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RESEARCH ARTICLE

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Comparison of sonography and MRI in the evaluation of stability of capitellar osteochondritis dissecans

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Abstract

Purpose: To compare the diagnostic accuracies of ultrasonography (US) and magnetic resonance imaging (MRI) with intraoperative capitellar osteochondritis dissecans (COCD) fragment stability findings.

Methods: Patients whose International Cartilage Repair Society (ICRS) osteochondritis dissecans (OCD) classifications were I/II (stable) or III (unstable) were included. Patients underwent preoperative US and MRI. On US, lesions were evaluated as unstable when irregular contours of the chondral surface were observed. On MRI, lesions were evaluated as unstable when articular bone irregularity, a T2 high signal intensity interface, or a high signal intensity line through the articular cartilage was observed. Using the surgical assessment as the gold standard, accuracies of fragment stability diagnoses were calculated for US and MRI.

Results: Thirty-four patients with OCD classifications of I/II (stable) or III (unstable) were included. Twenty-four patients (stable: 12, unstable: 12) underwent preoperative US; 22 (stable: 11, unstable: 11) underwent preoperative MRI. Preoperative US and MRI stability assessments correctly matched intraoperative fragment findings in 23 of 24 patients and 16 of 22 patients, respectively. US criteria in this study achieved superior accuracy compared with MRI criteria (96% vs. 73%; $P < .05$).

Conclusion: US was a useful tool for evaluating fragment instability in COCD.

KEYWORDS
capitellar osteochondritis dissecans, elbow, musculoskeletal system, stability, ultrasonography

1 | INTRODUCTION

Capitellar osteochondritis dissecans (COCD) typically occurs in adolescent athletes who are engaged in throwing sports that repetitively stress the immature capitellum, although the exact etiology remains unclear.[1,2] The choice of treatment for COCD mainly depends on the patient's age and characteristics of the lesion, including its size and fragment instability.[3] Evaluating the stability of the osteochondral fragment is important when choosing surgical versus non-surgical treatment options. Stable lesions are more likely to heal with elbow rest, whereas surgery provides better results for unstable lesions.[4,5]

Several studies have attempted to evaluate whether a fragment is stable or unstable by using magnetic resonance imaging (MRI).[3,6,7] Iwasaki et al. attempted to evaluate fragment stability according to MRI criteria published previously by De Smet et al.[8] and Dipaola et al.[9] and concluded that preoperative MRI cannot precisely diagnose fragment instability.[6] Satake et al. defined the fragment as unstable when MRI demonstrated one or more of the following findings: irregular contours of the articular bone and/or a T2 high signal intensity interface. Preoperative MRI was correlated with the intraoperative diagnosis (sensitivity 84%, specificity 70%).[3] The specificity of the MRI criteria tended to be low. Furthermore, this approach is expensive and time-consuming, which limits its repeated use.[10]

By contrast, ultrasonography (US) is very useful for the routine examination of COCD because it is non-invasive and cost-effective.[11] US imaging has been used to diagnose early COCD without elbow pain and to provide an opportunity for conservative treatment.[2,12] Kida et al. also used US imaging to investigate the prevalence of COCD among junior high-school and high-school baseball players who rarely visit medical institutions because of being minimally symptomatic.[13] Takahara et al. reported US criteria that distinguish between stable and unstable COCD lesions for patient management decisions. According to these criteria, when separation of the subchondral line with a wide gap is observed, the lesion is assessed as unstable.[14–16] However, to our knowledge, only a few previous studies correlating the US findings and surgical findings of COCD lesions have been published since Takahara et al. reported the US criteria for COCD instability. In this study, we evaluated only non-displaced fragments, and specifically whether these fragments can be distinguished as stable (International Cartilage Repair Society [ICRS] osteochondritis dissecans [OCD] I and II) or unstable lesions (ICRS OCD III). Furthermore, we compared the diagnostic accuracies of the US criteria with the MRI criteria described by Satake et al. regarding the intraoperative stability of the fragment.[3] We hypothesized that the US diagnostic accuracy of the fragment's instability would be equal to or better than that of MRI.

2 | MATERIALS AND METHODS

2.1 | Patient characteristics and evaluation of the intraoperative ICRS classification

We evaluated patients with COCD who were treated operatively between 2006 and 2016 at our institution. Some patients underwent direct open surgery and others were treated arthroscopically; because with arthroscopy alone it is difficult to assess the presence of holes in fragments and distinguish OCD II lesions with partial discontinuity from OCD III lesions with complete discontinuity, only patients who underwent direct open surgery were enrolled in this study.

Our indications for surgery included evidence of unstable lesions on plain radiographs (XR), computed tomography (CT), or MRI. We also performed surgery on stable lesions when healing of the lesion had ceased. A cessation in lesion healing was judged on the basis of XR and CT scans acquired at several-month intervals regarding osteosclerosis under the fragments and closure of the epiphysis, which indicate healing. One senior author (TS) performed all the surgeries. The COCD lesions were visualized through a posterolateral approach. Based on direct inspection and palpation, the intraoperative stability of the fragment was determined according to the ICRS OCD classification, which divides OCD lesions into four categories as follows: OCD I: stable lesions with a continuous but softened area covered by intact cartilage; OCD II: lesions with partial discontinuity that are stable when probed; OCD III: lesions with complete discontinuity that are not yet dislocated but are unstable when probed; and OCD IV: empty defects as well as defects with a dislocated or loose fragment within the bed.[3,17] OCD I and II lesions are considered stable, whereas OCD III and IV lesions are considered unstable. Preoperative radiographs were obtained for all patients.

2.2 | Evaluation of preoperative US findings

We retrospectively reviewed patients who underwent preoperative US evaluation for COCD. We excluded patients who had either a dislocated fragment or a loose body in the intraoperative findings (OCD IV lesions). We used a HI VISION Avius scanner with a 14-6 MHz linear probe or a Noblus scannerwith an 18-5 MHz linear probe (Hitachi Aloka Medical, Tokyo, Japan). All preoperative US examinations were performed with the elbow fully flexed to obtain a posterior longitudinal view and with the elbow fully extended to obtain an anterior longitudinal view. US images were obtained as part of daily clinical practice at our institution by two orthopedic surgeons (Y.N. and M.Y.). Two orthopedic surgeons (M.Y. and T.M.) reviewed static US images retrospectively, anonymously, and in consensus. The images had been stored on a Claio image filing system (FINDEX Inc., Tokyo, Japan) for the presence of the following features by modifying the method published previously by Takahara et al.[16]: subchondral bone continuity of the subchondral bone line (Figure 1A), separation of the subchondral bone line (Figure 1B,C), separation of the subchondral bone line with a wide gap (Figure 1D,E), and an irregular contour of the chondral surface with a chondral recess (Figure 2A-C). We recorded the proportions of patients in each group that exhibited each of the US findings. The fragments were considered unstable in the presence of an irregular contour of the chondral surface with a recess.

2.3 | Evaluation of preoperative MRI and correlations with operative ICRS classifications

We retrospectively reviewed patients who underwent preoperative MRI for COCD. We excluded patients who had either a dislocated fragment or a loose body (OCD IV lesions) and patients who underwent MRI more than three months before surgery. MRI examinations performed at our institution were performed using a Sigma 1.5-T or Sigma HDxt 3.0-T system (GE Yokogawa Medical Systems Ltd., Tokyo, Japan). T_2-weighted fat-suppressed sagittal and coronal images were retrospectively reviewed by two orthopedic surgeons (M.Y. and T.M.). The US and MR images were assessed separately and anonymously. The orthopedic surgeons documented the presence of the previously described MR imaging criteria for COCD instability by Satake et al.[3] These MRI criteria were as follows: (1) articular bone irregularity; (2) a T2 high signal intensity interface; and (3) a high-signal intensity line through the articular cartilage. The fragments were considered unstable in the presence of at least one of the following MRI features: articular

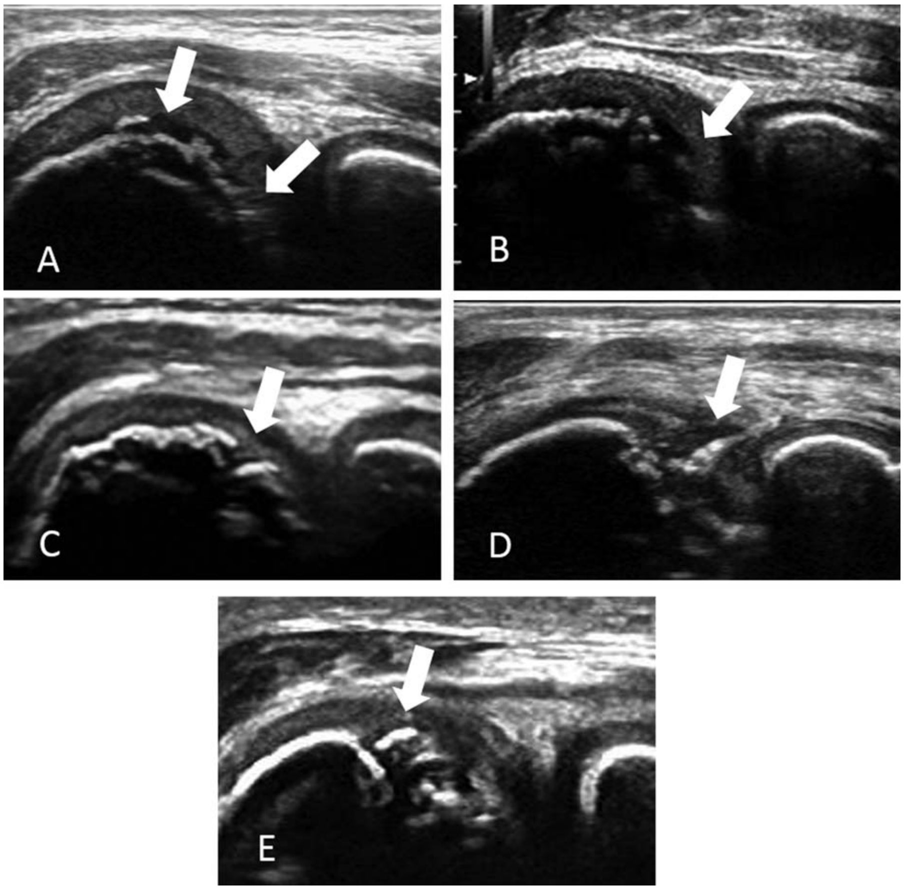

FIGURE 1 A, Sonogram shows the continuity of the subchondral bone line (arrows). B,C) Sonograms show the separation of the subchondral bone line (arrow). D,E, Sonograms show the separation of the subchondral bone line with a wide gap (arrow)

bone irregularity and/or a T2 high signal intensity interface and/or a high signal intensity line through the articular cartilage.

2.4 | Statistical analysis

Using the surgical assessment as the gold standard, the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy of the diagnosis of stability of the fragments were calculated for US and MRI. The comparison of accuracies of US and MRI was made using the chi-squared test. A probability value of less than .05 was considered statistically significant.

3 | RESULTS

3.1 | Patient characteristics

Fifty-seven patients (57 male subjects) with COCD were treated operatively between 2006 and 2016 at our institution. Fifty-four patients underwent direct open surgery and three patients were treated arthroscopically. The 54 patients who underwent direct open surgery were enrolled in this study. Patient age at the time of surgery ranged from 11 to 18 years (mean age: 14.5 years). According to the ICRS staging system, there were 3 OCD I lesions, 11 OCD II lesions, 20 OCD III lesions, and 20 OCD IV lesions. We performed drilling of the subchondral bone for one lesion in the OCD I category; fragment fixation for 2 lesions in the OCD I category, 9 lesions in the OCD II category, and 13 lesions in the OCD III category; and mosaicplasty for two lesions in the OCD II category, and seven lesions in the OCD III category. Of the 54 patients, 43 patients underwent preoperative CT evaluation, 32 patients underwent preoperative US evaluation, and 38 patients underwent preoperative MRI evaluation. Of the 34 patients with OCD I, II, and III lesions, 16 patients underwent both preoperative US and MRI.

We retrospectively reviewed 32 patients who underwent preoperative US evaluation for COCD. The interval between US and surgery ranged from 1 week to 11 weeks (mean, 4.5 weeks). We excluded eight patients who had either a dislocated fragment or a loose body in the intraoperative findings (OCD IV lesions). Of the remaining 24 patients, 12 had stable fragments (2 OCD I lesions and 10 OCD II lesions) and 12 had unstable fragments (OCD III lesions).

We retrospectively reviewed the records of 38 patients who underwent preoperative MRI for COCD. We excluded 13 patients who had either a dislocated fragment or a loose body (OCD IV lesions) and 3 patients who underwent MRI more than 3 months before surgery. Of the remaining 22 patients, the interval between MRI and surgery

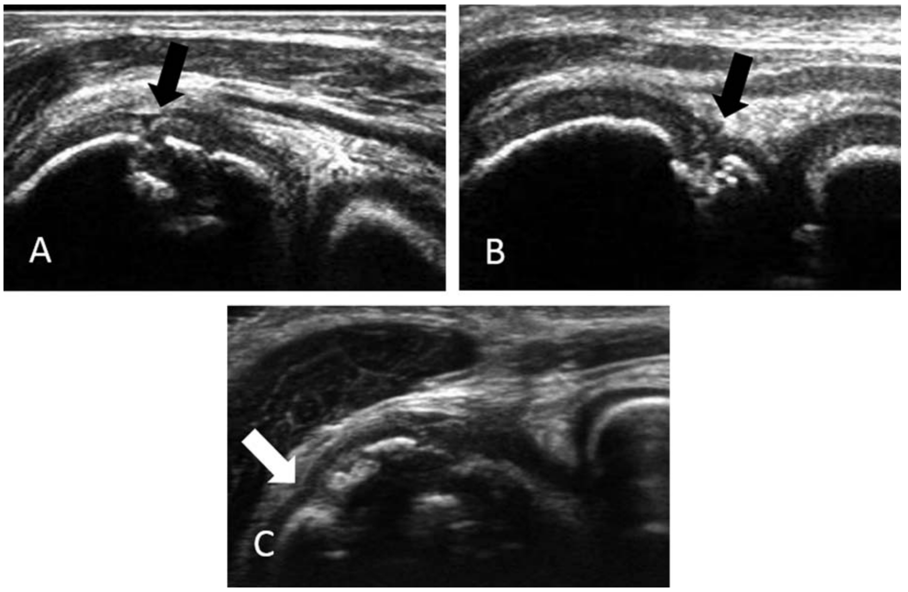

FIGURE 2 A-C, Sonograms show an irregular contour of the chondral surface with a chondral recess (arrow)

ranged from 1 week to 12 weeks (mean: 6.7 weeks). Eleven had stable fragments (1 OCD I: and 10 OCD II lesions) and 11 had unstable fragments (OCD III lesions).

3.2 | US findings

We evaluated the subchondral bone line and observed continuity in 33% ($n = 4$) of the patients in the stable group and in 8% ($n = 1$) of the patients in the unstable group; separation in 58% ($n = 7$) of the patients in the stable group and in 67% ($n = 8$) of the patients in the unstable group; and separation with a wide gap in 8% ($n = 1$) of the patients in the stable group and in 24% ($n = 3$) of the patients in the unstable group. We observed an irregular contour of the chondral surface with a recess in none of the patients in the stable group and in 92% ($n = 11$) of the patients in the unstable group. Based on US, we defined the fragment as unstable when there were irregular contours of the chondral surface with a recess and stable when none of these features were observed. The preoperative US imaging criteria correctly matched the intraoperative instability of the fragment in 23 of 24 patients with a sensitivity of 92%, specificity of 100%, PPV of 100%, NPV of 92%, and overall accuracy of 96%.

3.3 | MRI findings

We observed irregular contours of the articular bone in 18% ($n = 2$) of the patients in the stable group and in 55% ($n = 6$) of the patients in the unstable group and a T2 high signal intensity interface between the fragments and bed in 18% ($n = 2$) of the patients of the stable group and in 73% ($n = 8$) of the patients in the unstable group. A T2 high signal intensity line through the articular cartilage was observed in 18% ($n = 2$) of the patients in the stable group and in 64% ($n = 7$) of the patients in the unstable group. The preoperative MRI criteria described by Satake et al. correctly matched the intraoperative assessment of the fragment in 16 of 22 patients with a sensitivity of 82%; specificity of 64%, PPV of 70%, NPV of 78%, and overall accuracy of 73%. US criteria achieved superior accuracy in this study compared with the MRI criteria described by Satake et al. (96% vs. 73%, $P < .05$).

4 | DISCUSSION

Because the treatment of OCD largely depends on the presence or absence of fragment stability, preoperative assessment is based on clinical findings in combination with imaging results.[4] MRI is frequently utilized to differentiate between stable and unstable lesions. The specificity in this study was low, which was similar to the results of previous reports.[3,7]

Takahara et al. reported that when separation of the subchondral line with a wide gap was observed on US, the lesion was assessed as unstable.[14–16] However, in the US criteria described by Takahara et al., while both the subchondral bone and overlying articular cartilage are evaluated, priority is given to the subchondral findings over the cartilage findings. US showed various findings in the capitellar subchondral bone regardless of the existence of a stable or unstable lesion.[18] Therefore, sometimes it may be difficult to judge whether non-displaced fragments are stable or unstable by evaluating the subchondral bone line. In fact, we observed separation of the subchondral bone line in 58% of the patients in the stable group and in 91% of the patients in the unstable group. Thus, we focused on the contours of the chondral surface. We defined the fragment as unstable when irregular contours of the chondral surface with a chondral recess were observed and as stable when none of these features were observed. The preoperative US imaging criteria correctly matched the intraoperative assessment of the fragment in 23 of 24 patients. The US criteria in this study achieved superior accuracy compared with the MRI criteria described by Satake et al. (96% vs. 73% $P < .05$). A point of difference between the US criteria used in this study and the US criteria described by Takahara et al. is that our criteria assessed fragment stability by evaluating only the cartilage and without evaluating the subchondral bone. We emphasized that specific evidence to suggest fragment instability for the indication of operative treatment is an irregular contour of the chondral surface with a chondral recess.

Some lesions that appear stable on imaging will not respond to non-operative treatment and it is difficult to predict the patients for whom non-operative treatment will be successful.[19] Therefore, we must emphasize that stable US findings do not guarantee successful non-operative treatment because the treatment policy (surgical or non-surgical, conservative treatment) is determined by not only the stability of the lesions but also by the condition of the subchondral bone and extent of cartilage damage.[20]

In this study, we excluded cases with OCD IV lesions. We focused on only non-displaced fragments and whether it is possible to distinguish stable lesions (OCD I/II) from unstable lesions (OCD III), since this distinction is not easily achieved using MRI and other modalities.[7] An OCD IV lesion demonstrates various US findings such as a dislocated fragment, cartilage defect, replacement with fibrous cartilage, and non-displacement of the remaining fragment with a loose body. A large cartilage defect and a dislocated fragment are detected easily on US. In case of non-displacement of the remaining fragment with a loose body, an articular cartilage defect was sometimes replaced by fibrous cartilage and the subchondral bone was repaired. Such lesions must be distinguished from a stable lesion and classified as OCD IV.[16] US shows a highly echogenic structure at the surface of the defect replaced by fibrous cartilage; however, detecting the missing small loose body is sometimes difficult using US alone. Therefore, when joint blockage and extension deficit are present, XR, CT, and MRI imaging should be used to detect the loose body fragment.[21,22]

There are several limitations to this study. First, we excluded cases with OCD IV lesions. When the stability of fragment is evaluated including OCD IV cases with a small loose body, it is unknown whether MRI or US is useful. Second, two orthopedic surgeons (M.Y. and T.M.) reviewed only static US images. This might be another possible source of bias. Third, the intra- and interobserver reproducibility of US and MRI findings were not assessed. Fourth, of the patients with OCD I, II, and III lesions, only 16 patients underwent both preoperative US and MRI. Fifth, the interval between MRI and surgery (mean: 6.7 weeks) was longer than the interval between US and surgery (mean, 4.5 weeks). Furthermore, some MRI examinations were performed at other institutions.

5 | CONCLUSION

The US criteria in this study correctly matched the ICRS classification in 23 of 24 patients. The sensitivity, specificity, PPV, NPV, and accuracy of the US diagnoses were 92%, 100%, 100%, 92%, and 96%, respectively. Our US criteria achieved superior accuracy compared with the MRI criteria previously described.

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