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MAJOR ARTICLE

Predictors of Treatment Failure for Hip and Knee Prosthetic Joint Infections in the Setting of 1- and 2-Stage Exchange Arthroplasty: A Multicenter Retrospective Cohort

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Background. Prosthetic hip and knee joint infections (PJIs) are challenging to eradicate despite prosthesis removal and antibiotic therapy. There is a need to understand risk factors for PJI treatment failure in the setting of prosthesis removal.

Methods. A retrospective cohort of individuals who underwent prosthesis removal for a PJI at 5 hospitals in Toronto, Canada, from 2010 to 2014 was created. Treatment failure was defined as recurrent PJI, amputation, death, or chronic antibiotic suppression. Potential risk factors for treatment failure were abstracted by chart review and assessed using a Cox proportional hazards model.

Results. A total of 533 individuals with prosthesis removal were followed for a median (interquartile range) of 814 (235–1530) days. A 1-stage exchange was performed in 19% (103/533), whereas a 2-stage procedure was completed in 88% (377/430). Treatment failure occurred in 24.8% (132/533) at 2 years; 53% (56/105) of recurrent PJIs were caused by a different bacterial species. At 4 years, treatment failure occurred in 36% of 1-stage and 32% of 2-stage procedures (P = .06). Characteristics associated with treatment failure included liver disease (adjusted hazard ratio [aHR], 3.12; 95% confidence interval [CI], 2.09–4.66), the presence of a sinus tract (aHR, 1.53; 95% CI, 1.12–2.10), preceding debridement with prosthesis retention (aHR, 1.68; 95% CI, 1.13–2.51), a 1-stage procedure (aHR, 1.72; 95% CI, 1.28–2.32), and infection due to Gram-negative bacilli (aHR, 1.35; 95% CI, 1.04–1.76).

Conclusions. Failure of PJI therapy is common, and risk factors are not easily modified. Improvements in treatment paradigms are needed, along with efforts to reduce orthopedic surgical site infections.

Keywords. prosthetic joint infection; surgical site infection; revision arthroplasty.

Prosthetic joint infections (PJIs) are a feared complication of hip and knee arthroplasty and are associated with substantial morbidity through revision operations, prolonged courses of antibiotics, and joint function loss [1, 2]. PJIs are increasing in parallel with the rising number of hip and knee joint replacements occurring in aging populations [3, 4]. Treatment of PJIs usually requires an operative intervention in conjunction with prolonged courses of antibiotics that are guided by the causative microorganism and procedure performed [5]. To date, the most common operative approach in North America involves prosthesis removal followed by re-implantation, performed either concurrently—a 1-stage procedure—or subsequently—a 2-stage procedure [5].

Risk factors for PJI treatment failure identified in previous studies include a longer duration of symptoms before surgery, infection due to *Staphylococcus aureus*, prior revision arthroplasty, soft tissue integrity, and use of vancomycin [6–11]. These have been identified from cohorts typically involving homogenous patient populations under the care of a limited number of physicians [6, 7, 9–11]. Moreover, the duration of follow-up was often short, resulting in underestimates of the risk of treatment failure [6]. There is a need to assess risk factors for treatment failure over the long term in larger cohorts spanning multiple hospitals. The purpose of this study was to

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evaluate the characteristics associated with PJI treatment failure after operative intervention involving prosthesis removal in 5 hospitals in Toronto, Ontario, from 2010 until 2014.

METHODS

Patient Population

The study population included individuals at least 18 years of age and older who underwent a 1- or 2-stage procedure intended as definitive treatment of a prosthetic hip or knee joint infection at 1 of 5 hospitals (4 academic and 1 community) in Toronto, Ontario, Canada, between January 1, 2010, and December 31, 2014. Eligible patients were identified by reviewing listings of all orthopedic surgery procedures whose description contained any of the following words/phrases: revision, incision, debridement, first-stage procedure, second-stage procedure, single stage, or excision. Patients were excluded if follow-up was <30 days from hospital discharge or the only procedure recorded was the second stage of a 2-stage procedure. Three chart abstractors (Kandel, Garcia Jeldes, Sajja) independently reviewed the medical records to confirm the existence of a PJI using the definition of the Musculoskeletal Infection Society, which incorporates clinical, microbiological, histopathological, and biochemical criteria [12]. This study was approved by the research ethics boards of all participating institutions.

Predictors of Failure

Characteristics potentially associated with PJI treatment failure were abstracted through chart review, including patient (age, medical comorbidities, and prescribed antibiotics), joint (age of prosthesis, indication for initial arthroplasty, and previous revisions), infection (causative microorganism, duration of infectious symptoms, and antecedent antimicrobials), and surgical characteristics (procedure performed and spacer type). Underlying chronic medical conditions were as defined by the attending physician in the hospital chart, with the exception of chronic kidney disease—which was defined by the Kidney Disease: Improving Global Outcomes (KDIGO) guidelines as evidence of kidney damage or reduced function present for 3 months—and inflammatory arthritis, which required the receipt of a disease-modifying antirheumatic drug [13].

Microbiology

The causative microorganism for a PJI was defined as an organism isolated from at least 2 intraoperative specimens. If cultures were negative or not collected, preoperative arthrocentesis or operative specimens from prior debridement procedures were considered [12]. Each hospital cultured intraoperative specimens both directly onto multiple agar plates and into enrichment broth with 14-day incubation. Recurrent PJIs were categorized as relapse or reinfection according to whether the bacterial species was the same or different, respectively. If a recurrent PJI was culture negative or culture results were not available it was categorized as "unknown." Coagulase-negative staphylococci were not identified to the species level; if coagulase-negative staphylococci were the cause of the initial and recurrent PJI, it was classified as a relapse.

Primary Outcome

PJI treatment failure was defined as any 1 of recurrent PJI, receipt of chronic antibiotics for the purpose of infection suppression, excision arthroplasty, limb amputation occurring at any point during follow-up, or death in the 30 days after a surgical procedure [14, 15]. The definition of chronic antibiotic suppression was the intended provision of indefinite oral antibiotics at any time after a definitive operative intervention for a PJI (single-stage procedure, second stage of a 2-stage procedure, or after a spacer insertion when no further surgery was anticipated). The date of failure was defined as the date that a microbiologic specimen was obtained or operative procedure performed that confirmed the diagnosis of recurrent infection or the date of excision arthroplasty, amputation, or death. Treatment outcomes were also categorized according to the Musculoskeletal Infection Society consensus criteria [15].

Statistical Analysis

Data were entered in duplicate and cleaned. All statistical analyses were carried out using R, version 3.4.4. Descriptive statistics for the cohort are presented as proportions and medians with interquartile ranges (IQRs) for categorical and continuous variables, respectively. A Cox proportional hazards model was used to assess factors associated with treatment success once model assumptions were satisfied. A priori, the following covariates were included in the model, as they have been previously shown to be associated with PJI treatment outcome: age, sex, indication for initial arthroplasty (categorized into trauma and other), previous operation for the current PJI, the causative microorganism (categorized into *Staphylococcus aureus*, Gram-negative bacilli, and other), presence of a sinus tract, and whether the infection was a complication of primary joint replacement or a revision surgery [6–11]. Age was included in the multivariable model with a restricted cubic spline with 3 knots, as a linear relationship with treatment failure was not observed [16]. A sandwich-type variance estimator was used to account for hospital-level clustering [17]. Separate analyses were run for 2-stage procedures only, by time of treatment failure (separated into acute [3 months], subacute [3–24 months], and late [>24 months]), by joint, and by complete vs partial prosthesis removal (with complete defined as 2-stage procedures and 1-stage procedures in which all prosthetic components were excised).

RESULTS

There were 568 individuals with 573 prosthetic hip or knee joint infections for which a 1-stage or 2-stage procedure was performed for the treatment of a PJI over the 5-year study period. Of these,

28 (4.9%) patients were excluded because only a second-stage procedure was identified, 4 (0.7%) for follow-up of <30 days, and 8 (1.4%) for amputation, excision, or fusion, leaving 533 for analysis.

The median age at the time of index procedure (IQR) was 66 (59–75) years, the most common indication for joint replacement was osteoarthritis (421/533, 79%), the majority of PJIs occurred after primary rather than revision arthroplasty (340/533, 64%), and 9 (2%) occurred within 28 days of the primary arthroplasty (Table 1). Procedures were performed by 28 surgeons, with 21 performing >5 operations. Four hundred thirty patients with a PJI (176 hip joints, 41%) underwent the first of a planned 2-stage procedure, with 88% (377/430) ultimately receiving a second stage a median (IQR) of 118 (90–189) days later and 15% (56/377) undergoing at least 1 additional surgical intervention after the first stage. A 1-stage procedure was performed for the remaining 103 PJIs (75/103 hip, 73%), with complete prosthesis exchange occurring in 36% (37/103). Of the incomplete 1-stage procedures for hip PJIs only, the acetabulum was revised in 63% (35/56). For knee PJIs, the tibial component alone was revised in 40% (4/10). The median duration of follow-up (IQR) was 814 (235–1530) days.

PJIs were monomicrobial in 67% (359/533), polymicrobial in 9% (46/533), and culture-negative in 24% (128/533). The most commonly isolated organisms were coagulase-negative staphylococci (32%), followed by *S. aureus* (19%), Gram-negative bacilli (10%), and enterococci (8%). The proportions of PJI treatment failures by organism were similar (Table 2). Prescribed antibiotic regimens were available for 96.8% (516/533) of the cohort. Overall, vancomycin was the most commonly prescribed antibiotic for treatment, in 56% (288/516) of participants. For culture-negative infections, vancomycin or cefazolin was used in 80% (102/128); when a Gram-negative bacillus was identified, a fluoroquinolone was used in 54% (29/54); and when a *Staphylococcus* spp. was identified, adjunctive rifampin was used in 19% (51/269). In the setting of a 2-stage procedure without any intervening operation, the median duration of prescribed antibiotics (IQR) was 44 (42–56) days. For single-stage procedures without chronic antibiotic suppression, the median duration (IQR) was 56 (42–90) days.

Table 1. Characteristics of Individuals Undergoing Prosthesis Removal for the Treatment of a Prosthetic Hip or Knee Joint Infection at 5 Hospitals in Toronto, Ontario, Canada, Between 2010 and 2014

Characteristic	Overall Cohort (n = 533)	1-Stage (n = 103)	2-Stage (n = 430)
Age, median (IQR), y	66 (59–75)	67 (58–79)	66 (59–75)
Male sex	264 (50)	54 (52)	215 (50)
Joint type			
Hip	251 (47)	75 (73)	176 (41)
Knee	282 (53)	28 (27)	254 (59)
Arthroplasty indication			
Osteoarthritis	421 (79)	76 (74)	345 (80)
Trauma	63 (12)	13 (13)	50 (12)
Inflammatory arthritis	18 (3)	6 (6)	12 (3)
Other[a]	31 (6)	8 (8)	23 (5)
Prosthetic joint status[b]			
Primary	340 (64)	66 (64)	274 (64)
Revision	193 (36)	37 (36)	156 (36)
Previous failed debridement	99 (19)	2 (2)	97 (23)
Knee spacer type (n = 254)			
Dynamic	NA	NA	189 (74)
Static	NA	NA	65 (26)
Sinus tract present	161 (30)	18 (18)	143 (33)
Vancomycin in cement	355 (67)	31 (30)	324 (75)
Duration of symptoms			
Chronic (>21 d)	480 (90)	83 (81)	397 (92)
Culture negative	128 (24)	17 (17)	111 (26)
Organism known in advance	271 (37)	32 (31)	173 (41)
Comorbidity	214 (40)	39 (38)	175 (41)
Diabetes	124 (23)	24 (23)	100 (23)
Heart disease	95 (18)	16 (16)	79 (18)
Kidney disease	52 (10)	6 (6)	46 (11)
Liver disease	8 (1.5)	0 (0)	8 (2)

Data are presented as No. (%) unless otherwise indicated.

Abbreviations: IQR, interquartile range; NA, not applicable; PJI, prosthetic joint infection.

[a]Includes osteonecrosis, congenital conditions, previous malignancy, and native joint septic arthritis.

[b]Status of the prosthetic joint before the onset of the PJI.

Table 2. Microbiology of Prosthetic Hip and Knee Joint Infections in a Multicenter Retrospective Cohort Undergoing Prosthesis Removal for a Prosthetic Joint Infection at 5 Hospitals in Toronto, Ontario, Canada, Between 2010 and 2014

Organisms Causing Initial Infection	No. (%) Failing After Prosthesis Removal Surgery[a]	No. (%) With Recurrent PJI[b]
Coagulase-negative staphylococci	52/172 (30)	11/37 (30)
Staphylococcus aureus	31/101 (31)	10/21 (48)
MSSA	27/88 (31)	9/19 (47)
MRSA	4/13 (31)	1/2 (50)
Enterococcus species	15/45 (33)	2/9 (22)
Beta-hemolytic streptococci	9/23 (38)	1/5 (20)
Non-beta-hemolytic streptococci	6/20 (30)	0/4 (0)
Other Gram-positive bacteria[c]	6/37 (16)	1/3 (33)
Gram-negative bacilli	21/54 (39)	3/14 (21)[d]
Pseudomonas aeruginosa	7/12 (58)	0/3 (0)
Enterobacter spp.	6/11 (55)	1/6 (17)
Escherichia coli	1/10 (10)	1/1 (100)
Klebsiella pneumoniae	3/7 (43)	0/2 (0)
Other[e]	7/18 (39)	2/4 (50)
Candida species	2/5 (40)	1/2 (50)

Abbreviations: MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-sensitive *Staphylococcus aureus*; PJI, prosthetic joint infection.

[a]Numbers sum to >405 due to polymicrobial infections.

[b]Includes only those individuals who received antibiotics with the intent of cure as opposed to suppression of infection with indefinite antibiotics.

[c]Includes *Corynebacterium* spp., *Dermabacter hominis*, *Listeria monocytogenes*, *Cutibacterium* spp., *Clostridium* spp., and oral anaerobes.

[d]Sum is greater than the total number of prosthetic joint infections due to Gram-negative bacilli on account of polymicrobial infections.

[e]Includes *Ralstonia* spp., *Moraxella* spp., *Serratia marcescens*, *Proteus* spp., *Pasteurella* spp., *Morganella morganii*, *Capnocytophaga canimorsus*, *Bacteroides* spp., *Stenotrophomonas maltophilia*, and *Achrombacter* spp.

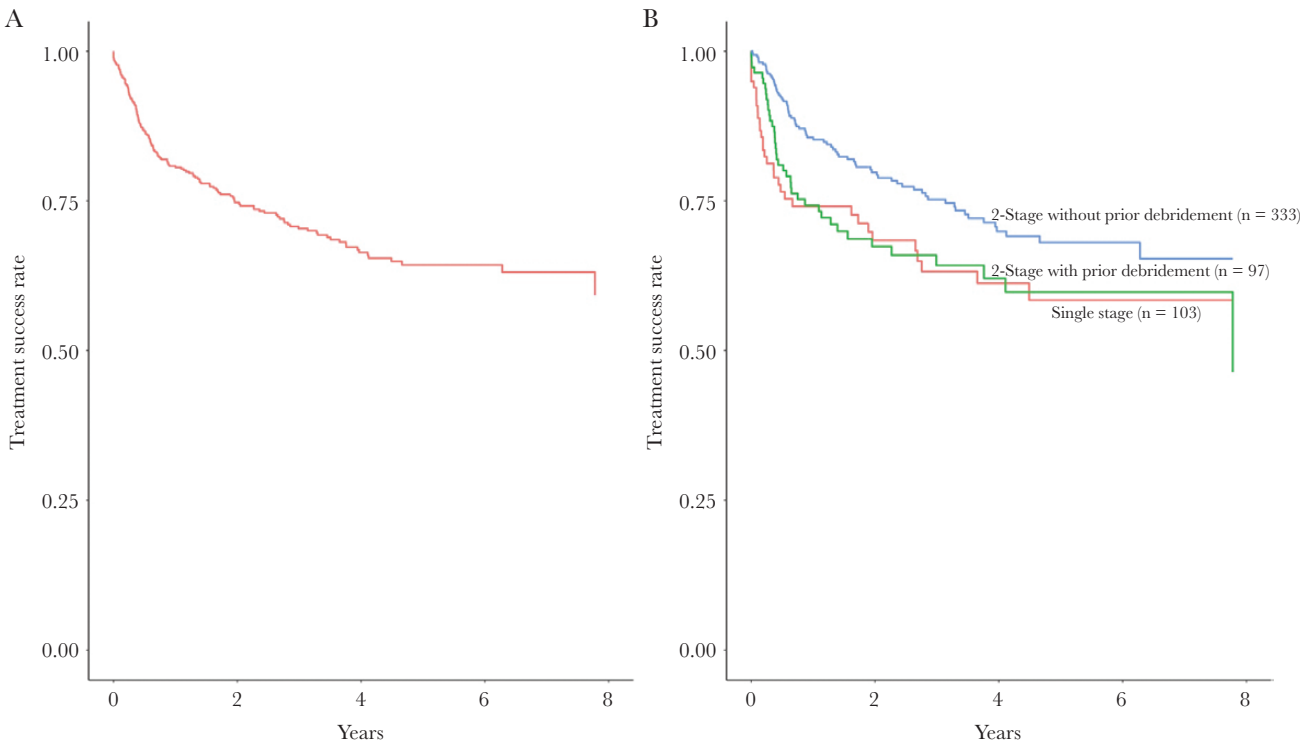

Figure 1. Prosthetic joint infection treatment success over time for 1- and 2-stage procedures using a Cox proportional hazard model adjusted for age, sex, surgical procedure, organism, medical comorbidities, presence of a sinus tract, prior debridement, joint status, and arthroplasty indication for the overall cohort (A) and conditional on the operative procedure performed (B).

Overall, treatment failure was 13.1% (95% confidence interval [CI], 10.2%–16%) within 6 months of the index operation, 24.8% (95% CI, 20.8%–28.6%) by 2 years, and 33.0% (95% CI, 28.1%–37.5%) by 4 years (Figure 1). For single-stage procedures, the failure rate at 6 months was 22% (95% CI, 15–32%), by 2 years it was 29% (95% CI, 21%–40%), and by 4 years it rose to 36% (95% CI, 27%–47%), whereas the corresponding values for 2-stage exchanges were 11% (95% CI, 8%–14%), 24% (95% CI, 20%–28%), and 32% (95% CI, 27%–38%). Rates of failure were similar between hip (28%, 70/251) and knee joint (29%, 82/282) PJIs. Failure was most often the result of a recurrent PJI (105/150, 70%), followed by antimicrobial suppression (32/150, 21%). Of the recurrent PJIs, re-infection occurred in 53% (56/105) and relapse in 23% (24/105); the remaining 25 (24%) infections were culture-negative. Death within 30 days of a surgical procedure occurred in 2% (10/533). When applying the Musculoskeletal Infection Society criteria, the optimal outcome of infection eradication without the need for chronic antimicrobials occurred in 64% (343/533), whereas a repeat operation occurred in 26% (140/533) (Table 3).

On multivariable analysis, the following characteristics were associated with treatment failure: liver disease (adjusted hazard ratio [aHR], 3.12; 95% CI, 2.09–4.66), the presence of a sinus tract (aHR, 1.53; 95% CI, 1.12–2.10), prior failed debridement with prosthesis retention (aHR, 1.68; 95% CI, 1.13–2.51), a 1-stage procedure (aHR, 1.72; 95% CI, 1.28–2.32), and infection with a Gram-negative bacillus (aHR, 1.35; 95% CI, 1.04–1.76) (Table 4). When excluding those who received chronic antibiotic suppression, an empiric antibiotic regimen having activity against all the causative pathogens did not impact treatment failure (HR, 0.98; 95% CI, 0.84–1.13).

There were no significant changes in the findings when restricting the analysis to PJI interventions involving removal of all prosthetic components or to PJIs treated with a 2-stage procedure, and there was no difference between PJI relapse or reinfection (data not shown). Inclusion of the second-stage procedure as a time-varying covariate did not change the risk factors identified. No factors examined were significantly associated with late treatment failure (occurring at >24 months).

Table 3. Prosthetic Joint Infection Treatment Outcomes According to Musculoskeletal Infection Society Categorization Scheme [15]

Outcome Tier	Frequency (%)
Tier 1: Infection control without antibiotics	343 (64)
Tier 2: Infection control with antibiotics	40 (8)
Tier 3: Reoperation or spacer retention	140 (26)
A: Aseptic revision >1 y after PJI treatment	11 (2)
B: Septic revision >1 y after PJI treatment	35 (7)[a]
C: Aseptic revision ≤1 y after PJI treatment	6 (1)
D: Septic revision ≤1 y after PJI treatment	50 (9)[a]
E: Amputation, excision, arthrodesis	13 (2)
F: Retained spacer	25 (5)
Tier 4: Death	10 (2)
A: Death ≤1 y after PJI treatment	9 (2)
B: Death >1 y after PJI treatment	1 (0.2)

Abbreviation: PJI, prosthetic joint infection.

[a]For Tiers 3B and 3D, the number of recurrent PJIs due to the same bacterial species was 21 and due to a different species was 33.

DISCUSSION

Among a cohort of 533 individuals with a hip or knee PJI treated with a 1- or 2-stage exchange arthroplasty at 1 of 5 hospitals in Toronto, Ontario, the 2-year failure rate was 25%. This high failure rate is similar to that found in other studies with different patient populations, reflecting the difficulty of successful PJI therapy despite prosthesis removal [9, 18, 19]. The majority of treatment failures occur within 2 years after surgical intervention. Patient, microbiologic, and procedure-related factors were found to be associated with treatment failure.

PJI Treatment Failure Risk Factors

Our findings support previous report's conclusions that failed debridement with prosthesis retention before prosthesis removal is a risk factor for treatment failure [20]. Risk factors for failure of incision and debridement with prosthesis retention include the duration of infectious symptoms, forgoing exchange of modular components, not using antibiotic regimens with high biofilm penetration, and short courses of antibiotics after debridement [21, 22]. These should be taken into consideration when debridement alone is pursued to maximize the likelihood of success, as subsequent prosthesis removal for ongoing infection is associated with a higher hazard of failure.

A 1-stage procedure is attractive by virtue of requiring only a single operation and subsequent recovery period. We found a higher hazard of failure when a 1-stage procedure was performed as compared with a 2-stage. This may reflect selection of individuals for a 1-stage procedure who have a higher likelihood of failure or an elevated surgical risk. Alternatively, the higher rate of failure for 1-stage procedures may be as a result of incomplete removal of all prosthetic components [5]. Our findings are in contrast to those of 2 recent systematic reviews of surgical interventions for hip and knee PJIs, which demonstrated similar failure rates for 1- and 2-stage procedures [23–25]. These reviews motivated an ongoing randomized trial comparing 1- vs 2-stage procedures for hip PJIs [26].

The presence of a sinus tract and liver disease were patient characteristics associated with treatment failure, which have been demonstrated previously [10, 27]. Sinus tracts are often indicative of long-standing infection, which may make biofilm eradication challenging and further perturb bone stalk. Moreover, a sinus tract disturbs the soft tissue envelope, the integrity of which is a risk factor for treatment failure [28]. Liver disease has been associated with the development of PJIs after primary arthroplasty and is a risk factor for treatment failure

Table 4. Univariate and Multivariate Hazard Ratios for Characteristics Associated With Prosthetic Joint Infection Treatment Failure in Patients Undergoing Prosthesis Removal for a Prosthetic Joint Infection at 5 Hospitals in Toronto, Ontario, Canada, Between 2010 and 2014

Characteristic[a]	Univariate Hazard Ratio (95% Confidence Interval)	*P* Value	Adjusted Hazard Ratio (95% Confidence Interval)	*P* Value
Nonprimary joint	1.34 (0.75–2.40)	.33		
Arthroplasty indication				
Trauma	1.38 (0.96–1.99)	.08		
Other	1 (referent)			
Failed prior debridement	1.78 (1.45–2.19)	<.001	1.68 (1.13–2.51)	.011
1-stage procedure	1.29 (0.99–1.69)	.06	1.72 (1.28–2.32)	<.001
Microbiology				
Staphylococcus aureus	1.30 (0.82–2.05)	.27		
Gram-negative bacilli	1.81 (1.44–2.29)	<.001	1.35 (1.04–1.76)	.026
Other	1 (referent)			
Sinus tract	1.77 (1.30–2.41)	<.001	1.53 (1.12–2.10)	.008
Diabetes mellitus	1.11 (0.84–1.46)	.45		
Liver disease	2.75 (1.93–3.92)	<.001	3.12 (2.09–4.66)	<.001
Kidney disease	1.03 (0.72–1.48)	.86		

[a]For each characteristic, the comparison is the absence of the characteristic unless a reference is specified. For 1-stage procedures, the reference group is 2-stage procedures.

when a prosthesis retention approach is adopted [29]. Similarly, we found that liver disease was associated with treatment failure in the setting of prosthesis removal.

Infections due to Gram-negative bacilli were associated with a higher hazard of treatment failure. Similar associations have been identified previously in the setting of both prosthesis retention and removal [6]. We did not, however, find that *Staphylococcus aureus* was associated with PJI treatment failure, which differs from the results of previous studies [30]. This may relate to including only PJIs treated with prosthesis removal, as this association is more pronounced in the setting of prosthesis retention [31]. The virulence factors of *Staphylococcus aureus* and propensity to form a biofilm may contribute to the decreased effectiveness of debridement alone [32]. Accordingly, prosthesis removal may be preferred in PJIs caused by these organisms when there are additional risk factors for treatment failure. Renal failure and underlying inflammatory arthritis are additional risk factors that were not corroborated in this cohort [33]. However, our study was underpowered to detect the previously estimated size of effect of these comorbidities. In addition, our definition of renal disease, which included only those with chronic renal failure according to the KDIGO criteria, was more stringent than that used in previous studies [29].

Treatment Failure

The newly recommended tiered reporting of outcomes of PJI management is complex but provides a useful illustration of the variability in treatment failure rates likely to be reported based on different definitions of treatment success and durations of follow-up [15, 34]. In our cohort, inclusion of chronic antibiotic suppression as treatment failure increased the overall failure rate to 29% from 22%; similarly, excluding spacer retention as a cause of failure lowered the failure rate by ~5%. It may not be possible to achieve universal consensus on a single definition of failure.

In our study, when an organism was identified in the setting of a recurrent PJI, which occurred in 75% of treatment failures, the majority were different from the initial causative organism. This is similar to a previous study demonstrating that the proportion of recurrent PJIs caused by the same organism was lower in the setting of prosthesis removal as compared with prosthesis retention [35, 36]. Our estimate of the proportion of recurrent infections due to a different organism is conservative, as coagulase-negative staphylococci were classified as the same organism because they were not routinely identified to the species level in our laboratories. Our results suggest that after collection of appropriate microbiological specimens in these patients, it is prudent to provide empiric antibiotic coverage directed not only toward previously detected pathogens, but also more broadly against other common causative pathogens, before adjusting therapy once microbiology results are available.

Limitations

There are limitations that merit emphasis. Our detection strategy for PJI was imperfect and may have missed some individuals, particularly if operative procedures were miscoded or treatment was provided at a different hospital. These scenarios are likely to include a small number of individuals and will minimally impact the results. In addition, by design, only those individuals who underwent an operation for the treatment of a PJI were included. However, the number of individuals treated with antibiotics alone for a PJI is expected to be small; the majority of those in whom an antibiotic suppression strategy is adopted undergo at least 1 operative intervention [37, 38]. Moreover, individuals treated medically opt to focus on attenuating symptoms, making them different from those for whom

the goal is infection eradication [39]. Some characteristics potentially associated with surgical site infection such as smoking and surgeon volume could not be obtained. Despite the size of the cohort, the subgroup analyses should be interpreted with caution. Finally, the retrospective nature of the study increases the possibility that unmeasured confounders might affect our results.

CONCLUSIONS

Prosthetic hip and knee joint infections are challenging to eradicate, with failure rates >20% even in the setting of complete prosthesis removal. Compatible with previous research, most patient risk factors associated with PJI treatment failure were not modifiable. There is an urgent need to improve treatment paradigms and interventions that will improve the treatment of these devastating infections.

Supplementary Data

Supplementary materials are available at *Open Forum Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

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