Journal of Clinical Orthopaedics and Trauma 11 (2020) S177–S183

Contents lists available at ScienceDirect

Journal of Clinical Orthopaedics and Trauma

journal homepage: www.elsevier.com/locate/jcot

Repeat irrigation & debridement for patients with acute septic knee arthritis: Incidence and risk factors

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ARTICLE INFO

Article history:
Received 15 October 2019
Received in revised form
2 December 2019
Accepted 7 December 2019
Available online 13 December 2019

Keywords:
Septic arthritis
Risk factors
Knee
White blood cell count

ABSTRACT

Background: Septic knee arthritis is considered an orthopedic emergency due to its significant morbidity and potential to be life-threatening. One important outcome in treatment of septic knee arthritis is whether return to the operating room for repeat irrigation and debridement is required. This complication presents extra burden to the patient, as well as to the health care system. This study aims to first isolate the incidence of repeat irrigation and debridement at the authors' home institution and then define risk factors for repeat washout for septic arthritis of the knee.

Methods: Records from all patients at a single academic institution with acute septic knee arthritis who had arthroscopic or open I&D of the knee joint from January 2005–December 2015 were collected retrospectively. Patients were initially identified on the basis of diagnosis coding in the institution's medical information system. Following collection/screening based on strict inclusion/exclusion criteria, a cohort of 63 patients was ultimately included. 18 patients were assigned to a "repeat washout" (RW) cohort and 45 patients were assigned to a "no repeat washout" (NRW) cohort. Univariate analyses and multivariable regression models were performed between the two washout cohorts to identify variables associated with repeat washout.

Results: Patients requiring a repeat washout (RW) had a statistically significant association with African American/Hispanic race, higher BUN levels, higher serum white blood cell (WBC) count on admission, concurrent infection, and isolated bacteremia when compared to those patients who did not require a repeat washout (NRW) (all respective $P < 0.05$). Multivariable regression analysis demonstrated concurrent infection and higher synovium WBC count to increase the risk for another repeat washout. Patients who had a concurrent infection were shown to have nearly 12-fold higher odds of needing a repeat washout than those without a concurrent infection (95% CI:2.40–56.88; $P = 0.0023$). For every 1000 unit increase in synovium WBC count, the odds of needing a repeat washout increased by 1% in patients with concurrent infection (95% CI:1-2%; $P = 0.0168$).

Conclusion: This study retrospectively isolated risk factors associated with repeat surgical lavage. In the multivariable regression analysis, both concurrent infection and increased synovial WBC count were significantly associated with the need for repeat knee I&D. This finding is significant, as it may signify a potential for increased infectious resilience for acute septic arthritis of the knee secondary to seeding from systemic infection, thus requiring multiple I&Ds to meet resolution. This finding may carry clinical significance in the early stages of patient counseling regarding hospital course and prognosis.

Level of evidence: IV.

1. Introduction

Septic arthritis is an orthopaedic emergency that can cause cartilage destruction and potentially life threatening systemic illness, such as sepsis.[1] The knee is the most commonly infected

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https://doi.org/10.1016/j.jcot.2019.12.006
0976-5662/

joint, and the incidence is increasing.[2] Patients typically present with pain, effusion, and sometimes systemic signs including: fever, leukocytosis, and elevated inflammatory markers.[2] Standard treatment for acute septic arthritis of the knee includes emergent operative management with irrigation and debridement (I&D) and culture-specific targeted intravenous antibiotic therapy. I&D may be performed arthroscopically or via open arthrotomy. The role of this therapy is to remove purulence, debris, and decrease the intra-articular microbial burden.[3] Delay in therapy can lead to irreversible destruction to the articular cartilage, worsening infection, and sepsis.[1]

Prognostic factors in the treatment of septic arthritis have previously been studied. One important outcome in treatment of septic knee arthritis is whether return to the operating room for repeat irrigation and debridement is required. Washout is performed through an open incision or arthroscopically; multiple studies have compared the rates of return to the operating room, as well as other outcomes for these two methods.[1–4] Bohler et al. identified male gender as a risk factor for repeat washout.[4] Other risk factors for return to the operating room include Gachter Stage III or IV, positive culture of drainage fluid collected 24 h after index procedure, and time to treatment after system onset.[5,6]

At the authors' home institution, knee I&D for acute septic knee arthritis is performed via arthroscopy or arthrotomy based on surgeon preference. The current body of literature on surgical care of acute septic knee arthritis generally favors arthroscopy to arthrotomy for I&D, citing lower rates of adverse events and better outcomes.[2,3] These improved outcomes include lower rates of sepsis, greater range of motion, and lower rates of return to the operating room.[2,3] However, it is our observation that regardless of approach, these patients frequently require repeat I&D to be sufficiently treated. The decision to perform a repeat procedure is typically based on post-washout operative cultures and/or worsening of symptoms post-operatively. The need for repeat washout presents extra burden to the patient, as well as to the health care system.[9] This study aims to determine the incidence of repeat washouts and identify possible risk factors for repeat washout after initial debridement for septic arthritis of the knee.

1.1. Patient selection and methods

Institutional Review Board approval was obtained for this study. Patients admitted to a single academic institution with acute septic knee arthritis who had arthroscopic or open I&D of the knee joint, between January 2005 and December 2015, were collected retrospectively. No consenting process for the patients was required for this study. Patients were identified on the basis of diagnosis coding in the institution's medical information system (ICD-10 Code M00.869 and related prior ICD codes).[7] All patients treated surgically for acute septic knee arthritis via arthroscopy or arthrotomy during the study period were included in the initial study group. Patients who did not fulfill the definition of septic arthritis were excluded. Patients were also excluded from the study if they did not undergo a formal I&D, had a prior knee arthroplasty, or had retained hardware from prior fracture. Patients that received initial surgical treatment at another facility before transferring to our institution were excluded. Patients with significant data missing from their medical records were excluded. Patients with prior periarticular fracture who underwent subsequent removal of hardware were included.

The diagnosis of septic arthritis was determined based on clinical exam and laboratory data. Classical clinical findings include knee pain and swelling, fever, joint-line tenderness, erythema, effusion, and decreased range of motion. Laboratory findings predictably demonstrate elevated inflammatory markers (ESR, CRP) and may or may not include leukocytosis.[7] Patients whose examination was concerning for septic arthritis underwent diagnostic arthrocentesis. The diagnosis of acute septic arthritis was based on a positive synovial culture or those who have a synovial WBC count greater than 50,000/mm^3. Patients with equivocal presentation were typically given a trial of NSAIDs and frequently re-examined.

The diagnosis of septic knee arthritis was determined based on clinical and laboratory evidence. If clinical suspicion is sufficient, sterile bedside knee arthrocentesis is performed. The diagnosis of acute septic arthritis was made based on a positive synovial culture or a synovial WBC count greater than 50,000/mm^3.

Surgical methods were included in the analysis and included arthroscopic or open techniques. At our institution, arthroscopic knee I&D is typically performed under general anesthesia with standard anterolateral and anteromedial portals. Infected joint material is sent for culture after portals are made. Necrotic and/or purulent joint material is debrided, and the joint is typically irrigated with sterile saline. A drain is often left within the joint post-operatively, and portal sites are closed. In arthrotomy, the procedure is again performed under general anesthesia. Arthrotomy is performed via either a medial or lateral parapatellar approach and synovial fluid cultures are sent prior to debridement. Infected and/or purulent material is debrided and the joint is irrigated with 9 L of sterile saline. A drain is typically left within the joint, and the arthrotomy is closed post-operatively. In both methods, post-I&D cultures are typically taken prior to closure.

Postoperatively, patients remain admitted and are rounded on daily by the orthopedic surgery service. The infectious disease team is consulted. Empiric intravenous antibiotics are continued post-operatively, most commonly 1 g vancomycin q12hr and 3.375 piperacillin/tazobactam q8hr, and then are tailored to the micro-organisms' sensitivities in concordance with infectious disease recommendations. Once drainage has decreased to less than 15 cc/shift, the drain is removed and patients may begin range-of-motion exercises as tolerated. Lack of clinical improvement, clinical deterioration, elevated inflammatory markers or positive post-irrigation cultures prompt repeat surgical irrigation. After final washout, patients are typically continued on IV antibiotics administered through a PICC line for 4–6 weeks, depending on the infectious agent.

Patients meeting inclusion/exclusion criteria are referenced in Fig. 1. 331 patients were admitted to our home institution during the study period under the diagnosis code of acute pyogenic septic arthritis (ICD-10 code M00.869). 171 patients who did not fulfill the clinical definition of septic arthritis were excluded. 56 patients were excluded on the basis of prior knee arthroplasty. 21 patients were excluded for retained hardware from prior fracture. 3 patients were excluded as no formal I&D was performed. An additional 17 patients were also ineligible for this study due to either significantly missing data or having had a prior I&D at an outside hospital prior to transfer. 63 patients were ultimately included in our final group for analysis. Of 63 patients, 18 patients (28.6%) required at least one repeat I&D procedure (RW group).

Patients who met inclusion/exclusion criteria were divided into two main cohorts of interest: patients requiring a repeat washout (RW) and patients who did not require a repeat washout (NRW). Univariate analysis between washout cohorts and demographics, comorbidities, laboratory and microbiology results, and hospital courses was performed by way of χ^2 testing, Fisher's exact test, independent samples *t*-test, or the Kruskal-Wallis test where appropriate in order to identify variables with unadjusted associations with repeat washout.

Covariates with corresponding univariate-test $P < 0.2$ were entered into a multivariable logistic regression model undergoing a stepwise backwards elimination process in order to identify

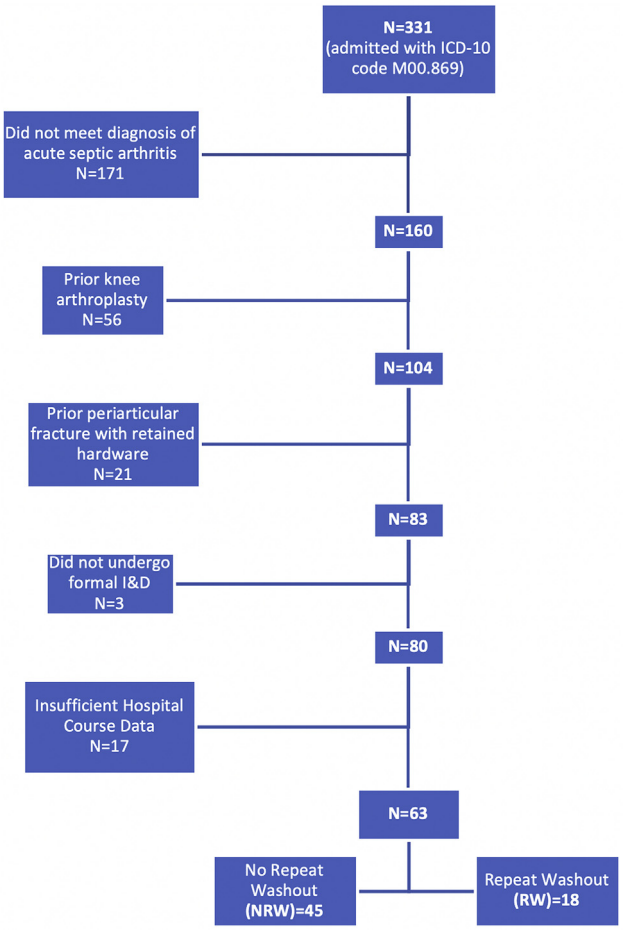

Fig. 1. Inclusion and exclusion criteria for patients with an ICD code corresponding to septic knee arthritis.

significant independent predictors of repeat washout and to develop a predictive model for repeat washout. Multicollinearity of covariates was assessed by way of variance inflation factor (VIF) analysis and the condition index. Detected collinearity was managed by way of factor analysis in conjunction with purposeful selection methods, with VIF <2 considered acceptable.

All statistical analysis was performed using SAS version 9.4 (SAS Institute Inc., Cary, NC), with $P < 0.05$ considered statistically significant.

2. Results

15 of the 63 patients who met inclusion/exclusion criteria at our home institution required a repeat irrigation and debridement, yielding an incidence of 23.8% during the study period. Of the 63 patients who met inclusion/exclusion criteria, the mean age was 53.3 ± 15.9 and the mean BMI was 28.3 ± 7.5 (mean ± standard deviation). 45 (71.4%) were Male gender, and 18 (28.6%) were Female gender. 37 (58.7%) were Black/African American race, 1 (1.6%) was Asian race, 3 (4.8%) were Hispanic race/ethnicity, and 22 (34.9%) were White/Caucasian race. 36 (57.1%) patients had a District of Columbia zip code.

Patients requiring a repeat washout (RW) had a statistically significant association with African American race/ethnicity, Hispanic race/ethnicity, higher BUN levels, higher serum white blood cell count on admission, a higher proportion of concurrent infection, and a higher proportion of isolated bacteria in serum when compared to those patients who did not require a repeat washout (NRW) (all respective $P < 0.05$; Table 1). RW was also associated with slightly lower body temperatures, a smaller proportion of patients presenting as febrile, a higher proportion of isolated bacteria in the synovial fluid, a higher proportion of gram positive bacteria in the synovium, higher synovium white blood cell counts, a higher proportion of crystals, and a higher proportion of diabetes (all respective $P < 0.2$; Table 1).

Multivariable regression analysis illuminated concurrent infection and synovium white blood cell count to have significant independent associations with the need for a repeat washout (Table 2). Patients who had a concurrent infection were shown to have 11.68 times higher odds of needing a repeat washout compared to those without a concurrent infection (95% CI: 2.40–56.88; $P = 0.0023$), and for every 1000 unit increase in synovium white blood cell count, the odds of needing a repeat washout increase by 1% (95% CI: 1%–2%; $P = 0.0168$).

The aforementioned multivariable model had a corresponding Receiver Operating Characteristic Curve generated, with Area under the Curve (AUC) = 0.8215 (Fig. 2), indicating strong predictive ability, and a Hosmer-Lemeshow Goodness-of-Fit Test *P*-value = 0.4949, indicating a well-calibrated predictive model.

3. Discussion

Acute septic knee arthritis is an orthopaedic emergency with potentially disastrous sequelae.[6] The need for repeat washout is an important prognostic factor, as this poses further risk to the patient and extra cost to the hospital system and health care system at large. This study retrospectively isolated risk factors associated with repeat surgical washouts using both univariate and multivariate analyses. In the multivariate analysis, both concurrent infection and increased synovial white blood cell count were significantly associated with a need for repeat knee I&D.

A goal of this study was to risk stratify patients with the diagnosis of acute septic arthritis and identify those who are potentially more likely to require a second procedure after initial I&D. When the two variables significantly associated with our primary outcome were entered into our multivariate analysis system separately, they only barely reached a level of significance. For instance, the unadjusted odds ratio estimate of concurrent infection and synovium WBC was 4.43 (1.38–14.21, P = 0.0123) and 1.01 (0.99–1.01, P = 0.0810), respectively. The interpretation of this data suggests that odds of reoperation are 4.43 times higher with concurrent infection, while higher WBC does not reach significance when these variables are analyzed exclusively. However, when these data were included in the system together, they reached a level of significance such that each increase in synovial fluid WBC of 1000 cells/mm^3 was associated with a 1% increased risk for repeat washout and concurrent infection increases odds of reoperation nearly 12-fold. This metric has the potential to be of clinical utility, if it is shown to be valid in other cohorts. Patients with concurrent infection and high synovial fluid WBC counts present a potential opportunity for additional intervention to minimize risk of return to the OR. What interventions may benefit these patients is an area for potential future study.

The incidence of failed I&D leading to repeat washout at our home institution was 23.8%. This value was similar to the incidence in the existing literature (19.1–41%). Table 3 is a comprehensive list of the existing literature summarizing previously noted risk factors for repeat I&D in acute septic arthritis (Table 3).

Septic arthritis can occur in isolation or in conjunction with systemic infection.[5] In isolation, the knee is directly seeded, often times due to trauma or misplaced IV drug administration.[8] In patients with infection elsewhere in the body, bacteremia can seed

Table 1
Repeat washout status by variables of interest.

Variable (N = 63)	No Repeat Washout (n = 45, 71.4%)	Repeat Washout (n = 18, 28.6%)	P-Value
DEMOGRAPHICS			
Sex (Female)	14 (31.1)	4 (22.2)	0.4805
Race			**0.0339**
African American	29 (64.4)	8 (44.4)	
Asian	1 (2.2)	-	
Hispanic	-	3 (16.7)	
White	15 (33.3)	7 (38.9)	
Age	52.2 ± 16.4	56.2 ± 14.4	0.3772
	51 (42, 63)	54.5 (48, 63)	
Zip Code			0.4687
DC	27 (60.0)	9 (50.0)	
Other (MD, VA, etc.)	18 (40.0)	9 (50.0)	
Body Mass Index (BMI)	28.2 ± 7.9	28.8 ± 6.6	0.3775
	24.8 (21.5, 35.3)	27.3 (24.8, 35.3)	
INITIAL LAB. VALUES			
RBC (n = 44, n = 18)	4.0 ± 0.7	4.1 ± 0.7	0.2062
	4 (3.5, 4.5)	4.2 (4.0, 4.6)	
HGB (n = 44, n = 18)	11.5 ± 2.1	11.6 ± 2.3	0.5765
	12 (10.3, 12.9)	12.6 (10.6, 13.2)	
HCT (n = 44, n = 18)	34.7 ± 5.5	34.6 ± 6.3	0.8706
	35.5 (32.1, 38.3)	35.8 (31.8, 39.2)	
MCV (n = 44, n = 18)	88.1 ± 6.9	84.7 ± 9.6	0.2264
	89.5 (82.7, 94.1)	87.2 (82.3, 90.2)	
PT (n = 35, n = 13)	16.0 ± 5.5	15.0 ± 1.4	0.6505
	14.5 (13.9, 15.7)	14.5 (14.3, 16.1)	
INR (n = 35, n = 13)	1.3 ± 0.7	1.2 ± 0.1	0.8344
	1.1 (1.1, 1.3)	1.1 (1.1, 1.3)	
PTT (n = 32, n = 11)	36.7 ± 7.9	37.0 ± 7.3	0.9224
	35.8 (31.8, 42.1)	37.7 (31.4, 41.9)	
Glucose (n = 44, n = 18)	136.4 ± 59.7	153.2 ± 80.4	0.3979
	121 (93, 157.5)	123.5 (102, 156)	
BUN (n = 44, n = 18)	16.6 ± 11.2	24.1 ± 15.8	**0.0182**
	13 (9.5, 19.5)	18 (13, 29)	
Creatinine (n = 44, n = 18)	1.3 ± 1.4	1.7 ± 2.0	0.2279
	0.8 (0.7, 1.1)	0.9 (0.7, 1.7)	
BUN/Creatinine ratio (n = 44, n = 18)	15.3 ± 4.9	18.8 ± 7.1	**0.0307**
	16 (12, 18)	20 (14, 24)	
Albumin (n = 32, n = 11)	3.6 ± 1.3	3.1 ± 0.7	0.2647
	3.2 (2.9, 4.1)	3.0 (2.7, 3.7)	
CRP (n = 40, n = 15)	149.8 ± 99.2	184.2 ± 97.4	0.2219
	160.5 (64.1, 231.7)	223.9 (60.9, 270)	
ESR (n = 35, n = 14)	70.8 ± 35.2	85.5 ± 29.2	0.2362
	76 (35, 103)	91.5 (65, 109)	
WBC (n = 42, n = 17)	11.0 ± 4.5	15.9 ± 5.6	**0.0025**
	11.0 (7.7, 13.4)	15.2 (12.4, 20.8)	
Temperature	98.9 ± 1.6	98.2 ± 1.1	0.0984*
	98.4 (97.9, 99.7)	98.0 (97.5, 98.8)	
Febrile	10 (22.2)	1 (5.6)	0.1097**
HOSPITAL COURSE			
Admitted to ICU	8 (17.8)	3 (16.7)	0.6155
Hours from ADM to OR (n = 45, n = 17)	37.5 ± 40.5	33.1 ± 32.8	0.6471
	25 (12, 50)	20 (9, 46)	
Concurrent Infection	14 (31.1)	12 (66.7)	**0.0096**
INFEC.PROC. DETAILS			
Positive Blood Culture (n = 40, n = 18)	16 (40.0)	10 (55.6)	0.2704
Positive Synovial Cult. (n = 43, n = 18)	27 (62.8)	13 (72.2)	0.4795
Isolated Bac. Serum (n = 26, n = 10)	15 (57.7)	10 (100.0)	**0.0129**
Number % gram +	6 (40.0)	8 (80.0)	
Isolated Bac. Syn. Fl. (n = 33, n = 13)	25 (75.8)	13 (100.0)	0.0532*
Number % gram +	11 (44.0)	10 (76.9)	
Overall gram + (n = 24, n = 16)	11 (45.8)	11 (68.8)	0.1535**
Synovium WBC (n = 39, n = 17)	86134.9 ± 70568.9	128042.1 ± 91450.4	0.0664*
	64800 (40663, 102250)	81000 (63600, 182600)	
Crystals (n = 40, n = 17)	3 (7.5)	4 (23.5)	0.1091**
1st/Original Washout			0.9132
Arthroscopic	38 (84.4)	15 (83.3)	
Open Arthrotomy	7 (15.6)	3 (16.7)	
COMORBIDITIES			
DM			0.1804**
Non-insulin dep.	8 (17.8)	7 (38.9)	
Insulin dep.	5 (11.1)	2 (11.1)	
CHF	4 (8.9)	0 (0)	0.2501
CAD	0 (0)	0 (0)	-
COPD	2 (4.4)	1 (5.6)	0.6427

Table 1 (*continued*)

Variable (N = 63)	No Repeat Washout (n = 45, 71.4%)	Repeat Washout (n = 18, 28.6%)	P-Value
HIV/AIDS	2 (4.4)	1 (5.6)	0.6427
HTN	26 (57.8)	12 (66.7)	0.5147
Immunosuppression	10 (22.2)	3 (16.7)	0.4535
Smoker	15 (33.3)	4 (22.2)	0.3853
Inflammatory Arthritis (n = 43, n = 16)	14 (32.6)	5 (31.3)	0.9238
Recent Arthroscopy (n = 44, n = 16)	10 (22.7)	3 (18.8)	0.5224

Reported as n (%), mean ± standard deviation, and/or median (IQR); analyzed using χ^2, Fisher's exact test, independent samples *t*-test, or the Kruskal-Wallis test where appropriate. Bold denotes statistically significant data $p < 0.05$, * denotes marginally significant data $p < 0.10$, ** denotes trend-level significant data $p < 0.20$.
BMI = Body Mass Index; RBC = Red Blood Cell; HGB = Hemoglobin; HCT = Hematocrit; MCV = Mean Corpuscular Volume; PT = Prothrombin Time; INR = International Normalized Ratio; PTT = Partial Thromboplastin Time; BUN = Blood Urea Nitrogen; CRP = C-Reactive Protein; ESR = Erythrocyte Sedimentation Rate; WBC = White Blood Cell; ICU = Intensive Care Unit; DM = Diabetes Mellitus; CHF = Congestive Heart Failure; CAD = Coronary Artery Disease; COPD = Chronic Obstructive Pulmonary Disease; HIV/AIDS = Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome; HTN = Hypertension.

Table 2
Multivariable Analysis: Reduced model of significant predictors.

Variable	Adjusted Odds Ratio (95% Confidence Interval)	*P-Value*
Concurrent Infection	11.68 (2.40–56.88)	0.0023
Synovium WBC (per 1000 unit)	1.01 (1.01–1.02)	0.0168

WBC = White Blood Cell.

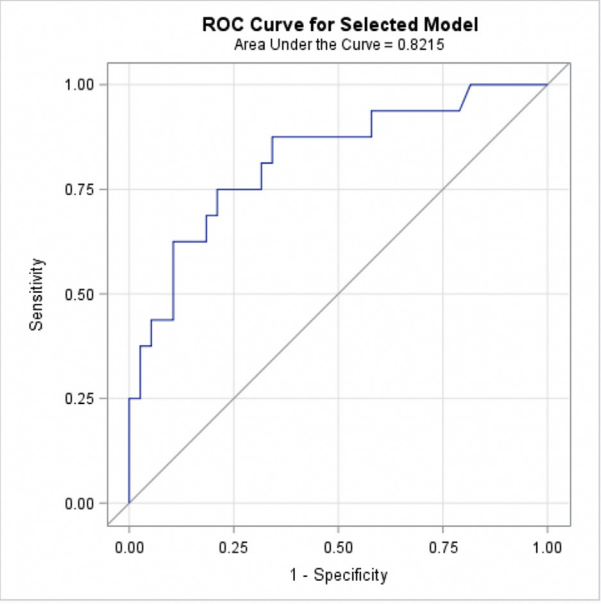

Fig. 2. Receiver operating curve of multivariable logistic regression model.

the blood through small capillaries that leak into the synovial fluid.[8] Patients in this study classified as having concurrent infection had culture-positive bacterial infections such as UTI or positive sputum culture. One potential explanation for the increased likelihood of treatment failure in these patients is continued seeding from the area of additional infection. This study did not verify whether the concurrent infection and septic joint were caused by the same organism, but this is a question that may be examined in future research. Interestingly, bacteremia was not an independent risk factor for repeat washout. Septic arthritis is commonly attributed to seeding by bacteria in the bloodstream. One potential explanation for the finding that concurrent infection was a significant risk factor for repeat washout while bacteremia was not is that in some cases, bacteremia may have been caused by or persisted due to the septic arthritis. Washout of the joint achieved source control sufficient to prevent continued infection. On the other hand, washout of the joint would not eliminate a UTI or pneumonia that could continue to seed the joint.

Prior studies have examined similar questions. In 2001, Seara et al. retrospectively evaluated prognostic factors dictating the prognosis of septic joints treated with arthroscopic washout. This study isolated time between onset of symptoms and surgery and kind of microorganism discovered, as significant factors correlated with poor functional outcome.[6] In 2014, Aim et al. reviewed 46 cases of septic arthritis and identified factors predictive of failure to achieve infection resolution after arthroscopic washout. 25% of patients required more than one arthroscopic lavage for resolution. Repeat lavage was associated with persistent drainage-fluid cultures after 24 h. This study was not specific to septic knee arthritis and included septic arthritis of the shoulder, hip, ankle and elbow joints.[5] One year later, Hunter et al. published a similarly designed study and found a certain synovial nucleated cell count (85,000 cells/HPF) to be significantly associated with treatment failure for septic arthritis.[9] Need for repeat lavage was also associated with a history of diabetes, *S. aureus* in the bacterial isolate, and a history of inflammatory arthropathy.[9] While this study did not specifically look at knees, it was high powered with 132 affected joints, 38% of which required repeat washout. The results of this study parallel our similarly designed report, as diabetes and gram-positive isolate were factors that correlated with the need for multiple lavages.[9] In 2019, Murphy et al. published a study focusing on risk factors for failed irrigation and debridement of septic hip arthritis in the pediatric population. This study found concomitant osteomyelitis to be a risk factor for re-infection following initial I&D. With open growth plates and intra-articular metaphyses, hip septic arthritis in children frequently has a similar, yet distinct pathophysiology compared to adults. Hematogenous seeding of intra-articular metaphyses, oftentimes with concurrent osteomyelitis, is far more common in children. Concurrent osteomyelitis was thus not a factor accounted for in this study. Murphy et al. also found elevated CRP and ESR on initial presentation to be associated with repeat I&D.[10] Elevated inflammatory markers are frequently cited as diagnostic criteria for septic hip arthritis in the pediatric population.[11,12] Elevated initial ESR ($P = 0.2362$) and CRP ($P = 0.2219$) were not significantly associated with repeat washout in this study. Murphy et al. also cited the presence of MRSA on synovial culture as a risk factor for repeat I&D. Outside of the

Table 3
Literature review of risk factors for repeat debridement in septic arthritis.

Authors	Study Design	Incidence of Repeat I&D	Risk Factors
Seara et al.	RR at a single institution identifying prognostic factors in arthroscopic I&D of septic joints.	N/A	Time from symptom onset to I&D, species of microorganism isolated
Aim et al.	RR at a single institution assessing outcomes of patients with septic joints (including knee, shoulder, hip, ankle) treated arthroscopically	25%	Gachter stage III or IV, positive intraoperative cultures resulting < 24 h of surgery
Bohler et al.	RR at a single institution comparing outcomes of I&D for septic arthritis via arthroscopic vs open approaches	N/A	Open I&D
Hunter et al.	RR at a single institution identifying potential risk factors for failure of a single surgical debridement for acute septic arthritis	38%	History of inflammatory arthropathy, large joint involvement, synovial fluid WBC count >85,000, *S. aureus* in synovial culture, history of diabetes
Johns et al.	RR at a single institution retrospectively comparing outcomes in patients treated with open vs arthroscopic I&D for septic knee arthritis	N/A	Open I&D
Jaffe et al.	RR of surgically treated native adult septic knees at a single institution performed to evaluate rates of unplanned return to the operating room following both arthroscopic and open treatment.	24.2% for open I&D, 19.2% for arthroscopic I&D	MRSA in synovial culture (only if treated arthroscopically), increased WBC count (160,000 vs. 52,000)
Faour et al.	Database RR to examine factors associated with complications following arthroscopic and open washouts for acute septic knee arthritis	N/A	N/A
Murphy et al.	Multicenter RR of pediatric population identifying risk factors for failed irrigation and debridement of septic hip arthritis	41%	Elevated initial ESR and CRP, infection with MRSA, presence of osteomyelitis

RR – retrospective review; I&D – Incision and drainage; N/A – not available; WBC – white blood cells; *S. aureus* – *Staphylococcus aureus*; MRSA – methicillin resistant *Staphylococcus aureus*; ESR – erythrocyte sedimentation rate; CRP – C-reactive protein.

pediatric hip population, bacterial virulence and infection with S. Aureus have been cited in the adult population as well as in recent literature.[6,13] While the nature of our institution's database did not allow for us to evaluate MRSA specifically, synovial fluid cultures isolated with gram-positive organisms were not associated with repeat washout ($P = 0.1535$).

This study has multiple limitations. Not all patients had blood cultures drawn, meaning the number of patients diagnosed with bacteremia is likely lower than the actual number of patients with bacteremia. The sample size of the study was small, with only 63 patients meeting inclusion criteria. Due to low power, some factors that may have reached significance on the multivariable regression analysis were not detected (type II error). This small sample size also limits our ability to perform internal validation and may have resulted in an over-fitted algorithm. Additionally, all patients were treated at the same institution by a small number of surgeons, with no standardized protocol in place. Indications for repeat washout may differ or weigh differently from surgeon to surgeon, or from one institution to another. As there is no standardized protocol, the amount of saline used intraoperatively, the use and indications for intraarticular drains and empiric antibiotic selection varied between cases. Lastly, while our data provide prognostic information on the risk that a patient will fail a single surgery, we do not have the data to dictate the prognosis of a patient's hospital course based on risk factors alone. Additional studies are needed to confirm our identified risk factors and evaluate whether these are associated with time to resolution of infection and functional status after resolution.

In conclusion, patients in our cohort with septic arthritis and concurrent infection were more likely to need to return to the operating room for repeat I&D. In those patients with concurrent infection, the risk of return to the operating room increased by 1% for every increase of 1000 nucleated cells in the synovial fluid. We believe that this algorithm may be useful in counseling adult patients with acute septic arthritis during their treatment course. This study should be validated in a larger cohort or in prospective studies to determine whether these findings are universally applicable.

Ethical review committee statement

The IRB application and approval for this study is attached to the main submission. This study complied with all required ethical guidelines and standards of practice.

This work was done at the George Washington University Hospital and School of Medicine and Health Sciences in Washington, D.C., USA.

CRediT Author Statement

Seth Stake: Conceptualization, methodology, formal analysis, investigation, writing – original draft, writing – review & editing, project administration. Ryan Scully: Conceptualization, methodology, formal analysis, investigation, writing – original draft, writing – review & editing, project administration. Samuel Swenson: investigation, writing – original draft, writing – review & editing. Danny Lee: investigation, writing – original draft, writing – review & editing. Ryan Lee: investigation, writing – original draft, writing – review & editing. Andrew Sparks: investigation, writing – original draft, writing – review & editing, formal analysis, project administration. Rajeev Pandarinath: investigation, writing – original draft, writing – review & editing, project administration, supervision.

Declaration of competing interest

One of the authors has received funding from Smith & Nephew (RP); however, no funding was received for the current work outlined in this study. All other authors certify that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

Acknowledgements

No acknowledgements. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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