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# Activity level and severity of dysplasia predict age at bernese periacetabular osteotomy for symptomatic hip dysplasia

Travis Matheney
*Boston Children's Hospital*

Ira Zaltz
*Oakland Orthopaedic Surgery*

Young-Jo Kim
*Boston Children's Hospital*

Perry Schoenecker
*St. Louis Children's Hospital*

Michael Millis
*Boston Children's Hospital*

***See next page for additional authors***

**A commentary by Carsten Frank Perka, MD** is linked to the online version of this article at jbjs.org.

# Activity Level and Severity of Dysplasia Predict Age at Bernese Periacetabular Osteotomy for Symptomatic Hip Dysplasia

Travis Matheney, MD, Ira Zaltz, MD, Young-Jo Kim, MD, PhD, Perry Schoenecker, MD, Michael Millis, MD, David Podeszwa, MD, David Zurakowski, PhD, Paul Beaulé, MD, and John Clohisy, MD, on behalf of the ANCHOR Study Group

**Background:** The age when patients present for treatment of symptomatic developmental dysplasia of the hip with periacetabular osteotomy (PAO) varies widely. Modifiable factors influencing age at surgery include preexisting activity level and body mass index (BMI). The severity of the hip dysplasia has also been implicated as a factor influencing the age at arthritis onset. The purpose of this study was to determine whether activity level, BMI, and severity of dysplasia are independent predictors of age of presentation for PAO.

**Methods:** A retrospective, institutional review board-approved review of prospectively collected data from a multicenter study group identified 708 PAOs performed for developmental dysplasia of the hip. Demographic factors that were considered in the analysis included age at surgery, BMI, history of hip disorder or treatment, and duration of symptoms. The severity of the developmental dysplasia of the hip was assessed by radiographic measurement of the lateral and anterior center-edge angles and acetabular inclination. Activity level was assessed with the University of California, Los Angeles (UCLA) activity score. Spearman correlations and t tests were used for univariable analysis. Multivariable regression analysis using generalized estimating equations was applied to determine independent predictors of age at PAO.

**Results:** Univariable analysis indicated that age at presentation for treatment of PAO correlated with the lateral and anterior center-edge angles ($p < 0.001$), UCLA score ($p < 0.001$), and BMI ($p = 0.04$). Since the lateral and anterior center-edge angles were similarly correlated (Spearman rho = 0.61, $p < 0.001$), the lateral center-edge angle alone was used to classify the severity of the developmental dysplasia of the hip. Multivariable linear regression confirmed that a high UCLA score and severe hip dysplasia were independent predictors of age at PAO ($p < 0.001$).

**Conclusions:** A high activity level and severe dysplasia lead to the development of symptoms and presentation for PAO at significantly younger ages. The combination of these two factors has an even greater effect on decreasing the age at presentation for hip-preserving surgery. An increased BMI was not independently associated with a younger age at surgery. Modifying activity level may be beneficial in terms of delaying the onset of symptoms from developmental dysplasia of the hip.

**Level of Evidence:** Prognostic Level IV. See Instructions for Authors for a complete description of levels of evidence.

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Developmental dysplasia of the hip remains the most common cause of hip osteoarthritis[1-4]. The incidence of adult hip dysplasia is not known as not all affected hips are believed to develop symptomatic osteoarthritis. Reports on hips that became symptomatic have described risk factors for end-stage arthritis leading to arthroplasty, including increased activity level, high body mass index (BMI), female sex, and increased severity of hip dysplasia, with the first two

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being considered modifiable[5-14]. We consider these factors when counseling this typically older patient group about changing potentially disease-modifying risk factors by losing weight and decreasing activity.

With increasing early recognition of hip dysplasia and well-described good-to-excellent outcomes of joint-preserving surgery, younger patients (typically less than forty years of age) are more commonly being referred for evaluation and treatment before end-stage osteoarthritis has occurred. Prior investigators have reported the radiographic appearance of hips treated with periacetabular osteotomy (PAO) and have demonstrated that increased severity of dysplasia is associated with a higher risk of end-stage hip osteoarthritis[15-23]. Debate continues as to whether modifiable factors, such as a higher BMI and activity level, increase the risk of hip osteoarthritis and the need for subsequent total hip arthroplasty. To our knowledge, no one has assessed how these same risk factors affect the age at onset of hip pain and/or the age at presentation for hip-preservation surgery in the adolescent and younger adult (less than forty-year-old) population. This becomes an important issue when this typically younger patient presents with an incidental finding of hip dysplasia but minimal or no symptoms and inquires about modifications to lifestyle or body habitus that might affect the onset of symptomatic osteoarthritis.

The primary aim of this study was to determine whether modifiable factors such as higher activity level and BMI lead to a decreased age at presentation for PAO. A secondary aim was to assess whether the severity of dysplasia has an effect on age at PAO and whether there is any additional effect when it exists in combination with the modifiable risk factors mentioned above. Finally, as adolescent and young adult patients with pre-arthritic hip dysplasia often inquire about the typical age at symptom onset, we sought to determine whether there was a consistent relationship between age at surgery and patient-reported duration of symptoms.

## Materials and Methods

We conducted a retrospective, institutional review board-approved analysis of data that had been prospectively collected at nine centers that perform the Bernese PAO. The primary inclusion criterion was symptomatic developmental dysplasia of the hip treated with Bernese PAO. Exclusion criteria were any evidence of concomitant femoroacetabular impingement morphology, neuromuscular conditions, a history of substantial hip trauma, or connective-tissue disease. When a patient had bilateral hip dysplasia and had undergone bilateral PAO, the date of the first surgery was used to determine the age at presentation for surgical treatment. On enrollment in this study, patients were asked to complete a questionnaire that included questions about their preoperative activity level and duration of hip-related symptoms.

We identified 756 PAOs performed for symptomatic developmental dysplasia of the hip, and complete radiographic and questionnaire data were available for final multivariable analysis for 708 of these hips. Of the remaining hips, thirty-two had missing radiographic data; twenty-six, missing activity scores; and six, missing BMI data. Demographic and clinical information included age at surgery, sex, BMI, duration of hip pain, and activity level. The BMI was categorized as either >30 kg/m$^2$ or ≤30 kg/m$^2$.

A history of a hip disorder or treatment may affect the timing of presentation for PAO for hip dysplasia. Therefore, we recorded whether patients had undergone treatment for any other condition related to hip dysplasia or femoroacetabular impingement. Included in this group were patients treated with bracing or surgery for infant or childhood hip dysplasia, arthroscopy for a labral tear or impingement, or osteotomy for proximal femoral deformity.

### *Radiographic Measures*

The severity of the acetabular dysplasia was assessed with standardized radiographs of the pelvis and hip, including anteroposterior and false-profile views. Radiographic measures included the lateral center-edge angle of Wiberg, anterior center-edge angle of Lequesne and de Sèze, and acetabular inclination (Tönnis sourcil angle)[24-26]. Radiographs were measured by the treating physician, as a prior study had shown adequate interobserver reliability of such measurements[27] and because of restrictions applied by the institutional review boards of individual centers. Patient data were anonymized before they were submitted to a central data-collection site. On the basis of prior work[28], center-edge angles of >15° to 25° were considered to indicate mild dysplasia; 5° to 15°, moderate; and <5°, severe. Acetabular inclination of 10° to 20° was considered to indicate mild dysplasia; 21° to 30°, moderate; and >30°, severe.

The association between the radiographic appearance of the osteoarthritis and arthritis-related pain can be variable[29-33]. Additionally, a primary goal of hip-preserving surgery is to prevent the onset of arthrosis. Thus, no hip that had greater than Tönnis grade-2 changes (grade 2 = joint space narrowing with subchondral cysts) were included in the study, and we did not include radiographic evidence of osteoarthritis as a measure to predict age at surgery[34].

### *Activity Assessment*

Activity level was assessed with the University of California, Los Angeles (UCLA) activity score (1 to 10), a validated, reliable, self-reported metric of physical activity of patients with osteoarthritis of the hip (Fig. 1)[35]. To evaluate the relationship between activity level and age at surgery, we subcategorized patients as being minimally active (a UCLA score of 1 to 4), moderately active (5, 6, or 7), or highly active (8, 9, or 10).

### *Duration of Symptoms and Age at Symptom Onset*

Several factors may contribute to the time that it takes to develop symptoms severe enough for an individual to seek medical advice regarding care. Because of the difficulty in evaluating and summarizing all possible reasons for a delay in treatment of symptomatic hip dysplasia, the patients were asked the duration of their symptoms before they underwent surgery. Symptom duration was classified as less than six months, six to twelve months, one to three years, three to five years, or more than five years. We then assessed whether the duration of symptoms was

**Check one level that best describes current activity level.**

1: Wholly Inactive, dependent on others, and can not leave residence

2: Mostly Inactive or restricted to minimum activities of daily living

3: Sometimes participates in mild activities, such as walking, limited housework and limited shopping

4: Regularly Participates in mild activities

5: Sometimes participates in moderate activities such as swimming or could do unlimited housework or shopping

6: Regularly participates in moderate activities

7: Regularly participates in active events such as bicycling

8: Regularly participates in active events, such as golf or bowling

9: Sometimes participates in impact sports such as jogging, tennis, skiing, acrobatics, ballet, heavy labor or backpacking

10: Regularly participates in impact sports

Fig. 1

The UCLA activity score, which is used to rate activity over the previous six months on a scale of 1 to 10, with 10 being the highest level of activity.

**TABLE I Demographic and Radiographic Variables Assessed for Effect on Age at PAO**

| | No. of Hips* | Mean Age at PAO and Stand. Dev. *(yr)* | Multivariable Analysis† |
|---|---|---|---|
| Sex | | | P = 0.176 |
| Male | 118 | 25.2 ± 8.8 | |
| Female | 638 | 25.4 ± 9.5 | |
| Side | | | P = 0.854 |
| Right | 422 | 25.5 ± 9.2 | |
| Left | 334 | 25.3 ± 9.7 | |
| Severity of developmental dysplasia of hip | | | |
| Per center-edge angle | | | P < 0.001 |
| Mild (>15°) | 252 | 26.0 ± 8.9 | |
| Moderate (5°-15°) | 286 | 26.9 ± 10.1 | |
| Severe (<5°) | 192 | 22.8 ± 8.2 | |
| Per acetabular inclination | | | P = 0.275 |
| Mild (10°-20°) | 215 | 25.1 ± 8.7 | |
| Moderate (21°-30°) | 279 | 26.4 ± 9.7 | |
| Severe (>30°) | 230 | 24.6 ± 9.5 | |
| UCLA score | | | P < 0.001 |
| 1-4 (minimal activity) | 209 | 26.5 ± 9.7 | |
| 5-7 (moderate activity) | 225 | 27.0 ± 9.4 | |
| 8-10 (high activity) | 296 | 23.4 ± 8.9 | |
| BMI | | | P = 0.097 |
| >30 kg/m$^2$ | 94 | 25.1 ± 9.5 | |
| ≤30 kg/m$^2$ | 656 | 27.3 ± 8.5 | |
| Prior hip treatment | | | P = 0.002 |
| No | 516 | 26.1 ± 9.6 | |
| Yes | 240 | 23.8 ± 9.0 | |

*Raw number of all hips available for univariable analysis. †Multivariable analysis based on 708 hips with complete demographic and radiographic data.

correlated with the age at surgery, with the specific goal of determining whether symptom duration was associated with an older age at surgery.

### *Statistical Analysis*

Spearman correlations, Student t tests, and analysis of variance (ANOVA) were used for univariable analysis. Age was normally distributed. However, the lateral center-edge angle, anterior center-edge angle, and acetabular inclination were not; therefore, Spearman rho correlations were used. Multivariable regression analysis using generalized estimating equations was applied to determine independent predictors of age at PAO. Statistical analysis was performed using SPSS Statistics (version 22.0; IBM). Two-tailed values of $p < 0.05$ were considered significant.

## Results

Univariable analyses were conducted using the number of hips for which the data on the specific factor were available (Table I). The multivariable analysis included the 708 hips for which complete radiographic and questionnaire data were available. Univariable analysis showed that, of the demographic factors studied, a BMI of >30 kg/m$^2$ was associated with a younger age at surgery ($p = 0.04$). A history of hip surgery was also associated with a younger age at PAO and proved to be independently predictive of an earlier age at PAO on multivariable analysis ($p = 0.002$). Patients with a history of a treated hip condition underwent osteotomy an average of 2.3 years earlier than those without a history of treatment

**TABLE II Duration of Symptoms by Category and Age at PAO**

| Duration of Symptoms | No. of Hips | Mean Age at PAO and Stand. Dev. *(yr)* |
|---|---|---|
| <6 mo | 35 | 20.7 ± 8.4 |
| 6-12 mo | 178 | 23.3 ± 9.4 |
| 1-3 yr | 298 | 25.4 ± 9.6 |
| 3-5 yr | 100 | 24.5 ± 7.9 |
| >5 yr | 126 | 29.9 ± 8.8 |

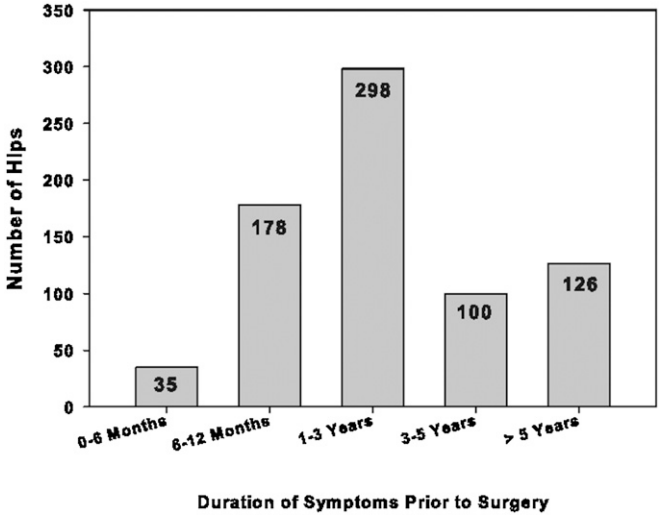


Fig. 2

Histogram illustrating the number of responses to the general question, "How long did you have hip pain/symptoms prior to PAO?" The number at the top of each bar is the number of respondents reporting that duration of symptoms; this number is based on all available respondent data.

(Table I). We did not find a significant correlation between activity level and BMI.

*Activity Level and Age at Surgery*

Univariable and multivariable linear regression analyses confirmed that the UCLA activity score was independently predictive of the age at PAO. With increasing activity level, patients presented at younger ages for PAO ($p < 0.001$). The most significant difference was between patients who were mildly or moderately active (mean age at PAO, 26.5 and 27.0 years, respectively) and those who described themselves as highly active (mean age at PAO, 23.4 years) ($p < 0.001$). There was no significant difference in age at presentation for surgery between patients who described themselves as minimally active and those who were moderately active ($p = 0.56$).

*Dysplasia Severity and Age at Surgery*

Univariable analysis indicated that age at PAO was directly correlated with the lateral center-edge angle (rho = −0.69, $p < 0.001$) and anterior center-edge angle (rho = −0.63, $p < 0.001$) but not with acetabular inclination (rho = −0.04, $p = 0.21$). Since the lateral and anterior center-edge angles showed a strong correlation with each other (rho = 0.68, $p < 0.001$), the lateral center-edge angle was used to define the severity of developmental dysplasia of the hip as mild (>15° to 25°), moderate (5° to 15°), or severe (<5°). Multivariable linear regression analysis confirmed that the lateral center-edge angle was independently predictive of the age at surgery ($p < 0.001$). Severe dysplasia was associated with a younger age at surgery. There was a significant difference between hips with mild or moderate dysplasia and those with severe dysplasia, with mean ages at surgery of 26.0 and 26.9 years versus 22.8 years, respectively ($p < 0.001$). There was no significant difference in the age at surgery between patients with mild and those with moderate dysplasia ($p = 0.28$).

*Duration of Hip Pain Prior to Surgery*

A majority of patients described having had symptoms for one to three years prior to surgery (Fig. 2). There was a trend for patients who were older at the time of surgery reporting that they had had symptoms for a longer period of time, with almost every increase in symptom-duration category associated with an increase in the average age at surgery (Table II). When we subtracted the duration of symptoms from the age at surgery, the majority of patients in this study group described symptom onset between the ages of twenty and twenty-five years.

*Relationship of Activity Level and Dysplasia Severity with Age at Surgery*

The most significant decreases in age at surgery for symptomatic hip dysplasia were for highly active patients with severe hip dysplasia. To evaluate the relationship between dysplasia severity and activity level, we compared four groups: (1) mild or moderate dysplasia and minimal or moderate activity, (2) mild or moderate dysplasia and a high activity level, (3) severe dysplasia and minimal or moderate activity, and (4) severe dysplasia and a high activity level (Fig. 3). Patients in Groups 2 and 3 presented for surgery at a significantly younger age than patients in Group 1. Patients in Group 4 presented at a significantly younger age than those in Groups 1, 2, and 3 (Fig. 3).

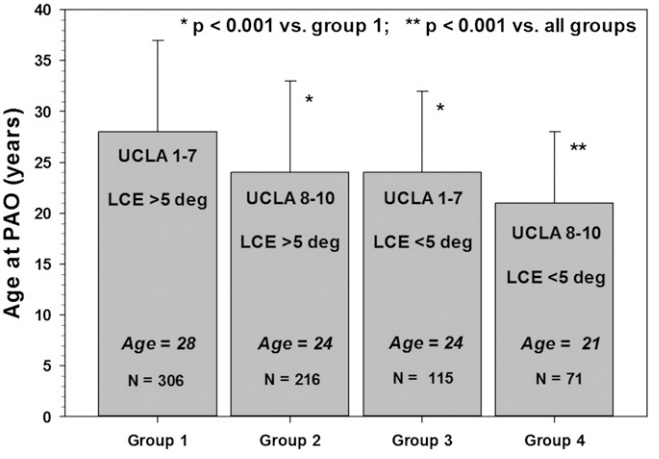


Fig. 3

Histogram comparing the average ages at PAO, with standard error bars, across four groups based on the patient's activity level and severity of developmental dysplasia of the hip. Group 1 = minimally or moderately active patients with mild or moderate dysplasia, Group 2 = highly active patients with mild or moderate dysplasia, Group 3 = minimally or moderately active patients with severe dysplasia, and Group 4 = highly active patients with severe dysplasia. Listed toward the bottom of each histogram bar are the average ages at the PAO and number of patients in the specific group. *Indicates that the average age at the PAO was significantly lower in Groups 2 and 3 compared with Group 1. **Indicates that the average age at the PAO in Group 4 was significantly lower compared with Groups 1, 2, and 3. UCLA = UCLA activity score, and LCE = lateral center-edge angle.

## Discussion

Highly active patients with more severe hip dysplasia presented for PAO at younger ages. The largest number of patients experienced hip pain between one and three years prior to treatment. On average, the majority of patients in this study reported that their symptoms began between the ages of twenty and twenty-five years. Additionally, if a patient had a known hip condition prior to PAO, they presented for surgery at an average of 2.3 years earlier than those who did not.

Activity level has been evaluated as a contributor to hip arthritis in population-based studies. Schmitt et al. found a slightly increased risk of early hip arthrosis in former elite marathon runners[36]. The UCLA activity score was utilized in the current study to assess physical activity. We found that, in this younger patient population with hip dysplasia, increased activity was directly associated with earlier presentation for hip-preserving surgery. Moreover, patients who described themselves as highly active presented at a significantly younger age than those who were minimally or moderately active in their daily lives. While the current study does not allow us to definitively state that decreasing activity level will change the rate at which a dysplastic hip becomes arthritic, this study of more than 700 cases of hip dysplasia revealed that patients with a "highly active" lifestyle (as determined by UCLA scoring criteria) developed pain and presented for treatment at significantly younger ages than less active patients with hip dysplasia of similar severity.

It seems intuitive that more severe dysplasia would place a hip at higher risk for early arthrosis. Several prior studies have shown an association between increasing severity of hip dysplasia and a younger age at the time of presentation for arthroplasty for end-stage hip arthritis[9,11,37]. In two separate large cohort studies, Jacobsen and Sonne-Holm[9] and Jingushi et al.[38] reported that more severe dysplasia led to an increased prevalence and earlier presentation of hip osteoarthritis and hip arthroplasty. We found the same relationship—i.e., a clear association between severity of dysplasia and age at surgery—in a younger patient population seeking hip-preservation surgery (PAO). The most significant decrease in age was seen in the patients with severe hip dysplasia (Table I), who presented for PAO at an average age of 22.8 years, compared with patients with mild or moderate dysplasia, who presented for surgery at average ages of 26.0 and 26.9 years, respectively.

There was no significant difference in age at surgery between the group with mild dysplasia and the group with moderate dysplasia. Although there are several possible reasons for this, this finding means that the hypothesis that moderately and severely dysplastic hips are more unstable than hips with mild dysplasia is only partially corroborated by our data. Also, due to the difficulty with clinical measurement, we were not able to accurately assess hip stability to corroborate this hypothesis.

After finding that activity level and severity of dysplasia were independently associated with age at surgery, we sought to determine whether there was a definable relationship among the three factors (Fig. 3). The patients with the highest level of activity (UCLA score of 8, 9, or 10) and those with severe dysplasia (lateral center-edge angle of <5°) had the youngest ages when they presented for surgery, an average of four years younger than those in the other subgroups for each variable. We studied the various combinations of these two variables, which to our knowledge has not been done before in this population to this degree. The combination of severe dysplasia and a high activity level seemed to have the greatest effect, causing patients to present for surgery at an average of seven years earlier (at an average age of twenty-one years) than patients who were minimally or moderately active and had mild to moderate amounts of hip dysplasia (twenty-eight years) (Fig. 3).

Other factors have also been associated with an increased risk of end-stage osteoarthritis. In the Melbourne Collaborative Cohort Study of more than 38,000 people, Wang et al. found that those with an increased BMI had an increased risk of total hip replacement[39]. Our univariable analysis demonstrated similar results with respect to PAO. However, the multivariable regression analysis failed to prove that BMI had a significant, independent effect on the age at surgery. Therefore, while BMI had an effect, it did not reach significance when the aforementioned factors of dysplasia severity and activity level were taken into account.

Finally, in addition to studying the factors that modify the age at which patients with symptomatic developmental dysplasia of the hip present for surgery, we wanted to assess whether there was a pattern with regard to how long patients had been experiencing pain prior to surgery. The goal was to determine whether it would be possible to provide patients with an average age at which their type of dysplasia might begin to produce symptoms on the basis of their level of activity. Although this was not a natural history study of all dysplastic hips, we evaluated more than 700 patients who varied with respect to demographic factors, amounts of dysplasia, and levels of activity and asked them how long they had been experiencing pain. We think that questioning patients regarding their duration of symptoms is appropriate as it is difficult to accurately and fully record the multitude of reasons that patients do not undergo joint-preserving surgery for their dysplasia. We found a spectrum of symptom durations, with the majority of patients noting that they experienced pain for one to three years prior to undergoing joint-preserving surgery (Fig. 2). When we considered the average age at surgery for the various groupings for duration of symptoms, there was a trend for patients who were older at the time of surgery reporting that they had had symptoms for a longer period of time.

There are several limitations of this analysis. The most important is that we did not know the number of patients with asymptomatic hip dysplasia who did not become symptomatic or present for surgery. Second, the UCLA score records activity level over the previous six months, not an average over the lifetime of the hip. It is difficult to determine how activity levels at younger ages may have contributed to the current activity level. Also, we did not assess osteoarthritis radiographically in this study. This was because of the poor correlation between radiographic appearance and symptoms and the typically poor interobserver reliability of radiographic assessment of osteoarthritis[27,40]. Finally, we cannot say whether modification of

weight and/or activity level will impact the development of osteoarthritis. We can only state that people who had a higher activity level and more severe dysplasia seemed to develop pain and undergo surgery at a younger age.

More patients are both learning about the etiology of their hip pain when it starts and choosing to undergo joint-preserving surgery. Given multiple reports of good-to-excellent mid-term to long-term outcomes in the majority of patients, and the fact that the average duration of hospitalization has decreased to three to four days from a week, more surgeons are considering hip-preservation surgery a viable option instead of asking patients to change their lifestyle, stop any substantial activity, and await hip replacement. Results from this study confirm previous beliefs that increased dysplasia severity and activity level may lead to painful arthrosis at a younger age and therefore could be utilized to advise patients who are considering activity modification and the timing of hip-preservation surgery. ■

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Travis Matheney, MD[1]
Ira Zaltz, MD[2]
Young-Jo Kim, MD, PhD[1]
Perry Schoenecker, MD[3]
Michael Millis, MD[1]
David Podeszwa, MD[4]
David Zurakowski, PhD[1]
Paul Beaulé, MD[5]
John Clohisy, MD[6]

[1]Boston Children's Hospital,
Boston, Massachusetts

[2]Oakland Orthopaedic Surgeons,
Royal Oak, Michigan

[3]St. Louis Children's Hospital,
St. Louis, Missouri

[4]Texas Scottish Rite Hospital for Children,
Dallas, Texas

[5]Department of Surgery,
University of Ottawa,
Ottawa, Ontario, Canada

[6]Washington University in St. Louis,
St. Louis, Missouri

E-mail address for T. Matheney:
Travis.matheney@childrens.harvard.edu

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