Risk Factors for Failure After 1-Stage Exchange Total Knee Arthroplasty in the Management of Periprosthetic Joint Infection

Mustafa Citak, MD, PhD,* Jasmin Friedenstab,* Hussein Abdelaziz, MD, Eduardo M. Suero, MD, Akos Zahar, MD, PhD, Jochen Salber, MD, and Thorsten Gehrke, MD

Investigation performed at the Department of Orthopaedic Surgery, Helios ENDO-Klinik Hamburg, Hamburg, Germany

Background: One-stage exchange arthroplasty in the management of periprosthetic joint infection was introduced at our institution. The purpose of this study was to analyze the risk factors of failure after periprosthetic joint infection following total knee arthroplasty treated with 1-stage exchange.

Methods: Ninety-one patients who underwent failed treatment following 1-stage exchange total knee arthroplasty due to periprosthetic joint infection from January 2008 to December 2017 were included. From the same period, we randomly selected a 1:1 matched control group without a subsequent revision surgical procedure. Bivariate analyses, including preoperative, intraoperative, and postoperative factors, as well as logistic regression, were performed to identify risk factors for failure.

Results: Bivariate analysis yielded 10 predictors (variables with significance at $p < 0.05$) for failure involving re-revision for any reason and 11 predictors for failure involving re-revision for reinfection. The binary logistic regression model revealed the following risk factors for re-revision for any reason: history of a 1-stage exchange for infection (odds ratio [OR], 26.706 [95% confidence interval (CI), 5.770 to 123.606]; $p < 0.001$), history of a 2-stage exchange (OR, 3.948 [95% CI, 1.869 to 8.339]; $p < 0.001$), and isolation of enterococci (OR, 16.925 [95% CI, 2.033 to 140.872]; $p = 0.009$). The risk factors for reinfection in the binary logistic regression analysis were history of 1-stage or 2-stage exchange arthroplasty, isolation of enterococci, and isolation of streptococci (OR, 6.025 [95% CI, 1.470 to 24.701]; $p = 0.013$).

Conclusions: We identified several risk factors of failure after 1-stage exchange arthroplasty for periprosthetic joint infection, most of which were not related to the patient comorbidities. Among them, previous exchange due to periprosthetic joint infection and the isolation of Enterococcus or Streptococcus species were associated with a higher risk of failure. Besides a multidisciplinary approach, being aware of the identified risk factors when evaluating patients with periprosthetic joint infection could lead to better outcomes.

Level of Evidence: Prognostic Level III. See Instructions for Authors for a complete description of levels of evidence.

Periprosthetic joint infection is a frequent cause of failed total knee arthroplasty, being the most common indication for early revision total knee arthroplasty[1-3]. The management of periprosthetic joint infection often requires surgical intervention in the form of resection arthroplasty and reimplantation. Worldwide, 2-stage exchange arthroplasty is the preferred surgical treatment for chronic periprosthetic joint infection[4-7]. Several factors influence the selection of an optimal approach for the treatment of periprosthetic joint infection, such as the timing of the infection, the general condition of the patient, the identified pathogen, and the extent of bone and soft-tissue compromise[7,8].

However, 1-stage exchange arthroplasty has demonstrated similar success rates and offers several advantages, such as

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decreased patient morbidity, avoidance of a second-stage major surgical procedure, and shorter treatment duration, while also often being the preferred choice among patients[4,5,9,10].

In the last few decades, several studies have shown the short-term and intermediate-term results of the 1-stage exchange due to periprosthetic joint infection in the management of periprosthetic joint infection after total knee arthroplasty[11-18]. In those studies, the reported eradication rate varied from 73.1% to 100%, with follow-up periods from 1.5 to 5 years. Since 2004, 3 studies have shown the long-term results of this approach, showing eradication rates ranging from 90.9% to 98%. The most common causes of failure were recurrence of infection or aseptic loosening of the prosthesis or components, as has been reported in previous studies.

However, we are not aware of any case-control studies analyzing the causes of and risk factors for failure following 1-stage exchange total knee arthroplasty. Therefore, the purpose of this study was to analyze the patient-related and procedure-related risk factors for failure after 1-stage exchange total knee arthroplasty for periprosthetic joint infection.

Materials and Methods

Study Design and Inclusion and Exclusion Criteria

Patients who were treated for a periprosthetic joint infection of the knee with a 1-stage exchange arthroplasty due to periprosthetic joint infection and who subsequently underwent revision in our hospital for any reason from January 2008 to December 2017 were identified.

Patients who underwent a 2-stage septic exchange, those who underwent a re-revision surgical procedure in an external hospital, and those without complete documentation were excluded from the study. The diagnosis of periprosthetic joint infection had been established according to criteria defined by the Musculoskeletal Infection Society (MSIS)[19].

A total of 697 one-stage revision knee arthroplasties due to periprosthetic joint infection were performed according to our hospital protocol during the study period, with a total of 93 patients who underwent subsequent revision for any reason. Two patients were excluded because of incomplete documentation, and the remaining 91 patients who fulfilled the inclusion and exclusion criteria were included in the final analysis.

From the same time interval, we randomly selected a control group of patients who were treated for periprosthetic joint infection after total knee arthroplasty with a 1-stage septic exchange arthroplasty but had not undergone revision for any reason at the time of the latest follow-up. The cases and controls were matched 1:1 by age, sex, and date of the surgical procedure.

There were 91 patients who underwent failed treatment and required a revision surgical procedure: 54 men (59%) and 37 women (41%), with a mean age (and standard deviation) of 66.6 ± 11.0 years (range, 27 to 84 years). The control group (without any revision surgical procedure at the time of the latest follow-up) consisted of 92 patients: 53 men (58%) and 39 women (42%), with a mean age of 69.6 ± 8.4 years (range, 35 to 83 years) (Table I).

Outcome Measures

The primary outcome of interest was the predictors of failure following 1-stage exchange total knee arthroplasty after periprosthetic joint infection. Failure was defined as any subsequent revision surgical procedure regardless of the reason, including reinfection as the foremost cause for failure.

To identify the patient-related and procedure-related risk factors for failure, >45 factors were compared between the failed treatment group and the control group. The following patient-related risk factors were analyzed: sex, age, body mass index (BMI), weight in kilograms, nicotine abuse, and preexisting illnesses such as diabetes mellitus, coronary heart disease, chronic obstructive pulmonary disease, liver disease, renal failure, rheumatoid arthritis, depression, dementia, tumor history, and history of a deep vein thrombosis. The comorbidity factors were also compared using the Charlson Comorbidity Index[20]. Serum laboratory parameters such as white blood-cell (WBC) count,

TABLE I Demographic and Baseline Characteristics of Both Patient Groups

	Failed Treatment Group (N = 91)	Control Group (N = 92)
Age*	66.6 ± 11.0 (27 to 84)	69.6 ± 8.4 (35 to 83)
Sex		
Female	37	39
Male	54	53
BMI* *(kg/m²)*	30.36 ± 5.46 (17.8 to 46.9)	29.78 ± 4.71 (19.7 to 47.3)
Duration of surgery* *(min)*	249.0 ± 68.6 (128 to 480)	227.9 ± 67.5 (110 to 440)
Length of hospital stay* *(days)*	25.2 ± 13.2 (8 to 114)	21.7 ± 7.5 (14 to 73)
Prior surgical procedures†	5 (5 [1 to 15])	3.6 (3 [1 to 13])
Charlson Comorbidity Index†	1.4 (1 [1 to 7])	1.36 (1 [1 to 8])

*The values are given as the mean and the standard deviation, with the range in parentheses. †The values are given as the mean, with the median in parentheses and the range in brackets.

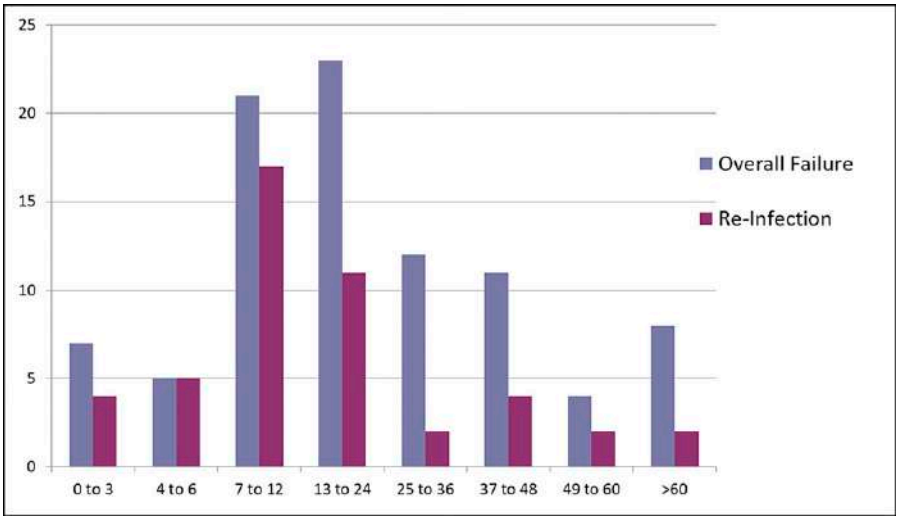

Fig. 1
Bar graph showing the distributions of failure by time interval.

C-reactive protein (CRP), potassium, sodium, and hemoglobin at admission were investigated.

The following procedure-related risk factors were determined in both groups: number of prior surgical procedures, history of sepsis after a surgical procedure, type of surgical procedure (debridement, antibiotics, irrigation, and retention [DAIR]; 1-stage; 2-stage; arthroscopic irrigation) after which sepsis developed, microorganism identified at the prior septic surgical procedure, number of prior microorganisms (1 compared with polymicrobial), intraoperative microorganism identification during the 1-stage procedure, the presence of a sinus tract, a substantial osseous defect requiring a reconstruction with tantalum cones, surgical procedure time in minutes, and wound closure (staples compared with suture). Postoperative variables such as the occurrence of urinary tract infection, pneumonia, acute renal failure, deep vein thrombosis or pulmonary embolism, postoperative persistent wound drainage during the hospital stay, the necessity of allogeneic blood transfusion after a 1-stage procedure, and the length of hospital stay were also included.

Statistical Analysis

All data were analyzed using SAS 9.3 (SAS Institute). Descriptive statistics are presented for both groups in the form of the number of occurrences and percentage or as the mean, standard deviation, and extrema. The Shapiro-Wilk method was used to test whether the data were normally distributed. For bivariate analyses of continuous variables, Student t tests

TABLE II Results of Bivariate Analysis of Risk Factors Significantly Associated with Re-Revision for Any Reason

Risk Factor	Failed Treatment Group*	Control Group*	OR†	P Value
Weight ≥100 kg	31 (34%)	18 (20%)	2.124 (1.083 to 4.164)	0.027
History				
Deep vein thrombosis	25 (28%)	11 (12%)	2.789 (1.278 to 6.085)	0.008
>4 operations	46 (51%)	19 (21%)	3.928 (2.049 to 7.530)	<0.0001
Polymicrobial infection	32 (37%)	14 (17%)	2.963 (1.440 to 6.096)	0.002
One-stage exchange due to periprosthetic joint infection	25 (30%)	2 (3%)	15.420 (3.420 to 66.153)	<0.0001‡
Two-stage exchange due to periprosthetic joint infection	37 (44%)	18 (25%)	2.405 (1.213 to 4.770)	0.002
Extensive osseous defect requiring tantalum cones	29 (32%)	14 (15%)	2.606 (1.269 to 5.353)	0.008
Surgery time >4 hours	44 (48%)	26 (28%)	2.379 (1.288 to 4.384)	0.005
Persistent wound drainage	12 (13%)	4 (4%)	3.390 (1.049 to 10.948)	0.0349‡
Isolation of Enterococcus	17 (19%)	1 (1%)	20.905 (2.718 to 160.77)	<0.0001‡

*The values are given as the number of patients, with the percentage of the available patient data in parentheses. †The values are given as the OR, with the 95% CI in parentheses. ‡Fisher exact test.

TABLE III Bivariate Analysis of Risk Factors Not Significantly Associated with Treatment Failure After 1-Stage Exchange Total Knee Arthroplasty

Variable	Failed Treatment Group	Control Group	P Value
Demographic characteristics			
Age* *(yr)*	66.6 ± 11.0 (27 to 84)	69.6 ± 8.4 (35 to 83)	0.096
Sex†			0.881
Female	37 (41%)	39 (42%)	
Male	54 (59%)	53 (58%)	
BMI* *(kg/m^2)*	30.4 ± 5.46 (17.8 to 46.9)	29.8 ± 4.71 (19.7 to 47.3)	0.450
Known disease†			
Diabetes mellitus	17 (19%)	21 (23%)	0.489
Coronary heart disease	16 (18%)	17 (19%)	0.875
Chronic obstructive pulmonary disease	13 (14%)	11 (12%)	0.641
Liver disease	5 (6%)	5 (5%)	0.620‡
Renal failure	22 (24%)	24 (26%)	0.766
Rheumatoid arthritis	6 (7%)	5 (5%)	0.492‡
Tumor history	16 (18%)	8 (9%)	0.059‡
Depression	7 (8%)	8 (9%)	0.509‡
Dementia	1 (1%)	0 (0%)	0.497‡
Charlson Comorbidity Index†			
0	37 (41%)	42 (46%)	0.921
1 to 4	50 (55%)	44 (48%)	0.335
≥5	4 (4%)	6 (7%)	0.380‡
Preoperative blood values*			
CRP *(mg/L)*	39.8 ± 36.49 (0.9 to 252.8)	57.1 ± 72.02 (0.7 to 351)	0.769
White blood-cell count *(× 10^9/L)*	7.8 ± 2.11 (3.5 to 15.5)	7.6 ± 2.18 (4 to 14.8)	0.564
Hemoglobin *(g/dL)*	11.8 ± 1.75 (8.5 to 15.2)	12.2 ± 1.91 (8.9 to 17.3)	0.293
Glucose *(mg/dL)*	107 ± 38.1 (55 to 321)	111 ± 37.3 (64 to 224)	0.880
Sodium *(mmol/L)*	140 ± 2.5 (133 to 146)	139.7 ± 3.2 (127 to 146)	0.762
Potassium *(mmol/L)*	4.27 ± 0.44 (3.4 to 5.4)	4.25 ± 0.51 (3.1 to 5.8)	0.823
Operative history†			
Arthroscopy	6 (7%)	13 (14%)	0.095
Aseptic exchange	16 (18%)	12 (13%)	0.394
Intraoperative organism†			
Staphylococcus aureus	9 (10%)	10 (11%)	0.828
Streptococci	11 (12%)	6 (7%)	0.149‡
Postoperative complications†			
Pneumonia	0 (0%)	4 (4%)	0.062‡
Urinary tract infection	3 (3%)	1 (1%)	0.306‡
Acute renal failure	2 (2%)	3 (3%)	0.505‡
Deep vein thrombosis	3 (3%)	1 (1%)	0.306‡
Pulmonary embolism	2 (2%)	3 (3%)	0.505‡
Wound factors†			
Sinus tract	24 (26%)	17 (19%)	0.2
Staples	51 (56%)	56 (61%)	0.359
Sutures	40 (44%)	36 (39%)	
Revision due to wound-healing disorder	13 (14%)	6 (7%)	0.069‡
Other factors			
Smoking†	5 (6%)	5 (5%)	0.620‡
Length of hospital stay* *(days)*	25.2 ± 13.2 (8 to 114)	21.7 ± 7.5 (14 to 73)	0.075
Blood transfusion†	70 (77%)	81 (88%)	0.05

*The values are given as the mean and the standard deviation, with the range in parentheses. †The values are given as the number of patients with available data, with the percentage in parentheses. ‡Fisher exact test.

TABLE IV Results of the Binary Logistic Regression Model for Risk Factors Associated with Re-Revision for Any Reason*

Variable	OR†	P Value
History of a 1-stage exchange due to periprosthetic joint infection	26.706 (5.770 to 123.606)	<0.001
History of a 2-stage exchange due to periprosthetic joint infection	3.948 (1.869 to 8.339)	<0.001
Isolation of Enterococcus	16.925 (2.033 to 140.872)	0.009

*This table uses the variables of Table II without persistent wound drainage. Additional variables that were included in the model, but that were not significant, were weight ≥100 kg, history of deep vein thrombosis, history of >4 operations, history of a polymicrobial infection, extensive osseous defect requiring tantalum cones, and surgery time >4 hours. †The values are given as the OR, with the 95% CI in parentheses.

were carried out when the data demonstrated a normal Gaussian distribution. Otherwise, the Mann-Whitney U test was employed. The frequency distribution of categorical variables in the 2 groups was compared using the chi-square test or the Fisher exact test, whenever appropriate according to the expected cell frequency. All tests were 2-tailed. For selected variables with significance of $p < 0.05$, odds ratios (ORs) were calculated. In addition to the bivariate analyses, binomial logistic regression models of re-revision as a function of potential risk factors were constructed. As covariates, we included those variables with significance of $p < 0.05$ in the bivariate analyses. All analyses were repeated using as cases only patients who had undergone failed treatment due to reinfection, comparing them with the same control group. Finally, both logistic regression models of re-revision for any reason and re-revision for reinfection only were reanalyzed by excluding persistent wound drainage as a predictor. The results for the models are presented as ORs, 95% confidence intervals (CIs), and 2-sided p values, wherever appropriate.

Results

The mean time from the index 1-stage exchange arthroplasty to the revision surgical procedure was 25.2 ± 22.4 months (range, 0 to 109 months). A total of 56 cases (62%) underwent failed treatment within 2 years, and 8 cases (9%) underwent failed treatment after >5 years (Fig. 1). Detailed information revealing the demographic and baseline characteristics of both groups is given in Table I.

Causes of Failure for Any Reason

We identified the following causes of failure: recurrence of infection (n = 47 [52%]), aseptic loosening (n = 37 [41%]), patellar problems (n = 3 [3%]), periprosthetic fracture (n = 3 [3%]), and knee dislocation (n = 1 [1%]). Among the 47 cases of reinfection as a reason for failure, 37 cases (79%) occurred within 2 years (Fig. 1). Recurrence of infection with the same causative organism occurred in 20 cases (43%), and periprosthetic joint infection with another organism was found in 27 cases (57%). No pathogen was isolated in 5 cases (6%) in the failed treatment group and in 8 cases (9%) in the control group. Two patients from the 5 culture-negative failed treatment cases

TABLE V Results of the Bivariate Analysis of Risk Factors Significantly Associated with Re-Revision for Reinfection

Risk Factor	Reinfection Group*	Control Group*	OR†	P Value
Weight ≥100 kg	18 (38%)	18 (20%)	2.552 (1.168 to 5.577)	0.017
History				
Deep vein thrombosis	18 (38%)	11 (12%)	4.571 (1.931 to 10.819)	<0.0001
>4 operations	22 (47%)	19 (21%)	3.381 (1.576 to 7.256)	0.001
Polymicrobial infection	19 (40%)	14 (15%)	3.519 (1.548 to 7.995)	0.001
One-stage exchange due to periprosthetic joint infection	13 (28%)	2 (2%)	15.574 (2.899 to 63.558)	<0.0001‡
Two-stage exchange due to periprosthetic joint infection	22 (47%)	18 (20%)	2.405 (1.213 to 4.770)	0.001
Surgery time >4 hours	22 (47%)	26 (28%)	2.234 (1.076 to 4.640)	0.03
Persistent wound drainage	8 (17%)	4 (4%)	4.462 (1.268 to 15.702)	0.016‡
Wound revision due to healing disorders	9 (19%)	6 (7%)	3.395 (1.129 to 10.212)	0.026‡
Isolation of Streptococcus	9 (19%)	6 (7%)	3.395 (1.129 to 10.211)	0.026‡
Isolation of Enterococcus	8 (17%)	1 (1%)	18.667 (2.258 to 154.34)	0.001‡

*The values are given as the number of patients with available data, with the percentage in parentheses. †The values are given as the OR, with the 95% CI in parentheses. ‡Fisher exact test.

experienced a reinfection. Among the patients in the failed treatment group, 5 underwent arthrodesis (6%) and 2 required amputation of the affected limb (2%).

Results of Bivariate Analysis

Bivariate analyses showed that several variables were potentially associated with re-revision following 1-stage revision knee arthroplasty due to periprosthetic joint infection. The results for these risk factors are listed in Table II. The risk of failure was 15-fold higher with prior 1-stage septic revision. Interestingly, the risk for failure was 21-fold higher when Enterococcus species had been intraoperatively identified (Table II). In contrast, several comorbidity factors or possible procedure-related risk factors did not increase the risk of re-revision (Table III).

Binomial Logistic Regression Analysis

Among the remaining variables in the final analysis, a history of 1-stage exchange arthroplasty, a history of a 2-stage exchange arthroplasty, and isolation of Enterococcus species were independently associated with failure; there was a higher risk of any revision surgical procedure with a history of a 1-stage exchange arthroplasty (27-fold higher), a history of a 2-stage exchange arthroplasty (4-fold higher), and isolation of Enterococcus species (17-fold higher) (Table IV).

Causes of Revision for Reinfection

Most of the identified risk factors for revision for any reason following a 1-stage exchange total knee arthroplasty due to periprosthetic joint infection were also found to be associated with re-revision because of a subsequent reinfection. The isolation of Enterococcus species was, in turn, a potential risk factor for infection recurrence (OR, 18.667 [95% CI, 2.258 to 154.34]; p = 0.001) (Table V). However, we also determined an additional potential factor for failure due to recurrent periprosthetic joint infection, namely the isolation of Streptococcus species (Table V).

The binary logistic regression analysis indicated that a history of 1-stage or 2-stage exchange arthroplasty and the isolation of Enterococcus and Streptococcus species were also independently associated with failure. The highest risks for reinfection in this model were a history of a 1-stage septic exchange (OR, 29.263 [95% CI, 5.147 to 166.381]; p < 0.001) and the isolation of enterococci (OR, 17.324 [95% CI, 1.470 to 204.160]; p = 0.023) (Table VI).

TABLE VI Results of the Binary Logistic Regression Model for Risk Factors Associated with Reinfection*

Variable	OR*†	P Value
History of a 1-stage exchange due to periprosthetic joint infection	29.263 (5.147 to 166.381)	<0.001
History of a 2-stage exchange due to periprosthetic joint infection	5.770 (2.162 to 15.397)	<0.001
Isolation of Streptococcus	6.025 (1.470 to 24.701)	0.013
Isolation of Enterococcus	17.324 (1.470 to 204.160)	0.023

*This table uses the variables of Table V without persistent wound drainage. Additional variables that were included in the model, but that were not significant, were weight ≥100 kg, history of deep vein thrombosis, history of >4 operations, history of a polymicrobial infection, surgery time >4 hours, persistent wound drainage, and wound revision due to healing disorders. †The values are given as the OR, with the 95% CI in parentheses.

Discussion

We were able to identify several potential risk factors for re-revision after 1-stage exchange total knee arthroplasty for periprosthetic joint infection. Among them, a history of an exchange arthroplasty due to periprosthetic joint infection and the isolation of Enterococcus species were independent risk factors for re-revision for any reason as well as for reinfection in the binary logistic regression analysis. Additionally, a streptococcal infection was independently associated with a higher risk of failure for reinfection.

We observed great similarity between the identified risk factors for revision for any reason and those detected through the repeated analyses involving reinfection. Reinfection was the most common cause for failure in this cohort. Moreover, the majority of those risk factors were procedure-related.

Except for a high body weight (≥100 kg) as a risk factor for both a re-revision for any reason and for reinfection and a history of deep vein thrombosis as a risk factor for a re-revision for any reason, all other investigated comorbidities did not have an impact on the need for a further revision. In a large database review comparing the rate of reinfection among the various treatment options[21], patients with higher Charlson Comorbidity Index scores had a higher risk for infection recurrence, which is not consistent with our results. We also noticed a trend toward significance with regard to patients with a tumor history, which has been reported to be a risk factor for periprosthetic joint infection[12]. Of 18 one-stage reimplantations for total knee arthroplasty due to periprosthetic joint infections, 2 patients with rheumatoid arthritis underwent failure of the treatment due to reinfection in the study by Göksan and Freeman[12]. Other studies analyzing the predictors of failure after a 2-stage revision total knee arthroplasty found a significant relationship between reinfection and some patient comorbidities, such as diabetes mellitus, obesity, gout, liver cirrhosis, heart disease, and lymphedema[22-24].

The risk of treatment failure and reinfection after 2-stage exchange total knee arthroplasty was significantly higher in obese and morbidly obese patients[23,25]. A body weight of ≥100 kg was determined as the threshold for a significant increase in periprosthetic joint infection following primary total joint arthroplasty in the study by Lübbeke et al.[26].

In our analysis, the isolation of Enterococcus species was a risk factor for failure, with a 17-fold to 21-fold higher risk of

re-revision for any reason and for reinfection. Enterococcus species are known antibiotic-resistant opportunistic pathogens, which are classified as difficult to treat[27]. Enterococcal periprosthetic joint infection had poor outcomes with a high rate of reinfection and were significantly associated with a polymicrobial pattern of infection in previous studies[28,29]. Similar to our results, the isolation of enterococci was one of the most significant risk factors for failure of a 2-stage exchange total knee arthroplasty due to periprosthetic joint infection[23].

Streptococcus species was also identified as one of the risk factors for reinfection in our study, but with a lower risk than Enterococcus species. Contrasting success rates following the management of streptococcal periprosthetic joint infection (59% and 84%) have been presented in previous studies[30,31].

Two-stage exchange for polymicrobial periprosthetic joint infection due to multiple infectious organisms has been noted to result in a lower cure rate compared with monomicrobial infections[32]. We found that a history of a polymicrobial infection of the same joint is a predictor for failure, in particular, due to reinfection. Pelt et al.[33] and Ma et al.[23] demonstrated in their analyses that a polymicrobial infection was associated with a higher risk of failure.

Previous studies have shown that the more often the affected joint had undergone a previous operation, the higher the likelihood that the 2-stage exchange will fail[24,34,35]. This coincides with our results. According to our bivariate analysis, >4 previous surgical procedures increase the risk of failure.

Furthermore, regardless of the number of prior operations, a previous exchange due to periprosthetic joint infection was a significant risk factor for both re-revision for any cause and reinfection in our comparative analysis, in which the level of significance for a 1-stage exchange was much higher than that for a 2-stage exchange. A 2-stage procedure should be considered after the failure of ≥2 previous 1-stage hip revisions due to periprosthetic joint infection[36].

A cutoff of >4 hours of operative time increased the risk for re-revision for any reason and for reinfection among other series. Increased operative time has been considered as a risk factor for reinfection with 2-stage reimplantation due to periprosthetic joint infection[23,37]. We selected this cutoff level on the basis of the recommendation of the International Consensus Meeting on Periprosthetic Joint Infection with regard to the redosing interval for perioperative antibiotic prophylaxis[38].

Although the presence of an osseous defect during a 2-stage reimplantation was associated with reinfection in the study by Ma et al.[23], this was not confirmed in our study.

The postoperative persistence of wound drainage can be an early sign of periprosthetic joint infection[39,40]. Persistent wound drainage was one of the predictors of failure resulting in a further revision in our study.

We observed a higher prevalence of a preoperative sinus tract in the failed treatment group but without an increased risk of failure. In contrast, it was associated with infection recurrence in 1-stage and 2-stage total knee arthroplasty exchanges in the study by Massin et al.[41]. Also, we did not identify any significant difference between the patient groups with regard to the wound closure material used (sutures compared with staples).

Many of the previous reports on the results of single-stage revision total knee arthroplasty due to periprosthetic joint infection had considered only reinfection as a failure[12,14,16,17]. We defined failure as the need for a re-revision, as the goal of the 1-stage approach is not only to overcome the infection, but also to avoid further surgical procedures, and hence be more likely to achieve a better outcome. In our series, reinfection (52%) and aseptic loosening (41%) were the most common causes for a subsequent revision, and these were also the reasons for re-revision in the previously reported long-term results of 1-stage exchange due to periprosthetic joint infection after a total knee arthroplasty at our institution[18].

The mean duration to reinfection varied from 14 to 43 months for a 2-stage reimplantation total knee arthroplasty in previous reports[22-24]. However, 80.3% of the reinfections occurred within 1 year after the selected treatment in the study by Cochran et al., which included infections after 16,622 total knee arthroplasties and compared the results among 3 treatment options[42].

A recent systematic review indicated that the reinfection rate varied from 0% to 41% in 2-stage studies and from 0% to 11% in single-stage studies. Our previously reported rate lies within this range[43]. However, the main goal of this current study was to define and analyze the risk factors for failure of 1-stage exchange total knee arthroplasty for periprosthetic infection by analyzing all such treatment failures; because we therefore used a short minimum follow-up, the failure rates will not be directly comparable with those in the above-mentioned studies. Thus, the above-mentioned success range should not be considered, as we included all performed procedures from 2008 to December 2017, with a short minimum follow-up.

Our study had limitations. First, the retrospective study design had inherent limitations related to the accuracy and availability of the data collected. Second, we did not include other possible risk factors, which could have been valuable in these kinds of analyses, such as socioeconomic parameters. Third, the performance of the binary logistic regression model may have been limited because of the relatively large number of investigated covariates in relation to the sample size, which could result in overfitting. Given that our data were gathered from a single center, though, we believe that the analysis of risk factors after the 1-stage knee exchange following a standardized management protocol is reliable.

In conclusion, 1-stage exchange total knee arthroplasty has several advantages and remains our preferred approach when indications have been well considered. We determined several risk factors for failure, most of which are procedure-related. Among them, the isolation of Enterococcus species and a previous 1-stage exchange total knee arthroplasty increased the risk of failure significantly. We believe that an awareness of the identified risk factors when evaluating patients with periprosthetic joint infection with a multidisciplinary team may lead to better outcomes. ■

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Mustafa Citak, MD, PhD[1]
Jasmin Friedenstab[1,2]
Hussein Abdelaziz, MD[1]
Eduardo M. Suero, MD[3]
Akos Zahar, MD, PhD[1]
Jochen Salber, MD[2]
Thorsten Gehrke, MD[1]

[1]Department of Orthopaedic Surgery, Helios ENDO-Klinik Hamburg, Hamburg, Germany

[2]Department of Surgery, Ruhr-University Hospital, Bochum, Germany

[3]Department of General, Trauma and Reconstructive Surgery, Ludwig-Maximilians-University München, München, Germany

E-mail address for M. Citak: mcitak@gmx.de

ORCID iD for M. Citak: 0000-0003-3207-7101
ORCID iD for J. Friedenstab: 0000-0001-5037-2644
ORCID iD for H. Abdelaziz: 0000-0002-1750-3451
ORCID iD for E.M. Suero: 0000-0002-7578-8440
ORCID iD for A. Zahar: 0000-0001-8831-4415
ORCID iD for J. Salber: 0000-0001-9738-2305
ORCID iD for T. Gehrke: 0000-0002-4124-1682

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