RESEARCH ARTICLE

Outcome of Two-Stage Revision Total Hip and Knee Arthroplasty as a Salvage Procedure for Deep Infection of Peri-Articular Fracture Fixation: Propensity Score-Matched Study

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Abstract

Background: Failed open reduction internal fixation (ORIF) of peri-articular fractures due to deep infection is associated with decreased functional outcomes and increased mortality rates. Two-stage revision total joint arthroplasty (TJA) is often needed as a salvage procedure. The aim of this study was to evaluate the outcome of two-stage revision total hip and knee arthroplasty as a salvage procedure for the treatment of deep infection of peri-articular fracture fixation.

Methods: Using propensity score-matching, a total of 120 patients was evaluated: 1) 40 consecutive patients were treated with planned salvage two-stage revision for the treatment of deep peri-articular infection, and 2) a control group of 80 patients who underwent two-stage revision for periprosthetic joint infection (PJI) after non-IF TJA. An infection occurred after a fracture of the acetabulum (27.5%), femoral neck (22.5%), intertrochanteric femur (15.0%), subtrochanteric femur (5.0%), femoral shaft (7.5%), distal femur (5.0%), and tibia (15.0%).

Results: At an average follow up of 4.5 years (range, 1.0-25.8), the overall failure rate was 42.5% for the IF group compared to 21.3% for the non-ORIF group (*P=0.03*). There was a significantly higher reinfection rate for the IF group compared to the non-IF group (35.0% vs. 11.3%, *p*=0.005). Tissue cultures for the IF patients demonstrated significantly higher polymicrobial growth (30.0% vs. 11.3%, *P=0.01*) and methicillin-resistant Staphylococcus aureus (20.0% vs. 7.5%, *P=0.04*).

Conclusion: Salvage two-stage revision arthroplasty for infected IF of peri-articular fractures was associated with poor outcome. The overall post-operative complications after salvage two-stage revision for infected IF of peri-articular fractures was high with 35% reinfection rates associated with the presence of mixed and resistant pathogens.

Level of evidence: III

Keywords: Deep infection, Open reduction internal fixation, Periprosthetic joint infection, Salvage procedure, Total joint arthroplasty

Introduction

Closed reduction and internal fixation (CRIF) and open reduction and internal fixation (ORIF) represent treatment options for patients with a peri-articular fracture of the hip or knee (1, 2). ORIF of peri-articular fractures of the hip or knee can fail due to complications including nonunion and infection (2,

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3). When deep infection after fracture fixation occurs, it is typically associated with decreased functional outcomes and an increased mortality (4). Furthermore, deep infection can lead to delayed- or non-union of the fracture (4). Even though peri-articular fractures are not always intracapsular, the hip or knee joint space may be involved when fixation of peri-articular regions of the acetabulum, femur, tibia, or patella fails (4). Deep infection occurs in approximately 3.9% of peri-articular hip fractures treated with IF, and septic arthritis in 2.4% of peri-articular knee fractures (5, 6). The infection rates after IF of peri-articular fracture are similar to those for periprosthetic joint infection (PJI) after primary TJA, with reported rates between 1.6% to 3.4% of patients (6).

Treatment options for infected IF of peri-articular fractures include resection arthroplasty, arthrodesis, and salvage one-stage or two-stage TJA (7, 8). To optimize patient outcomes and infection control, a salvage two-stage revision is often performed following removal of all hardware and thorough irrigation and debridement (I&D) of all infected and necrotic tissue (9). A two-stage approach allows to eradicate the infection before the definitive prosthesis is implanted, and thus to reduce the recurrence rate (8). A similar two-stage approach is applied for patients with PJI after TJA for non-traumatic indications, with recent meta-analyses demonstrating successful infection eradication rates in approximately 85% of patients(10). Deep articular infection after IF for peri-articular fractures is an important complication associated with serious consequences, and a limited number of studies has assessed the outcomes of complex salvage TJA for the treatment of these infections after failed ORIF of the hip or knee(11). Therefore, the aim of this study was to evaluate the results and complications of two-stage revision total hip and knee arthroplasty as a salvage procedure for deep infection of peri-articular fracture fixation.

Materials and Methods

Patients

Following approval of the Institutional Review Board, all patients who underwent a planned two-stage revision arthroplasty for infection of the hip and knee joint were selected from a prospectively maintained institutional database at a large tertiary referral center. The diagnosis of infection was defined according to the criteria proposed by the workgroup of the Musculoskeletal Infection Society (MSIS) (12). This includes the presence of at least one of the major criteria (a sinus tract communicating with the prosthesis or 2 positive cultures with the same pathogen collected separately), or the presence of at least 4 minor criteria (elevated Erythrocyte Sedimentation Rate (ESR) and C-reactive Protein (CRP), elevated synovial White Blood Cell (WBC) count, elevated synovial Polymorphonuclear percentage (PMN%), presence of purulence in the affected joint, isolation of microorganism in 1 culture of a tissue or fluid sample, or histologic analysis of periprosthetic tissue demonstrating more than 5 neutrophils per high-power field at ×400 magnification (12) . In accordance with institutional clinical practice, a two-stage revision consisted of a first stage open procedure with debridement and removal of all prostheses generally followed by placement of antibiotic-loaded cement spacers. The type and amount of antibiotic included vancomycin (2g; 104 patients) and gentamicin (2g; 16 patients). The second stage consisted of extraction of any cement spacers and reimplantation of revision TJA components. Patients in both cohorts underwent the same treatment protocol for two-stage revision surgery. In consultation with infectious disease specialists, patients were treated with organism-specific intravenous antibiotics for a minimum six weeks followed by serum inflammatory markers to ensure normalization prior to reimplantation. In culture-negative infections, IV combination antibiotic therapy was used, consisting of vancomycin and cefepime. Oral antibiotics were used for a duration of at least six weeks in the culture-positive and culture-negative cohorts. The mean duration between first and second-stage reimplantation was 108 days for patients treated with planned salvage two-stage revision for the treatment of deep-peri-articular infection (IF group) as well as 99 days for patients who underwent two-stage revision for PJI after non-IF TJA (non-IF group). Cases not meeting the MSIS criteria, patients who did not undergo two-stage revision, and cases with missing outcome data due to incomplete reporting were excluded.

Propensity Score Matching

A total of 40 patients who underwent planned two-stage revision as a salvage procedure for deep infected internal fixation (IF) of a peri-articular fracture of the acetabulum, femur, tibia, or patella (IF group) were identified. Furthermore, a total of 471 patients who underwent planned two-stage revision for PJI of the hip or knee after non-traumatic TJA (non-IF group) were selected. The raw cohorts demonstrated significant differences in age, body mass index (BMI), gender, joint, smoking status, and comorbidities. In order to reduce bias due to the large number of potential confounders, propensity score-matching was used (13). Propensity scores were determined for each patient in order to achieve balance on the confounding covariates between the IF and non-IF groups. The propensity score estimate was derived using factors related to the infection outcome, including patient age, BMI, gender, joint, smoking status, cardiovascular disease, diabetes mellitus, and inflammatory disease as covariates. A generalized overlap weighting scheme was then applied to the distribution of independent propensity scores to check and ensure that patients after matching have approximately the same probabilities of being assigned to all other cohorts (14). This process ensured to obtain a naturally representative subsample from the 471 patients who underwent planned two-stage revision for PJI of the hip or knee after non-traumatic TJA. A control group was created using propensity score-matching in a 1:2 sampling ratio, as this will result in optimal estimation of treatment effects. All of the 40 patients were matched to 2 controls who sustained a PJI after non-traumatic TJA, resulting in a control group of 80 patients (13).

The electronic hospital files were reviewed for all

included patients. Data was collected on patient demographics, including age, gender, body mass index (BMI), and American Society of Anesthesiologists classification (ASA) score. Moreover, the files were evaluated for data on the index surgery, fracture type and date, revision surgery type, laboratory findings, and final infection diagnosis. Outcomes including length of hospital stay, reinfection and re-revision, were retrieved from electronic medical hospital records.

Fracture Types and Treatment

The internal fixation (IF) group consisted of 37 fractured joints (3 patients were excluded due to loss of follow-up), including 28 hips and 9 knees. For hips, 11 patients experienced a fracture of the acetabular, all of which were treated with plate fixation. An intertrochanteric fracture was observed in 6 patients (15.0%), of which 5 were treated with an intramedullary (IM) nail and 1 with a DHS. A femoral neck fracture was encountered in 9 patients, of which 7 were treated with a dynamic hip screw (DHS) and 2 with cannulated screws. 2 patients (5.0%) sustained a subtrochanteric fracture, of which 1 was treated with a DHS and 1 with an IM nail. For knees, a fracture of the femoral shaft occurred in 3 patients (7.5%), of which 2 were treated with a retrograde femur nail and 1 with plate fixation. 6 patients experienced a fracture of the proximal tibia, of which 5 patients with tibia plateau fractures were treated using plate fixation and 1 patient with a proximal tibia fracture using an expert tibia nail (ETN). Lastly, 1 patient (2.5%) sustained a fracture of the patella and this was treated with cerclage wiring. The fracture types and treatments are summarized in [Table 1].

Table 1. Index fracture types and treatments

	Infected Internal Fixation (n=40)
Acetabulum	11 (27.5%)
Plate Fixation	11
Intertrochanteric Femur	6 (15.0%)
Intramedullary Nail	5
Dynamic Hip Screw	1
Femoral Neck	9 (22.5%)
Dynamic Hip Screw	7
Cannulated Screws	2
Subtrochanteric Femur	2 (5.0%)
Dynamic Hip Screw	1
Intramedullary Nail	1
Femoral Shaft	3 (7.5%)
Retrograde Femur Nail	2
Plate Fixation	1
Distal Femur	2 (5.0%)
Plate Fixation	1
Expert Tibia Nail	1
Proximal Tibia	6 (15.0%)
Plate Fixation	5
Expert Tibia Nail	1
Patella	1 (2.5%)
Cerclage Wiring	1

Clinical outcomes

Post-operative follow-up was scheduled at 2 months, 1 year, 2 years, 5 years and every 5 years after surgery. The clinical follow-up for all patients was a minimum of 1 year, until subsequent re-revision due to failure, or until death. The outcome was defined as successful when there were no clinical signs of infection during follow up. Moreover, the outcome was successful when no subsequent surgical interventions were necessary, such as debridement, antibiotics and implant retention (DAIR) with modular exchange, additional one- or two-stage revision was not needed, and no successive amputation occurred. If any additional surgical procedure took place for infection control, the treatment was defined as failure(15).

Statistical analysis

Propensity score-matching was performed using greedy nearest-neighbor matching technique without replacement in a 1:2 sampling ratio(14). For the comparison of the treatment outcomes, the reinfection, re-revision, readmission, 2-year mortality, and amputation rates were compared. The propensity score-matched data were compared using a dependent t-test or Wilcoxon signed-rank test for continuous values, and a conditional logistic regression was fitted to test the hypothesis for binary values. All data analyses were performed using the Statistical Package for Social Sciences (SPSS®) statistics for Windows (version 26.0, Armonk, NY, USA: IBM Corp.).

Results

Patient cohort

After propensity score-matching, the study cohort consisted of 120 patients who underwent planned two-stage revision arthroplasty for the treatment of an infected hip or knee joint consisting of two groups: 1) 40 patients with deep infection of peri-articular IF, and 2) 80 patients with PJI after non-IF TJA. The baseline characteristics of the patients did not differ significantly between the two groups [Table 2]. The mean age was 64.1 (SD ± 13.3) years and the mean BMI was 32.1 (SD ± 7.5). Patients presented more often with an infected hip than knee, with infected hips accounting for 67.5% in the ORIF group and 68.8% in the non-IF group (*P=0.83*). The propensity matched covariates with corresponding standardized mean differences before and after matching are summarized in [Table 3]. There was no significant difference between both cohorts in terms of duration between first and second stage revision surgery (99 days vs 108 days; *P=0.23*).

Clinical outcomes

At an average follow up of 4.5 years (range, 1.0-25.8), the overall failure rate was 42.5% for IF patients and 21.3% for non-IF patients (*P=0.03*). Reinfection was the most common indication for failure, occurring in 14 out of 40 IF patients (35.0%) and 9 out of 80 non-IF patients (11.3%, *P=0.005*). Of those 14 IF patients, 10 out of 14 sustained a deep recurrent infection, which were treated with DAIR and modular exchange (5 patients), implant removal (3 patients), or one-stage revision (2 patients). 1 patient ultimately underwent amputation due to continued infection. 4 patients sustained a superficial reinfection not communicating with the joint, and these were treated with I&D. In the non-IF group, 9 patients developed a deep reinfection, which were treated with DAIR and modular exchange (5 patients), implant removal (3 patients), or additional two-stage revision (1 patient).

Aseptic failures requiring re-revision occurred in 2 out of 40 IF patients (5.0%) compared to 7 out of 80 non-IF patients (8.8%, *P=0.49*). In the IF group, 2 patients underwent re-revision for recurrent dislocation. In the non-IF group, there were 3 patients who underwent re-revision for recurrent dislocation, 1 patient with adverse local tissue reaction, 1 patient with aseptic loosening, 1 patient with THA malalignment, and 1 patient developed

Table 2. Patient demographics

	Total (n=120)	Infected Internal Fixation (n=40)	Infected Non-Internal Fixation (n=80)	*P-value*
Age (mean ± SD)	64.1 ± 13.3	63.2 ± 14.4	64.1 ± 13.3	0.86
BMI (mean ± SD)	32.1 ± 7.5	31.0 ± 7.8	30.9 ± 7.4	0.87
Follow up (mean (range))	4.5 (1.0-25.8)	5.0 (1.0-25.8)	4.2 (1.0-14.5)	0.18
ASA score				0.30
1	11 (9.2%)	1 (2.5%)	10 (12.5%)	
2	61 (50.8%)	21 (52.5%)	40 (50.0%)	
3	47 (39.2%)	18 (45.0%)	29 (36.3%)	
4	1 (0.8%)	0 (0.0%)	1 (1.3%)	
Joint				0.83
Hip	82 (68.3%)	27 (67.5%)	55 (68.8%)	
Knee	38 (31.7%)	13 (32.5%)	25 (31.2%)	
Laterality				0.92
Right	75 (62.5%)	25 (62.5%)	50 (62.5%)	
Left	45 (37.5%)	15 (37.5%)	30 (37.5%)	
Gender				0.87
Male	65 (54.2%)	20 (50.0%)	45 (56.3%)	
Female	55 (45.8%)	20 (50.0%)	35 (43.8%)	
Risk factors				
Smoking	34 (28.3%)	11 (27.5%)	23 (28.8%)	0.84
Alcohol	42 (35.0%)	14 (35.0%)	28 (35.0%)	1.00
Drugs	9 (7.5%)	3 (7.5%)	6 (7.5%)	1.00
Comorbidities				
Cardiovascular Disease	44 (36.7%)	14 (35.0%)	30 (37.5%)	0.64
Renal Disease	7 (5.8%)	3 (7.5%)	4 (5.0%)	0.60
Diabetes Mellitus	26 (21.7%)	9 (22.5%)	17 (21.3%)	0.85
Malignant tumor	15 (12.5%)	3 (7.5%)	12 (15.0%)	0.21
Inflammatory disease	14 (11.7%)	4 (10.0%)	10 (12.5%)	0.64

SD, Standard Deviation

Table 3. Propensity Matched Covariates

Covariates	Means IF		Means Non-IF		SD Non-IF		Std. Mean Diff.	
	Before	After	Before	After	Before	After	Before	After
Propensity Score	0.152	0.152	0.091	0.150	0.067	0.095	0.633	0.019
Age	63.163	63.163	65.190	64.519	11.095	12.867	-0.141	-0.094
Gender	0.500	0.500	0.567	0.488	0.496	0.503	-0.132	0.025
BMI	30.962	30.962	31.356	30.798	7.078	7.255	-0.051	0.021
Joint	0.675	0.675	0.420	0.663	0.494	0.476	0.538	0.026
Smoking	0.275	0.275	0.104	0.288	0.306	0.455	0.378	-0.028
Cardiovascular Disease	0.350	0.350	0.548	0.375	0.498	0.487	-0.410	-0.052
Diabetes Mellitus	0.225	0.225	0.225	0.213	0.418	0.412	0.001	0.030
Inflammatory Disease	0.100	0.100	0.086	0.125	0.28	0.333	0.048	-0.082

SD, Standard Deviation; Std. Mean Diff., Standardized Mean Difference; BMI, Body Mass Index

painful effusion and underwent modular exchange. Length of hospital stay after the first stage was longer for the IF group compared to the non-IF group, however not significant (13.5 ± 8.6 days vs. 10.5 ± 7.5 days, *P=0.09*). Length of stay after second stage surgery did not significantly differ between the groups (6.8 ± 3.2 vs. 6.2 ± 4.2, *P*=0.50). No significant differences were observed for 30; 60; and 90-day readmission rates between the IF and non-IF groups (15.0% vs. 11.3%, *P=0.56*; 20.0% vs. 15.0%, *P=0.37*; and 20.0% vs. 18.8%, *P=0.66*). No significant differences were observed for amputation rates (2.5% vs. 1.3%, *P=0.62*) [Table 4].

Subgroup analyses to assess the outcomes for the hip and knee cohorts were performed. In the hip subgroup, higher failure due to reinfection was encountered for IF patients compared to non-IF patients (29.6% vs. 9.1%, *P=0.02*). In the IF group, there were 6 deep and 2 superficial reinfections, and in the non-IF group there were 5 deep reinfections. For the knee subgroup, more reinfections occurred for the IF patients compared to the non-IF patients (46.2% vs. 16.0%, *P=0.04*). In the IF group, there were 4 deep and 2 superficial reinfections, and in the non-IF group there were 4 deep reinfections [Tables 5; 6].

Microbiology Results

Significantly higher polymicrobial growth (30.0% vs. 11.3%, *P=0.01*), methicillin-resistant Staphylococcus aureus (MRSA) (20.0% vs. 7.5%, *P=0.04*), and other Gram-positive organisms (7.5% vs. 0.0%, *P=0.04*) were encountered for the IF cohort, when compared to the non-IF cohort [Table 7]. For patients sustaining a recurrent infection, patients in the IF group demonstrated higher

Table 4. Comparison of postoperative complication rates and clinical outcomes between both study cohorts

	Total (n=120)	Infected Internal Fixation (n=40)	Infected Non-Internal Fixation (n=80)	*P-value*
Overall Complication Rate	34 (28.3%)	17 (42.5%)	17 (21.3%)	0.03
Reinfection	23 (19.2%)	14 (35.0%)	9 (11.3%)	0.005
Re-revision	9 (7.5%)	2 (5.0%)	7 (8.8%)	0.49
30-day Readmission	15 (12.5%)	6 (15.0%)	9 (11.3%)	0.56
60-day Readmission	20 (16.7%)	8 (20.0%)	12 (15.0%)	0.37
90-day Readmission	23 (19.2%)	8 (20.0%)	15 (18.8%)	0.66
2-year Mortality	6 (5.0%)	2 (5.0%)	4 (5.0%)	1.00
Amputation	2 (1.7%)	1 (2.5%)	1 (1.3%)	0.62
Length of Stay 1, days (mean ± SD)	10.0 ± 7.3	13.5 ± 8.6	10.5 ± 7.5	0.09
Length of Stay 2, days (mean ± SD)	6.0 ± 4.0	6.8 ± 3.2	6.2 ± 4.2	0.50

SD, Standard Deviation

Table 5. Clinical outcomes for the hip subgroup

	Total (n=82)	Infected Internal Fixation (n=27)	Infected Non-Internal Fixation (n=55)	*P-value*
Reinfection	13 (15.9%)	8 (29.6%)	5 (9.1%)	**0.02**
Re-revision	5 (6.1%)	2 (7.4%)	3 (5.5%)	0.73
30-day Readmission	13 (15.9%)	5 (18.5%)	8 (14.5%)	0.90
60-day Readmission	16 (19.5%)	7 (25.9%)	9 (16.4%)	0.47
90-day Readmission	20 (24.4%)	7 (15.9%)	13 (23.6%)	0.82
2-year Mortality	2 (2.4%)	1 (3.7%)	1 (1.8%)	1.00
Amputation	1 (1.2%)	1 (3.7%)	0 (0.0%)	0.61
Length of Stay 1, days (mean ± SD)	9.9 ± 6.9	13.3 ± 8.6	8.1 ± 5.1	0.31
Length of Stay 2, days (mean ± SD)	5.8 ± 3.1	6.4 ± 3.3	5.5 ± 2.9	0.82

SD, Standard Deviation

Table 6. Clinical outcomes for the knee subgroup

	Total (n=38)	Infected Internal Fixation (n=13)	Infected Non-Internal Fixation (n=25)	*P-value*
Reinfection	10 (26.3%)	6 (46.2%)	4 (16.0%)	**0.04**
Re-revision	4 (10.5%)	0 (0.0%)	4 (16.0%)	0.28
30-day Readmission	6 (15.8%)	1 (7.7%)	5 (20.0%)	0.56
60-day Readmission	8 (21.1%)	1 (7.7%)	7 (28.0%)	0.34
90-day Readmission	9 (23.7%)	1 (7.7%)	8 (32.0%)	0.22
2-year Mortality	1 (2.6%)	1 (7.7%)	0 (0.0%)	0.61
Amputation	1 (2.6%)	0 (0.0%)	1 (8.0%)	1.00
Length of Stay 1, days (mean ± SD)	10.2 ± 8.1	13.5 ± 8.7	8.8 ± 5.4	**0.04**
Length of Stay 2, days (mean ± SD)	6.4 ± 5.3	6.5 ± 3.4	6.4 ± 5.1	0.13

SD, Standard Deviation

Table 7. Overview of causative pathogens at salvage two-stage revision

Pathogens	Total (n=120)	Infected Internal Fixation (n=40)	Infected Non-Internal Fixation (n=80)	*P-value*
Staphylococcus aureus	19 (15.8%)	5 (12.5%)	14 (17.5%)	0.48
Methicillin-resistant Staphylococcus aureus	14 (11.7%)	8 (20.0%)	6 (7.5%)	0.04
Streptococcus species	8 (6.7%)	2 (5.0%)	6 (7.5%)	0.61
Staphylococcus species	5 (4.2%)	1 (2.5%)	4 (5.0%)	0.37
Coagulase-negative Staphylococci	9 (7.5%)	2 (5.0%)	7 (8.8%)	0.46
Propionibacterium acnes	3 (2.5%)	0 (0.0%)	3 (3.8%)	0.55
Other gram positive organisms	3 (2.5%)	3 (7.5%)	0 (0.0%)	0.04
Other gram negative organisms	5 (4.2%)	0 (0.0%)	5 (6.3%)	0.17
Anaerobes	1 (0.8%)	0 (0.0%)	1 (1.2%)	1.00
Other	1 (0.8%)	0 (0.0%)	1 (1.2%)	1.00
Negative culture	31 (25.8%)	7 (17.5%)	24 (30.0%)	0.11
Cultures with Mixed growth	21 (17.5%)	12 (30.0%)	9 (11.2%)	0.01

Table 8. Overview of causative pathogens for patients sustaining a reinfection

Pathogens	Total (n=23)	Infected Internal Fixation (n=14)	Infected Non-Internal Fixation (n=9)	*P-value*
Staphylococcus aureus	4 (17.5%)	1 (7.1%)	3 (33.3%)	0.26
Methicillin-resistant Staphylococcus aureus	4 (17.5%)	3 (21.5%)	1 (11.2%)	0.63
Streptococcus species	1 (4.3%)	1 (7.1%)	0 (0.0%)	1.00
Staphylococcus species	2 (8.7%)	2 (14.3%)	0 (0.0%)	0.50
Coagulase-negative Staphylococci	1 (4.3%)	1 (7.1%)	0 (0.0%)	1.00
Propionibacterium acnes	2 (8.7%)	0 (0.0%)	2 (22.2%)	0.14
Pseudomonas aeruginosa	1 (4.3%)	1 (7.1%)	0 (0.0%)	1.00
Negative culture	5 (21.7%)	2 (14.3%)	3 (33.3%)	0.34
Cultures with Mixed growth	3 (13.0%)	3 (21.5%)	0 (0.0%)	0.25

rates of MRSA (21.4% vs. 11.1%), Staphylococcus species (14.3% vs. 0.0%) and polymicrobial growth (21.4% vs. 0.0%), whereas the non-IF group demonstrated a higher prevalence of MSSA (33.3% vs. 7.1%), Propionibacterium acnes (22.2% vs. 0.0%), and culture-negative infections (33.3% vs. 14.3%) [Table 8].

Discussion

Deep infection involving the hip or knee joint is a complication that may occur after failed IF for peri-articular fracture, for which treatment consists of resection arthroplasty, arthrodesis, and salvage one-stage or two-stage TJA (10, 12). Similar to PJI after non-traumatic TJA, these joint infections are often treated with revision arthroplasty using a two-stage approach. Aseptic failures of peri-articular IF have been reported to show high complication rates after salvage THA and TKA. However, the outcomes of salvage two-stage revision for deep infected peri-articular fracture remain largely unknown. This study aimed to analyze the outcomes of revision arthroplasty as a salvage procedure for deep infection after peri-articular fracture fixation in comparison with a propensity score-matched cohort of patients who underwent two-stage revision for PJI after non-traumatic TJA. Both patient groups underwent the same treatment protocol and surgical approach in order to allow a comparison. The findings of this study demonstrate high overall post-operative complications after salvage two-stage revision for infected IF of peri-articular fractures with 35% reinfection rates and the presence of mixed and resistant pathogens.

Treatment failure of a peri-articular fracture presents a difficult challenge to the orthopaedic surgeon. It is estimated that approximately 14.3% and 7.3% of patients with failed ORIF of hip and knee fractures respectively require salvage TJA (16, 17). The majority of the literature on conversion TJA after failed ORIF has focused on aseptic failures of fracture fixation, reporting high postoperative complication rates for these patients when compared to patients undergoing elective TJA(18, 19). Studies assessing the outcomes of salvage two-stage TJA for failed infected ORIF of the hip and knee are limited. Few series have described two-stage revision for the treatment of infected ORIF of a combined total of 25 intracapsular femur fractures, and 2 studies evaluated a combined total of 34 extracapsular fractures of the femur (8, 10). 1 study included 4 intracapsular and 1 acetabular fracture in their analysis of salvage two-stage revision for septic hip arthritis in 13 patients. For the treatment of infected ORIF of the knee, 1 case-control study was identified reporting on the outcomes for 6 tibia plateau fractures (12). However, different treatment strategies were used and study populations varied. The present study aimed to address the outcomes for salvage two-stage revision arthroplasty for deep infection after IF of peri-articular fractures of both the hip and knee.

After two-stage revision for non-IF PJI in the present study, complications were observed in 21.3% of patients, with reinfection accounting for 11.3%. The reinfection rate presented in our study is comparable to the results reported in recent meta-analyses on PJI, ranging from 8% to 13.5% of patients (20). The overall failure rate after salvage two-stage revision for the IF group in our study was significantly higher (42.5%), with reinfection presenting the most common complication observed in 32.5% of patients. Patients in the knee IF subgroup demonstrated a high recurrent infection rate of 46.2%, with deep and superficial reinfection occurring in 30.8% and 15.4% of patients, respectively. This finding is similar to Larson et al., who reported on the occurrence of a reinfection in 2 of the 6 patients that underwent two-stage revision for infected failed tibia plateau fixation in his study (12). Furthermore, the reinfection rate for the hip subgroup was 25.9%, with deep reinfection in 18.5% of patients and superficial reinfection in 7.4%. This finding is in accordance with 2 previous studies reporting reinfections in 20.0% to 25.0% of patients after two-stage revision for infected hip IF(21). Conversely, Hsieh et al. reported no recurrent infection in 12 patients with antibiotic-loaded cement spacers, in which only 1 superficial reinfection occurred(8). Moreover, Ebied et al.

reported on 26 two-stage procedures for intracapsular and extracapsular femur fractures, with no recurrence of infection or further revision surgery (10).

The microbiology results in our study may have attributed to the high reinfection rates of the IF group, as polymicrobial growth was encountered in 30% of patients and MRSA in 20% of patients. These pathogens are associated with worse outcomes for fracture fixation infections, and their incidence rates in the United States have been reported in up to 35% of patients for polymicrobial infections and in up to 32% for MRSA (22). However, few studies on salvage two-stage revision arthroplasty have reported on microbiology results. 1 study demonstrated high infection control rates in 19 out of 20 patients with coagulase-negative Staphylococcus in 9, MSSA in 5, MRSA in 1, and Gram-negative pathogens in 5 cases (8). Furthermore, 1 study demonstrated infection eradication in all patients, even though high polymicrobial and MRSA rates we encountered(10). However, no cases with negative cultures were present, yet this occurred in 17.5% of our IF group. Moreover, when assessing the outcomes for two-stage revision, multiple studies demonstrated the presence of MRSA and cases with polymicrobial growth to be at increased risk for reinfection (23). This is potentially due to the high virulence pathogens and the need for antibiotic selection in patients with cultures demonstrating mixed growth, highlighting the importance to identify causative pathogens for culture-guided antibiotic therapy and treatment planning.

The findings of the present study should be interpreted in the context of its limitations. Firstly, due to the retrospective nature of the study, possible selection- and misclassification bias for the different indications may have occurred. However, in an effort to alleviate this risk, all patients who underwent planned two-stage revision TJA for any joint infection of the hip or knee were identified and reviewed for inclusion. Secondly, the sample size of the study may be regarded as limited. However, this study represents one of the largest series on salvage two-stage revision for infected peri-articular IF, utilizing a propensity score-matched control group consisting of patients who underwent two-stage revision for PJI after non-traumatic TJA. This limitation in sample size has further not allowed the separate comparison of outcomes for patients with hip and knee arthroplasties.

In conclusion, salvage two-stage revision arthroplasty for infected IF of peri-articular fractures was associated with poor outcome. The overall post-operative complications after salvage two-stage revision for infected IF of peri-articular fractures was high with 35% reinfection rates associated with the presence of mixed and resistant pathogens.

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References

1. Swart E, Roulette P, Leas D, Bozic KJ, Karunakar M. ORIF or arthroplasty for displaced femoral neck fractures in patients younger than 65 years old: an economic decision analysis. JBJS. 2017;99(1):65-75.
2. Schreiner AJ, Schmidutz F, Ateschrang A, Ihle C, Stöckle U, Ochs BG, et al. Periprosthetic tibial fractures in total knee arthroplasty–an outcome analysis of a challenging and underreported surgical issue. BMC Musculoskeletal Disorders. 2018;19(1):1-8.
3. Sanal HT, Boulton C, Neyisci C, Erdem Y, Lowe J. Imaging of Pelvic and Femoral Fixation Hardware: Normal Findings and Hardware Failure. InSeminars in Musculoskeletal Radiology 2019 (Vol. 23, No. 02, pp. e1-e19). Thieme Medical Publishers.
4. Steinmetz S, Wernly D, Moerenhout K, Trampuz A, Borens O. Infection after fracture fixation. EFORT Open Reviews. 2019;4(7):468-75.
5. Hsieh PH, Chang YH, Chen SH, Shih CH. Staged arthroplasty as salvage procedure for deep hip infection following intertrochanteric fracture. International orthopaedics. 2006;30(4):228-32.
6. Norris GR, Checketts JX, Scott JT, Vassar M, Norris BL, Giannoudis PV. Prevalence of deep surgical site infection after repair of periarticular knee fractures: a systematic review and meta-analysis. JAMA network open. 2019;2(8):e199951-.
7. Klatte TO, O'Loughlin PF, Citak M, Rueger JM, Gehrke T, Kendoff D. 1-stage primary arthroplasty of mechanically failed internally fixated of hip fractures with deep wound infection: good outcome in 16 cases.

Acta orthopaedica. 2013;84(4):377-9.
8. Mohanty SS, Agashe MV, Sheth BA, Dash KK. Outcome of total hip arthroplasty as a salvage procedure for failed infected internal fixation of hip fractures. Indian journal of orthopaedics. 2013;47(1):87-92..
9. Haidukewych GJ, Berry DJ. Hip arthroplasty for salvage of failed treatment of intertrochanteric hip fractures. JBJS. 2003;85(5):899-904.
10. Ebied AM, Elseedy AI, Gamal O. A protocol for staged arthroplasty to salvage infected nonunion of hip fractures. Journal of Orthopaedics and Traumatology. 2017;18(1):43-50.
11. Duckworth AD, Phillips SA, Stone O, Moran M, Breusch SJ, Biant LC. Deep infection after hip fracture surgery: predictors of early mortality. Injury. 2012;43(7):1182-6.
12. Parvizi J, Tan TL, Goswami K, Higuera C, Della Valle C, Chen AF, Shohat N. The 2018 definition of periprosthetic hip and knee infection: an evidence-based and validated criteria. The Journal of arthroplasty. 2018;33(5):1309-14.
13. Rosenbaum PR, Rubin DB. The central role of the propensity score in observational studies for causal effects. Matched Sampl Causal Eff. 2006;70(1):170-184.
14. McCaffrey DF, Griffin BA, Almirall D, Slaughter ME, Ramchand R, Burgette LF. A tutorial on propensity score estimation for multiple treatments using generalized boosted models. Statistics in medicine. 2013;32(19):3388-414.
15. Diaz-Ledezma C, Higuera CA, Parvizi J. Success after treatment of periprosthetic joint infection: a Delphi-based international multidisciplinary consensus. Clinical Orthopaedics and Related Research®. 2013;471(7):2374-82.
16. Stockton DJ, O'Hara LM, O'Hara NN, Lefaivre KA, O'Brien PJ, Slobogean GP. High rate of reoperation and conversion to total hip arthroplasty after internal fixation of young femoral neck fractures: a population-based study of 796 patients. Acta Orthopaedica. 2019;90(1):21-5.
17. Wasserstein D, Henry P, Paterson JM, Kreder HJ, Jenkinson R. Risk of total knee arthroplasty after operatively treated tibial plateau fracture: a matched-population-based cohort study. JBJS. 2014;96(2):144-50.
18. Winemaker M, Gamble P, Petruccelli D, Kaspar S, de Beer J. Short-Term Outcomes of Total Hip Arthroplasty After Complications of Open Reduction Internal Fixation for Hip Fracture. J Arthroplasty. 2006;21(5):682-688.
19. Softness KA, Murray RS, Evans BG. Total knee arthroplasty and fractures of the tibial plateau. World journal of orthopedics. 2017;8(2):107-114.
20. Pangaud C, Ollivier M, Argenson JN. Outcome of single-stage versus two-stage exchange for revision knee arthroplasty for chronic periprosthetic infection. EFORT open reviews. 2019;4(8):495-502.
21. Cherney DL, Amstutz HC. Total hip replacement in the previously septic hip. JBJS. 1983;65(9):1256-65.
22. Kremers HM, Nwojo ME, Ransom JE, Wood-Wentz CM, Melton III LJ, Huddleston III PM. Trends in the epidemiology of osteomyelitis: a population-based study, 1969 to 2009. The Journal of bone and joint surgery. American volume. 2015;97(10):837.
23. Sakellariou VI, Poultsides LA, Vasilakakos T, Sculco P, Ma Y, Sculco TP. Risk factors for recurrence of periprosthetic knee infection. The Journal of Arthroplasty. 2015;30(9):1618-22.