Age Predicts Disruption of the Articular Surface of the Femoral Condyles in Knee OCD: Can We Reduce Usage of Arthroscopy and MRI?

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Background: The purpose of this study was to determine if patient age could accurately identify disrupted articular cartilage overlying an osteochondritis dissecans (OCD) lesion of the femoral condyle in adolescents. This could have important implications for imaging and treatment decisions.

Methods: All patients from 2001 to 2014 who were arthroscopically treated for a femoral condyle OCD were included in this Institutional Review Board-approved study. Exclusion criteria were trochlear and patellar OCD lesions, idiopathic arthritis, and traumatic osteochondral injuries. Arthroscopy was performed to visualize and probe the articular surface. Arthroscopic and magnetic resonance imaging (MRI) findings were recorded as "intact" or "disrupted" cartilage. Extra-articular drilling was performed when the articular cartilage was intact.

Results: There were 119 patients (81 male, 68%) with 139 OCD lesions in 136 knees. The mean age at time of surgery was 13.0 years (range, 7.2 to 19.3 y). At arthroscopy, 115 knees had intact cartilage and 24 had disrupted cartilage. There was a significant difference in age between patients with intact versus disrupted cartilage at arthroscopy (12.5 vs. 15.3 y; $P < 0.0001$). Eighty-eight OCD lesions had MRIs preoperatively, showing 69 as intact and 19 (24%) disrupted. MRI reading for cartilage status had 94% sensitivity and 97% specificity. Multivariable regression analysis revealed that age ($P < 0.01$) and MRI status ($P < 0.0001$) were strong predictors of cartilage status. Sixteen years was the critical age in which both sensitivity was maximized and false positive probability was minimized. Over the age of 17 years, 7 of 7 (100%) had disrupted cartilage. Age alone was 100% sensitive for children below the age of 10, and 96% sensitive below the age of 13.

Conclusions: Age was a good predictor of cartilage status in both younger (< 13 y) and older (≥ 17 y) patients in this study. For patients in the mid-range group (13 through 16 y), age alone is not an adequate predictor of cartilage status, but adding MRI increased accuracy.

Significance: Age can be used to stratify patients and thereby influence diagnostic and treatment strategies.

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Osteochondritis dissecans (OCD) was initially described by Paget in 1870,[1] and it is a problematic cause of pain and dysfunction among adolescents.[2] In 2010, the incidence rate of knee OCD among adolescents was estimated to be approximately 9.5 cases per 100,000 adolescents.[3] Published rates of healing without surgical intervention ranged from 24% to 66%.[4–7] Subsequently, a variety of surgical interventions are used to treat lesions that fail nonoperative treatment. The status of the articular cartilage is a significant factor in the determination of appropriate treatment for OCD lesions.[8,9] Therefore, arthroscopy and magnetic resonance imaging (MRI) are often used as diagnostic strategies.

A common intervention for OCD is extra-articular, or transepiphyseal, drilling when nonoperative treatment fails to relieve symptoms.[9–13] When extra-articular drilling is performed, diagnostic arthroscopy is often only done to confirm the presence of intact cartilage. If greater certainty that the cartilage is intact can be obtained preoperatively through noninvasive measures such as prediction algorithms, then diagnostic arthroscopy may be unnecessary. Noninvasive measures, such as prediction algorithms, may increase preoperative certainty regarding cartilage status, leading to reduction in use of unnecessary diagnostic arthroscopy. Eliminating unnecessary arthroscopy would reduce the need for invasive instrumentation placed into the joint space and significantly decrease the length of the procedure, duration of anesthesia, and cost. The *a priori* purpose of this study was to determine if patient age could be used to identify knee OCD lesions with articular intact cartilage, thereby reducing the need for arthroscopy at the time of OCD surgical management. In addition, MRI findings were added as a potential predictor of cartilage status.

METHODS

Participants

Retrospective chart review was performed for this Institutional Review Board-approved study for all patients over a 14-year period (2001 to 2014) who were treated

surgically for femoral condyle OCD lesions. Patients were identified through billing records using Current Procedural Terminology (CPT) codes 29885, 29886, and 29887. Chart review was performed for all patients initially identified by CPT code to determine eligibility for this study. Inclusion criteria were patients 19 years of age or younger at the time of surgery with a femoral condyle OCD lesion. For patients with multiple surgical procedures on the same OCD, only the index surgical procedure was included. Patients with OCD lesions of other locations, such as the trochlea or patella, were excluded. Patients were also excluded if they had juvenile idiopathic arthritis or a traumatic osteochondral lesion.

Imaging

All MRI studies performed at our institution were performed on either 1.5 or 3.0-T magnet systems. The 5 magnets available within our institution changed over the course of this retrospective review with pediatric knee MRI studies performed on GE (GE Healthcare, Little Chalfont, UK), Siemens (Siemens Medical Solutions USA, Inc., Malvern, PA), and Philips (Philips Healthcare, Andover, MA) systems. Standard knee sequences performed included coronal T1 and fat-saturated T2, sagittal proton density, sagittal oblique fat-saturated T2, axial gradient echo T2*, and axial fat-saturated T2 images. The slice thickness for the prescribed sequences is standardized at 3 mm. Optional sequences included a volumetric dual echo gradient isovoxel dataset. Ten of the 88 studies were performed at outside institutions, uploaded into PACS, and reviewed retrospectively for inclusion into the study. To qualify, the outside MRIs, at a minimum, included a coronal and sagittal (or sagittal oblique) fat-saturated proton density or T2 sequences in addition to 1 standard short TE sequence without fat saturation performed in any plane. For patients who had MRI available but no radiologist interpretation, an experienced pediatric musculoskeletal radiologist viewed and interpreted the imaging, blinded to the arthroscopy findings. A new interpretation from our radiologist was also performed if the available interpretation did not clearly comment on the status of the overlying cartilage.

Data Collection

Documented variables included patient age at time of surgery, sex, laterality of the lesion, concomitant procedures, and type of procedure performed. Preoperative MRI reports were reviewed to determine if the patient had "intact" or "disrupted" cartilage overlying the OCD lesion. If multiple preoperative MRIs were available, the most recent MRI before the surgery was used. Ultimately, the cartilage status for the OCD lesion was determined based on arthroscopy findings, where the overlying cartilage was identified as intact or disrupted.

Surgical Procedure

For all patients, arthroscopy was performed by a single surgeon to visualize and probe the articular surface for fissures, and data on articular cartilage status at the time of arthroscopy were abstracted retrospectively from the operative reports and photos. If a lesion could be broached at the notch, but had intact articular cartilage (a locked door or trap door lesion), it was considered to be unstable and "disrupted." For extra-articular drilling, fluoroscopy was used to guide 0.062 K-wires placed through parallel guide (ConMed Linvatec, Utica, NY) to create a three by three drilling pattern for 9 drill tracts. The K-wires were placed through the femoral condyle into the subchondral area of the OCD lesion to perforate the sclerotic rim to stimulate revascularization of the lesion without violation of the intact cartilage surface. When the articular surface was disrupted, additional treatment was performed as guided by lesion severity.

Statistical Analyses

All statistical analyses were conducted using SAS 9.3 (Cary, NC). Descriptive statistics were computed for all variables of interest, including mean, median, SD, and range. Each predictor variable of interest (age at time of surgery and cartilage status on MRI) was analyzed independently to determine an association with cartilage status at time of arthroscopy. Two-sample t test was used to analyze the association between age and cartilage status at time of arthroscopy, as the data were normally distributed. Fischer exact test was used to analyze the association between MRI finding and cartilage status at time of arthroscopy. Fischer exact test was also used to analyze the association between patient's sex and cartilage status at time of arthroscopy.

Multivariable logistic regression was performed to assess the association between the predictors and cartilage status at time of arthroscopy. For combined analyses using both predictors, only patients who had no missing data for either predictor were included. For continuous predictors, receiver operating characteristic (ROC) curve analysis was performed to determine the area under the curve, and the Youden Index was used to determine an optimal cutoff value for the continuous predictor of age. The Youden Index identified the point on the curve where sensitivity was maximized and false-positive probability (1 − specificity) was minimized. Sensitivity, specificity, positive predictive value, and negative predictive value were calculated for the individual predictors of cartilage status on MRI and age, using a dichotomous age variable at each 1-year cut point. Patients above the age cut point were considered "test positive" (ie, assumed to have disrupted cartilage) and patients below "test negative" (ie, assumed to have intact cartilage). Statistical significance was defined as $P < 0.05$.

RESULTS

One hundred and nineteen patients met the inclusion criteria for this study, including 81 males and 38 females. Eighty-eight OCD lesions (64%) had preoperative MRI at a mean of 3.5 ± 6.5 months' preoperative. There were 139 OCD lesions in 137 knees, with 70 left and 67 right knees. The mean age at time of surgery was 13.0 years (range, 7.2 to 19.3 y). There were 115

lesions (84%) with intact cartilage and 24 (16%) with disrupted cartilage at the time of arthroscopy. Of those with disrupted cartilage, 13 lesions were in male patients and 11 were in female patients ($P = 0.09$).

One hundred and fourteen lesions underwent extra-articular drilling for treatment of the OCD lesion, all of which had intact cartilage at time of arthroscopy. Five lesions underwent arthroscopic headless screw fixation. Four of these had disrupted articular surfaces and 1 had intact cartilage, but a ballotable bony fragment. Of the remaining lesions with disrupted cartilage, 9 underwent microfracture, 5 osteochondral allograft transfer, 3 open reduction and internal fixation, and 3 underwent debridement.

In addition, 8 knees (6%) underwent concomitant procedures. There were 5 knees that underwent partial meniscectomies for discoid menisci; MRI identified all these ahead of time. There were 2 planned patellar stabilizations unrelated to the OCD, both due to recurrent patellar instability. In 1 case, a plica was found to be larger than average, so it was incidentally resected to reduce the possibility of it becoming symptomatic later. Of the knees that underwent concomitant procedures, 3 knees had disrupted articular cartilage and 5 had intact articular cartilage.

Age

There was a significant difference in age between patients with intact cartilage and patients with disrupted cartilage (12.5 vs. 15.3 y; $P < 0.0001$), with the probability of intact cartilage decreasing with age (Fig. 1). The number of disrupted lesions found at the time of arthroscopy grouped by age is listed in Table 1. The 2 youngest patients with disrupted cartilage were 10.9 and 12.6 years of age. Over the age of 14.0 years, 18/41 (44%) had disrupted articular cartilage of the femoral condyles. Over the age of 17.0 years, 7 of 7 (100%) had disrupted cartilage. Age alone was 100% sensitive for children below the age of 10, and 96% sensitive below the age of 13.0 (Table 2).

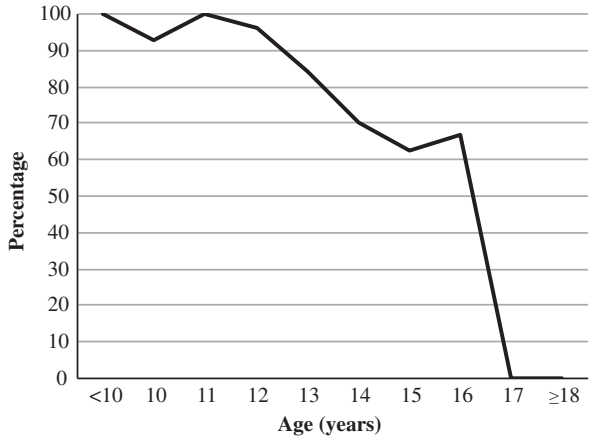

FIGURE 1. Line graph indicating the percent of intact cartilage surfaces overlying the osteochondritis dissecans lesions by age (N = 139).

TABLE 1. Count of Disrupted Cartilage Lesions Found at Time of Arthroscopy and at Time of Magnetic Resonance Imaging by Age Among Patients With Osteochondritis Dissecans Lesions

	Arthroscopy (N = 139)			MRI (N = 88)		
Age Category	n	Disrupted	Intact	n	Disrupted	Intact
Age < 10	7	0	7	7	0	7
Age 10	14	1	13	12	2	10
Age 11	26	0	26	17	0	17
Age 12	26	1	25	15	1	14
Age 13	25	4	21	19	2	17
Age 14	20	6	14	8	6	2
Age 15	8	3	5	6	4	2
Age 16	6	2	4	2	2	0
Age 17	5	5	0	3	2	1
Age ≥ 18	2	2	0	1	1	0

MRI

There were 70 (80%) intact and 18 (20%) disrupted cartilage lesions on MRI. Of the 18 lesions that did not have intact cartilage at the time of arthroscopy, 17 had MRI findings suggestive of disrupted cartilage on MRI, thus a 94% true-positive rate. Of the 70 that were interpreted as intact, 3 were disrupted according to arthroscopic probing, yielding a 4% false-negative rate. Using arthroscopic probing as the standard, MRI alone had an overall sensitivity of 94% and specificity of 97% for detecting whether the articular cartilage was disrupted.

Age+MRI

Combining age and MRI findings, multivariable regression analysis revealed that age ($P < 0.01$) and MRI status ($P < 0.0001$) were strong predictors of cartilage status. On the basis of ROC curve analysis, age and MRI findings were excellent clinical predictors of cartilage status at time of arthroscopy with an area under the curve of 0.99 (Fig. 2). In addition, 16.0 years was identified as the critical age by ROC analysis; however, 17.0 years was identified as the best cutoff value for maximizing sensitivity (Table 3). When considering combining a "test" of positive MRI result (cartilage disrupted) and patient age

TABLE 2. Sensitivities, Specificities, PPV, and NPV for Age Alone Considered as a "Test*" for Cartilage Status at Time of Arthroscopy (N = 139)

Predictors	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Age 10	100	6	18	100
Age 11	96	17	19	95
Age 12	96	40	25	98
Age 13	92	62	33	97
Age 14	75	83	44	94
Age 15	50	92	57	90
Age 16	38	97	69	88
Age 17	29	100	100	87
Age 18	8	100	100	84

*Each age cutoff value assumes all patients greater than that age have disrupted cartilage and all less than or equal to that age have intact cartilage.
NPV indicates negative predictive value; PPV, positive predictive value.

of >16 years, the sensitivity of was 100% and specificity was 97%.

DISCUSSION

The original purpose of this study was to assess whether age at time of surgery could reliably predict the status of the articular cartilage overlying a knee OCD lesion in children and adolescents. Our data suggest that with age <13.0 years the probability of disrupted cartilage is very low with only 2 of 71 (3%) patients under that age found to have a disrupted articular surface. Under the age of 10, all articular surfaces were intact. In patients >16 years, age was highly predictive for disrupted cartilage. Thus, age was a good predictor of cartilage status in both the younger (< 13 y) and the older (≥ 17 y) patients in this cohort.

Given that age alone was not found to have high sensitivity for detecting disrupted cartilage in the mid-range ages (13 through 16 y), we decided to expand our analysis to explore MRI as a predictor of cartilage status. Reliability of MRI to properly stage an OCD lesion has been questioned,[14–16] but recent improvements in MRI technology have led to improved consistency between MRI findings and arthroscopic findings.[17] Overall, MRI reading was very accurate, with 94% sensitivity and 97% specificity for identifying disrupted cartilage. There were only 2 cases in which the MRI report suggested that the cartilage was intact but the cartilage was disrupted at the time of arthroscopy. Thus, MRI was more reliable than age alone for predicting the status of the articular cartilage, but still not perfect.

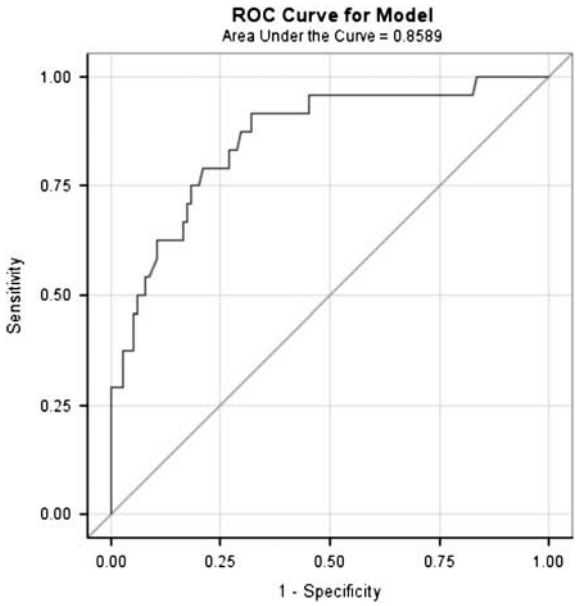

FIGURE 2. Receiver operating curve (ROC) graph for continuous age and dichotomous magnetic resonance imaging findings as predictors of the status cartilage overlying a knee osteochondritis dissecans lesion (N = 88).

By combining age and MRI status, we found that these 2 predictors had an overall 100% sensitivity and 97% specificity when using a cutoff of 16 years (assuming all patients ≥17 y have disrupted cartilage and all ≤16 y have intact cartilage). It is important to note though, that in patients <13 years, age alone was highly predictive, making the addition of MRI results of minimal benefit in this age group. In addition, in patients ≥17 years, age alone was highly predictive of disrupted cartilage, again making the addition of MRI results of marginal benefit in this age group.

These data call into question the value of routine MRI and diagnostic arthroscopy at various ages. For most physicians, the status of the articular cartilage is an important branch point in their treatment algorithm. Our conclusion is that age is very useful in predicting cartilage status. Our data suggest that adolescent OCD patients can be sorted into 3 groups: <13 years, 13 through 16 years, and ≥17 years.

Patients <13 years have a very high probability of intact cartilage, so MRI only marginally increases the sensitivity in detecting cartilage disruption (96% vs. 100%). Similarly, diagnostic arthroscopy provides little increased incremental accuracy. Therefore, arthroscopy may be unnecessary if extra-articular drilling is the planned treatment. For patients in the mid-range group (13 through 16 y), age alone is not an adequate predictor of cartilage status, but adding MRI increases accuracy. In this age group, MRI and/or diagnostic arthroscopy probably provide significant value. In older patients, ≥17 years, the probability of disrupted cartilage is so high that MRI and diagnostic arthroscopy may be of marginal value and should be carefully considered in the context of the physician's treatment algorithm.

It is important to note that diagnostic arthroscopy may also be beneficial for assessing concomitant intra-articular pathology. In our series, 8 knees (6%) underwent concomitant procedures at the time of arthroscopy. Three knees had disrupted articular cartilage, whereas 5 had intact cartilage. All but one had a preoperative MRI. These findings suggest that the percentage of knees with OCD lesions of the femoral condyles that require concomitant procedures for intra-articular pathology is small, but the findings also underscore the fact that even the best predictive algorithms do not apply to 100% of cases. Predictive algorithms should be used as a tool to assist with clinical decision making, in combination with a variety of patient, radiographic, and clinical examination factors. Predictors of cartilage status can be used as a tool to assist with determining appropriate surgical treatment strategies and potentially limit unnecessary diagnostic arthroscopy at the time of OCD surgical management.

Limitations

There are limitations that should be considered when analyzing these results. First, the number of patients with disrupted cartilage was small. With more cases of disrupted cartilage, we would have a better sense of the predictive values of our tests. Second, not all patients had

TABLE 3. Sensitivities, Specificities, PPV, and NPV for MRI Alone and Age+MRI Findings Considered as a "Test*" for Cartilage Status at Time of Arthroscopy Among Patients With OCD Lesions (N = 88)

Predictors	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
MRI+	94	97	89	99
Age 10.0 and MRI+	100	10	22	100
Age 11.0 and MRI+	100	23	25	100
Age 12.0 and MRI+	100	45	31	100
Age 13.0 and MRI+	100	67	44	100
Age 14.0 and MRI+	100	90	72	100
Age 15.0 and MRI+	100	94	82	100
Age 16.0 and MRI+	100	97	90	100
Age 17.0 and MRI+	100	97	90	100
Age 18.0 and MRI+	94	97	89	99

*Each age cutoff value assumes all patients greater than that age have disrupted cartilage and all less than or equal to that age have intact cartilage.
MRI indicates magnetic resonance imaging; NPV, negative predictive value; OCD, osteochondritis dissecans; PPV, positive predictive value.

an MRI, which could affect the generalizability of our findings. Our original study question assessed only age and arthroscopy findings, thus we included patients regardless of preoperative MRI. With the expansion of our study to include MRI findings, we chose to continue to include those patients without preoperative MRI due to the sample size for analyzing the predictability of age alone. Also, a single musculoskeletal radiologist performed all MRI readings to determine the cartilage status. Finally, other variables might also predict cartilage status, such as examination findings or patient factors. Unfortunately, these data were not consistently available for review in this retrospective study.

CONCLUSIONS

The results of this study suggest that predictors, such as age and MRI findings, can be used to determine cartilage status before surgery for OCD lesions. Age was a good predictor of cartilage status in both younger (< 13 y) and older (≥ 17 y) patients in this study. For patients in the mid-range group (13 through 16 y), age alone is not an adequate predictor of cartilage status, but adding MRI increases accuracy. These predictors can be used to determine appropriate surgical treatment strategies and potentially limit unnecessary diagnostic arthroscopy at the time of OCD surgical management. Future prospective studies should validate these findings and include other potential predictors of interest.

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