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Research article

Predictors and trajectories of chronic postoperative pain following hip preservation surgery

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ABSTRACT

Factors contributing to chronic postoperative pain (CPOP) are poorly defined in young people and developmental considerations are poorly understood. With over 5 million children undergoing surgery yearly and 25% of adults referred to chronic pain clinics identifying surgery as the antecedent, there is a need to elucidate factors that contribute to CPOP in surgical patients. The present study includes patients undergoing hip preservation surgery at a children's hospital. The HOOS and SF-12 Health Survey were administered to 614 pre-surgical patients with 421 patients completing follow-up (6-months, 1-year and 2-years post-surgery). Pain, quality of life, and functioning across time were examined for each group within the population. A three trajectory model (low pain, pain improvement and high pain) emerged indicating three categories of treatment responders. Pain trajectory groups did not differ significantly on gender, pre-surgical age, BMI, prior hip surgery, surgical type, joint congruence or Tönnis grade. The groups differed significantly from each other on pre-surgical pain, pain chronicity, quality of life and functioning. Those in the high pain and pain improvement groups endorsed having pre-surgical depression at significantly higher rates and lower pre-surgical quality of life compared to those in the low pain group ($P < 0.01$). Those in the high pain group reported significantly worse pre-surgical functioning compared to those in the pain improvement ($P < 0.0001$) and low pain groups ($P < 0.0001$).The results demonstrate the need for preoperative screening prior to hip preservation surgery, as there may be a subset of patients who are predisposed to chronic pain independent of hip health.

Chronic postoperative pain (CPOP) represents a significant clinical problem [1] with insufficient attention devoted to it [2]. Approximately, 25% of adult chronic pain patients identify surgery as the antecedent [3] and between 5 and 50% of adult surgical patients report CPOP greater than 2 months post-surgery [4, 5], though this definition is disputed as being overly simplistic [1]. With chronic pain costing $635 billion annually in the US [6], there is a need to elucidate factors that contribute to CPOP.

Causal factors contributing to CPOP are poorly defined and misunderstood, particularly in adolescents and young adults (AYAs) [7]. Approximately, 15–25% of adolescents are affected by chronic pain [8, 9], with surgery a potential trigger. One prospective study found that 15% of AYAs reported moderate to severe levels of pain 2 years post-operation [10]. Excluding high risk patients with a history of chronic pain, major surgery, or psychiatric conditions, another study found that 13% of AYAs claimed disability due to chronic pain 6-months post-surgery [11]. In addition, because chronic pain produces changes in attention, cognition, and affect, the sequelae of chronic pain may contribute to behavioural and other developmental health problems [12, 13].

The incidence of CPOP is particularly high in orthopedics relative to other disciplines and research investigating risk factors for CPOP in orthopedic surgeries is gaining momentum [14]. Nonetheless, much of the research examining CPOP has been limited by small sample sizes, retrospective data collection and heterogeneous surgical populations [15]. The present study addresses these concerns by prospectively examining longitudinal pain trajectories for AYA and adult (AYA&A) patients undergoing hip preservation surgery as part of the Academic Network of Conservational Hip Outcomes Research (ANCHOR).

Hip preserving surgical treatments were developed in response to the finding that osteoarthritis of the hip is rarely idiopathic and commonly secondary to correctable anatomical abnormalities [16, 17]. Within the ANCHOR group, over 1400 PAOs were performed from 2008–14 and over 1100 FAI surgeries between 2008–11 [18, 19]. Although indications for hip preservation surgery vary, pre-operative pain is the most common [12, 20, 21]. Despite being a primary clinical diagnostic factor, chronic pain has been largely disregarded as a surgical outcome measure.

Recently, Zaltz et al. examined complications associated with PAO [22]. Though potential etiologies for chronic pain were included, chronic pain was not considered as an independent problem.

Podeszwa et al. demonstrated that pre-operative evaluation of patients undergoing hip preservation surgery can be used to identify patients who report at-risk or clinically significant symptoms of anxiety and/or depression, which correlate with increased risk for CPOP [23]. Given this, research targeted at discerning pre-operative risk factors in AYA&As undergoing hip preservation surgery has significant value. Indeed, there is already research developing improved pain screening tools which fully integrate mental health [24]. Previous research utilized pain trajectories to identify risk factors for spinal fusion surgery [10]. AYA&As taking part in a prospective study of idiopathic scoliosis reported on pain, activity, mental health and self-image pre-surgically to 5-years post-surgery. The five trajectory pain model that emerged included significant differences in self-image, mental health and age. Identifying these predictors of poor long-term outcomes in patients with CPOP may help to guide future treatment.

We hypothesized that patients who reported lower quality of life and increased disability prior to surgery would follow a higher pain trajectory compared to patients who endorsed higher quality of life and less disability. Given prior research [10, 23], we hypothesized that older age would be associated with more post-operative pain. We also hypothesized that increased BMI and a history of prior hip surgeries would result in high pain after surgery [25]. Once identified, the ultimate goal of our research is to improve patient care via modification of these risk factors in a future interventional study.

MATERIALS AND METHODS

To characterize pain trajectories among AYA&As treated with hip preservation surgery for dysplasia or FAI, we examined pain ratings collected as part of the ANCHOR study at pre-surgical visits as well as 6-months, 1-year and 2-years post-surgery. Pain outcomes across time were examined using the SAS PROC TRAJ procedure [26], a mixture model that estimates longitudinal regression models for discrete groups within a given population. After deriving pain trajectory groups, we examined baseline pre-operative characteristics of age, gender, preoperative pain, quality of life, functioning, radiographic measurements, clinical indicators and mental health as potential distinguishing characteristics of trajectory group.

Participants

Participants were patients from Boston Children's Hospital enrolled in the ANCHOR study between 2009 and 2015. The ANCHOR study is a prospective cohort study of AYA&A patients who underwent hip preservation surgery to treat symptomatic hip dysplasia or FAI. Patient assent and parent consent was obtained. The current study included only patients from BCH to ensure a consistent surgical treatment regimen and to assess the 6-month post-surgical time-point, only collected at our site. Patients were required to have a diagnosis of DDH or FAI, be English speaking, between the ages of 10–55, and without significant neuromuscular disorder. The study consists of assessments at pre-surgery, 6-months, 1 and 2-years post-surgery. Of the 612 patients who have baseline data, 421 patients completed follow-up data.

Measures

The Hip disability and Osteoarthritis Outcome Score (HOOS) is an adaptation of the Knee disability and Osteoarthritis Outcome Score (KOOS) and contains all WOMAC LK 3.0 questions in unchanged form [27]. The HOOS consists of 40 items assessing five dimensions: pain, stiffness, activities of daily living, sports and recreation function and hip-related quality of life. Each of the five subscales has been demonstrated to have good construct validity with the SF-36 [27]. All answers are in the form of Likert scale responses scored from 0–4. Final scores for each subscale are then normalized on a 0–100 worst to best scale [28]. The HOOS has been demonstrated to have good internal consistency, reliability, construct validity, responsiveness and no floor or ceiling

effects, including for patients with different levels of osteoarthritis [27, 29, 30].

Depression. As part of the pre-surgical assessment, patients are asked whether they have a history of depression and provide a yes or no response.

Procedures

Data obtained for secondary data analysis for the present study was approved by the Institutional Review Board. Patients completed the questionnaire at the time of the pre-operative visit no more than 4 weeks before the procedure. Standard post-operative visits occurred at 6-months, 1-year and 2-years after surgery with completion of questionnaires at the time of each visit.

Statistical analyses

All analyses were conducted in SPSS version 21 and SAS. Descriptive statistics were calculated for all demographic and study variables and One-way ANOVAs were used to compare participants with only pre-surgical data to those who had both pre-surgical and follow-up data. Next, we conducted trajectory analyses in order to examine patterns of pain prevalence. The SAS PROC TRAJ procedure [26] was used to determine models of pain across pre-operative and post-operative time points. The TRAJ procedure is a mixture model that estimates a regression model for each discrete group within the population. It is exploratory in nature, allowing modelling within and between patients, with each patient having an observed trajectory with an approximate model description. Polynomials were limited to quadratic time due to having four time points. Individuals with missing observations can be included because PROC TRAJ uses all values available from each case to estimate an individual's timeline, which allows missing observations to be included in the analyses. Model complexity and overall fit in PROC TRAJ is determined partly on Bayesian information criterion (BIC) scores, which are negative values in which values closer to 0 indicate a better fit. Trajectory group membership for each individual was then used as the independent variable to compare groups across baseline characteristics using one-way analyses of variance. Post-hoc Scheffe tests compared means across multiple trajectories and allowed for the correction of Type I errors. We conducted a post-hoc power analysis for the three group one-way ANOVA comparisons. With a significance level of 0.05 and power of 80%, the sample size of 421 was adequate for detecting medium to large effects of 0.15 and higher [31].

Although the focus of the present study is on baseline predictors of pain trajectories, we were curious as to whether pain trajectories would differ on post-surgical radiographic data; thus we also examined whether there were significant differences between pain trajectory groups on post-surgical radiographic data (Tönnis grade, LCEA and joint conguence).

RESULTS

We examined baseline differences between patients who completed follow-up ($n = 421$) and those who did not ($n = 191$). There were no significant differences found on age, sex, race, BMI, surgical approach, type of surgery, or pre-surgical pain duration; however, there was a significant difference found between those who had a prior hip surgery (33%) and those without (67%); patients for whom this surgery was their first were more likely to complete follow-up questionnaires, X^2 ($2\ N = 612$) = 63.91, $P < 0.001$. For all subsequent analyses, we examined patients who had one or more follow-up data ($n = 421$). Demographics and surgical variables are presented in Table I. While 421 patients completed follow-up data, there was missing data present at each time-point. At 6-months post-surgery, only 21% of patients completed the pain subscale used in the analyses while 41% and 22% completed at 1 and 2-years post-surgery, respectively.

Pain trajectories

SAS PROC TRAJ was run with 1–6 trajectory solutions in order to determine the most appropriate and parsimonious solutions for pain across pre- and post-surgical time points. A logistic model of dropout probability was included for each time point to account for non-random attrition. Similar to cluster and exploratory factor analysis, solutions are selected largely based on judgment so, along with the BIC, an inspection of graphic model curves was employed to determine the number of trajectories to include in analyses [32]. BIC values were inspected for each solution and were found to have similar values providing no clear indication of the superiority from this standpoint. Ultimately we chose a three-trajectory solution as each group was clinically interpretable, whereas we felt that with fewer grouping there was unique information lost (e.g. the two-trajectory model collapses the low pain and pain improvement groups, whereas the three trajectory model teases apart differential outcomes of baseline pain) and a larger number of trajectory solutions yielded difficult to interpret groups (see Fig. 1). The three trajectories consisted of:

'Low pain' group ($n = 115$): little to no pain before surgery and continued on that trajectory at all follow-up points showing improvement in pain over time.

Table I. Participant characteristics (n = 421)

Variable	*Frequency*
Age (range, M [SD])	11–53, 25.36 [9.48]
Gender	
Female	76
Male	24
Race	
White	87
Asian or Asian American	4
Black or African American	1
Native American	1
Other	4
Occupation	
Student	42
Full-time	35
Part-time	7
Homemaker	3
Disabled	2
BMI (range, M [SD])	17–55, 24.90 [5.18]
LCEA (range)	–34°–106°
LCEA Follow-up (range)	–11°–48°
Joint congruity (Baseline, [Follow-up])	
Excellent	45.1 [32.3]
Good	34.7 [44.2]
Fair	6.4 [20.2]
Poor	0.7 [3.1]
Tönnis grade (Baseline, [Follow-up])	
0	44.9 [35.0]
1	38.5 [44.8]
2	8.3 [14.8]
3	1.4 [5.4]
Surgical indication	
Dysplasia/Instability	85
FAI	15
Surgical procedure	
PAO only	49
PAO + Arthrotomy + Femoral head/Neck	11.8
Osteochondroplasty/PAO + Femoral head/Neck	4.8
Osteochondroplasty	3.6
PAO + Arthrotomy (No femoral	1.2
Head/Neck Osteochondroplasty)	0.7
PAO + Other	0.2
PAO + Arthroscopy	
PAO + Femoral intertrochanteric	
Osteotomy	
PAO + Arthroscopy + Femoral	
Osteochondroplasty	

Note: Values represent percentages unless otherwise noted.

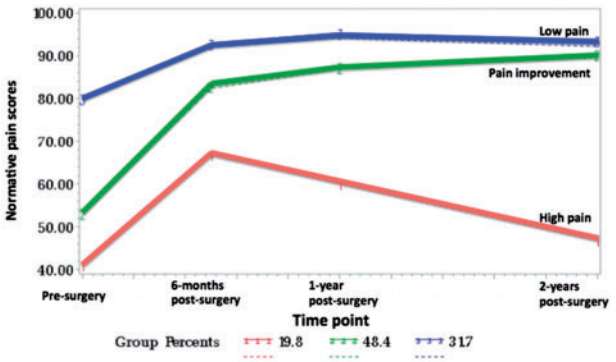

Fig. 1. Pain trajectory solutions.
Note: The 95% confidence level for the 'low pain' group is 0.79–0.85. The 95% confidence level for the 'pain improvement' is 0.80–0.83. The 95% confidence level for the 'high pain' is 0.82–0.90.

'Pain improvement' group ($n = 183$): reported moderate pre-surgical pain and decreases over time.

'High pain' group ($n = 71$): reported high levels of pain pre-surgically and while some improvement is noted at 6-month post-surgery, pain becomes much worse 1 year post-surgery and then continues to worsen 2 years post-surgery.

PROC TRAJ provides individual fit estimates, probabilities that each patient belongs to each of the three trajectory groups. Cote et al. recommend that the average probability for members of a trajectory group should be ≥0.70 [33]. The three averages ranged from 0.82 (SD = 0.16) for the 'low pain' group to 0.81 (SD = 0.12) for the 'pain improvement' group and 0.86 (SD = 0.16). These estimates suggest that the average model fit was adequate for the three trajectories.

Baseline trajectory group differences

Chi-square analyses. Regarding depression, those in the 'high pain' (43%) and 'pain improvement' (47%) groups endorsed having pre-surgical depression at significantly higher rates compared to those in 'low pain' (10%) $\chi^2(4, N = 256) = 18.21$, $P < 0.01$ (Table II). The pain trajectory groups did not differ significantly on gender, prior hip surgeries, surgical type, joint congruence, or Tönnis grade.

One-way ANOVAs. Table III shows mean levels of variables by pain trajectory group with test statistics for each predictor variable. The pain trajectory groups differed significantly from each other on pre-surgical pain, pain chronicity, quality of life and functioning. The pain trajectory groups did not differ significantly on pre-surgical age, BMI, or LCEA.

The 'pain improvement' group had significantly longer pain chronicity prior to surgery compared to the 'low pain' group (difference = 0.44, $P = 0.034$). Pre-surgical pain was also a risk factor for being in a higher pain trajectory. Patients in the 'high pain' group had significantly worse pre-surgical pain compared to the 'pain improvement' (difference = –14.80, $P < 0.01$) and the 'low pain' groups (difference = –43.24, $P = 0.000$). The 'pain improvement' group also had significantly worse pre-surgical pain compared to the 'low pain' group (difference = –28.44, $P < 0.01$). Regarding quality of life, patients in the 'high pain' group reported significantly worse pre-surgical quality of life compared to the 'pain improvement' (difference = –12.97 $P < 0.01$) and the 'low pain' groups (–35.72, $P < 0.01$). The patients in the 'pain improvement' group also reported significantly worse quality of life compared to the 'low pain' group (difference = –22.75, $P < 0.01$). Similarly, those in the 'high pain' group reported significantly worse functioning prior to surgery compared to the 'pain improvement' (difference = –17.08, $P < 0.01$) and 'low pain' groups (difference = –38.51, $P < 0.01$). Those in 'pain improvement' also endorsed significantly worse functioning prior to surgery compared to those in 'low pain' (difference = –21.43, $P < 0.01$) (Table III).

Post-surgical radiographic group differences

The mean follow-up for obtaining post-surgical radiographic data was 56 months (SD = 21 months). Chi-square analyses did not show that the pain trajectory groups differed significantly on post-surgical joint congruence or Tönnis grade (Table II) and a one-way ANOVA did not reveal a significant difference across pain trajectory groups on post-surgical LCEA (Table III).

DISCUSSION

CPOP represents a significant clinical and financial problem in medicine [1, 6]. Yet, despite its pervasiveness [3–5, 8–11], there has been insufficient attention devoted to CPOP [2]. For AYAs, the sequelae of chronic pain takes place at critical developmental stages and may continue for decades into adulthood [13, 34].

The aim of the present study was to examine the longitudinal pain trajectories of patients undergoing hip preservation surgery with consideration of pre-surgical variables that impact long-term pain outcomes. AYA&As with hip pain constitute an appropriate study population because they are otherwise typically healthy, the indicated surgical treatment is extensive, and the ANCHOR cohort allowed for a large, prospective, homogeneous sample [15]. In examining longitudinal pain trajectories, three groups emerged: low pain, high pain and pain improvement. It is noteworthy that demographic and surgical variables, such as LCEA, Tönnis grade, and surgery type did not significantly impact pain outcomes and also that there were no significant differences found between groups on post-surgical radiographic assessments. This suggests the impact of other variables (e.g. mental health, biological) that may influence post-surgical pain outcomes and warrant further investigation. Given that pre-surgical pain is widely known to be a significant predictor of CPOP [35], it is not surprising that both pre-surgical pain and pain chronicity were risk factors for higher pain trajectories. This suggests potential central sensitization or excessive pain sensitivity as a result of amplification of neural signalling within the central nervous system compared to the low pain group [36]. The interplay between psychosocial variables and the neural underpinnings of

Table II. Differences across trajectory groups

Variable		*High pain (% within group)*	*Pain improvement (% within group)*	*Low pain (% within group)*	*Pearson Chi-Square*[a]
Gender	Male	17.8	46.7	35.6	0.894
	Female	18.6	52.9	21.1	
Surgical type	PAO	19.3	50.7	30.0	3.866
	Anteverting/Reverse	0	80.0	20.0	
	PAO	17.4	52.2	30.4	
	FAI				
Prior hip surgeries	No	16.4	57.3	26.3	8.761
	Yes	22.9	39.8	37.3	
Joint congruity	Poor	0	100	0	5.450
	Fair	23.5	47.1	29.4	
	Good	22.7	51.5	25.8	
	Excellent	13.7	53.8	32.5	
Tönnis grade	Grade 0	14.4	56.8	28.8	6.680
	Grade 1	25.3	48.5	26.3	
	Grade 2	13.6	45.5	40.9	
	Grade 3	0	50.0	50	
Depression	No	14.9	52.3	32.9	18.206*
	Yes	43.3	46.7	10	
Joint congruity (Follow-up)	Poor	0	50.0	50.0	3.394
	Fair	24.2	48.5	27.3	
	Good	19.8	53.1	27.2	
	Excellent	15.8	50.9	33.3	
Tönnis grade (Follow-up)	Grade 0	16.1	58.1	25.8	7.818
	Grade 1	13.8	48.8	38.5	
	Grade 2	34.8	43.5	21.7	
	Grade 3	20.0	50.0	30.0	

[a]Cells have expected count less than 5.
Note: Variables that differ significantly at $^*P < 0.05$.

sensory pain modulation to predict chronic pain outcomes in young people has not been examined and is warranted. Detection of central sensitization can identify patients who may benefit from centrally mediated pharmacotherapies that can be coupled with cognitive behavioural approaches to pain management.

It is unclear why patients in the pain improvement trajectory had significantly longer pain chronicity prior to

Table III. Significant differences across pain trajectory groups

Variable	*Total* (n = *421*) Mean (SD)	*High pain* (n = *71*) Mean (SD)	*Pain improvement* (n = *183*) Mean (SD)	*Low pain* (n = *115*) Mean (SD)	F *Ratio*
Age	25.90 (9.59)	27.03 (9.78)	26.27 (9.26)	24.54 (10.00)	1.203
BMI	24.98 (5.17)	26.13 (4.97)	25.10 (5.67)	24.05 (4.20)	2.464
LCEA	12.56 (12.70)	13.81 (10.02)	13.23 (12.97)	10.53 (13.69)	1.285
Presurgical pain chronicity	3.36 (1.17)	3.53 (1.06)	3.48 (1.23)[c]	3.04 (1.07)[b]	4.039*
Presurgical pain	58.23 (21.83)	37.72 (19.05)[b,c]	52.52 (15.53)[a,c]	80.96 (11.50)[a,b]	131.761**
Presurgical quality of life	35.11 (23.16)	17.61 (13.90)[b,c]	30.59 (19.14)[a,c]	53.33 (22.28)[a,b]	57.747**
Presurgical functioning	71.35 (21.83)	50.68 (20.87)[b,c]	67.76 (19.83)[a,c]	89.19 (9.65)[a,b]	65.812**
Preoperative mental health	52.66 (10.75)	50.19 (11.28)	52.54 (11.38)	54.28 (9.05)	2.010
LCEA Follow-up[d]	25.72 (7.24)	24.36 (5.23)	26.63 (7.51)	24.99 (7.71)	1.59

[a]High pain.
[b]Pain improvement.
[c]Low pain.
[d]Sample size for the LCEA Follow-up data are as follows, total ($n = 180$), high pain ($n = 33$), pain improvement ($n = 93$), low pain ($n = 54$).
Note: Baseline variables that differ significantly at $^{*}P < 0.05$; $^{**}P < 0.01$ across pain trajectory groups are indicated with the superscript of the differing group. (e.g. Patients who had no pain at preop had significantly less pain compared to those in groups a–c).

surgery than patients in the low pain trajectory. There were no significant differences in pain chronicity between the other trajectories. It may be that the pain improvement trajectory had more to gain from surgery having had such a long duration of pre-surgical pain and thus experienced more optimal outcomes over time compared to the high pain trajectory. More research is warranted in this area.

Pre-surgical depression and poor quality of life were also risk factors for being in a higher pain trajectory. The depression variable was dichotomous, which is a limitation; however, these findings corroborate work done by Podeszwa and colleagues [23] and indicate the importance of mental health assessment and treatment prior to surgery. It is unclear as to why a subset of those who endorse a history of depression ended up in the pain improvement group; however, this is worth further investigation, especially as it relates to overall psychosocial functioning in patients in this trajectory. There is a need to assess variables such as pain-related fear, pain acceptance and pain catastrophizing, which have been identified as being important in the maintenance and exacerbation of chronic pain in children [37, 38]. A pain-specific screening tool [24] may be more sensitive to risk of persistent pain post-operatively. Consistent with prior research [10], functional limitations prior to surgery appear to be a risk factor for persistent pain outcomes over time, as observed in the high pain trajectory group.

The current study must be viewed in light of its limitations. Despite a large sample with longitudinal data, only one measure was used to assess pain and functioning. Although the HOOS has been shown to have good construct validity, responsiveness and internal consistency [27–30], it fails to adequately capture all the factors contributing to CPOP. This study assumes that surgeries were successful and had been carried out without complications, which are surgical factors that future research should examine. Another future direction should be the analysis of other causes of pain, including psoas overload, inguinal hernia and referred pain, which could potentially contribute to patients having 'high pain' and CPOP. It also would have been beneficial to have data during the acute phase of postoperative pain. Having data shortly after surgery would have allowed for a clearer picture of the acute-to-chronic pain transition. Attrition was also a significant limitation; however, using a trajectory model is useful when there is missing data as individuals with missing observations can be included because PROC TRAJ uses all values available from each case to estimate an individual's timeline, which allows missing observations to be included in the analyses.

Additionally, the database captures race and not ethnicity, making it difficult to understand how surgical pain outcomes may differentially relate to ethnic minorities. Likewise, this sample was predominantly white and female, which limits conclusions based on males and other underrepresented groups.

Despite these limitations, the present study underscores the importance of examining post-operative pain in patients undergoing hip preservation surgery and demonstrates the need for pre-operative screening prior to surgery. While surgery may be beneficial for patients within all pain trajectory groups, as surgical intervention may correct the dysplasia or FAI in this population, the results of this study support the importance of a prospective, interventional study which identifies hip preservation surgery patients at risk for a poor pain trajectory and intervenes pre-operatively in an effort to reduce the risk of CPOP. With recent economic costs of adult chronic pain estimated to be between $560–$635 billion per year [6], research on the role of persistent pain is important in order to positively impact pre-surgical preparation and postsurgical care. These findings, which suggest that there are factors associated with CPOP that are independent of surgical outcome, highlight the need for a multidisciplinary approach in order to address the relationship between hip surgery and pain.

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CONFLICT OF INTEREST STATEMENT

None declared.

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