The Preoperative Prediction of Success Following Irrigation and Debridement With Polyethylene Exchange for Hip and Knee Prosthetic Joint Infections

Leonard T. Buller, BA, Fady Youssef Sabry, MD, Robert W. Easton, MD, Alison K. Klika, MS, and Wael K. Barsoum, MD

Abstract: Although the criterion standard for the treatment of prosthetic joint infections (PJIs) is 2-stage revision with interim placement of an antibiotic-loaded spacer, irrigation and debridement with polyethylene exchange offer advantages such as fewer surgeries, reduced potential for intraoperative complications, and lower direct costs. The purpose of this study was to develop a tool to preoperatively predict the probability of successful infection eradication following irrigation and debridement with polyethylene exchange for hip or knee PJIs. A total of 10 411 surgical cases were retrospectively reviewed, and data were collected from 309 charts. Overall, 149 (48.2%) cases failed to eradicate the infection following irrigation and debridement with polyethylene exchange. Univariate analysis identified multiple variables independently associated with reinfection including duration of symptoms, preoperative inflammatory markers, and infecting organism. Logistic regression was used to generate a model (bootstrap-corrected concordance index of 0.645) to predict successful eradication of the infection, which was the basis for a nomogram. Using commonly obtained preoperative variables, the nomogram can be used to predict the probability of infection-free survival at 1, 2, 3, 4, and 5 years. Preoperative knowledge of the probability that a treatment strategy will eradicate a patient's PJI may improve risk assessment. **Keywords:** total knee arthroplasty, total hip arthroplasty, predictive modeling, nomogram, revision, infection.

Prosthetic joint infections (PJIs) are the leading cause for revision total knee arthroplasty [1] and the third most common cause for revision total hip arthroplasty [2]. These devastating complications are associated with considerable morbidity [3,4] and economic burden [4]. With prevalences ranging from 0.4% to 4.0% in knee arthroplasties [5,6] and from 0.3% to 4.0% in hip arthroplasties [7-9], the total number of PJIs is projected to increase over the next 25 years because of the greater number of primary and revision procedures [10,11].

The ultimate goal of medical and surgical management of PJIs is the restoration of a pain-free, functional joint with eradication of the infection. Various treatment protocols are available to manage PJIs [12,13], ranging from conservative management with antibiotic suppression [14] to surgical options including irrigation and debridement with or without polyethylene exchange [15,16], single-stage revision arthroplasty [17,18], 2-stage revision with antibiotic-laden spacer placement, arthrodesis [19], and amputation [20]. Currently, the most effective and appropriate surgical approach for a given patient population is unknown [21]; and outcomes following revision total joint arthroplasty for infection are less favorable than those after revision for other causes of failure not involving infection [22], indicating the importance of identifying the appropriate treatment strategy to eradicate the infection on the first attempt.

Of the many PJI management options, the irrigation and debridement with polyethylene exchange [12] procedure involves arthrotomy, synovectomy, irrigation, and debridement of all infected soft tissues and implantation of a new polyethylene liner in the same procedure. Few studies have investigated patient outcomes following irrigation and debridement with polyethylene exchange; and comparison of these studies is difficult because of heterogeneous definitions

From the Department of Orthopaedic Surgery, Orthopaedic and Rheumatologic Institute, Cleveland Clinic, Cleveland, Ohio.
Supplementary material available at www.arthroplastyjournal.org.
Submitted July 15, 2011; accepted January 11, 2012.
The Conflict of Interest statement associated with this article can be found at doi:10.1016/j.arth.2012.01.003.
Reprint requests: Alison K. Klika, MS, Department of Orthopaedic Surgery-A41, Cleveland Clinic, 9500 Euclid Ave, Cleveland, OH 44195.

0883-5403/2706-0006$36.00/0
doi:10.1016/j.arth.2012.01.003

of infection, various postoperative antibiotic regimens, and a lack of agreement regarding treatment failure [23]. Importantly, the irrigation and debridement with polyethylene exchange procedure has potential advantages over 2-stage procedures. First, irrigation and debridement with polyethylene exchange procedures require fewer surgeries, which may reduce costs. In addition, 2-stage procedures can cause substantial joint pain and reduced mobility for patients during the interim period [24]. Moreover, patients are at increased risk of complications during 2-stage procedures in terms of degradation of bone stock, soft tissue deformation, and perioperative fracture secondary to the removal of well-fixed prostheses and implantation of the antibiotic spacer [25-27]. Current guidelines for selecting the appropriate procedure to eradicate a hip or knee PJI are primarily based upon the duration of symptoms; the condition of the implant and soft tissue evaluated during surgery; and, if known, the infecting microorganism [28]. A more robust tool to identify the risk of failure for irrigation and debridement with polyethylene exchange patients may improve preoperative risk assessment and help surgeons appropriately select a procedure that will eradicate the infection without requiring subsequent procedures.

The goals of this study were to (1) establish independent predictors of failure following irrigation and debridement with polyethylene exchange; (2) generate Kaplan-Meier survival analyses for irrigation and debridement with polyethylene exchange categorized by infecting organism and duration of symptoms; and (3) develop a nomogram to predict a patient's probability of *success*, defined as an absence of symptoms or signs of infection requiring removal of the prosthesis, regardless of surgeries on the affected joint for indications other than infection, following treatment with irrigation and debridement with polyethylene exchange for a hip or knee PJI.

Materials and Methods

Following institutional review board approval, data were collected as a retrospective series of all cases of hip or knee PJIs managed with irrigation and debridement with polyethylene exchange that took place between January 1, 1996, and October 19, 2010, at a single academic medical center. To obtain the cohort, a combination of 97 Current Procedural Terminology–4 and 67 International Classification of Diseases–9 codes was used to create an exhaustive list of all revision hip and knee arthroplasties performed between January 1, 1996, and October 19, 2010 (Fig. 1; available online at www.arthroplastyjournal.org). *Cases* were defined as those having a clinical syndrome of arthroplasty infection leading to irrigation and debridement with polyethylene exchange.

Although there is no universally accepted definition of a PJI [21], the following, as previously described [15,29-31], was used for inclusion in our study: either (1) acute inflammation detected on histopathological examination of periprosthetic tissue or (2) sinus tract communicating with the prosthesis or (3) gross purulence in the joint space and/or (4) isolation of the same microorganism from 2 or more cultures of joint aspirates or intraoperative periprosthetic-tissue specimens or (5) isolation of the organism in substantial amounts (ie, ≥20 colony-forming units per 10 mL from the implant in a total volume of 400 mL of sonicate fluid), or (6) in knees, a synovial fluid leukocyte count of more than 1700/mm^3 after correction or a finding of more than 65% neutrophils [32] and, in hips, a synovial fluid leukocyte count of more than 4300/mm^3 after correction or a finding of more than 80% neutrophils [33,34]. Cases were excluded for the following reasons: (1) revisions for indications other than infection or without a confirmed infection, (2) arthroscopic procedures, and (3) other hip or knee operative procedures for infection.

A total of 309 patients were identified (247 knees and 62 hips) who had undergone irrigation and debridement with polyethylene exchange to control their hip or knee PJI (Fig. 1; available online at www.arthroplastyjournal.org). Included within this population were patients who may have had a primary total hip or knee arthroplasty elsewhere and were referred for treatment of their infected total joint arthroplasty. Subjects were evaluated using time to event as the outcome, with *treatment failure* defined as the requirement for revision arthroplasty due to recurrent microbiologically proven infection at any time following the irrigation and debridement with polyethylene exchange. *Successful treatment* of the PJI was defined as an absence of symptoms or signs of infection, without requiring removal of the prosthesis for infection, regardless of surgeries on the affected joint for indications other than infection at last known follow-up.

Patient follow-up involved reviewing physician (orthopedic surgeon or infectious disease) notes in the electronic medical record from subsequent visits following the irrigation and debridement with polyethylene exchange. All patients who received irrigation and debridement with polyethylene exchange (failures and successes) were followed up for an average of 34.0 months (range, 8 days to 12.9 years). Successful cases were followed up for an average of 30.1 months (range, 22 days to 12.5 years). Failures were followed up for an average of 39.8 months (range, 8 days to 12.9 years).

The average age of the irrigation and debridement with polyethylene exchange cohort at the time of their index total joint arthroplasty was 61 years (range, 12-91 years), and the average age at the time of their irrigation and debridement with polyethylene exchange was 65 years (range, 12-94 years). The average time from the index surgery (primary hip or knee arthroplasty) to the irrigation and debridement with polyethylene exchange was 52 months (range, 7 days to 29.5 years). There were

157 male patients (50.8%) in the cohort, and all patients presented with clinical symptoms associated with infection. The duration of symptoms before irrigation and debridement with polyethylene exchange averaged 10.4 days (range, 1-360 days).

Postoperatively, all cases were managed by infectious disease physicians and orthopedic surgeons as part of a multidisciplinary team. Following the irrigation and debridement with polyethylene exchange, the median (interquartile range) duration of postoperative antibiotic coverage was 42 days (42-70 days), with monitoring of each patient by infectious disease during this period. It should be noted that patients were typically initiated on broad-spectrum antibiotics until culture results returned and were subsequently switched to an organism-specific antibiotic. Furthermore, no standard treatment algorithm for the infected joint was used because of the retrospective nature of this study; and treatment decisions, both surgical and regarding the antibiotic regimen, were dependent upon the surgical and infectious disease team managing the patient.

Data Collection

Data were extracted from electronic and paper medical records. All patient charts were reviewed to determine demographics (gender, age, body mass index [BMI]), type of joint (knee or hip), duration of symptoms, previous infections, previous joint infections, infecting organism(s) culture and sensitivity, duration of postoperative antimicrobial therapy, antimicrobial therapies used postoperatively, synovial fluid white blood cell count (WBC), synovial fluid red blood cell count, synovial fluid percentage neutrophils, American Society of Anesthesiologists (ASA) score, C-reactive protein, erythrocyte sedimentation rate, WBC, hemoglobin, hematocrit, blood urea nitrogen, creatinine, comorbidities (diabetes, inflammatory arthropathy, malignancy, steroid use, anemia, heart disease), additional operative procedures, final outcome, as well as reinfecting organism(s) culture and sensitivity where applicable.

Microbiologic Diversity

Table 1 (available online at www.arthroplastyjournal.org) depicts the identity and number of microorganisms responsible for infection in the cohort. Because of their significant diversity, organisms were ultimately grouped into 1 of 4 groups to provide the most clinical utility for the nomogram. These groups were (1) methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant *Enterococcus*, and methicillin-resistant *S. epidermidis*; (2) methicillin-sensitive coagulase-negative *Staphylococcus* species or methicillin-sensitive *S. aureus*; (3) other gram-positive organisms or fungus; and/or (4) gram-negative organism. In the case of mixed cultures, each infecting organism was recorded in its respective group. In the case of a culture-negative joint infection, nothing was recorded for any of the groups. It should be noted that all of the culture-negative PJIs were included in this study based upon criterion 6 (see above methods) describing the joint synovial fluid leukocyte count, with the majority also showing evidence of acute inflammation on histopathologic examination and gross purulence in the joint space.

Statistical Analysis

A univariate analysis with medians and interquartile ranges for continuous variables and proportions for categorical variables was performed to determine which factors favored successful infection eradication following irrigation and debridement with polyethylene exchange. Medians of continuous variables were compared using Wilcoxon rank sum test and χ^2 for parametric categorical data or Fisher exact test for nonparametric categorical data. We considered a *P* value of less than .05 statistically significant. We performed an unadjusted analysis to assess the differences in clinical, demographic, microbiological, perioperative, and medical comorbidity variables between patients who failed treatment and those who had a successful outcome (SAS 9.2, Cary, NC).

The overall success of irrigation and debridement with polyethylene exchange was analyzed via Kaplan-Meier survival analysis (SAS 9.2). Kaplan-Meier analysis was also performed on cases that received an irrigation and debridement with polyethylene exchange and categorized by infection group as well as duration of symptoms. Comparison between groups was done using the Wilcoxon significance test to report χ^2 and *P* values.

Cox regression was used to construct a prediction model for the probability of successful infection eradication following the procedure. Missing data were handled using multiple imputation before fitting a model. Restricted cubic splines were used to relax the linearity assumption for continuous variables. Using the predictive model, a nomogram was generated to calculate the probability of successful infection eradication at a specific time for future patients (R software, Vienna, Austria). The model was internally validated by bootstrapping, which is advantageous because it allows for the entire data set to be used for model development and it has been shown to provide relatively unbiased estimates of predictive accuracy with low variance, while also requiring fewer model fits than other internal validation techniques [35]. One thousand bootstrap samples were generated, and a bias-corrected C statistic (area under the curve) was used to evaluate the model fitting. We did not perform a stepwise procedure (ie, variable selection) because of the findings of Harrell et al [35], which state that the elimination of even nonsignificant variables may damage predictive accuracy. To accurately assign a higher risk to a patient that failed treatment, for each discordant pair of patients, we quantified discrimination using a bias-corrected concordance index for the internal validation.

Results

A total of 309 cases (247 knees and 62 hips) of irrigation and debridement with polyethylene exchange were confirmed to be eligible and included in the study. One hundred forty-nine (48.2%) cases failed to eradicate the infection (122 knees and 27 hips), with failure occurring at an average of 240 days (range, 2-1545 days) following the irrigation and debridement with polyethylene exchange procedure. The duration of postoperative antibiotics was not statistically significantly different between successes and failures, with a median of 42 days of postoperative antibiotics for both.

Results of the univariate analysis indicate that several variables were significantly different between successes and failures (Table 2; available online at www.arthroplastyjournal.org). Notably, patients with a recurrent infection had a longer duration of symptoms, a higher erythrocyte sedimentation rate at presentation, a previous joint infection or previous infection in the same joint, and an infection by a group 1 or group 2 organism. There were no significant differences detected between successes and failures with regard to BMI, age, ASA score, diabetes, inflammatory arthropathy, malignancy, or heart disease.

Table 3 shows the cumulative survival rates for all cases of irrigation and debridement with polyethylene exchange. Cumulative survival rates for patients with a group 1, group 2, group 3, or group 4 organism or a culture-negative infection are depicted in Fig. 2. The difference in infection-free survival following a group 1 organism infection is significantly lower than the survival rate following infection with a group 3 organism ($P < .0001$), a group 4 organism ($P = .0409$), or a culture-negative infection ($P = .0007$), but not following infection with a group 2 organism ($P = .0616$). In addition, the difference in infection-free survival following a group 2 organism infection is significantly lower than following infection with a group 3 organism ($P = .0041$) or a culture-negative infection ($P = .012$), but not following infection with a group 4 organism ($P = .3057$). Fig. 3 shows that the cumulative infection-free survival rates following irrigation and debridement with polyethylene exchange for patients with symptoms greater than or equal to 21 days are significantly less ($P < .0001$) than patients with less than 21 days of symptoms.

Table 3. Cumulative Survival Rates for All Cases of Irrigation and Debridement With Polyethylene Exchange

Time	Percentage Survival and 95% CI
6 mo	69.7 (64.5-75.0)
1 y	59.4 (53.6-65.1)
2 y	50.0 (43.7-56.2)
3 y	43.9 (37.1-50.7)
4 y	39.7 (32.5-47.0)
5 y	38.4 (31.0-45.9)

CI indicates confidence interval.

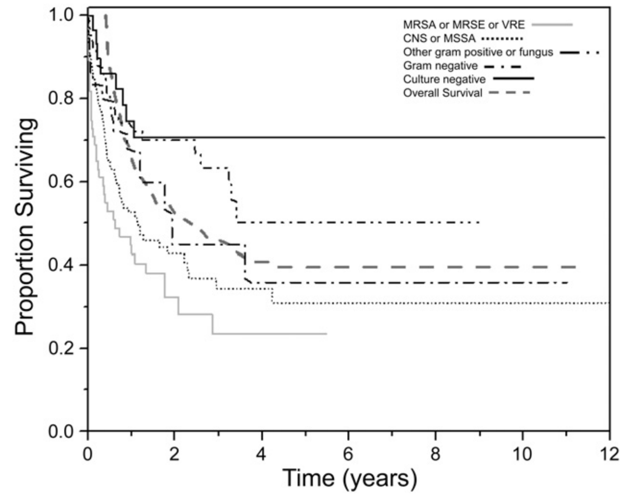

Fig. 2. Kaplan-Meier survival analysis for irrigation and debridement with polyethylene exchange for all infection types.

Fig. 4 depicts the nomogram generated from Cox regression analysis of the irrigation and debridement with polyethylene exchange data. The bootstrap-corrected concordance index of this model was 0.645.

Discussion

The results of this study identified variables independently associated with failure to eradicate a PJI following irrigation and debridement with polyethylene exchange. The results were also used to generate useful Kaplan-Meier curves for clinicians to reference when considering management options for a particular patient and develop a nomogram to predict a patient's probability of failure following surgery.

Results of the univariate analysis found that failure of the irrigation and debridement with polyethylene exchange to eradicate infection was associated with multiple variables. Similar to previous studies [15,36,37], failure to eradicate

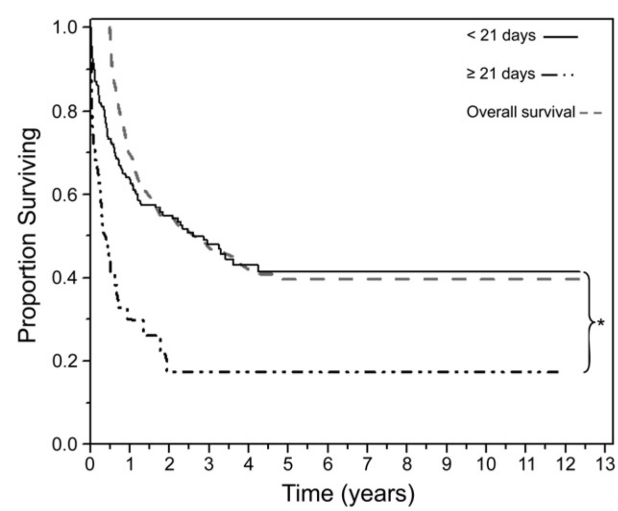

Fig. 3. Kaplan-Meier survival analysis for irrigation and debridement with polyethylene exchange for patients with symptoms for less than 21 days and at least 21 days. $P < .05$.

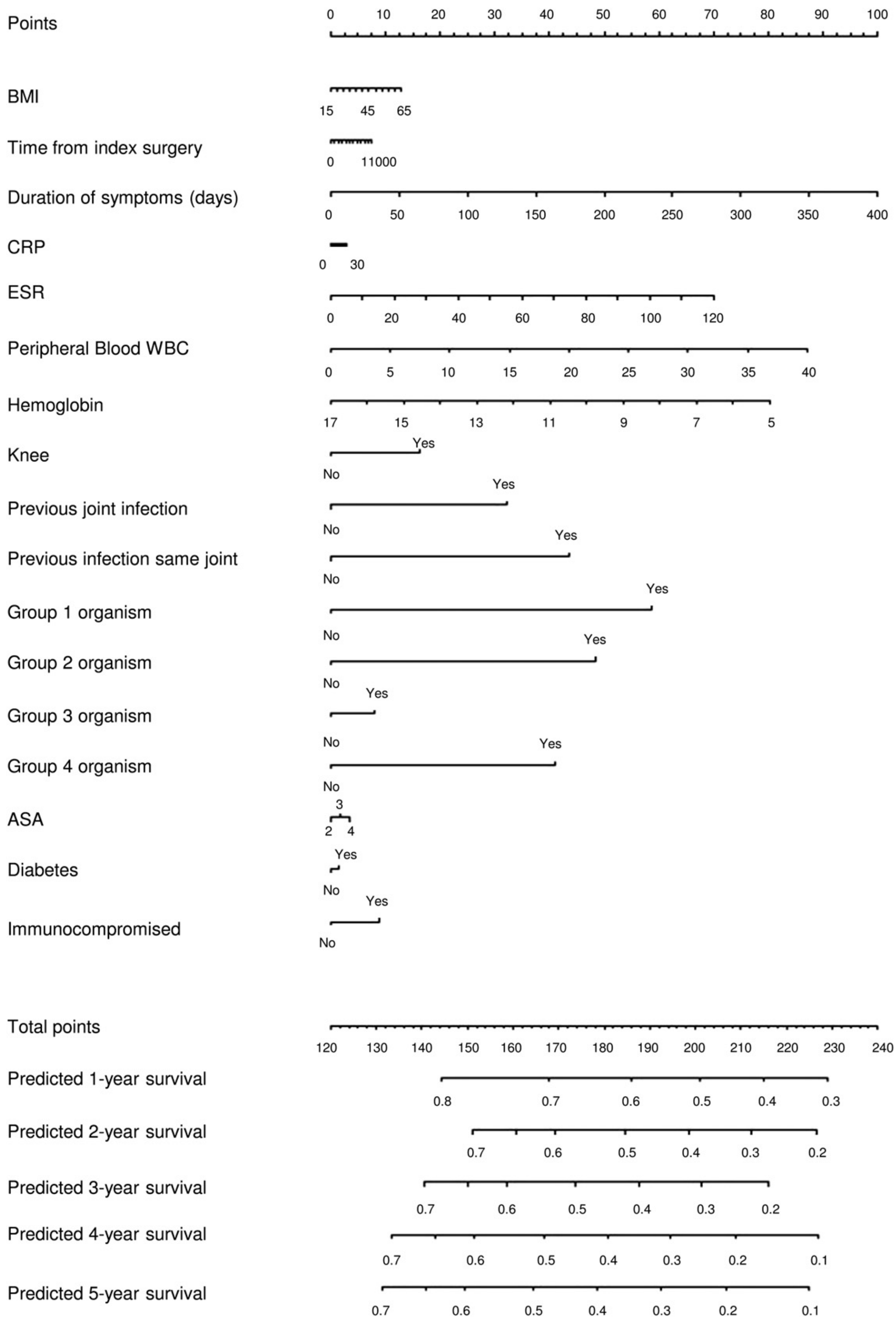

Fig. 4. Instructions for nomogram: Locate the patient's BMI on the BMI axis. Draw a line straight upward to the Points axis to determine how many points toward predicted survival the patient receives for his/her BMI. Repeat this process for the remaining axes, each time drawing straight upward to the Points axis. Sum the points achieved for each predictor, and find this location on the Total points axis. Draw a line straight down to find the patient's probability of success at 1, 2, 3, 4, and 5 years postoperation.

the infection was associated with a longer duration of symptoms before operation. The duration of symptoms of patients in this study was similar to the findings of Burger et al (4 days) [38] and Tattevin et al (5 days) [36]. Three weeks from the onset of symptoms is traditionally considered the point after which retention of prosthetic joint components is not suggested [28]. This study illustrates that the cumulative infection-free survival rates following irrigation and debridement with polyethylene exchange for patients with symptoms greater than or equal to 21 days is significantly less than patients with less than 21 days of symptoms. In addition, like the study by Tattevin et al [36], the results of this study found no correlation between the time from index surgery and outcome. It is possible that the discrepancy between our study and other studies that have found a correlation between the times from index surgery is the fact that those studies [39,40] dichotomize the time from index surgery to detect a difference. This study did not detect a statistically significant difference between successes and failures with regard to BMI, age, ASA score, presence of diabetes, inflammatory arthropathy, malignancy, or heart disease. Previous studies have found the development of a PJI to be associated with these variables [25,41,42]. However, it is possible that this study was underpowered to detect a difference, as only 38 patients (12.3%) in the entire cohort had an inflammatory arthropathy, or that the patient population was particularly unhealthy, given the fact that around 70% had evidence of heart disease in their medical record. Alternatively, these variables may only be associated with development of a PJI; and once a PJI has developed, it is possible that these variables do not effect whether eradication of the infection is possible.

The results of this study corroborate that PJIs with certain microorganisms have a poorer prognosis. This study found that the overall failure rate of patients treated with the procedure was 65.6% when infected with a group 1 organism and 54.8% when infected with a group 2 organism. In contrast, the overall failure rates were 38.9%, 35.9%, and 26.7% for patients infected with group 3 organisms, group 4 organisms, or a culture-negative infection, respectively. Similar to our findings, Brandt et al [43] evaluated 30 patients with 33 *S. aureus* PJIs treated with debridement and retention and found 1- and 2-year cumulative probabilities for recurrent infection of 54% and 69%, respectively. Furthermore, Deirmengian et al [16] found that infection recurrence rates of 31 knee PJIs treated with debridement, component retention, and intravenous antibiotics were different between those infected with *S. aureus* (92%) and those infected with other gram-positive organisms (34%). This study also showed similar distributions of infecting organisms as other studies [24,30,44]. Although consideration of the principal pathogen and any antibiotic resistance is essential in the management of PJIs, many surgeons agree that delaying treatment until culture results return is unreasonable. Therefore, the use of our nomogram, which takes into consideration multiple variables, in addition to culture result, may aid in the decision making until the infecting organism is identified.

Overall, 48.2% of all the irrigation and debridement with polyethylene exchanges for hip or knee PJIs were successful in eradicating the infection, which is similar to previously published reports. For example, a study by Marculescu et al [15] evaluated 99 episodes of hip or knee PJI treated with debridement and retention of the prosthesis and found an overall success rate of 46% after 700 days of follow-up. Similarly, Gardner et al [18] reported a 42% success rate after treating 44 patients who had knee PJIs with open debridement and polyethylene liner exchange. Other studies have also found success rates of less than 50% for similar procedures, such as the study by Tattevin et al [36] who found that out of 34 patients with a hip or knee PJI treated with debridement alone, 38% were successful.

The bias-corrected C statistic (area under the curve) of our predictive model for predicting the success of irrigation and debridement with polyethylene exchange procedures was good (0.645). The model generated in this study states that a patient's best predicted probability of infection-free survival at 1 year is 80%. This tool should thus be used to aid the clinician and patient in deciding on the most appropriate treatment strategy by allowing consideration of a patient's entire preoperative condition, not just a single variable. One reason for the average C statistic may be that there are unknown variables affecting the outcome of the procedure that we did not consider. It is also possible that our consideration of the comorbidities was overly general. For instance, instead of dichotomizing patients into diabetics and nondiabetics, perhaps we should have observed preoperative blood glucose levels. Data collection is ongoing to externally validate the nomogram. In the future, the nomogram generated from this study should be prospectively compared with current treatment guidelines on candidates for irrigation and debridement with polyethylene exchange to determine if use of the nomogram improves PJI management.

Limitations of this study include the potential for information bias and variability in data collection. However, the likelihood of obtaining data for the evaluated variables was equally as likely for successes or failures at the time of the procedure because the treating surgeon could not have known the ultimate outcome, only that the patients had a presumed PJI. An alternative approach would be a prospective cohort design. However, given the low frequency of PJIs, the benefits of a prospective approach would not outweigh the potential drawbacks of such a long-term study. The heterogeneous population in this study likely represents practice realities, giving the study greater equipoise. Because of the retrospective nature of this study, a potential selection bias exists, as clarification of the rationale for deciding on a particular surgical technique was impossible. The decision making was largely surgeon dependent, and inconsistencies in treatment strategy and the procedures themselves may have occurred. This may have introduced a proficiency bias, which occurs when treatments are not applied equally to subjects because of either skill or training differences and/or differences in resources or procedures used over time. However, by including multiple surgeons in this study, we were able to give the study greater equipoise and to increase the generalizability of the results beyond the experience of a single surgeon at a single center.

Although this study is the largest of its kind to investigate the irrigation and debridement with polyethylene exchange procedure for hip and knee PJI control, the Cox regression analysis used to generate our nomogram included some patients with a relatively short follow-up. Therefore, some patients with limited follow-up may ultimately present with a recurrent infection in the future. However, previous studies have included patients with a similar range of follow-up time [15]. Furthermore, the ideal follow-up, after which infection is highly unlikely, for patients with a history of PJI is unknown, as incidences of infection have been reported to be as high as 0.5% between 2 and 10 years following primary total knee arthroplasty [45]. Another limitation of this nomogram is the inclusion of a single fungal infection in the gram-positive organism group during Cox regression analysis. Inclusion of only one fungal infection may decrease the generalizability of the nomogram for fungal infections. Additional research should investigate outcomes of irrigation and debridement with polyethylene exchange for fungal PJIs. Moreover, inclusion of culture-negative PJIs may represent a nondifferential misclassification type of information bias in the fact that some of these joints may not have been infected by a culturable organism, potentially diluting the results obtained in this study. However, by basing our inclusion criteria upon the results of Trampuz et al [32], Parvizi et al [33], and Schinsky et al [34] and including patients with culture-negative PJIs, the resulting nomogram has increased generalizability by representing practice realities. Similarly, it should be noted that all 309 of the PJIs included in this study were defined as having an infection based upon criterion 4, 5, or 6. Acute inflammation is expected during the early postoperative period; and none of the irrigation and debridement with polyethylene exchange procedures reviewed for inclusion in this study were performed for PJIs based upon criterion 1, 2, or 3 alone. Finally, because the hospital from which the records were recovered is a tertiary referral center, many patients had extensive medical histories with multiple surgeries and "chronic" PJIs. These extensive histories may present an uncontrolled negative selection bias of a single-center study that might decrease the generalizability of our findings to other centers.

It is conventionally accepted that attempting an irrigation and debridement with polyethylene exchange presents little harm to patients. A logical next question from this research is what influence the irrigation and debridement with polyethylene exchange procedure has on the potential for eradication of the infection from the joints of patients that fail an irrigation and debridement with polyethylene exchange procedure. The reader should note that this was not the objective of the present study and that generalizations regarding the influence of a failed irrigation and debridement with polyethylene exchange procedure on subsequent attempts at eradication of the infection cannot be made here. However, Gardner et al [18] followed 25 failures of "open debridement and polyethylene exchange" and found that 19 of these were treated with a 2-stage revision as the next step following failure, 11 of which were ultimately successful after the 2-stage revision. They state that their success rate following the failed open debridement and polyethylene exchange was lower than the results for 2-stage reimplantation as the initial treatment, suggesting that the initial irrigation and debridement with polyethylene exchange procedure may have lowered the chance of a successful reimplantation. Furthermore, a recent study by Sherrell et al [46] found higher failure rates of 2-stage revision in patients treated with a previous irrigation and debridement. A future study should prospectively compare patients that failed irrigation and debridement with polyethylene exchange to a control group to determine if the single-stage procedure, alone, had an appreciable effect on the final outcome. In conclusion, this study identified variables independently associated with failure to eradicate infection following irrigation and debridement with polyethylene exchange, multiple Kaplan-Meier survival analyses, and an easy-to-use tool for predicting a patient's probability of successfully eradicating a hip or knee PJI with an irrigation and debridement with polyethylene exchange. Until research is conducted to determine the effect of a previous irrigation and debridement with polyethylene exchange procedure on the ability of subsequent procedures to eradicate the infection, clinicians should proceed with the procedure cautiously.

References

1. Bozic KJ. The epidemiology of revision total knee arthroplasty in the United States. Clin Orthop Relat Res 2010;468:1.
2. Bozic KJ. The epidemiology of revision total hip arthroplasty in the United States. J Bone Joint Surg Am 2009;91:1.

3. Darouiche RO. Treatment of infections associated with surgical implants. N Engl J Med 2004;350:14.
4. Bozic KJ. The impact of infection after total hip arthroplasty on hospital and surgeon resource utilization. J Bone Joint Surg Am 2005;87:8.
5. Blom AW. Infection after total knee arthroplasty. J Bone Joint Surg Br 2004;86:5.
6. Jamsen E. Risk factors for infection after knee arthroplasty. A register-based analysis of 43,149 cases. J Bone Joint Surg Am 2009;91:1.
7. Choong PF. Risk factors associated with acute hip prosthetic joint infections and outcome of treatment with a rifampin-based regimen. Acta Orthop 2007;78:6.
8. Phillips JE. The incidence of deep prosthetic infections in a specialist orthopaedic hospital: a 15-year prospective survey. J Bone Joint Surg Br 2006;88:7.
9. Blom AW. Infection after total hip arthroplasty. The Avon experience. J Bone Joint Surg Br 2003;85:7.
10. Kurtz S. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am 2007;89:4.
11. Kurtz SM. Infection burden for hip and knee arthroplasty in the United States. J Arthroplasty 2008;23:7.
12. Tsukayama DT. Diagnosis and management of infection after total knee arthroplasty. J Bone Joint Surg Am 2003; 85-A(Suppl 1).
13. Cuckler JM. The infected total knee: management options. J Arthroplasty 20:4 Suppl 2005;2.
14. Moran E. The diagnosis and management of prosthetic joint infections. J Antimicrob Chemother 2010;65(Suppl 3).
15. Marculescu CE. Outcome of prosthetic joint infections treated with debridement and retention of components. Clin Infect Dis 2006;42:4.
16. Deirmengian C. Limited success with open debridement and retention of components in the treatment of acute Staphylococcus aureus infections after total knee arthroplasty. J Arthroplasty 2003;18(7 Suppl 1).
17. Silva M. Results of direct exchange or debridement of the infected total knee arthroplasty. Clin Orthop Relat Res 2002;404.
18. Gardner J. Can this prosthesis be saved? Implant salvage attempts in infected primary TKA. Clin Orthop Relat Res 2011;469:4.
19. Ellingsen DE. Intramedullary arthrodesis of the knee after failed total knee arthroplasty. J Bone Joint Surg Am 1994;76:6.
20. Isiklar ZU. Amputation after failed total knee arthroplasty. Clin Orthop Relat Res 1994;299.
21. Del Pozo JL. Infection Associated with Prosthetic Joints. N Engl J Med 2009;361:8.
22. Barrack RL. Patient satisfaction and outcome after septic versus aseptic revision total knee arthroplasty. J Arthroplasty 2000;15:8.
23. Mont MA. Multiple irrigation, debridement, and retention of components in infected total knee arthroplasty. J Arthroplasty 1997;12:4.
24. Choi HR. Can implant retention be recommended for treatment of infected TKA? Clin Orthop Relat Res 2011;469:4.
25. Pulido L. Periprosthetic joint infection: the incidence, timing, and predisposing factors. Clin Orthop Relat Res 2008;466:7.
26. Garvin KL. Infected total knee arthroplasty: diagnosis and treatment. Instr Course Lect 2008;57.
27. Fisman DN. Clinical effectiveness and cost-effectiveness of 2 management strategies for infected total hip arthroplasty in the elderly. Clin Infect Dis 2001;32:3.
28. Zimmerli W. Prosthetic-joint infections. N Engl J Med 2004; 351:16.
29. Berbari EF. Risk factors for prosthetic joint infection: case-control study. Clin Infect Dis 1998;27:5.
30. Berbari EF. Culture-negative prosthetic joint infection. Clin Infect Dis 2007;45:9.
31. Betsch BY. Treatment of joint prosthesis infection in accordance with current recommendations improves outcome. Clin Infect Dis 2008;46:8.
32. Trampuz A. Synovial fluid leukocyte count and differential for the diagnosis of prosthetic knee infection. Am J Med 2004;117:8.
33. Parvizi J. Diagnosis of infected total knee: findings of a multicenter database. Clin Orthop Relat Res 2008;466:11.
34. Schinsky MF. Perioperative testing for joint infection in patients undergoing revision total hip arthroplasty. J Bone Joint Surg Am 2008;90:9.
35. Harrell Jr FE. Multivariable prognostic models: issues in developing models, evaluating assumptions and adequacy, and measuring and reducing errors. Stat Med 1996;15:4.
36. Tattevin P. Prosthetic joint infection: when can prosthesis salvage be considered? Clin Infect Dis 1999;29:2.
37. Chiu FY. Surgical debridement and parenteral antibiotics in infected revision total knee arthroplasty. Clin Orthop Relat Res 2007;461.
38. Burger RR. Implant salvage in infected total knee arthroplasty. Clin Orthop Relat Res 1991;273.
39. Teeny SM. Treatment of infected total knee arthroplasty. Irrigation and debridement versus two-stage reimplantation. J Arthroplasty 1990;5:1.
40. Hartman MB. Periprosthetic knee sepsis. The role of irrigation and debridement. Clin Orthop Relat Res 1991; 273.
41. Cataldo MA. Prosthetic joint infection: recent developments in diagnosis and management. J Infect 2010;61:6.
42. Moyad TF. Evaluation and management of the infected total hip and knee. Orthopedics 2008;31:6.
43. Brandt CM. Staphylococcus aureus prosthetic joint infection treated with debridement and prosthesis retention. Clin Infect Dis 1997;24:5.
44. Sia IG. Prosthetic joint infections. Infect Dis Clin North Am 2005;19:4.
45. Kurtz SM. Prosthetic joint infection risk after TKA in the Medicare population. Clin Orthop Relat Res 2010; 468:1.
46. Sherrell JC. The Chitranjan Ranawat Award: fate of two-stage reimplantation after failed irrigation and debridement for periprosthetic knee infection. Clin Orthop Relat Res 2011;469:1.

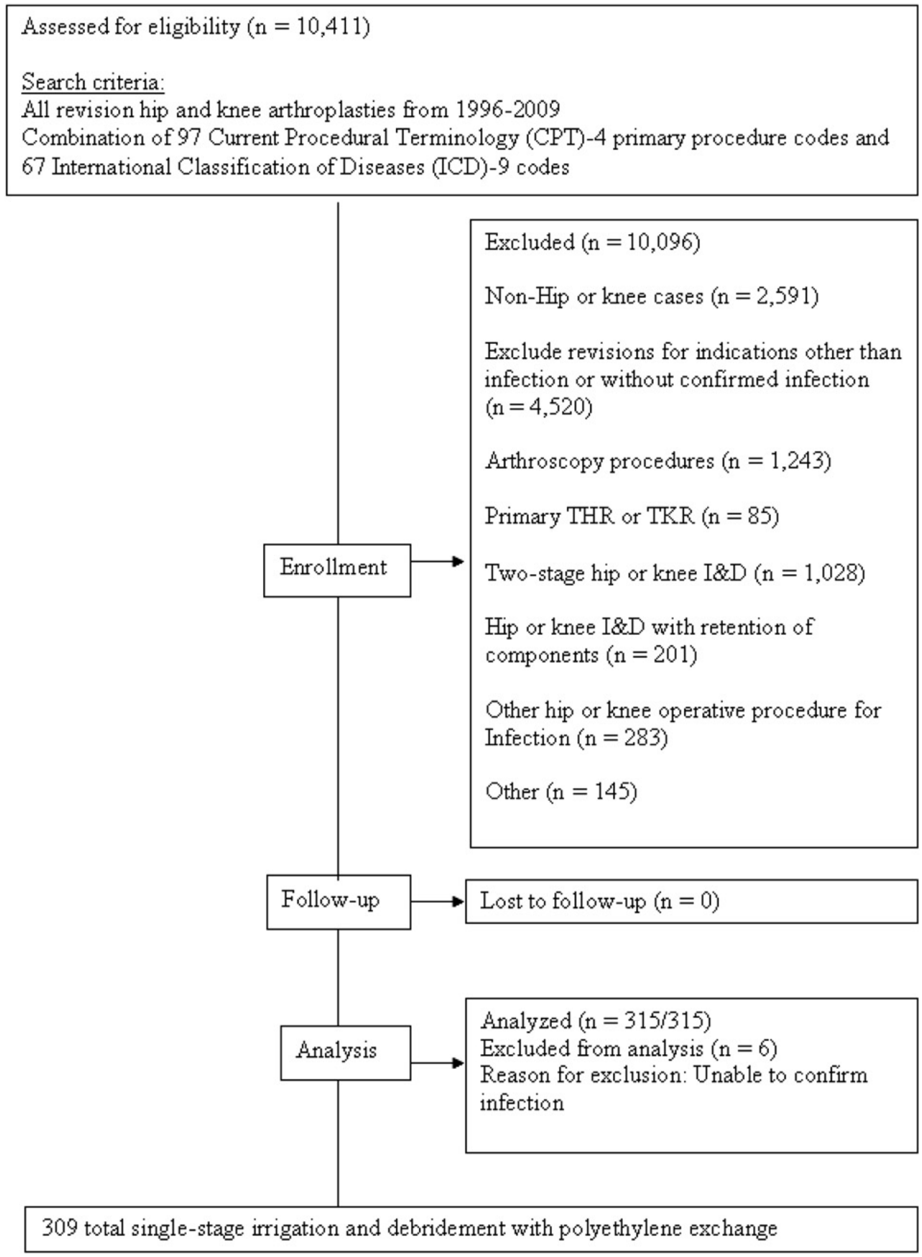

Fig. 1. E-flowchart for identifying all hip and knee PJIs treated with irrigation and debridement with polyethylene exchange between 1996 and 2010.

Table 1. Number and Percentage of Total of Infecting Organisms

Organism (n =342)	Number (Percentage)	Group
Staphylococcus species		
Methicillin-resistant *Staphylococcus aureus*	46 (13.5)	1
Methicillin-resistant *Staphylococcus epidermidis*	7 (2.0)	1
Methicillin-sensitive *Staphylococcus aureus*	67 (19.6)	2
Methicillin-sensitive coagulase-negative *Staphylococcus*	68 (19.9)	2
Streptococcus species		
α-Hemolytic *Streptococcus*	13 (3.8)	
Streptococcus pneumoniae	1 (0.3)	3
Streptococcus viridans	12 (3.5)	3
β-Hemolytic *Streptococcus*	21 (6.1)	
Group B *Streptococcus*	7 (2.0)	3
Group C *Streptococcus*	2 (0.6)	3
Group G *Streptococcus*	4 (1.2)	3
γ-Hemolytic *Streptococcus*	14 (4.1)	
Group D *Streptococcus*	2 (0.6)	3
Vancomycin-sensitive *Enterococcus* species	10 (2.9)	3
Vancomycin-resistant *Enterococcus* species	2 (0.6)	1
Streptococcus milleri	2 (0.6)	3
Peptostreptococcus magnus	6 (1.8)	3
Peptostreptococcus micros	2 (0.6)	3
Gram-positive rods		
Corynebacterium striatum	1 (0.3)	3
Enterobacter aerogenes	2 (0.6)	3
Enterobacter cloacae	12 (3.5)	3
Propionibacterium acnes	10 (2.9)	3
Gram negative		
Escherichia coli	11 (3.2)	4
Haemophilus species	1 (0.3)	4
Citrobacter koseri	1 (0.3)	4
Klebsiella species	2 (0.6)	4
Klebsiella pneumoniae	2 (0.6)	4
Proteus mirabilis	7 (2.0)	4
Pseudomonas aeruginosa	11 (3.2)	4
Salmonella dublin	1 (0.3)	4
S.almonella enteritidis	2 (0.6)	4
Serratia marcescens	1 (0.3)	4
Bacteroides fragilis	1 (0.3)	4
Yeasts		
Candida parapsilosis	1 (0.3)	3
Culture negative	30 (8.8)	

Table 2. Results of the Univariate Analysis Comparing the Influence of Continuous and Categorical Variables on the Final Outcome (Recurrent Infection vs No Recurrent Infection)

		Recurrent Infection		No Recurrent infection		
Continuous Variable		Number	Median (25th, 75th)	Number	Median (25th, 75th)	*P* value
Age		149	66.6 (57.2, 74.5)	160	64.7 (56.2, 75.1)	.83
BMI		148	31.3 (26.6, 37.2)	159	31.9 (25.7, 37.3)	.81
Time from index surgery		146	585.5 (42.0, 2529.0)	154	641.5 (49.0, 2211.0)	.76
Duration of symptoms		142	7.0 (4.0, 14.0)	155	5.0 (2.0, 10.0)	.001
Synovial fluid WBC		91	35175.0 (10500.0, 97020.0)	112	39387.5 (16807.5, 87412.5)	.76
Synovial fluid RBC		89	28200.0 (7890.0, 105840.0)	109	21105.0 (4830.0, 146160.0)	.44
Synovial fluid neutrophils %		89	91.0 (87.0, 96.0)	107	92.0 (84.0, 96.0)	.46
ESR		122	81.5 (53.0, 112.0)	140	70.5 (37.0, 98.0)	.02
WBC		149	9.7 (7.2, 13.6)	160	9.0 (7.2, 11.9)	.1
Hemoglobin		149	10.2 (9.3, 11.4)	160	10.5 (9.5, 12.1)	.09
Hematocrit		149	32.0 (29.3, 35.3)	160	32.6 (29.2, 37.3)	.11
BUN		148	15.0 (11.0, 22.5)	159	16.0 (11.0, 24.0)	.35
Creatinine		149	0.9 (0.7, 1.2)	159	0.9 (0.7, 1.2)	.27
Categorical Variable	Category	Number	(%)	Number	(%)	*P* value
Gender						.77
	Female	72	48.3	80	50	
	Male	77	51.7	80	50	
Type of joint						.54
	Left knee	60	40.3	71	44.4	
	Right knee	62	41.6	54	33.8	
	Left hip	14	9.4	17	10.6	
	Right hip	13	8.7	18	11.3	
Knee or hip						.41
	Hip	57	18.1	35	21.9	
	Knee	122	81.9	125	78.1	
Previous joint infection						.044
	No	84	56.4	108	67.5	
	Yes	65	43.6	52	32.5	
Previous infection in same joint						.009
	No	91	61.1	120	75	
	Yes	58	38.9	40	25	
ASA score						.62
	2	24	17.3	32	21.3	
	3	90	64.8	95	63.3	
	4	25	18	23	15.3	
Diabetes						.66
	No	98	65.8	109	68.1	
	Yes	51	34.2	51	31.9	
Inflammatory arthropathy						.56
	No	129	86.6	142	88.8	
	Yes	20	13.4	18	11.3	
Malignancy						.31
	No	130	87.3	133	83.1	
	Yes	19	12.8	27	16.9	
Steroids						.47
	No	130	87.3	135	84.4	
	Yes	19	12.8	25	15.6	
Anemia						.097
	No	47	31.5	65	40.6	
	Yes	102	68.5	95	59.4	
Heart disease						.73
	No	43	28.9	49	30.6	
	Yes	106	71.1	111	69.4	
Group 1 organism						.005
	No	113	75.8	141	88.1	
	Yes	36	24.2	19	11.9	
Group 2 organism						.024
	No	78	52.4	104	65	
	Yes	71	47.7	56	35	

Table 2. (*continued*)

Categorical Variable	Category	Number	(%)	Number	(%)	*P* value
Group 3 organism						.026
	No	123	82.6	115	71.9	
	Yes	26	17.5	45	28.1	
Group 4 organism						.99
	No	123	82.6	132	82.5	
	Yes	26	17.5	28	17.5	

RBC indicates red blood cell count; ESR, erythrocyte sedimentation rate; BUN, blood urea nitrogen.