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## Clinical and Translational Research

## Factors associated with subsequent surgery after septic arthritis of the knee in children

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Septic arthritis of the knee in children is a challenging problem. Surgical debridement is an established treatment, but there is a paucity of literature on long-term prognosis.

**AIM**

To determine the rates and factors associated with return to surgery (RTS) and readmission after index surgical debridement for septic arthritis of the knee in children.

**METHODS**

This is a retrospective cohort study that utilizes data from the Healthcare Cost and Utilization Project (HCUP). We included patients between ages 0 to 18 years that underwent surgical debridement for septic arthritis of the knee between 2005 and 2017. Demographic data included age, gender, race, hospital type and insurance type. Clinical data including index admission length of stay (LOS) and Charlson Comorbidity Index (CCI) were available from the HCUP database. Descriptive statistics were used to summarize the data and univariate and multivariate analyses were performed.

**RESULTS**

Nine-hundred thirty-two cases of pediatric septic knee were included. This cohort was 62.3% male, with mean age of 9.0 ( $\pm$  6.1) years. Approximately 46% of patients were white and approximately half had Medicaid insurance. Thirty-six

patients (3.6%) required RTS at a minimum of 2 year after index surgery, and 172 patients (18.5%) were readmitted at any point. The mean readmission LOS was 11.6(± 11.3) d. Higher CCI was associated with RTS ( $P = 0.041$ ). There were no significant associations in age, gender, race, insurance type, or type of hospital to which patients presented. Multivariate analysis showed that both increased CCI ( $P = 0.008$ ) and shorter LOS ( $P = 0.019$ ) were predictive of RTS.

### CONCLUSION

Septic arthritis of the knee is an important condition in children. The CCI was associated with RTS at a minimum of 2 years after index procedure. No association was found with age, gender, race, insurance type, or hospital type. Shorter LOS and CCI were associated with RTS in multivariate analysis. Overall, risk of subsequent surgery and readmission after pediatric septic knee arthritis is low, and CCI and shorter LOS are predictive of RTS.

**Key Words:** Septic arthritis; knee; Orthopaedic surgery; Infection; Osteomyelitis; Debridement

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**Core Tip:** Septic arthritis of the knee is an important condition in children. The Charlson Comorbidity Index and shorter length of stay during index admission were associated with return to surgery after index procedure. No association was found with age, gender, race, insurance type, or hospital type. Risk of subsequent surgery and readmission after pediatric septic arthritis of the knee is low; however, presence of comorbidities and shorter length of stay are predictive of subsequent surgery.

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## INTRODUCTION

Septic knee occurs in children at a rate between 5 and 12 per 100000[1,2]. This pathological invasion of the joint in children can place patients at risk for osteomyelitis, recurrent joint infection, and sepsis. Septic arthritis is often diagnosed clinically in pediatric patients, or can be diagnosed and treated based on arthrocentesis. Timely diagnosis and management is critical to decrease the risk of damage to articular cartilage and the joint[3]. Acute septic arthritis is typically of hematogenous origin in children. It is more common in boys and the most common causative agent is *Staphylococcus aureus*, with methicillin-resistant strains on the rise[4].

Treatment is typically comprised of antibiotics as well as surgical irrigation and debridement, either *via* arthroscopy or arthrotomy, which is typically determined by surgeon preference. Long-term sequelae of septic arthritis in children can include persistent infection, growth disturbance, chondrolysis, and degenerative arthritis[5]. However, it is important to note that complications such as symptomatic osteoarthritis develop slowly, and longer follow-up is required to detect all possible sequelae[6]. The rate of these sequelae has been cited at 10% among all patients with septic arthritis of the knee, and is increased when diagnosis and treatment are delayed[7]. To our knowledge, there are no studies investigating the need for subsequent surgery for these issues after septic arthritis of the knee.

This outcome has been similarly studied in septic arthritis of the hip in children[8-10]. Livingston *et al* [8] found that presence of left shift or higher C-reactive protein pre-operatively, higher post-operative temperature, and positive cultures were associated with increased risk for repeat surgery. As such, we hypothesize that similar preoperative risk factors may exist for recurrent septic arthritis of the knee.

The purpose of this study was to determine the incidence of patients that require any subsequent surgery after septic arthritis of the knee initially managed with irrigation and debridement. We also assess risk factors for subsequent surgery after septic arthritis of the knee. We hypothesized that in this database, demographic factors such as age, race, or ethnicity would have no effect on increased risk, and that clinical factors such as medical comorbidities would carry increased risk of subsequent surgery.

## MATERIALS AND METHODS

### Data collection

This study was reviewed by the Institutional Review Board and exempt as a database study. Data were collected from the Healthcare Cost and Utilization Project database from the states of California and Florida. Inclusion criteria were patients age 0 to 18 years, who underwent knee irrigation and debridement for septic arthritis from 2005 to 2017 and had at least two years of follow-up data.

Demographic data including age, sex, ethnicity, race, insurance, and state were collected for all patients. Clinical data included length of stay (LOS), type of hospital (pediatric, academic, county), and significant comorbidities. The Charlson Comorbidity Index (CCI) was utilized as a composite measure to capture the occurrence of major comorbidities[11-13]. The CCI is a validated tool and accounts for age and comorbidities such as myocardial infarction, heart failure, liver or kidney disease, diabetes, and cancer [11]. Our primary outcome of interest was any surgical procedure after index irrigation and debridement of the knee, including those that occurred during the index or subsequent hospital admissions. Secondary outcomes included readmission and length of stay for re-operation.

### Statistical analysis

Descriptive data are expressed as means  $\pm$  standard deviation, or for categorical variables as percentage with counts. Differences among outcome groups and categorical variables were tested by chi-square test. Differences between continuous variables were analyzed using student's *t*-test. Pearson's correlation was used to analyze association between all studied parameters. The values  $P < 0.05$  were considered statistically significant. Multivariate logistic regression analysis was then performed using any variables with  $P < 0.10$  in univariate analysis, which was established *a priori*. Statistical analysis was done using Stata 17 (StataCorp LLC, College Station, TX, United States).

## RESULTS

A total of 932 cases of septic arthritis of the knee were identified over the study period. Table 1 displays the demographic characteristics of this cohort. At the time of index admission for septic arthritis, the median age was  $9.0 \pm 6.1$  years and 62% of patients were male. Approximately, 2% of patients were of Asian race, 26% were Hispanic, 22% were Black, 46% were white, and 3% identified as other race. Thirty percent of patients were seen at a county hospital, 13% were seen in an academic hospital, and 15% were seen in a children's hospital. Forty-nine percent of patients were state-insured and 41% were privately insured. The majority (58.5%) of admissions were emergent. The mean LOS for the index hospitalization was  $9.3 \pm 12.0$  d, with a median of 6 d. The mean CCI of patients was  $0.26 \pm 0.73$ , with a range from 0 to 8.

In total, 36 (3.9%) of these patients underwent subsequent surgery at a median of 11.5 d after index debridement (range 1-1641 d). Readmission was for a mean of 11.6 d ( $\pm 11.3$  d). The most common readmission diagnosis was pyogenic arthritis, and the most common subsequent surgery code was knee arthroscopy. There were no significant differences in demographics, payor type or presenting hospital between patients that did or did not undergo a subsequent knee-related procedure. In univariate analysis, CCI at the time of initial treatment was significantly higher in the cohort who underwent subsequent surgery ( $P = 0.041$ ). Shorter length of stay at the time of index admission trended towards significance as well and was therefore included in the subsequent multivariate analysis ( $P = 0.066$ ). Multivariate analysis showed that both increased CCI ( $P = 0.008$ ) and shorter LOS ( $P = 0.019$ ) were predictive of subsequent surgery.

## DISCUSSION

This retrospective database study demonstrated that in a population of 932 children who underwent initial surgical irrigation and debridement for septic arthritis of the knee, subsequent surgery was undertaken in 3.9% ( $n = 39$ ) of them. Higher index CCI and shorter LOS were significantly associated with the group requiring repeat irrigation and debridement.

In the literature, it has been shown that in septic hip arthritis, risk factors for repeat debridement include methicillin-resistant *Staphylococcus aureus* infection, higher inflammatory markers and higher fevers. There are few similar studies that have looked at septic knee arthritis, and none have looked at the rates among a large patient population. We utilized a multi-state database to examine similar trends in septic knee arthritis in children. The current study shows that majority of patients with septic arthritis of the knee managed with surgical debridement do not require any subsequent surgery. However, baseline comorbidities and shorter LOS at the time of index admission may be associated with need for subsequent surgery.

Table 1 Cohort characteristics

Characteristics	Total	No return to surgery	Return to surgery	P value
<i>n</i>	932	896 (96.1)	36 (3.9)	
Age	8.96 6.07	8.90 6.09	10.47 5.53	0.129
Sex, % male	581 (62.3)	557 (62.2)	24 (66.7)	0.709
Race, %				0.366
Asian	19 (2.0)	17 (1.9)	2 (5.6)	
Black	185 (19.9)	181 (20.2)	4 (11.1)	
Hispanic	220 (23.6)	208 (23.2)	12 (33.3)	
White	382 (41.0)	367 (41.0)	15 (41.7)	
Native American	3 (0.3)	3 (0.3)	0 (0)	
Other	26 (2.8)	26 (2.9)	0 (0)	
County hospital, %	282 (30.3)	271 (30.3)	11 (30.6)	0.968
Academic hospital, %	120 (12.9)	113 (12.6)	7 (19.4)	0.230
Children's hospital, %	138 (15.0)	134 (15.1)	4 (11.4)	0.551
Insurance				0.716
Commercial	380 (40.8)	366 (40.9)	14 (38.9)	
Medicaid	460 (49.4)	444 (50.0)	16 (44.4)	
Other	67 (7.2)	62 (6.9)	5 (13.9)	
Self pay	19 (2.0)	18 (2.0)	1 (2.8)	
No charge	5 (0.5)	5 (0.6)	0 (0)	
Admission type				0.646
Elective	221 (23.8)	211 (24.7)	10 (27.8)	
Urgent	157 (16.9)	149 (16.7)	8 (22.2)	
Emergent	544 (58.5)	528 (58.9)	16 (44.4)	
State				0.268
CA	383 (41.1)	365 (40.7)	18 (50)	
FL	549 (58.9)	531 (59.3)	18 (50)	
Length of index stay	9.3 12.0	9.4 12.1	5.7 6.1	0.066
Charlson Comorbidity Index	0.26 0.73	0.25 0.73	0.5 0.81	0.041 <sup>a</sup>

<sup>a</sup>Significant.

The rate of subsequent surgery after index irrigation and debridement for septic arthritis of the knee is low. There may be several reasons for this finding. In cases of septic arthritis of the knee, joint aspiration is more readily accessible as a bedside procedure, and therefore an aspirate sample is obtained faster and treatment with antibiotics may be initiated sooner in the hospital course. The knee is also a larger joint without the tenuous vascularity as is noted in the hip. Most cases of septic arthritis of the knee are methicillin-sensitive *Staphylococcus aureus*, or other less virulent organisms such as *Kingella* which overall portend a more benign clinical course. Overall, these findings help to counsel patients that most will not require any subsequent surgery after initial irrigation and debridement.

The choice between arthrotomy and arthroscopy is actively studied in the literature[14]. One study suggests that arthrotomy was associated with reduced repeat surgeries and faster recovery[15]. However, additional research is needed. All these factors from microbiology to method of debridement can contribute to the success of the surgery in eradicating infection. One consequence of inadequate treatment is need for repeat surgery[16].

Comorbidities are an established risk factor for infections such as septic arthritis[17,18]. Additionally, greater comorbidities have been shown to contribute to poor outcomes after septic arthritis in adults [17]. The CCI has been used to quantify comorbid conditions in pediatric patients, and our study shows

that pediatric patients with comorbidities are at risk for requiring subsequent surgery after index irrigation and debridement. This information may be useful in counseling patients and families regarding the risk for subsequent surgery, and it may also help clinicians in determining postoperative management after index debridement.

Additionally, a shorter LOS was associated with a need for subsequent surgical management. A shorter LOS is likely associated with a shorter course of IV antibiotics and presumably less postoperative observation. Shorter courses of IV antibiotics have been associated with persistent infection and it is important to ensure appropriately clinical and laboratory improvement prior to transitioning to oral antibiotics for discharge[19]. This data is also helpful for healthcare systems to provide clinical pathways, which have been shown in previous studies to reduce the risk for readmission[20]. It should be noted, however, that our length of stay was long with mean of 9 d, and the standard deviation was wide.

This study found no significant differences across socioeconomic factors such as insurance type or hospital where patients were hospitalized. This is reassuring given the obvious disparities in healthcare; however, the number of subsequent surgeries in our cohort is low. Further study using data from more sources and including direct measures of patient socioeconomic status, such as household income, are needed to confirm this finding. Furthermore, sex and race were not significantly associated with subsequent surgery. However, it is important to note that the majority of our patients were male, which is consistent with the epidemiology of septic arthritis[17].

Limitations in this study include the retrospective nature of this database study, and the limited clinical data available. We did not have available data such as time to diagnosis, pre-operative inflammatory markers, microbiology results, or post-operative vital signs. Similarly, we are unable to determine the specific reasons or diagnosis codes for subsequent surgery such as growth disturbance or joint degeneration, or comorbidities such as osteomyelitis. Also, the data available are not able to determine with specificity between open and arthroscopic index procedures. We intend to study future cohorts with more clinical data available and explore the variables which best predict need for repeat surgeries in similar populations. Additionally, it is possible that some patients may have sought care elsewhere; however, this study utilized a large database and provides a baseline assessment of risk for subsequent surgery. Lastly, we only included patients that underwent a subsequent procedure and not all hospitalizations. It is likely that readmissions may be more common than the rate of subsequent surgery reported in this study; however, the goal of this study was to determine the rates of significant outcomes such as subsequent surgery after index septic arthritis of the knee.

Few patients require subsequent surgery after irrigation and debridement for septic arthritis of the knee. However, patients with comorbidities and shorter LOS at index admission are risk factors for subsequent surgery. Additional research is needed to determine the appropriate length of stay for patients with septic arthritis of the knee in order to optimize patient care and minimize the need for repeat surgery.

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## CONCLUSION

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In conclusion, this retrospective database study demonstrated that in a population of 932 children who underwent initial surgical irrigation and debridement for septic arthritis of the knee, subsequent surgery was undertaken in 3.9% ( $n = 39$ ) of them. Higher index CCI and shorter LOS were significantly associated with the group requiring repeat irrigation and debridement.

## ARTICLE HIGHLIGHTS

### **Research background**

Septic arthritis in children is a challenging clinical problem and carries with it many long-term sequelae. Repeat surgeries are sometimes necessary to eradicate infection. Understanding the rate of repeat irrigation and debridement in this population, and the risk factors associated, can help to focus clinical interventions and future studies.

### **Research motivation**

Septic arthritis of the knee can be a serious clinical problem, and affects children and their families greatly. Understanding further the rate and risk of requiring multiple surgeries can help surgeons in counseling of these patients and their families.

### **Research objectives**

To determine the rate of repeat irrigation and debridement in children who undergo surgical washout of the knee. Secondarily, the aim is to highlight any significant risk factors associated with repeat surgery.

### Research methods

This is a retrospective cohort study that utilizes data from the Healthcare Cost and Utilization Project (HCUP). We included patients between ages 0 to 18 years that underwent surgical debridement for septic arthritis of the knee between 2005 and 2017. Demographic data included age, gender, race, hospital type and insurance type. Clinical data including index admission length of stay and Charlson Comorbidity Index (CCI) were available from the HCUP database. Descriptive statistics were used to summarize this data. Univariate and multivariate analyses were performed with all variables with  $P < 0.10$  on univariate analysis.

### Research results

Nine-hundred thirty-two patients were included in this retrospective database study. In total, 36 (3.9%) of these patients underwent subsequent surgery after surgical irrigation and debridement for septic arthritis of the knee. In univariate analysis, CCI at the time of initial treatment was significantly higher in the cohort who underwent subsequent surgery ( $P = 0.041$ ). Shorter length of stay at the time of index admission trended towards significance as well and was therefore included in the subsequent multivariate analysis ( $P = 0.066$ ). Multivariate analysis showed that both increased CCI ( $P = 0.008$ ) and shorter LOS ( $P = 0.019$ ) were predictive of subsequent surgery.

### Research conclusions

In conclusion, this retrospective database study demonstrated that in a population of 932 children who underwent initial surgical irrigation and debridement for septic arthritis of the knee, subsequent surgery was undertaken in 3.9% ( $n = 39$ ) of them. Higher index CCI and shorter LOS were significantly associated with the group requiring repeat irrigation and debridement.

### Research perspectives

Future research in this area should include prospective studies of septic arthritis of the knee in children, and can follow patients long-term for sequelae of disease. This study was limited as a retrospective database study to the clinical data available.

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## FOOTNOTES

**Author contributions:** O'Donnell JM, Ekunseitan E, and Swarup I all contributed to this work; O'Donnell JM and Swarup I designed the research study; O'Donnell JM and Ekunseitan E performed the research; O'Donnell JM analyzed the data; O'Donnell JM wrote the manuscript; Ekunseitan E and Swarup I edited and reviewed the manuscript; All authors have read and approve the final manuscript.

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**Data sharing statement:** The authors will make available all data which are also part of a publicly available database.

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