EDITOR'S CHOICE

Magnetic Resonance Imaging in Osteochondritis Dissecans of the Humeral Capitellum: Preoperative Assessment of Lesion Size and Lateral Wall Integrity

J. Sam Broughton, BS,* Mitchel R. Obey, MD,* Travis J. Hillen, MD,† Matthew V. Smith, MD,* Charles A. Goldfarb, MD*

Purpose Magnetic resonance imaging (MRI) is a helpful tool in the evaluation of osteochondritis dissecans (OCD) of the humeral capitellum. The relationship between MRI appearance and clinically relevant intraoperative findings is incompletely understood. The goal of this study was to evaluate capitellar OCD lesions via preoperative MRI and to determine its accuracy in predicting lesion characteristics including lesion size and capitellar lateral wall integrity.

Methods Patients surgically treated for capitellar OCD between January 2010 and June 2018 were reviewed. Preoperative MRI images were assessed by a musculoskeletal radiologist with documentation of lesion size, location, violation of the lateral wall, and stage, in accordance with previously established criteria. These data were compared with intraoperative findings. Involvement of the lateral wall of the capitellum was defined using 2 methods: (1) subchondral edema or articular cartilage disruption in the lateral third of the capitellum (lateral third method) or (2) disruption of the proximal-distal subchondral line along the lateral border of the capitellum descending vertically before the subchondral bone turns horizontally to form the radiocapitellar articulation (capitellar lateral wall sign method). Diagnostic test characteristics were compared for both methods.

Results We reviewed the preoperative MRIs of 33 elbows with capitellar OCD and found no significant difference in mean lesion size between preoperative MRI (1.12 cm^2) and intraoperative measurement (1.08 cm^2). For detection of lateral wall integrity, preoperative MRI evaluation using the capitellar lateral wall sign method had an accuracy of 93%, sensitivity of 80%, specificity of 96%, positive predictive value of 80%, and negative predictive value of 96%.

Conclusions Preoperative MRI is a valid predictor of lesion size. The capitellar lateral wall sign method is highly accurate in the identification of lateral wall involvement, which may influence preoperative planning. *(J Hand Surg Am. 2021;46(6):454−461. Copyright © 2021 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Diagnostic II.

Key words Capitellum, lateral wall, magnetic resonance imaging, osteochondritis dissecans.

*From the *Department of Orthopedic Surgery and †Department of Radiology, Washington University, School of Medicine, St Louis, MO.*

Received for publication April 17, 2020; accepted in revised form January 29, 2021.

No benefits in any form have been received or will be received related directly or indirectly to the subject of this article.

Corresponding author: Charles A. Goldfarb, MD, Department of Orthopedic Surgery, Washington University School of Medicine, 660 S. Euclid Ave., Campus Box 8233 St. Louis, MO 63110; e-mail: goldfarbc@wustl.edu.

0363-5023/21/4606-0002$36.00/0
https://doi.org/10.1016/j.jhsa.2021.01.024

Osteochondritis dissecans (OCD) of the humeral capitellum is most commonly seen in adolescents, particularly young athletes such as gymnasts and those who throw overhead, placing repetitive valgus stress on the elbow.[1,2] The etiology of this condition is becoming better understood, with previous studies suggesting trauma secondary to repetitive stress on the radiocapitellar joint as a potential cause, combined with the relative hypovascularity of the area.[1,3,4] Patients are typically first treated without surgery with rest and activity modification; in selected patients failing these measures, surgical intervention is indicated. Surgical options include arthroscopic debridement, marrow stimulation, fragment fixation, and osteochondral transplantation.[1] Treatment selection is guided in part by patient symptoms (ie, the presence or absence of mechanical symptoms), but primarily by lesion characteristics, such as lesion size, location, and stability. The International Cartilage Repair Society (ICRS) classification is currently the reference standard for assessment of lesion stability, however, it requires direct or arthroscopic visualization.[5,6]

Magnetic resonance imaging (MRI) is an essential tool in the preoperative evaluation of OCD lesions, clarifying lesion location, size, and stability.[7–11] Lesion location is an important factor in determining treatment, in particular, lesion location in the sagittal plane[12,13] and involvement of the lateral wall of the capitellum. The lateral wall is defined as the subchondral bone along the most lateral proximal-distal surface of the capitellum before it turns medially to form the radiocapitellar articulation. Lesions involving the lateral wall may be described as uncontained, have been associated with greater loss of motion at presentation, and may be associated with instability.[14] Lateral wall involvement has implications for treatment planning because insufficient remodeling of the lateral wall has been associated with poorer clinical outcomes, related to increased shear forces on the capitellum.[15] For this reason, osteochondral graft techniques are often considered to be superior to microfracture or fragment fixation in the treatment of uncontained lesions.

Few studies have evaluated the ability of preoperative MRI to accurately predict lesion appearance at the time of surgery. Kohyama et al[10] proposed an MRI-based staging system focused on the outline of the capitellum and articular cartilage status. Comparing their results with the ICRS arthroscopic classification, [6] they reported 89% agreement. The staging system also proved a reliable predictor of lesion stability. However, intraoperative findings including lesion dimensions and lateral wall involvement have not been compared with preoperative MRI findings in previous studies. The goals of this study were to (1) describe OCD lesion size, location, stage, and lateral wall involvement on preoperative MRI using previously described systems[10] and correlate those findings with intraoperative assessments; (2) assess the performance of a new elbow MRI tool in detecting lateral wall involvement based on disruption of the proximal-distal subchondral line bordering the capitellum. We hypothesized that most lesions would involve the middle capitellar third, be Kohyama stage 3 or 4,[10] and preoperative MRI would be an accurate predictor of both lesion size and lateral wall involvement.

MATERIALS AND METHODS

Patient selection

This was a retrospective study of patients with a diagnosis of OCD of the humeral capitellum treated between January 1, 2010, and June 1, 2018. We obtained institutional review board approval prior to the initiation of the study. We included patients younger than 18 years at the time of arthroscopic treatment of the capitellar OCD by a fellowship-trained orthopedic surgeon in sports medicine (M.V.S.) or hand/upper extremity (C.A.G.) at a single institution. Each patient had both preoperative MRI imaging and intraoperative arthroscopic imaging available for review. We excluded patients with incomplete or inadequate imaging available for review or a prior surgical intervention.

The MRIs were performed on either 1.5 T or 3 T Siemens scanners. We used a small flexible coil wrapped around the elbow. Imaging was performed in the coronal, sagittal, and axial planes, and measurements were primarily obtained on sagittal or coronal sequences. The cartilage imaging sequences were fast spin echo proton-density fat suppressed images with 3- or 4-mm slice thickness. Coronal proton density fat-suppressed sequences were most informative for assessing for the lateral wall sign. We only included patients with MRIs from our institution or those obtained outside of our institution of adequate quality.

MRI evaluation

Capitellar OCD lesions were staged in accordance with the MRI-based staging system proposed by Kohyama et al.[10] This 4-stage MRI classification system focuses on the outline of the capitellum and articular cartilage:

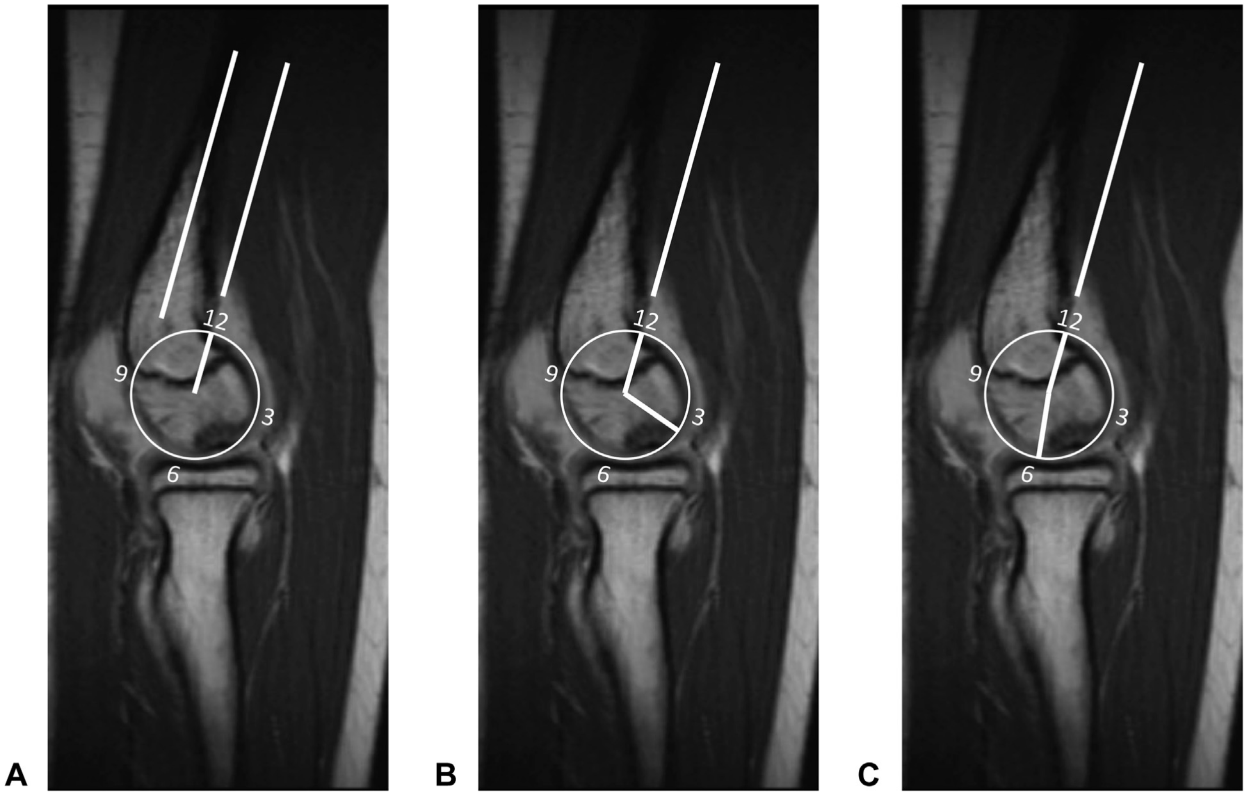

FIGURE 1: Illustration of the clock face lesion localization method developed by Johnson et al. Localization is demonstrated using a sagittal MRI from a sample patient in our study with a lesion spanning from 4 to 6 o'clock. **A** The 12 o'clock axis is defined as a line parallel to the humeral shaft that intersects with the center of the capitellum. **B** The anterior limit of the lesion is marked at the 4 o'clock position. **C** The posterior limit of the lesion is marked at the 6 o'clock position.

Stage 1: normal-shaped capitellum and articular cartilage without signal intensity change

Stage 2: normal-shaped capitellum and articular cartilage with signal intensity change

Stage 3: irregular-shaped capitellum and discontinuity of the articular cartilage

Stage 4: dislocated lesion with an articular cartilage defect

Stages 1 and 2 lesions are considered stable, and stages 3 and 4 lesions are considered unstable.

We also described the location of the capitellar OCD lesion in accordance with the clock face localization system developed by Johnson et al.[16] In their study, the OCDs were measured in the sagittal plane, and lesions were first measured in degrees with respect to their location on the capitellum. Zero degrees equated to 12-o'clock and was defined as a line parallel to the anterior humeral line and running through the middle of the capitellum. Degrees were then converted into the clock face format. Lesion borders were described using the clock face system, as was clock face width, or the number of hours between lesion borders (Fig. 1). In addition, lesion dimensions of width on coronal cuts and depth on sagittal cuts were measured. Furthermore, on coronal sequences, the capitellum was also divided into thirds (ie, medial third, middle third, lateral third), and lesion location based upon involvement of those areas was determined. Finally, involvement of the lateral wall of the capitellum was evaluated using 2 methods: (1) subchondral edema or articular cartilage disruption in the lateral third of the capitellum (lateral third method). In this method, radiocapitellar subluxation, with or without radial head enlargement, was considered supporting evidence for lateral wall involvement; (2) disruption of the proximal-distal subchondral line along the lateral border of the capitellum descending vertically before the subchondral bone turns horizontally to form the radiocapitellar articulation. If the proximal-distal subchondral line along the lateral border of the capitellum was disrupted at any point along this turn, the lateral wall was determined to be disrupted by the lesion (Fig. 2). This was termed the capitellar lateral wall sign. All MRI images were reviewed by a single, board-certified musculoskeletal radiologist (T.J.H.), who was blinded to the intraoperative results. The accuracy, sensitivity, specificity, positive predictive value

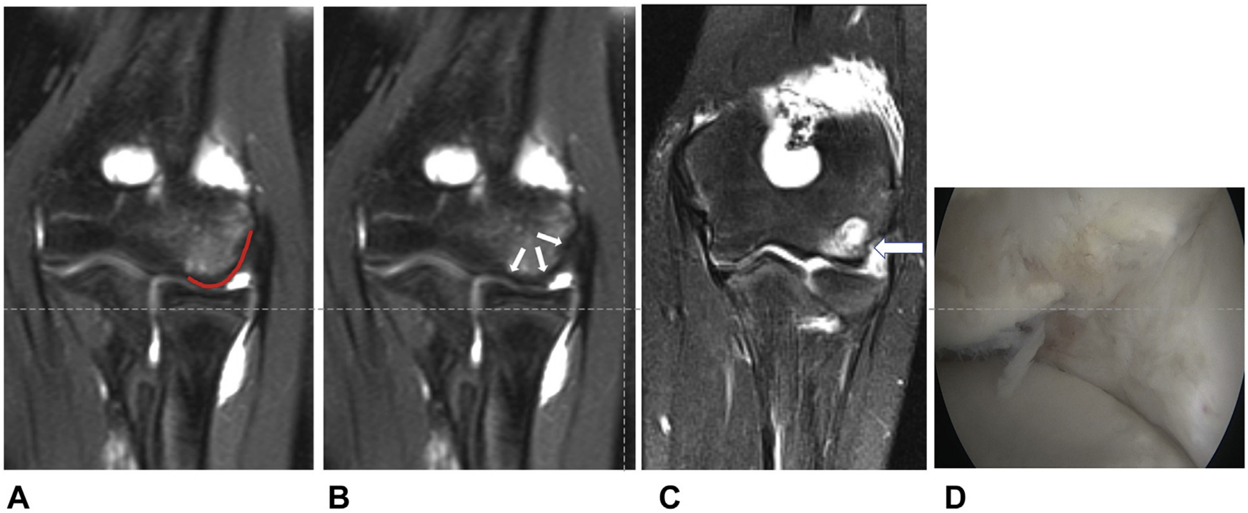

FIGURE 2: In a capitellum with an intact lateral wall, the proximal-distal subchondral line along the bone plate forming the lateral border of the capitellum descends vertically and then turns horizontally and runs medially at the radiocapitellar joint. If the subchondral border line was interrupted at any point along this turn, the lateral wall was determined to be disrupted by the lesion. This was termed the capitellar lateral wall sign. Sample preoperative coronal MRIs are shown for 2 representative patients. The lateral wall was intact in one, as illustrated by the **A** red line and **B** arrows. **C** It was disrupted in the other sample patient, as shown by the arrow. **D** Arthroscopic image of a disrupted lateral wall of the capitellum.

(PPV), and negative predictive value (NPV) were determined using both methods, with direct arthroscopic visualization as the reference standard.

Arthroscopic evaluation

Intraoperative images are routinely obtained and stored for all patients who undergo arthroscopic surgery for OCD lesions of the capitellum, and these were assessed for this investigation, in addition to a review of the surgical report documentation. Images were reviewed by 2 board-certified orthopedic surgeons specializing in the upper extremity (M.V.S. and C.A.G.). Lesion dimensions, stability, and lateral wall involvement were assessed during surgery using a standardized method and collected retrospectively from patient charts.

Statistical analysis

Correlations between continuous variables were measured using Pearson coefficient.

Student *t* tests were performed for comparison of means between 2 groups. One-way analyses of variance were used to compare means between more than 2 groups. The level of significance was set at *P* less than .05. No outside funding was acquired for this study.

RESULTS

Ninety-four patients (104 elbows) were surgically treated for capitellar OCD during the study period. Thirty-one patients (33 elbows) had both satisfactory preoperative MRIs and intraoperative imaging available for review. This included elbows in 17 males and 16 females, with a mean age of 13 years (range, 9–17 years).

The MRI assessments are described in Table 1. Eighteen of the 33 OCDs were Kohyama stage 4, with the remaining 15 a mixture of other stages. Based on Kohyama staging, preoperative MRI predicted that 23 (70%) of 33 lesions were unstable. The mean clock face width (from most anterior point to posterior point) was 2:18 (SD, 0:36), and mean anterior and posterior limits were 3:38 (SD, 0:39), and 6:00 (SD, 0:38). The range of clock face positions covered by all lesions was from the 3 to the 7 o'clock positions. The medial and middle capitellar thirds were affected in 18 lesions, and 13 larger lesions affected the entire width of the capitellum.

Intraoperative assessment of lesion size, stability, and lateral wall integrity was documented for 25, 33, and 30 of the 33 elbows, respectively (Table 2).

There was no significant difference in mean lesion size as assessed on preoperative MRI (1.12 cm^2; SD, 0.67 cm^2), and during surgery (1.08 cm^2; SD, 0.87 cm^2); *P* was .83. There was a positive correlation between lesion size measured on preoperative MRI and during surgery ($R = 0.69$; $P < .05$) (Fig. 3). There was also a significant positive correlation between preoperative MRI clock face width and both lesion size and anteroposterior width on both

TABLE 1. Preoperative MRI Descriptive Statistics

Statistic	Value
Lesion size (cm^2)	
N	33
Range	0.28–2.8
Mean (SD)	1.12 (0.67)
Lateral wall (lateral third)	
Intact	18
Involved	12
Lateral wall (J sign)	
Intact	25
Involved	5
Kohyama stage	
1 (stable)	2
2 (stable)	8
3 (unstable)	5
4 (unstable)	18
Capitellar thirds affected	
Medial	31
Middle	33
Lateral	15
Medial and middle	18
Middle and lateral	2
All	13
Clock face anterior limit	
3	15
4	15
5	3
Mean (SD)	3:38 (0:39)
Clock face posterior limit	
5	7
6	20
7	6
Mean (SD)	6 (0:38)
Clock face width	
1	1
2	21
3	10
4	1
Mean (SD)	2:18 (0:36)

preoperative MRI and intraoperative measurement (Fig. 4). The most significant correlation was between clock face width and MRI lesion size ($R = 0.75$; $P < .05$).

Intraoperative findings demonstrated that 27 (82%) of 33 lesions were unstable. For detection of lesion instability, preoperative MRI (using the Kohyama staging system) yielded 21 true positives, 4 true negatives, 2 false positives, and 6 false negatives, for an accuracy of 76%, sensitivity of 78%, specificity of 67%, PPV of 91%, and NPV of 40%.

TABLE 2. Intraoperative Descriptive Statistics

Lesion size (cm^2)	
N	25
Range	0.25–4
Mean (SD)	1.08 (0.87)
Stability	
Stable	6
Unstable	27
Lateral wall	
Intact	25
Involved	5
Total	30

The lateral wall of the capitellum was affected in 5 of 30 elbows (16.7%) on intraoperative assessments. Using the lateral third method to determine lateral wall integrity, preoperative MRI yielded 4 true positives, 17 true negatives, 8 false positives, and 1 false negative, for an accuracy of 70%, sensitivity of 80%, specificity of 68%, PPV of 33%, and NPV of 94%. Using the capitellar lateral wall sign criterion to detect lateral wall integrity, preoperative MRI yielded 4 true positives, 24 true negatives, 1 false positive, and 1 false negative for an accuracy of 93%, sensitivity of 80%, specificity of 96%, PPV of 80%, and NPV of 96%. Of 30 cases, 2 MRI assessments of lateral wall integrity did not match intraoperative observations. The first case was a false negative in which an intact subchondral line turned from vertical to horizontal, suggesting the lateral wall remained intact on MRI. The second was a false positive in which the appearance of the lateral subchondral line was indistinct, suggesting the lateral wall had been eroded, with only remnants of bone left behind.

DISCUSSION

Our findings reinforce the utility of previously described MRI classification systems for capitellar OCD lesions, while also providing additional context for these systems. Furthermore, we formalize and evaluate the concept of the capitellar lateral wall sign for assessing lateral wall integrity.

Our investigation of preoperative MRI characteristics of capitellar OCD lesions demonstrated that these surgically treated lesions were at least 1 cm[2], commonly classified as Kohyama stage 4, and most

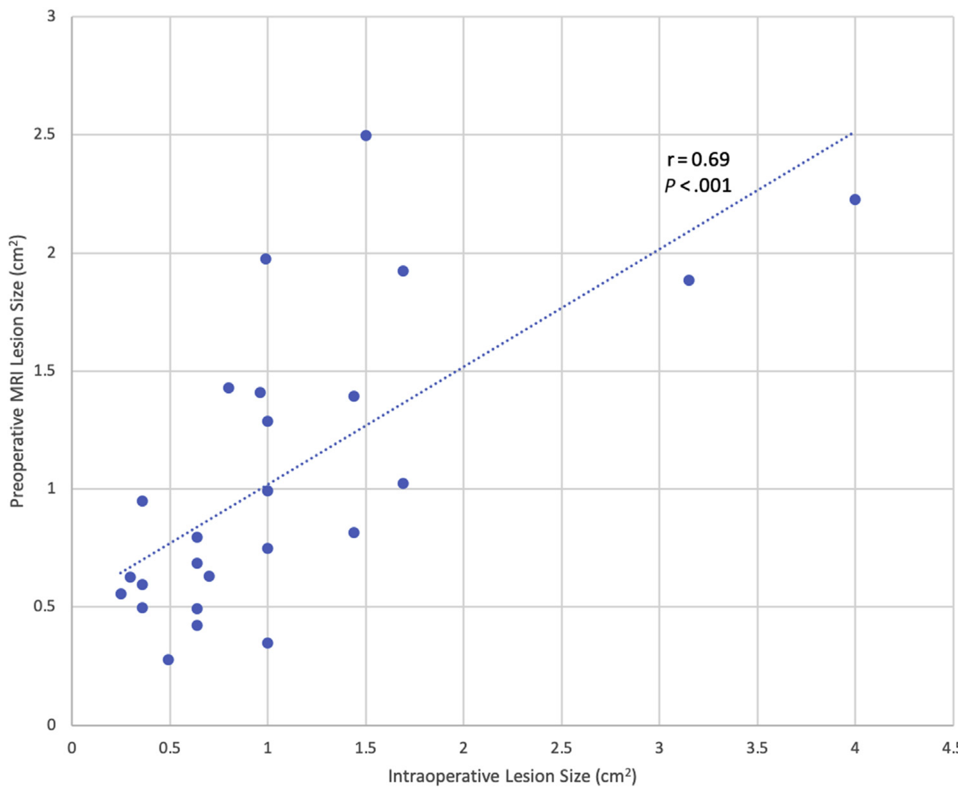

FIGURE 3: Correlation between intraoperative and preoperative lesion size.

frequently affected the middle and medial thirds of the capitellum. Most lesions spanned 2 or more positions using the Johnson et al[16] clock face localization method and covered a range from the 3 to the 7 o'clock positions.

Preoperative MRI, compared with intraoperative assessment, was a valid predictor of lesion size because there was a significant correlation between preoperative and intraoperative lesion sizes and no significant difference between mean sizes. This finding is in contrast to a recent study regarding MRI prediction of lesion size in OCD of the talus[17] and suggests that MRI is better suited for evaluation of capitellar lesion size.

In their initial study of 81 surgically treated capitellar OCD patients, Kohyama et al[10] found that 26 patients (32%) had stage 4 lesions. This was a notably smaller proportion than the 18 patients (53%) with stage 4 lesions in our study. The difference is not likely attributable to a difference in MRI assessment because the Kohyama classification[10] was found to have a high interrater reliability (intraclass correlation coefficient $>$ 0.9). Institutional treatment preferences likely explain this large difference; their patients were possibly advanced to surgical intervention before their lesions progressed to stage 4.

Magnetic resonance imaging has previously been shown to be a valid predictor of OCD lesion stability. Kijowski and De Smet[18] investigated the relationship between MRI appearance and intraoperative appearance with regards to predicting stability. They found lesions with a high signal intensity interface on T2-weighted images were unstable during surgery, and lesions without a high signal interface were stable. Similar reports were described by Satake et al.[5] In the original article, for prediction of lesion instability, the Kohyama staging system had an accuracy of 88.9%, sensitivity of 98.4%, specificity of 84.2%, PPV of 95.3%, and NPV of 94.1%.[10] Our study did not replicate these findings but did show that preoperative MRI and the Kohyama staging system demonstrated a strong accuracy (76%), sensitivity (78%), and PPV (91%) in prediction of lesion instability. However, NPV was only 40%. The reduced NPV was likely due in part to the small number of stable lesions observed.

The clock face lesion localization system developed by Johnson et al[16] has been demonstrated to have high interrater reliability. This led the authors to conclude the clock face localization system was a reliable modality for describing OCD lesion location and provides information useful for treatment

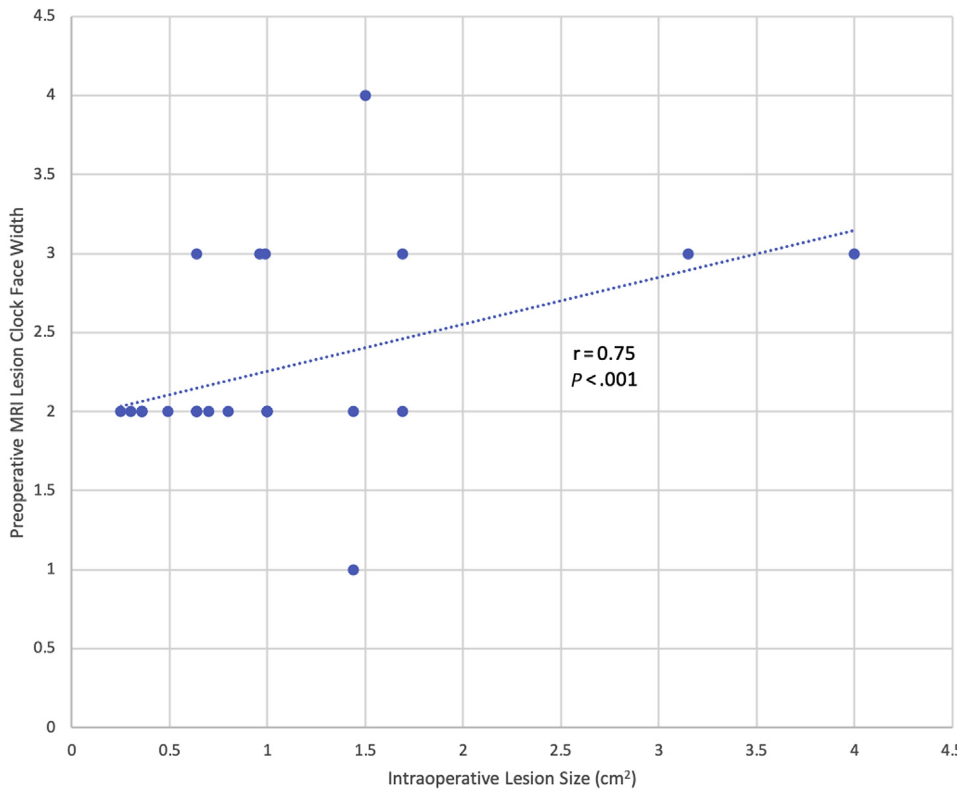

FIGURE 4: Correlation between intraoperative lesion size and clock face width.

planning because anterior lesions cannot always be accessed through the commonly used posterior surgical approach. In their initial study of 104 lesions, Johnson et al[16] found that the average lesion was between 3:04 and 5:00 on the clock face. The average lesion in our study spanned from 3:38 to 6:00, suggesting lesions requiring surgical treatment were somewhat more posterior. This assessment technique was useful and all of the OCDs in our study were able to be accessed from posterior portals.

Both the Kohyama classification and the Johnson clock face localization system are recent descriptions and have not been replicated or further validated since their initial publication.

With an accuracy of 93%, preoperative MRI assessment using the capitellar lateral wall sign criterion was a highly accurate means to assess involvement of the lateral wall of the capitellum. An accurate understanding of the size, location, and stability of the lesion is important to preoperative planning and surgical decision-making. When evaluating diagnostic tests for rare events, traditional evaluation metrics can be misleading.[19] Our evaluation of the capitellar lateral wall sign could be considered in this category of investigation because the positive event rate was only 5 of 30. To mitigate this issue, alternative metrics have been developed to balance the performance of the diagnostic test for events and nonevents. One such measure is the g-means; the geometric mean between sensitivity and specificity.[20] The g-means for the capitellar lateral wall sign in detection of lateral wall involvement in our study was 0.87, suggesting excellent accuracy for both events and nonevents.

Lateral wall involvement has important implications for treatment planning of OCD lesions. Microfracture and fragment fixation techniques are generally used for the treatment of OCD lesions with an intact capitellar lateral wall (contained lesions), whereas many believe that lesions affecting the lateral wall are better served by osteochondral graft techniques. In a study of 27 surgically treated pediatric capitellar OCD patients, Mihara et al[14] found that insufficient remodeling of the lateral wall led to worse clinical outcomes, including degenerative changes in the radiohumeral joint and decreased range of motion. Shi et al[15] found a significant association between uncontained lesions and joint effusion, as well as greater loss of elbow motion at presentation and at early follow-up after surgical treatment. No prior studies have examined the accuracy of preoperative MRI for detection of lateral wall involvement in capitellar OCD lesions. We propose the capitellar lateral wall sign as a practical and highly accurate method to detect disruption of the lateral wall of the capitellum on preoperative MRI. This information can then be used for preoperative planning, to select the optimal surgical technique from multiple options with widely varying degrees of invasiveness and expectations for recovery.

Limitations of this study include its retrospective nature and relatively small sample size. Owing to the rarity of capitellar OCD lesions, the observation of lesions with a specific characteristic such as lateral capitellar wall involvement is inherently infrequent. Although our study employs statistical methods to compensate for the small number of lesions with lateral wall involvement, future studies could reinforce this finding with a larger sample size. The MRIs evaluated in this study were obtained retrospectively from patient charts, meaning that imaging was obtained according to institutional protocols and that image quality and technique were not necessarily standardized. However, we believe that this improves the generalizability of our data, because our diagnostic methods yield clinically useful results despite being applied to preoperative MRIs that are not obtained using identical protocols. Furthermore, we recognize that orthopedists may already assess lateral wall integrity when evaluating capitellar OCD lesions on MRI. However, we believe that the formalization and evaluation of this process using the capitellar lateral wall sign will allow for a more robust understanding of the capacity of MRI to predict lateral wall involvement. Intra- and interrater reliability were not assessed because the MRI images were evaluated by a single radiologist. Intraoperative assessments of lesion size and lateral wall involvement were also not uniformly available for all participants. Intraoperative assessment of lateral wall involvement was based on recorded intraoperative observation where available but, in some cases, was determined by the examination of arthroscopic photographs. Despite these limitations, we believe that the findings of this study are important for surgeons using MRI to evaluate capitellar OCDs as a planning tool for surgical intervention.

REFERENCES

1. Smith MV, Bedi A, Chen NC. Surgical treatment for osteochondritis dissecans of the capitellum. *Sports Health*. 2012;4(5):425−432.
2. Ruchelsman DE, Hall MP, Youm T. Osteochondritis dissecans of the capitellum: current concepts. *J Am Acad Orthop Surg*. 2010;18(9): 557−567.
3. Schenck RC Jr, Goodnight JM. Osteochondritis dissecans. *J Bone Joint Surg Am*. 1996;78(3):439−456.
4. Yamaguchi K, Sweet FA, Bindra R, Morrey BF, Gelberman RH. The extraosseous and intraosseous arterial anatomy of the adult elbow. *J Bone Joint Surg Am*. 1997;79(11):1653−1662.
5. Satake H, Takahara M, Harada M, Maruyama M. Preoperative imaging criteria for unstable osteochondritis dissecans of the capitellum. *Clin Orthop Relat Res*. 2013;471(4):1137−1143.
6. International Cartilage Repair Society. ICRS Cartilage Injury Evaluation Package 2000. Available at http://www.cartilage.org/_files/contentmanagement/ICRS_evaluation.pdf. Accessed October 1, 2019.
7. Takahara M, Shundo M, Kondo M, Suzuki K, Nambu T, Ogino T. Early detection of osteochondritis dissecans of the capitellum in young baseball players: report of three cases. *J Bone Joint Surg Am*. 1998;80(6):892−897.
8. Dipaola JD, Nelson DW, Colville MT. Characterizing osteochondral lesions by magnetic resonance imaging. *Arthroscopy*. 1991;7(1): 101−104.
9. Itsubo T, Murakami N, Uemura K, et al. Magnetic resonance imaging staging to evaluate the stability of capitellar osteochondritis dissecans lesions. *Am J Sport Med*. 2014;42(8):1972−1977.
10. Kohyama S, Ogawa T, Mamizuka N, hara Y, Yamazaki M. A magnetic resonance imaging−based staging system for osteochondritis dissecans of the elbow: a validation study against the International Cartilage Repair Society classification. *Orthop J Sport Med*. 2018;6(9):2325967118794620.
11. Jans LBO, Ditchfield M, Anna G, Jaremko JL, Verstraete KL. MR imaging findings and MR criteria for instability in osteochondritis dissecans of the elbow in children. *Eur J Radiol*. 2012;81(6): 1306−1310.
12. Bauer M, Jonsson K, Josefsson PO, Lindén B. Osteochondritis dissecans of the elbow: a long-term follow-up study. *Clin Orthop Relat Res*. 1992;284:156−160.
13. Gancarczyk SM, Makhni EC, Lombardi JM, Popkin CA, Ahmad CS. Arthroscopic articular reconstruction of capitellar osteochondral defects. *Am J Sport Med*. 2015;43(10):2452−2458.
14. Mihara K, Suzuki K, Makiuchi D, Nishinaka N, Yamaguchi K, Tsutsui H. Surgical treatment for osteochondritis dissecans of the humeral capitellum. *J Shoulder Elbow Surg*. 2010;19(1):31−37.
15. Shi LL, Bae DS, Kocher MS, Micheli LJ, Waters PM. Contained versus uncontained lesions in juvenile elbow osteochondritis dissecans. *J Pediatr Orthop*. 2012;32(3):221−225.
16. Johnson CC, Roberts S, Mintz D, Fabricant PD, Hotchkiss RN, Daluiski A. Location of osteochondritis dissecans lesions of the capitellum. *J Hand Surg Am*. 2018;43(11):1039.e1−1039.e7.
17. Yasui Y, Hannon CP, Fraser EJ, et al. Lesion size measured on MRI does not accurately reflect arthroscopic measurement in talar osteochondral lesions. *Orthop J Sports Med*. 2019;7(2): 2325967118825261.
18. Kijowski R, De Smet A. MRI findings of osteochondritis dissecans of the capitellum with surgical correlation. *AJR Am J Roentgenol*. 2005;185(6):1453−1459.
19. Blagus R, Goeman JJ. What (not) to expect when classifying rare events. *Brief Bioinform*. 2018;19(2):341−349.
20. Lin WJ, Chen JJ. Class-imbalanced classifiers for high-dimensional data. *Brief Bioinform*. 2013;14(1):13−26.