The relationship between pre-operative pain characteristics and periacetabular osteotomy outcomes in patients with acetabular dysplasia

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ABSTRACT

The aims of this study were to determine if pre-operative pain characteristics (location of maximum severity of pain, presence of non-groin pain, maximum severity of pain and number of pain locations) affect patient-reported outcome measures in patients undergoing periacetabular osteotomy (PAO) for acetabular dysplasia. We reviewed 52 hips (48 patients) treated with PAO for acetabular dysplasia from February 2017 to July 2020 using modified Harris Hip Score (mHHS), Hip Outcome Score (HOS) and international Hip Outcome Tool (iHOT-12) score, radiographic analysis and pain location/severity questionnaires. Descriptive statistics, analysis of covariance and Spearman partial correlation coefficients were implemented. Twenty-six hips experienced the most severe pre-operative pain in the groin, and 26 hips experienced equal or more severe pain in the same location. Twenty-six hips experienced the most severe pre-operative pain in the groin, and 26 hips experienced equal or more severe pain in the same location. Twenty-six hips experienced the most severe pre-operative pain in the groin, and 26 hips experienced equal or more severe pain in the same location.

INTRODUCTION

Acetabular dysplasia in young adults plays a large role in the pathogenesis of early osteoarthritis leading to total hip arthroplasty (THA) [1–3]. Therefore, hip preservation with the Bernese Periacetabular Osteotomy (PAO) is the preferred procedure for acetabular dysplasia since PAO is well-tolerated and has favourable outcomes that allow for an active lifestyle [4–7].

Patients undergoing PAO for acetabular dysplasia report different presentations of pain. Acetabular dysplasia has been attributed as a major cause of hip pain in adolescents because it can result in hip instability [5]. Pain can arise due to inflammation or capsulitis of the hip joint itself. However, other locations of pain can arise as the instability of the hip places increased load on other stabilizers, such as the iliopsoas [8]. In a study of 65 hips, Nunley et al. found that patients with acetabular dysplasia most commonly have pain in the groin (72%), lateral hip (66%) anterior thigh (29%) and the buttock (18%) [9]. Based on where the hip instability places the most stress, and the intensity of that stress, it can lead patients with acetabular dysplasia to have varying pre-operative pain characteristics.

Although pain characteristics, outcomes and potential complications for patients who undergo PAO are understood, to our knowledge, no study has evaluated the relationship between pre-operative pain characteristics and post-operative patient-reported outcome measures (PROM). Moreover, the relationship between pain severity and the number of pain locations with post-operative PROM is unknown. As PAO is becoming more widely used [10–14], there is a need to study the relationship between pain characteristics and patient outcomes to better educate providers and determine, which patients will most benefit from PAO.

We therefore sought to answer the following questions in patients who underwent PAO for acetabular dysplasia: (i) Does maximum severity of pain in a location other than the groin that...
is greater or equal to that of the groin affect PROM? (ii) Does the presence of non-groin pain affect PROM? (iii) Does the severity of pain affect PROM? (iv) Does the number of pain locations affect PROM?

**MATERIALS AND METHODS**

**Participants**

This is a prospective case series of 52 hips (48 patients) that underwent PAO by a single, fellowship-trained orthopaedic surgeon in hip preservation. We obtained institutional review board approval for the study. Inclusion criteria were all patients who underwent PAO for symptomatic acetabular dysplasia from February 2017 to July 2020. Exclusion criteria were patients with neuromuscular disorders, prior trauma or diagnosis other than acetabular dysplasia. Patients who presented to the treating orthopaedic surgeon with acetabular dysplasia [9], radiographic evidence of femoral head uncovering and a lateral centre-edge angle of <25° were offered treatment with PAO. In total, 52 PAOs were performed on 48 patients during the study period with no patients meeting the exclusion criteria or being lost to follow-up.

**Surgical technique**

The PAO surgical technique reported by Matheney *et al.* [15] was performed according to Ganz *et al.* [16] with the abductor-sparing approach described by Murphy and Millis [17]. PAO was performed on 30 right hips (58%) and 22 left hips (42%). Forty-six hips (88%) had concurrent procedures. Forty-three hips underwent hip arthroscopy for the treatment of labral resection or repair, and 15 hips underwent femoral head-neck osteochondroplasty using an arthrotomy via a Smith-Petersen approach for the treatment of abnormal femoral head-neck offset resulting in hip impingement. Twelve of the 43 hips that underwent concurrent labral resection or repair also had concurrent osteochondroplasty.

**Clinical and radiographical outcomes**

Location of maximum pain severity, number of pain locations, maximum severity of pain, modified Harris Hip Score (mHHS), Hip Outcome Score (HOS) and international Hip Outcome Tool (iHOT-12) were assessed by patient self-reported hip questionnaires completed at pre-operative and post-operative visits [18–21]. Post-operative measures were taken at the most current follow-up appointment. The mHHS, HOS and iHOT-12 range on a scale of 0–100, with 100 being the highest possible score for each outcome measure. The minimal clinical important difference (MCID) values used in this study for mHHS, HOS and iHOT-12 are 8, 6 (Kemp *et al.* reported individual MCIDs for HOS-ADL and HOS-SS subscales. When these are combined, taking into account the weight of the individual sub-scores, the HOS MCID is 5.3. We rounded this up to 6 to be more rigorous.) and 13.0, respectively [22, 23].

Patients marked their locations of pain on the questionnaires. Pain could be located in the groin, anterior thigh, knee, lower back, buttck, posterior thigh, trochanter and/or lateral thigh. In addition, patients noted the severity of pain at each location based on the following, previously reported scale [24–27]:

0 = No Pain, 1 = Pain with extreme activity only, 2 = Pain with moderate activity or specific movements only, 3 = Pain with daily activities, 4 = Pain at rest during the day and 5 = Pain at night that wakes you up or pain all the time (Fig. 1, p. 14).

Pre-operative and post-operative radiographical measurements were made by the treating orthopaedic surgeon. These included Tonnis Grade, anterior centre-edge angle (ACEA), lateral centre-edge angle (LCEA), Tonnis Angle, Alpha angle measured in the Frog-leg view and Alpha angle measured in the Dunn view. Intra-reader reliability values (k) for these measurements are k(Tonnis Grade) = 0.57, k(ACEA) = 0.88, k(LCEA) = 0.88, k(Tonnis Angle) = 0.83, k(Alpha Frog) = 0.76 and k(Alpha Dunn) = 0.98 [28, 29]. Age, sex, race, previous hip surgery, weight, height and body mass index (BMI) data were collected from medical records.

**Statistical analysis**

Demographic and clinical characteristics for the sample of patients who underwent PAO for symptomatic acetabular dysplasia were described using the sample mean and standard deviation for continuous variables and the frequency and percentage for categorical variables. A separate fixed-effects general linear model analysis of covariance (ANCOVA), with robust standard errors (HC3 sandwich first order residual empirical estimator), was used to examine the main effect of PAO location on each post-operative PROM, while controlling for pre-operative patient-reported measures, age, BMI and follow-up time. Least squares means (LSM, adjusted means) of the PROM were estimated as part of the ANCOVA model and were then compared between various pain locations. Cohen’s d was calculated and interpreted as the effect size estimator for the between-subjects group effect. Next, the mean of mHHS, HOS and iHOT12 at pre- and post-treatment stratified by pain level was compared using the dependent samples t-test. Finally, a correlation analysis, using the Spearman partial correlation coefficient (r_s), was conducted to evaluate the relationship between pre-operative maximum severity of pain and number of pain locations with post-operative PROM while controlling for pre-operative patient-reported measures, age, BMI and follow-up time. Statistical analyses were carried out using SAS software, version 9.4 (SAS Institute, Inc., Cary, NC). The level of significance was set at $\alpha = 0.05$ (two-tailed).

**RESULTS**

**Participant characteristics**

The sample of 48 patients was 90.38% female, with a mean age of 25.57 ± 6.89 years (range = 14–41 years). Mean BMI was 27.00 ± 5.15 kg/m². The mean follow-up time 463.32 ± 320.78 days (range = 75–1270 days). Patient demographic and pre-operative clinical characteristics are presented in Table I (p. 15). Additionally, 50 hips had pre-operative groin pain (96%), 42 hips had trochanteric pain (81%), 23 hips had lower back pain (44%), 19 hips had buttck pain (37%), 16 hips had anterior thigh pain (31%), 16 hips had knee pain (31%), 12 hips had lateral thigh pain (23%) and 7 hips had posterior thigh pain (13%).
Location of maximum severity of pre-operative pain
Patients were grouped by the location of maximum pre-operative pain severity based on whether their worst pain was in the groin (26 hips) or if they had greater or equal pain to that felt in the groin at another location (26 hips) on the diagram in Fig. 1 (p. 16). The ANCOVA results revealed none of the post-operative PROM between these two locations were significantly different (mHHS $P = 0.59$, HOS $P = 0.48$, iHOT-12 $P = 0.99$) (Table II, p. 17).

Presence of non-groin pain
The ANCOVA also examined the relationship between each of the pre-operative pain locations specified above, except for groin as 96% of hips experienced groin pain, and each of the post-operative hip outcome scores, while controlling for pre-operative patient-reported measures, age, BMI and follow-up time. The ANCOVA results revealed that there was no significant relationship between non-groin pain location and any post-operative PROM ($P$-value range for outcome scores at each pain location: Trochanter $P = 0.14$–0.53, lower back $P = 0.40$–0.99, buttock $P = 0.20$–0.48, anterior thigh $P = 0.63$–0.99, knee $P = 0.39$–0.96, lateral thigh $P = 0.29$–0.57, posterior thigh $P = 0.30$–0.80) (Table III, p. 18).

Maximum severity of pain
No hips had a maximum pain severity of 0 or 1. For maximum severity of 2–5, every group saw an improvement in all outcome
Table I. Demographic and clinical characteristics of the overall sample

| Pre-operative characteristics | Overall sample (N = 52) |
|------------------------------|-------------------------|
| **Patient demographics**     |                         |
| Age, years, M (SD, Range)    | 25.57 (6.89, 14–41)     |
| Female gender, % (n)         | 90.38% (47)             |
| **Patient factors**          |                         |
| BMI, kg/m², M (SD, Range)    | 27.00 (5.15, 17–39)     |
| Time pre-to post-treatment, days, M (SD, Range) | 463.32 (320.78, 75–1270) |
| Pain Severity Score, M (SD, Range) | 4.09 (0.97, 2–5)       |
| Number of pain locations, M (SD, Range) | 3.55 (2.03, 1–8)       |
| HHS, M (SD, Range)           | 52.88 (11.43, 7–77)     |
| HOS, M (SD, Range)           | 53.84 (15.09, 14–88)    |
| iHOT12, M (SD, Range)        | 30.34 (14.28, 5–73)     |
| LCFA, M (SD, Range)          | 13.05 (5.62, –1–19)     |
| ACEA, M (SD, Range)          | 14.67 (10.46, –15–40)   |
| Alpha Dunn, M (SD, Range)    | 65.90 (15.62, 38–102)   |
| Alpha frog, M (SD, Range)    | 62.48 (12.56, 41–94)    |
| Tonnis angle, M (SD, Range)  | 14.09 (6.15, 2–27)      |
| Tonnis Grade 0, % (n)        | 78.85% (41)             |
| Tonnis Grade 1, % (n)        | 21.15% (11)             |
| Previous hip arthroscopy, % (n) | 19.23% (10)            |

M = Sample Mean; SD = standard deviation. Pain severity scale ranges from 1 to 5 (higher score = greater severity of pain).

Table II. Patient-reported outcomes by location of maximum pain severity

| Post-operative outcome measure | Location of maximum pain severity | Adjusted LSM estimate (SE) | P-value (d) |
|-------------------------------|----------------------------------|---------------------------|-------------|
| mHHS                          | Groin                            | 82.09 (3.27)              | 0.59 (0.15) |
|                               | Other                            | 84.59 (3.05)              |             |
| HOS                           | Groin                            | 80.95 (2.95)              | 0.48 (0.20) |
|                               | Other                            | 83.83 (2.47)              |             |
| iHOT-12                       | Groin                            | 71.03 (5.12)              | 0.99 (0.003) |
|                               | Other                            | 70.95 (4.36)              |             |

SE = Standard Error. P-value = ANCOVA was used to test for the difference of the LSM estimate between groin and other locations on each post-operative outcome. d = Cohen's d. Sample size was 26 per group for the ‘groin’ and ‘other’ locations. ‘Other’ includes patients with maximum severity of pain in a non-groin location that is equal or greater than the severity of pain in groin.

measurements from pre-operative to post-operative (Table IV, p. 20). Three hips had a maximum severity of 2 (6%), 13 hips had a maximum severity of 3 (25%), 12 hips had a maximum severity of 4 (23%) and 24 hips had a maximum severity of 5 (46%). Post-operative PROM was similar across every severity group. Spearman partial correlation coefficients \( r_s \) showed that there was no significant relationship between pre-operative maximum severity of pain and post-operative PROM while controlling for pre-operative patient-reported measures, age, BMI and follow-up time (mHHS: \( r_s = -0.033 P = 0.82 \), HOS: \( r_s = -0.001 P = 0.99 \), iHOT-12: \( r_s = -0.133 P = 0.36 \)).

Number of pain locations

There were 12 hips with two pain locations (23%), 11 hips with three pain locations (21%), 8 hips with four pain locations (15%), 7 hips with one pain location (13%), 5 hips with five pain locations (10%), 4 hips with eight pain locations (8%), 3 hips with six pain locations (6%) and 2 hips with seven pain locations (4%). Hips in every pain location group scored similarly on all post-operative outcome measurements. Spearman partial correlation analysis found no significant relationship between number of pain locations (2–3 vs. >3) and post-operative outcome measures (mHHS: \( r_s = -0.064 P = 0.66 \), HOS: \( r_s = 0.280 P = 0.053 \), iHOT-12: \( r_s = 0.159 P = 0.28 \)).

**DISCUSSION**

As PAO is increasingly performed for patients with acetabular dysplasia, it is important to understand the relationship between pain presentation and outcomes. To our knowledge, this study is the first study to examine the relationship between pre-operative pain characteristics and post-operative PROM. Our goal was to report how different pain locations, maximum pain severity and number of pain locations affect PROM, as patient presentations may vary.

A large majority of patients saw improvements in their mHHS, HOS and iHOT-12 scores from their pre- to post-operative visit. Table IV (p. 22) shows that, on average, patients, regardless of pain severity level, exceeded the MCID for each outcome score. Individually, 47 (90.4%) met the mHHS MCID, 45 hips (86.5%) met the HOS MCID and 43 (82.7%) met the iHOT-12 MCID. These findings are consistent with other studies that found most patients have favourable short- and long-term outcomes after PAO [4–7, 30].

The most common pain locations in our study were the groin (96%) and lateral hip (trochanter) (81%). In a study of 65 hips, Nunley et al. also found that the most common pain locations were in the groin (72%) and trochanter (66%) [9]. Another study characterizing pain in 443 hips with osteoarthritis secondary to acetabular dysplasia found that pain was located in the groin of 393 hips (89%), in the buttoc of 170 hips (38%), in the anterior thigh of 130 hips (29%), at the greater trochanter of 118 hips (27%), in the low back of 76 hips (17%) and in the lower leg of 34 hips (8%) [31].

We found that having the most severe pain in the groin or another location does not appear to affect post-operative outcomes. Although it is generally believed that intra-articular joint pathologies most often present with most severe pain in the groin [32, 33], the results of our study show that patients may experience similar post-operative outcomes whether the location of maximum pain severity is in the groin or not. Additionally, the
Tables III and IV provide post-operative patient-reported outcomes (PROMs) by presence or absence of pain in non-groin locations and pre-operative maximum severity of pain, respectively.

### Table III. Post-operative patient-reported outcomes by presence or absence of pain in non-groin locations

| Pain location      | Adjusted LSM (SE) | P-value (d) | Adjusted LSM (SE) | P-value (d) | Adjusted LSM (SE) | P-value (d) |
|--------------------|------------------|-------------|------------------|-------------|------------------|-------------|
|                    | mHHS             | HOS         | iHOT-12          |
| Trochanter         |                  |             |                  |
| Yes \((n = 42)\)   | 84.15 (2.37)     | 0.53 (0.18) | 84.71 (2.07)     | 0.21 (0.36) | 74.10 (3.50)     | 0.14 (0.43) |
| No \((n = 10)\)    | 79.76 (6.22)     |             | 76.86 (4.66)     |             | 57.94 (9.86)     |             |
| Lower back         |                  |             |                  |
| Yes \((n = 23)\)   | 82.32 (2.72)     | 0.67 (0.12) | 84.24 (2.10)     | 0.40 (0.24) | 70.97 (4.41)     | 0.99 (0.003)|
| No \((n = 29)\)    | 84.09 (3.07)     |             | 80.93 (2.99)     |             | 71.01 (5.04)     |             |
| Buttock            |                  |             |                  |
| Yes \((n = 19)\)   | 85.22 (3.15)     | 0.48 (0.20) | 85.70 (2.75)     | 0.20 (0.38) | 70.97 (4.41)     | 0.31 (0.29)|
| No \((n = 33)\)    | 82.21 (2.77)     |             | 80.49 (2.52)     |             | 68.10 (4.97)     |             |
| Anterior thigh     |                  |             |                  |
| Yes \((n = 16)\)   | 84.27 (3.50)     | 0.75 (0.09) | 82.38 (3.35)     | 0.99 (0.003)| 68.56 (4.81)     | 0.63 (0.14)|
| No \((n = 36)\)    | 82.88 (2.61)     |             | 82.41 (2.12)     |             | 72.07 (4.72)     |             |
| Knee               |                  |             |                  |
| Yes \((n = 16)\)   | 80.37 (4.46)     | 0.39 (0.25) | 82.54 (3.42)     | 0.96 (0.01) | 70.52 (5.39)     | 0.92 (0.03)|
| No \((n = 36)\)    | 84.61 (2.21)     |             | 82.33 (2.16)     |             | 71.20 (4.21)     |             |
| Lateral thigh      |                  |             |                  |
| Yes \((n = 12)\)   | 87.27 (4.17)     | 0.29 (0.31) | 84.24 (3.75)     | 0.57 (0.16) | 74.51 (6.12)     | 0.54 (0.17)|
| No \((n = 40)\)    | 82.12 (2.37)     |             | 81.84 (2.04)     |             | 69.93 (4.02)     |             |
| Posterior thigh    |                  |             |                  |
| Yes \((n = 7)\)    | 80.13 (5.27)     | 0.52 (0.19) | 80.98 (6.15)     | 0.80 (0.07) | 63.40 (7.48)     | 0.30 (0.30)|
| No \((n = 45)\)    | 83.80 (2.18)     |             | 82.62 (1.88)     |             | 72.17 (3.67)     |             |

SE = standard error, \(P\)-value = ANCOVA was used to test for the difference of the LSM estimate between non-groin pain location and each post-operative outcome. \(d\) = Cohen’s \(d\).

### Table IV. Patient-reported outcomes by pre-operative maximum severity of pain

| Outcome measure | Maximum severity of Pain | n   | Mean ± SD (Pre-OP) | Mean ± SD (Post-OP) | \(P\)-value |
|-----------------|--------------------------|-----|--------------------|--------------------|-------------|
| mHHS            | 2                        | 03  | 51.66 ± 11.71      | 72.00 ± 11.79      | 0.0019      |
|                 | 3                        | 13  | 57.00 ± 7.81       | 89.00 ± 10.39      | <0.0001     |
|                 | 4                        | 12  | 58.50 ± 7.19       | 84.41 ± 10.27      | <0.0001     |
|                 | 5                        | 24  | 48.00 ± 13.04      | 81.08 ± 16.27      | <0.0001     |
| HOS             | 2                        | 03  | 56.25 ± 13.21      | 76.24 ± 14.94      | 0.0210      |
|                 | 3                        | 13  | 54.54 ± 10.37      | 81.98 ± 12.70      | <0.0001     |
|                 | 4                        | 12  | 59.31 ± 15.99      | 86.40 ± 9.77       | <0.0001     |
|                 | 5                        | 24  | 50.42 ± 16.80      | 81.36 ± 12.88      | <0.0001     |
| i-HOT12         | 2                        | 03  | 33.33 ± 2.31       | 65.33 ± 22.36      | 0.1413      |
|                 | 3                        | 13  | 31.53 ± 10.39      | 71.92 ± 22.34      | 0.0004      |
|                 | 4                        | 12  | 32.75 ± 17.66      | 78.12 ± 15.76      | <0.0001     |
|                 | 5                        | 24  | 28.12 ± 15.36      | 67.62 ± 24.28      | <0.0001     |

SD = standard deviation. \(P\)-value (two-tailed) = Dependent samples t-test was used to test for differences in sample means from pre- to post-OP. Change was operationally defined as post- minus pre-OP score. FDR values were 0.0023 (for \(P\) = 0.0019), 0.0002 (for \(P\) < 0.0001), 0.0229 (for \(P\) = 0.0210), 0.0005 (for \(P\) = 0.0004) and 0.1413 (for \(P\) = 0.1413).

The presence of pre-operative pain at any non-groin location is not significantly related to any PROM when compared to hips without pain in that location. For some pain locations (buttocks, trochanter and lateral thigh), the presence of pre-operative pain yielded slightly better outcomes in each of the three measures, while in one location (posterior thigh), the absence of pain yielded slightly better outcomes. Some pain locations had mixed results (anterior thigh, knee and lower back); the presence of pre-operative pain resulted in better outcomes for some measures, while the absence of pain resulted in better outcomes for the other measures. Thus, even if a patient with acetabular dysplasia does not present with the typical most-severe pain in the groin, PAO could still be indicated and produce a favourable outcome if the patient meets the criteria for surgery.

This study also found that there was no significant relationship between either maximum severity of pain or number of pain locations and post-operative PROM. However, there was a modest inverse correlation between pre-operative maximum pain severity and PROM, suggesting that more severe pain could be related with slightly lower post-operative outcome scores. This could be due to pain catastrophizing, as certain patients with more severe pain could be exaggerating pain, and potentially these patients may report worse post-operative outcomes [34–36]. The relationship between pain severity and pain catastrophizing...
is not well understood. Bierke et al. established that patients with higher pain catastrophizing scores can experience worse outcomes; however, their study evaluated total knee replacement, whereas this study evaluated PAO. Another potential explanation for this slight inverse correlation is that more severe pre-operative pain could be associated with more advanced disease, ultimately resulting in worse post-operative outcomes. However, in osteoarthritic joints, the extent of joint damage has little relation to the severity of joint pain [37]. Further studies looking at the relationship between pre-operative pain severity and radiographic and visual evidence of damage in patients with acetabular dysplasia are warranted.

Additionally, we observed a positive relationship between number of pain locations and PROM, but the correlation coefficients were small and not significant. Furthermore, when hips were grouped by less than or equal to three pain locations and greater than three pain locations, there was no significant difference in the mean post-operative outcome scores, although hips with greater than three pain locations had slightly higher PROM. This might indicate that hips with more pain locations have better outcomes. This would contradict the hypothesis that patients who have more pain locations, and thus may be catastrophizing, have worse post-operative outcomes. However, the observed correlations for both pain severity and pain locations were not statistically significant.

This study has limitations. First, these surgeries were performed by one surgeon. Therefore, the results may not be representative of other surgeons or centres. However, clear and consistent PAO indications were used, and previously validated PROM were used. Additionally, some of the categories used for statistical analysis had small sample sizes due to the overall smaller number of hips included in the study. The observed effect sizes in this study were very small; thus, the small sample size could have, in part, contributed to a Type II error affecting the findings of this study. Finally, a large percentage of patients received concurrent procedures during PAO, which could have introduced some selection bias.

In summary, this study is a comprehensive analysis on the relationship between pre-operative pain characteristics and post-operative PROM in patients with symptomatic acetabular dysplasia undergoing PAO. The study evaluated whether the maximum pain being in or outside of the groin, the presence of non-groin pain, the maximum severity of pain and the number of locations of pain had an impact on post-operative PROM. The study found that there was no significant relationship between maximum severity of pain in or outside of the groin and PROM. Further, we found no significant relationship between the presence of non-groin pain and PROM. We also found that there was no significant relationship between maximum severity of pain experienced by the patient pre-operatively and PROM, although there was a modest inverse correlation. Finally, we found that there was no significant relationship between the number of pain locations and PROM, although there was a slight positive correlation. To our knowledge, this is the first study that has assessed these questions. Further efforts should ask patients to clearly indicate where they are experiencing the worst pain and include more patients. To conclude, a wide array of patients with acetabular dysplasia might expect similar, favourable outcomes from PAO regardless of the location, severity and number of locations of pre-operative pain and pre-operative pain characteristics.

DATA AVAILABILITY
Data available upon request.

ACKNOWLEDGEMENT
None declared.

FUNDING
This work was supported by The Hoglund Foundation.

CONFLICT OF INTEREST STATEMENT
None declared.

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