density–weighted imaging with fat suppression was performed. After patient-identifying information was eliminated, the magnetic resonance images were evaluated by 3 physicians (1 musculoskeletal radiologist with 15 years of experience and 2 residents of orthopedic and trauma surgery with 6 and 3 years of experience). A consensus reading was organized, and a protocol for the evaluation of MRI findings was established. To ensure a reliable statement on inter-rater and intra-rater reliability, the evaluation was performed twice, always in a blinded manner because patient data were eliminated from the images. For cases of discrepancies, a consensus meeting was held and a common decision was achieved. The integrity of the trapezoid ligament (ligamentum trapezoideum [LT]) and conoid ligament (ligamentum conoideum [LC]) was evaluated and graded as intact, partial disruption, and complete disruption. A partial tear was defined as a tear in which the remaining fibers were visible, whereas a complete tear showed no continuous fibers or both ends were visible accompanied by fluid in the CC interspace. In the same way, the integrity of the AC capsule and ligaments was rated. Furthermore, the localization of disruption of the CC ligaments was assessed, distinguishing the presence of intraligamentous, coracoid, or clavicular avulsion. Fluid along the clavicle, where the trapezoid and deltoid muscles usually attach, was graded as partial or complete avulsion of the delto-trapezoidal fascia (DTF). Finally, the clinical type according to the RW classification was graded based on the MRI findings and compared with the radiographic findings. The MRI classification was based on the injury definitions of the RW classification, which were already described in the introduction.

Statistics

Statistical analyses were performed using SPSS software (version 23.0; IBM, Armonk, NY, USA). The Kolmogorov-Smirnov test was used to test for normal distribution. To perform a group comparison, the Mann-Whitney *U* test was applied. To determine intra-rater reliability and inter-rater reliability, we used the Cohen κ and Fleiss κ, respectively. According to Landis and Koch,[13] a κ value of $r = 0.21$-0.40 was rated as fair; $r = 0.41$-0.60, moderate; and $r = 0.61$-0.80, substantial. Descriptive values are demonstrated as mean values. The level of significance was defined as $P = .05$.

Results

Ligamentous injury pattern and MRI results

In all patients, the capsule of the AC joint with its surrounding ligaments was affected. In 9 patients (20%), a partial sprain was observed. The majority of patients (n = 36, 80%) presented a complete tear of the AC joint, which was always associated with partial disruption (n = 9, 25%) or complete disruption (n = 27, 75%) of the LT (Figs. 1-4). Among the patients with a complete tear of the AC ligaments, the LC was intact in 6 (16.7%) and only partially torn in 9 (25%).

The LT was affected in 42 patients (93.3%), with a partial disruption in 14 (31.1%) and a complete tear in 28 (62.2%). The LC was affected in 34 patients (75.6%), with a partial disruption in 13 (28.9%) and a complete tear in 21 (46.7%). Overall, the CC ligaments were completely torn in 21 patients (46.7%). No isolated disruption of the LC was detected, and the LT was always at least as severely injured as the LC. The localization of CC disruption was intraligamentous in the majority of patients for both the LC (n = 22, 64.7%) and LT (n = 32, 76.2%). A clavicular avulsion of the LC was observed in 7 patients (20.5%), whereas a clavicular avulsion of the LT was found in 5 patients (11.1%). Avulsions of the LC and LT from the coracoid were found in 5 patients (14.7%) and 5 patients (11.9%), respectively (Fig. 4).

Among the 5 radiographically defined RW type I dislocations, a partial disruption of the LT was observed in 3

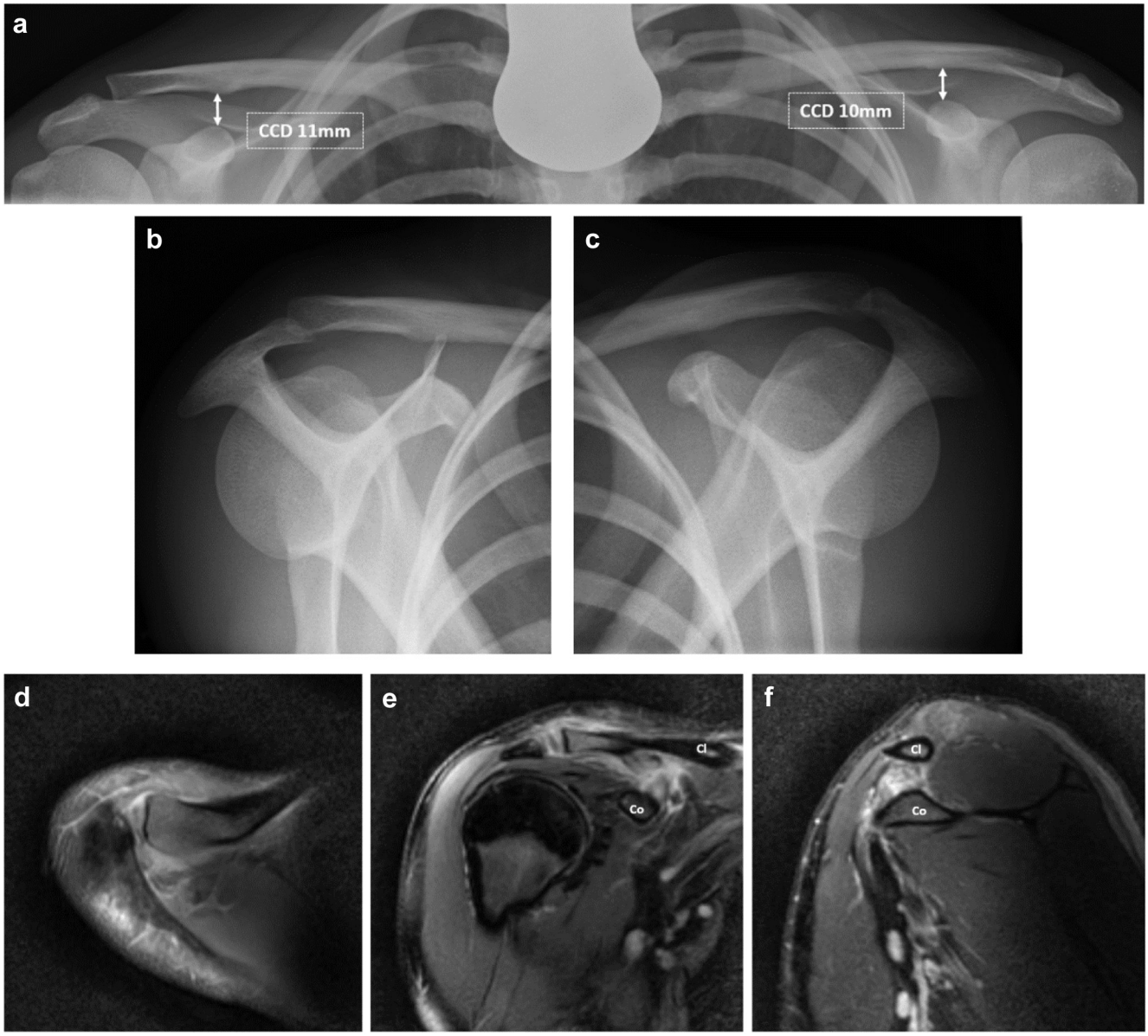

Figure 1 Radiographs (**a-c**) and magnetic resonance images (**d-f**) (all with proton density–weighted imaging with fat suppression) in a patient with an injury classified radiographically as a Rockwood type I injury, which was reclassified after magnetic resonance imaging to a Rockwood type III injury. (**a**) Bilateral weighted stress view showing a coracoclavicular distance *(CCD, ⇳)* of 11 mm vs. 10 mm. (**b, c**) Bilateral Alexander view showing partial dynamic horizontal translation on the right side. (**d, e**) Acromioclavicular joint capsular disruption in the axial and paracoronal planes. (**e, f**) Complete tear of the coracoclavicular ligaments in the paracoronal and parasagittal planes. *Cl*, clavicle; *Co*, coracoid.

patients. In 1 of these patients, the LC was also affected (Fig. 1). By definition, lesions of the CC ligaments are present in more severe AC joint dislocations only; hence, 60% of injuries in this group were reclassified to a more severe type lesion (RW type II in 2 and RW type III in 1). In only 1 patient (12.5%) among the patients with RW type II dislocations, the injury was reclassified to the less severe type (ie, type I). In this patient, neither of the 2 CC ligaments was involved and only the AC capsule was sprained. More than half of the RW type III injuries (n = 11, 61.1%) were misjudged and reclassified after evaluation of the MRI findings. The LT was affected in all RW type III patients and was completely torn in 14 cases. The LC was intact in 2 patients. Eight patients (44.4%) showed a partial disruption of the LC, and their injuries were reclassified to RW type II injuries (Fig. 2). One patient's injury was reclassified to a type V injury because of complete disruption of both the LC and LT and avulsion of the DTF. Among the patients with RW type V dislocations, 1 patient showed remaining continuous fibers of the LC and the injury was therefore graded as a type II

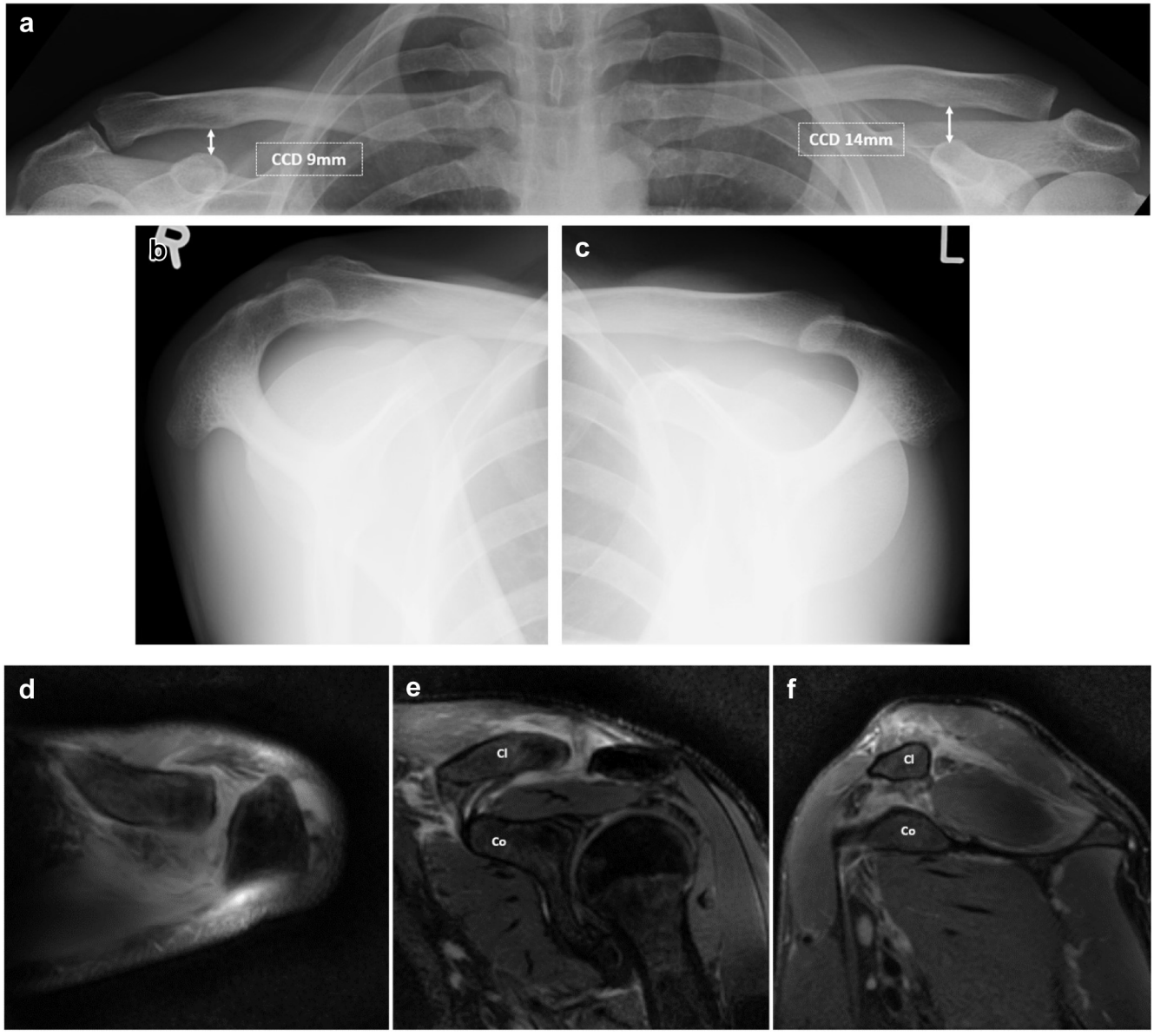

Figure 2 Radiographs (**a-c**) and magnetic resonance images (**d-f**) (all with proton density–weighted imaging with fat suppression) in a patient with an injury classified radiographically as a Rockwood type III injury, which was reclassified after magnetic resonance imaging to a Rockwood type II injury. (**a**) Bilateral weighted stress view showing a coracoclavicular distance *(CCD,* ⇳*)* of 14 mm vs. 9 mm. (**b, c**) Bilateral Alexander view showing no dynamic horizontal translation. (**d, e**) Acromioclavicular joint capsular disruption in the axial and paracoronal planes. (**e, f**) Tear and partial lesions of the coracoclavicular ligament in the paracoronal and parasagittal planes. *R*, right; *L*, left; *Cl*, clavicle; *Co*, coracoid.

injury. The MRI findings are listed and compared in Tables I and II. Treatment decisions were based on the radiographic and clinical findings and were not changed by the MRI findings in this study.

Complete avulsion of the DTF was found in 10 patients (22.2%, Fig. 3), and partial avulsion, in 23 (51.1%). However, we found that evaluation of the DTF was difficult and the MRI findings were inconsistent among the 3 raters, with only fair reliability. Therefore, we did not further evaluate the results for the DTF.

Concomitant pathologies

Concomitant glenohumeral pathologies apart from the AC joint separation were detected by MRI in 3 patients. In 1 patient with an RW type V injury (determined by radiographs and MRI in concordance), a subtotal articular-sided tear of the supraspinatus tendon was observed (Fig. 3). In this patient, an arthroscopic AC joint stabilization and rotator cuff repair were performed. Another 2 patients showed signs of minor subscapularis lesions in

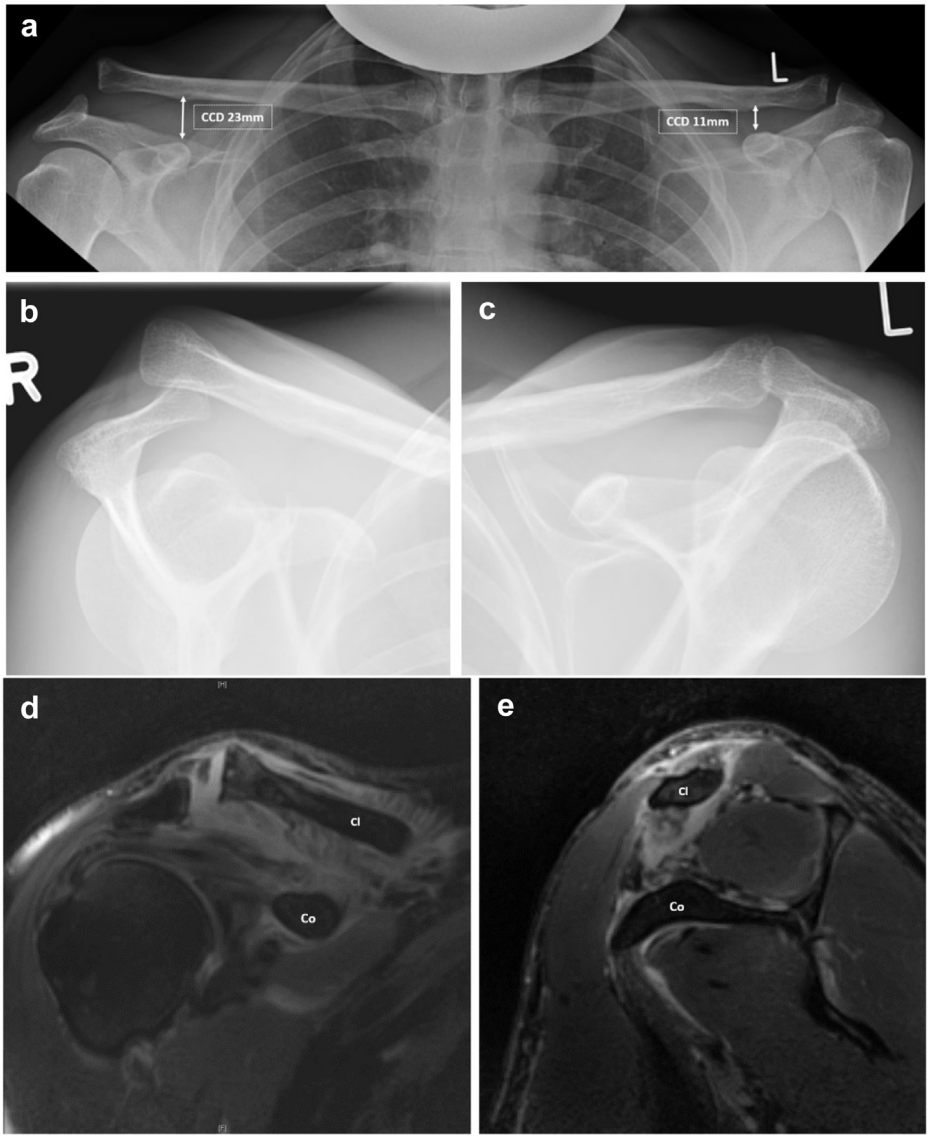

Figure 3 Radiographs (**a-c**) and magnetic resonance images (**d, e**) (both with proton density–weighted imaging with fat suppression) in a patient with a Rockwood type V injury classified radiographically and confirmed by magnetic resonance imaging. (**a**) Panoramic view showing a coracoclavicular distance *(CCD,* ⇳*)* of 23 mm vs. 11 mm. (**b, c**) Bilateral Alexander view showing complete dynamic horizontal translation on the right side. (**d**) Acromioclavicular joint capsular disruption in the paracoronal plane. (**d, e**) Complete disruption of the coracoclavicular ligaments in the paracoronal and parasagittal planes with avulsion of the delto-trapezoidal fascia and a concomitant subtotal articular-sided lesion of the supraspinatus tendon. *L*, left; *R*, right; *Cl*, clavicle; *Co*, coracoid.

the cranial aspect of the tendon (Fox and Romeo type I). In these cases, débridement was performed in addition to the arthroscopic AC joint repair. In total, 22 patients underwent arthroscopic AC joint stabilization. The indication for surgery was based on clinical and radiographic findings. Bidirectional (vertical and horizontal) instability of the AC joint—which becomes evident clinically as well as radiographically—is, for us, an indication for surgery in patients who are physically active. The treatment decision in this study was not changed based on MRI findings. Concomitant pathologies were found in 7 of these patients (31.8%). Most of these pathologies were not necessarily associated with the trauma, were rated as pre-existing, and did not require any further surgical intervention apart from débridement. Only the aforementioned patient with repair of the supraspinatus tendon required an additional surgical procedure. The detection rate of glenohumeral pathologies by MRI was 42.9% (3 of 7 patients), and that of pathologies requiring an additional surgical procedure was 100%.

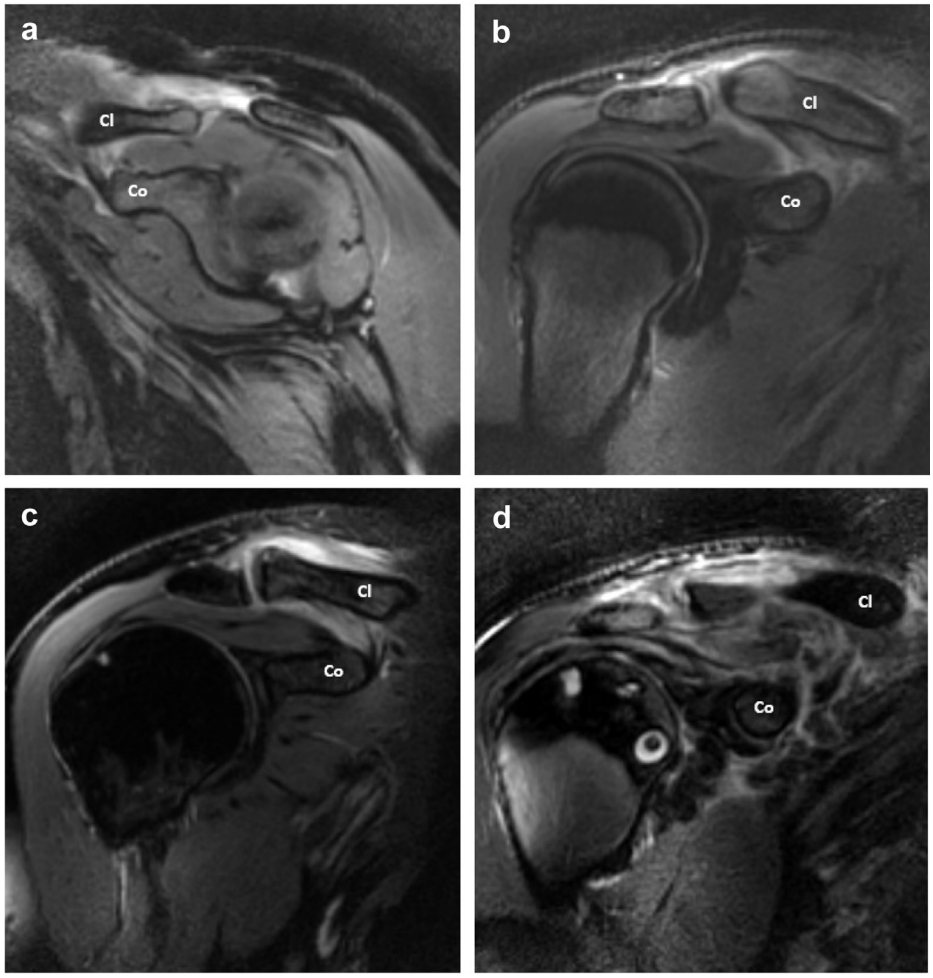

Figure 4 Localizations of coracoclavicular ligament disruption. (**a**) Trapezoid ligament with clavicular avulsion. (**b**) Trapezoid ligament with coracoid avulsion. (**c**) Conoid ligament with clavicular avulsion. (**d**) Conoid ligament with coracoid avulsion (patient with previous rotator cuff repair). *Cl*, clavicle; *Co*, coracoid.

Comparison of radiographic and MRI results

Overall, radiographic and MRI classifications were concordant in 23 of 45 patients (51%). In 22 patients (49%), the injuries were misjudged when compared with MRI evaluation and then reclassified. In 6 cases (13%), the AC joint dislocation was reclassified to a more severe type. In 16 patients (36%), the injury was reclassified to a less severe type. The distribution of patients' injuries graded according to the RW classification by radiography and MRI is presented in Table III.

n total, 28 patients (62.2%) showed a CCD > 30%. Among these patients, a complete tear of the LC became evident in 67.9% (n = 19) and a complete tear of the LT, in 89.3% (n = 25). A complete tear of the AC joint capsule was observed in almost all of these patients (n = 27, 96.4%). Concerning DPT, 20 patients (44.4%) showed a complete dislocation of the AC joint in the Alexander view. A concomitant, complete disruption of the LC was found in 75% of those patients (n = 15) and of the LT in 85% (n = 17). The AC joint capsule was completely torn in 18 patients (90%). A comparison of MRI findings with radiographic parameters for vertical and horizontal instability is presented in Table IV.

Comparison of radiologic and clinical parameters

For patients with a CCD > 30%, inferior results for all scores became evident compared with patients with a CCD ≤ 30%. These differences were significant for the AC joint–specific scoring systems (Taft score and ACJI, $P < .01$). The same observations were made for DPT. Patients with complete translation in the horizontal plane showed significantly inferior results for the Taft score and ACJI (both $P < .01$). Similar findings were noted for the ligamentous injury pattern determined by MRI. Patients with a complete tear of the AC joint capsule achieved significantly worse results for the Taft score and ACJI ($P = .03$ and $P = .02$, respectively). For the LC, significant differences between intact, partial

Table I Comparison of MRI findings in acute AC joint injury concerning coracoclavicular ligaments and AC joint capsule

MRI finding	LC disruption			LT disruption			AC joint sprain	
	Intact	Partial	Complete	Intact	Partial	Complete	Partial	Complete
LC disruption								
Intact	n = 11	—	—	27.3% (n = 3)	72.7% (n = 8)	—	45.5% (n = 5)	54.5% (n = 6)
Partial	—	n = 13	—	—	46.2% (n = 6)	53.8% (n = 7)	30.8% (n = 4)	69.2% (n = 9)
Complete	—	—	n = 21	—	—	100% (n = 21)	—	100% (n = 21)
LT disruption								
Intact	100% (n = 3)	—	—	n = 3	—	—	100% (n = 3)	—
Partial	57.1% (n = 8)	42.9% (n = 6)	—	—	n = 14	—	35.7% (n = 5)	64.3% (n = 9)
Complete	—	25% (n = 7)	75% (n = 21)	—	—	n = 28	3.6% (n = 1)	96.4% (n = 27)
AC joint sprain								
Partial	55.6% (n = 5)	44.4% (n = 4)	—	33.3% (n = 3)	55.6% (n = 5)	11.1% (n = 1)	n = 9	—
Complete	16.7% (n = 6)	25% (n = 9)	58.3% (n = 21)	—	25% (n = 9)	75% (n = 27)	—	n = 36

MRI, magnetic resonance imaging; *AC*, acromioclavicular; *LC*, ligamentum conoideum; *LT*, ligamentum trapezoideum.

disruption, and complete disruption were observed for the AC joint–specific scores, as well as the CS (Fig. 5).

Inter-rater and intra-rater reliability

Overall, the inter-rater reliability of MRI findings and evaluation of the CC and AC ligaments was moderate. The intra-rater reliability was evaluated for 2 raters (N.K. and M.M.) and was moderate for the LC and AC joint capsule and moderate to substantial for the LT. For the DTF, the inter-rater and intra-rater reliability was only fair. Therefore, no further evaluation concerning this parameter was conducted. All κ values are presented in Table V.

Discussion

MRI allows adequate assessment of the ligamentous structures of the AC joint. Its results can change the grading of AC joint dislocations determined with radiography and may

Table II Comparison of MRI findings in different types of AC joint injuries according to Rockwood classification based on radiographic findings

MRI finding	Rockwood type according to radiographic findings, % (n)			
	I (n = 5)	II (n = 8)	III (n = 18)	V (n = 14)
LC disruption				
Intact (n = 11)	36.4 (4)	45.5 (5)	18.2 (2)	0
Partial (n = 13)	7.7 (1)	23.1 (3)	61.5 (8)	7.7 (1)
Complete (n = 21)	0	0	38.1 (8)	61.9 (13)
LTdisruption				
Intact (n = 3)	66.7 (2)	33.3 (1)	0	0
Partial (n = 14)	21.4 (3)	50 (7)	28.6 (4)	0
Complete (n = 28)	0	0	50 (14)	50 (14)
AC joint sprain				
Partial (n = 9)	33.3 (3)	55.6 (5)	0	11.1 (1)
Complete (n = 36)	5.6 (2)	8.3 (3)	50 (18)	36.1 (13)

MRI, magnetic resonance imaging; *AC*, acromioclavicular; *LC*, ligamentum conoideum; *LT*, ligamentum trapezoideum.

Table III Distribution of patients with AC joint injuries according to Rockwood classification determined by radiography and MRI

	Injury type according to Rockwood classification, n (%)			
	I	II	III	V
Radiography	5 (11.1)	8 (17.8)	18 (40)	14 (31.1)
MRI	3 (6.7)	18 (40)	14 (31.1)	10 (22.2)

AC, acromioclavicular; *MRI*, magnetic resonance imaging.

consequently influence decisions on their treatment.[15,18] Nemec et al[15] enrolled 44 patients (mean age 29 years) with suspected unilateral AC joint dislocation in a retrospective study. Within 3 weeks after trauma, MRI was performed. Among the 44 patients with RW type I-IV injuries, classification on radiographs and MRI was concordant in 23 (52.2%). The injury was reclassified to a less severe type in 16 patients (36%) and to a more severe type in 5 patients (11%) after assessment of the MRI findings. Schaefer et al[18] also found that MRI results caused the clinical grade of some AC joint dislocations to be upgraded. Similarly, Barnes et al[4] found that the RW classification system failed to correlate with the pathoanatomy seen on MRI and suggested that improvements in the classification of these injuries may be necessary. In our prospective study, we found a concordance in the grade of severity according to the RW classification based on radiographic and MRI findings in 51% of the patients. In contrast to the aforementioned studies, we had more cases of reclassification to a less severe type of injury (36%) than to a more severe type. We could also show that there was no isolated tear of the LC and that the LT was always at least as severely injured as the LC. On the basis of the assumption of a sequential injury mechanism like Cadenet and Petersson[5] suggested in 1917, this means that the LT is always injured first, and a partial or complete tear of the LC is an indicator of a high-grade AC joint dislocation.

All the studies mentioned earlier applied slightly different techniques concerning the orientation of the planes and technical adjustments. In our study, the MRI planes were chosen according to a comprehensive protocol published by Alyas et al.[2] Schaefer et al[18] and Antonio et al[3] showed that T1-weighted imaging demonstrates the CC ligaments best and that fat-suppressed proton density–weighted or T2-weighted imaging demonstrates the ligamentous disruption when surrounded by blood or fluid best. All studies comparing MRI and radiography in acute AC joint injuries concluded that there is a greater spectrum of tears and sprain combinations than suggested in the RW classification system. In our study, we found that some patients showed only minor vertical and/or horizontal translation radiographically but the MRI scan revealed a complete disruption of the AC and CC ligaments. On the other hand, there were patients showing a major instability on the radiographs but in whom the MRI scan revealed that the AC or CC ligaments were intact or only partially disrupted. These findings underline that acute AC joint instabilities are more diverse than the RW and Tossy classifications suggest. Furthermore, dynamic horizontal translation is neglected by the current classifications. In our opinion, DPT should also be evaluated in minor AC joint separations, and we suggest a new classification system that has recently been published.[12]

So far, no study comparing findings on MRI with clinical and radiographic parameters in acute AC joint separations has been established. We found that the integrity of the CC and AC ligaments assessed on MRI had a statistically significant impact on clinical parameters, especially the AC joint–specific scores. Patients with a complete disruption of the AC and CC ligaments showed significantly inferior

Table IV Comparison of MRI findings with radiographic parameters for vertical and horizontal instability

MRI finding	CCD, % (n)		DPT, % (n)		
	≤30% (n = 17)	>30% (n = 28)	Stable (n = 14)	Partial (n = 11)	Complete (n = 20)
LC disruption					
Intact (n = 11)	52.9 (9)	7.1 (2)	42.9 (6)	27.3 (3)	10 (2)
Partial (n = 13)	35.3 (6)	25.0 (7)	42.9 (6)	36.4 (4)	15 (3)
Complete (n = 21)	11.8 (2)	67.9 (19)	14.3 (2)	36.4 (4)	75 (15)
LT disruption					
Intact (n = 3)	17.6 (3)	0	21.4 (3)	0	0
Partial (n = 14)	64.7 (11)	10.7 (3)	57.1 (8)	27.3 (3)	15 (3)
Complete (n = 28)	17.6 (3)	89.3 (25)	21.4 (3)	72.7 (8)	85 (17)
AC joint sprain					
Partial (n = 9)	47.1 (8)	3.6 (1)	50.0 (7)	0	10 (2)
Complete (n = 36)	52.9 (9)	96.4 (27)	50.0 (7)	100.0 (11)	90 (18)

MRI, magnetic resonance imaging; *CCD*, coracoclavicular difference; *DPT*, dynamic posterior translation; *LC*, ligamentum conoideum; *LT*, ligamentum trapezoideum; *AC*, acromioclavicular.

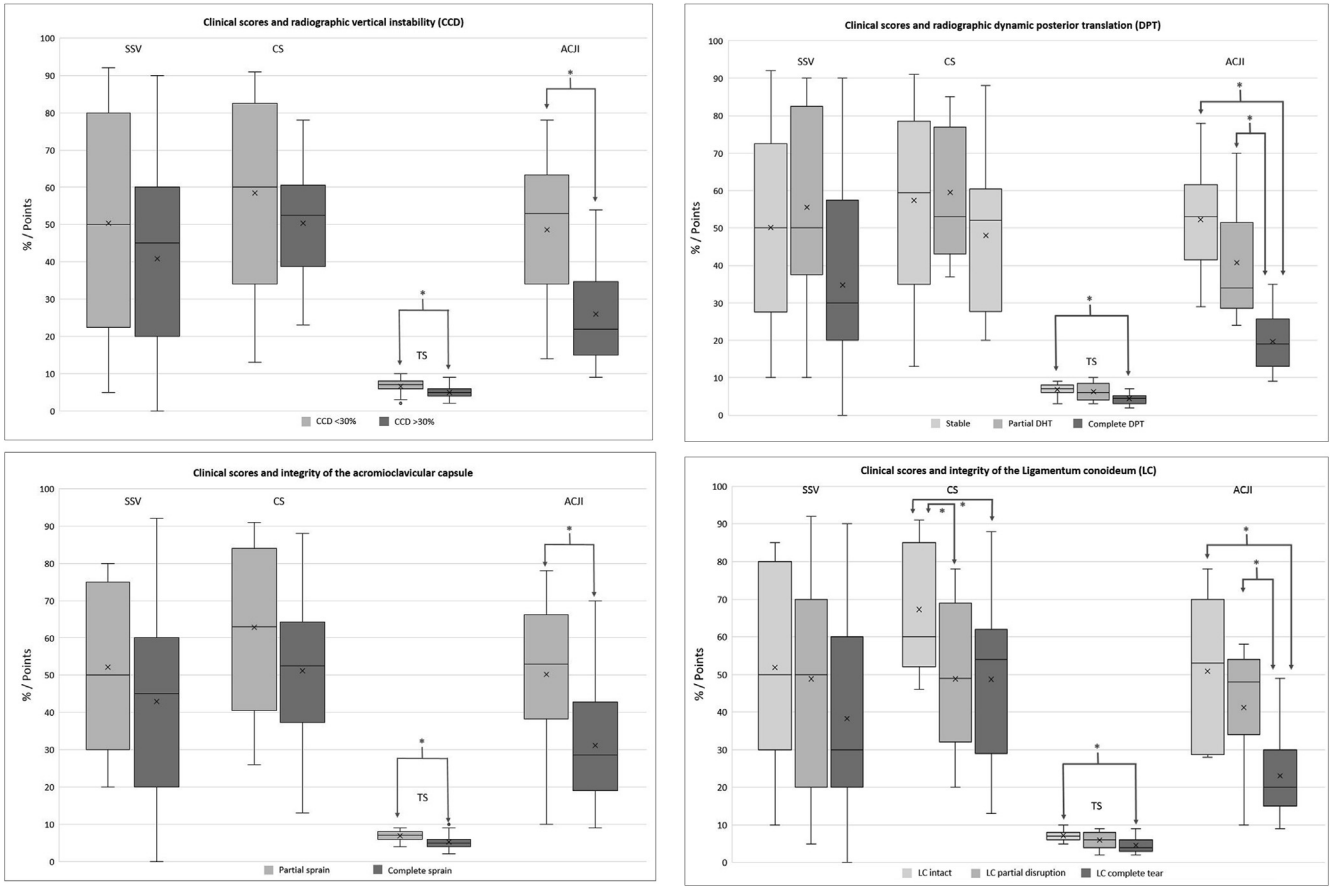

Figure 5 Clinical scores according to radiological findings. *SSV*, Subjective Shoulder Value; *CS*, Constant score; *TF*, Taft Score; *ACJI*, Acromioclavicular Joint Instability Index; *CCD*, coracoclavicular difference; *DPT*, dynamic horizontal translation; *LC*, Ligamentum conoideum. $*P > .05$.

Table V Inter-rater and intra-rater reliability of MRI findings in acute AC joint injury

MRI finding	Inter-rater reliability	Intra-rater reliability	
		Rater 1	Rater 2
LC disruption	0.457	0.550	0.499
LT disruption	0.434	0.662	0.461
AC joint sprain	0.523	0.595	0.471
DTF avulsion	0.334	0.192	0.244

MRI, magnetic resonance imaging; *AC*, acromioclavicular; *LC*, ligamentum conoideum; *LT*, ligamentum trapezoideum; *AC*, acromioclavicular; *DTF*, delto-trapezoidal fascia.

results for the Taft score and ACJI. The same observations were made for vertical translation, determined by the CCD, as well as horizontal translation, determined in the Alexander view.

When comparing our results with those of other authors using MRI to evaluate the severity of AC joint dislocations, it becomes evident that assessing AC joint dislocations with conventional grading by radiography does not always correlate with MRI findings. The concordance in only half of our patients shows that evaluating the ligamentous structures using MRI gives additional information on the severity of the AC joint dislocation and might change the decision on whether surgical repair or conservative treatment is indicated. A possible advantage of assessing acute AC joint instabilities by MRI is that concomitant pathologies might be detected. In our patient population, the detection rate of glenohumeral pathologies by MRI was 42.9% (3 of 7 patients), and it was 100% for pathologies requiring an additional surgical procedure. However, the majority of lesions were minor, not necessarily associated with the trauma, and their clinical impact was at least questionable. We do not propose to perform routine MRI examinations of patients with acute AC dislocations. However, in patients scheduled for conservative treatment, an MRI study might be conducted to exclude concomitant pathologies. In contrast, in patients with an RW type V injury with severe clinical and radiologic instability in whom surgery is scheduled, no better visualization than arthroscopy (with AC joint stabilization) can be conducted. In particular, in patients with an RW type III injury, in whom the indication for surgery is questionable, an MRI

scan in the acute situation might be helpful. The quintessence of our study is that the RW classification is insufficient for classification of AC joint instability as it only relies on radiography and neglects DPT. On the basis of our findings, radiographs may overestimate injury and MRI might be applied in patients with questionable indications.

The limitations of our study should be taken into consideration. Although we included the largest cohort of patients to date, the subgroups are relatively small, which limits the value of reclassification and the comparison of the groups. The inter-rater and intra-rater reliability in this study is overall moderate. This finding shows that, generally, assessment of the ligamentous injury in acute AC joint instability is reproducible. However, a certain discrepancy occurs among different raters, which should be kept in mind. A consensus meeting between raters was helpful to find a common decision.

Conclusion

The ligamentous injury pattern in acute AC dislocations using special MRI planes for evaluating the AC joint might change the RW classification, which is based on radiographic findings. Evaluating the integrity of the capsuloligamentous structures stabilizing the AC joint is reproducible and gives additional information on the severity of the injury, which might also influence the treatment decision. The integrity of the CC and AC ligaments found on MRI has an impact on clinical and radiographic parameters.

Disclaimer

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. Alexander OM. Radiography of the acromioclavicular articulation. Med Radiogr Photogr 1954;40:34-9.
2. Alyas F, Curtis M, Speed C, Saifuddin A, Connell D. MR imaging appearances of acromioclavicular joint dislocation. Radiographics 2008;28:463-79; quiz 619. https://doi.org/10.1148/rg.282075714.
3. Antonio GE, Cho JH, Chung CB, Trudell DJ, Resnick D. Pictorial essay. MR imaging appearance and classification of acromioclavicular joint injury. AJR Am J Roentgenol 2003;180:1103-10. https://doi.org/10.2214/ajr.180.4.1801103
4. Barnes CJ, Higgins LD, Major NM, Basamania CJ. Magnetic resonance imaging of the coracoclavicular ligaments: its role in defining pathoanatomy at the acromioclavicular joint. J Surg Orthop Adv 2004;13:69-75.
5. Cadenet FM, Petersson CJ. The treatment of dislocation and fractures of the outer end of the clavicle. Int Clin 1917;1:24.
6. Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. Clin Orthop Relat Res 1987;214:160-4.
7. Emery R. Acromioclavicular and sternoclavicular joints. In: Copeland S, editor. Shoulder surgery. London: WB Saunders; 1997.
8. Fuchs B, Jost B, Gerber C. Posterior-inferior capsular shift for the treatment of recurrent, voluntary posterior subluxation of the shoulder. J Bone Joint Surg Am 2000;82:16-25.
9. Hann C, Kraus N, Minkus M, Maziak N, Scheibel M. Combined arthroscopically assisted coraco- and acromioclavicular stabilization of acute high-grade acromioclavicular joint separations. Knee Surg Sports Traumatol Arthrosc 2018;26:212-20. https://doi.org/10.1007/s00167-017-4643-2
10. Hedtmann A, Fett H, Ludwig J. [Management of old neglected post-traumatic acromioclavicular joint instability and arthrosis]. Orthopade 1998;27:556-66 [in German].
11. Ibrahim EF, Forrest NP, Forester A. Bilateral weighted radiographs are required for accurate classification of acromioclavicular separation: an observational study of 59 cases. Injury 2015;46:1900-5. https://doi.org/10.1016/j.injury.2015.06.028
12. Kraus N, Hann C, Gerhardt C, Scheibel M. Dynamic instability of the acromioclavicular joint: a new classification for acute AC joint separation. Obere Extrem 2018;13:279-85. https://doi.org/10.1007/s11678-018-0469-x
13. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159-74.
14. Minkus M, Hann C, Scheibel M, Kraus N. Quantification of dynamic posterior translation in modified bilateral Alexander views and correlation with clinical and radiological parameters in patients with acute acromioclavicular joint instability. Arch Orthop Trauma Surg 2017;137:845-52. https://doi.org/10.1007/s00402-017-2691-1
15. Nemec U, Oberleitner G, Nemec SF, Gruber M, Weber M, Czerny C, et al. MRI versus radiography of acromioclavicular joint dislocation. AJR Am J Roentgenol 2011;197:968-73. https://doi.org/10.2214/AJR.10.6378
16. Nordqvist A, Petersson CJ. Incidence and causes of shoulder girdle injuries in an urban population. J Shoulder Elbow Surg 1995;4:107-12.
17. Rockwood C. Injuries in the acromioclavicular joint: subluxations and dislocations about the shoulder. In: Rockwood C, editor. Fracture in adults. Philadelphia: JB Lippincott; 1984. p. 860-910.
18. Schaefer FK, Schaefer PJ, Brossmann J, Hilgert RE, Heller M, Jahnke T. Experimental and clinical evaluation of acromioclavicular joint structures with new scan orientations in MRI. Eur Radiol 2006;16:1488-93. https://doi.org/10.1007/s00330-005-0093-1
19. Scheibel M, Droschel S, Gerhardt C, Kraus N. Arthroscopically assisted stabilization of acute high-grade acromioclavicular joint separations. Am J Sports Med 2011;39:1507-16. https://doi.org/10.1177/0363546511399379
20. Taft TN, Wilson FC, Oglesby JW. Dislocation of the acromioclavicular joint. An end-result study. J Bone Joint Surg Am 1987;69:1045-51.
21. Tauber M, Koller H, Hitzl W, Resch H. Dynamic radiologic evaluation of horizontal instability in acute acromioclavicular joint dislocations. Am J Sports Med 2010;38:1188-95. https://doi.org/10.1177/0363546510361951
22. Tossy JD, Mead NC, Sigmond HM. Acromioclavicular separations: useful and practical classification for treatment. Clin Orthop Relat Res 1963;28:111-9.
23. Zanca P. Shoulder pain: involvement of the acromioclavicular joint. (Analysis of 1,000 cases). Am J Roentgenol Radium Ther Nucl Med 1971;112:493-506.