The Otto Aufranc Award

Modifiable versus Nonmodifiable Risk Factors for Infection After Hip Arthroplasty

Guy Maoz MD, Michael Phillips MD, Joseph Bosco MD,
James Slover MD, MS, Anna Stachel MPH, Ifeoma Inneh MPH,
Richard Iorio MD

Published online: 15 July 2014

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Abstract

Background Periprosthetic joint infections (PJIs) are associated with increased morbidity and cost. It would be important to identify any modifiable patient- and surgical-related factors that could be modified before surgery to decrease the risk of PJI.

Questions/purposes We sought to identify and quantify the magnitude of modifiable risk factors for deep PJIs after primary hip arthroplasty.

Methods A series of 3672 primary and 406 revision hip arthroplasties performed at a single specialty hospital over a 3-year period were reviewed. All deep PJIs were

identified using the Centers for Disease Control and Prevention case definitions (ie, occurs within 30–90 days postoperatively, involves deep soft tissues of the incision, purulent drainage, dehiscence and fever, localized pain or tenderness). Univariate and multivariate analyses determined the association between patient and surgical risk factors and PJIs. For the elective patients, the procedure was performed on the day of admission (“same-day procedure”), whereas for the fracture and nonelective patients, the procedure was performed 1 or more days postadmission (“nonsame-day procedure”). *Staphylococcus aureus* colonization, tobacco use, and body mass index (BMI) were defined as patient-related modifiable risk factors.

Results Forty-seven (1.3%) deep PJIs were identified. Infection developed in 20 of 363 hips of nonsame-day procedures and 27 of 3309 same-day procedures ($p = 0.006$). There were eight (2%) infections in the revision group. After controlling for confounding variables, our multivariate analysis showed that $\text{BMI} \geq 40 \text{ kg/m}^2$ (odds ratio [OR], 4.13; 95% confidence interval [CI], 1.3–12.88; $p = 0.01$), operating time > 115 minutes (OR, 3.38; 95% CI, 1.23–9.28; $p = 0.018$), nonsame-day surgery (OR, 4.16; 95% CI, 1.44–12.02; $p = 0.008$), and revision surgery (OR, 4.23; 95% CI, 1.67–10.72; $p < 0.001$) are significant risk factors for PJIs. Tobacco use and *S aureus* colonization were additive risk factors when combined with other significant risk factors (OR, 12.76; 95% CI, 2.47–66.16; $p = 0.017$).

Conclusions Nonsame-day hip and revision arthroplasties have higher infection rates than same-day primary surgeries. These characteristics are not modifiable and should be categorized as a separate cohort for complication-reporting purposes. Potentially modifiable risk factors in our patient population include operating time, elevated BMI, tobacco use, and *S aureus* colonization. Modifying risk factors may

One or more of the authors certifies that he (JB, RI), or a member of his or her immediate family, has or may receive payments or benefits, during the study period, an amount of USD 10,000 to USD 100,000 from 3M (Minneapolis, MN, USA) and USD 10,000 to USD 100,000 from IMDS (Orlando, FL, USA) and Kyocera (Kyoto, Japan).

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G. Maoz, J. Bosco, J. Slover, I. Inneh, R. Iorio (✉)
Department of Orthopaedic Surgery, NYU Langone Medical
Center, Hospital for Joint Diseases, 301 East 17th Street,
New York, NY 10003, USA
e-mail: Richard.iorio@nyumc.org

M. Phillips, A. Stachel
Department of Medicine: Epidemiology and Infection Control,
NYU Langone Medical Center, New York, NY, USA

decrease the incidence of PJIs. When reporting deep PJI rates, stratification into preventable versus nonpreventable infections may provide a better assessment of performance on an institutional and individual surgeon level.

Level of Evidence Level IV, prognostic study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

Periprosthetic joint infection (PJI) rates after elective arthroplasties have been reported in large series to be up to 1.7% for primary THA and up to 2.0% for primary TKA [7, 18, 19]. PJIs are associated with increased morbidity and cost. The cost of treating PJIs after joint arthroplasty in the United States is estimated to be in the range of USD 0.78 billion to USD 3.18 billion annually [13]. As the volume of primary joint arthroplasties and revisions increases, the total cost of treating PJIs and the morbidity that follows will also increase.

Over the last 50 years, numerous strategies have been used to reduce the risk of PJIs, including preoperative bacterial decolonization, incision site antisepsis, more intensive antimicrobial prophylaxis regimens, laminar airflow operating room environment, ultraviolet light in the operating room, antibiotic cement, antibiotic-impregnated closure material, intraoperative local antibiotic application, and contained surgeon exhaust suits, strategies that focus on optimizing the hospital environment and surgical technique [4, 6, 8, 9, 12, 23]. In addition to these measures, there are patient-related and procedure-related factors that have been reported to increase the risk for PJI: diabetes mellitus, rheumatoid arthritis, psoriasis, immune-compromised state, malignancy, corticosteroid use, obesity, tobacco use, emergent or semiemergent surgery, *Staphylococcus aureus* colonization, revision surgery, and operating time [1, 25]. Among these patient-related risk factors, we postulated that there are modifiable factors that should be identified and optimized before surgery to decrease the incidence of PJIs.

The primary purpose of this study was to identify risk factors for PJI and quantify the magnitude of the increased risk they confer in our surgical population of patients undergoing hip arthroplasty. The secondary purpose was to categorize these risk factors as either modifiable or nonmodifiable.

Materials and Methods

We abstracted and analyzed data from a series of 3672 primary and 406 revision hip arthroplasties performed at our single-specialty institution over a 3-year time period

(January 1, 2009, to December 31, 2011). There were 1987 women with a mean age of 63.0 ($\pm$ 13.3) years and 1685 men with a mean age of 60.0 ($\pm$ 12.6) years. Cases consisted of 3309 patients admitted for elective THA and 363 patients admitted urgently for the treatment of displaced femoral neck fractures or other nonelective hip arthroplasty (13 patients had elective THA on a nonsame-day admission). One hundred forty-seven hemiarthroplasties were included in the 363 patients with hip fracture and 216 had THA. For the elective patients, the procedure was performed on the day of admission ("same-day procedure"), whereas for the fracture and nonelective patients, the procedure was performed 1 or more days postadmission ("nonsame-day procedure"). The minimum followup was 1 year (mean, 2 years; range, 1–4 years). We used the New York State Hospital Infection Control database to ensure identification of all PJIs.

Patients were screened for *S aureus* colonization before surgery by nasal culture. Patients were provided instructions for use of topical chlorhexidine the evening before and on the day of surgery, and all patients underwent *S aureus* nasal decolonization regardless of culture result. Patients colonized with methicillin-resistant *S aureus* were given vancomycin for perioperative antimicrobial prophylaxis. Infection prophylaxis during the study timeframe included administration of intravenous antibiotic(s) within 1 hour of the arthroplasty and 24 hours postoperatively. All surgeries were performed with surgeons wearing contained exhaust suits. Anesthesia administered ranged from neuraxial anesthesia to general anesthesia according to clinical, anesthesia, and patient preference. The preferred method of anesthesia at our institution was epidural with spinal anesthesia as a distant second choice during this study period of 2009 to 2011. General anesthesia was rarely used.

Surgeries for THA or hemiarthroplasty were performed using an anterior, posterior, or direct lateral approach. Because this was not a single-surgeon series, implant type and vendor as well as the use of cemented versus noncemented components varied. Deep venous thromboembolism prophylaxis included various regimens that adhered to the American Association of Orthopedic Surgeons and American College of Chest Physicians guidelines, including mainly subcutaneous administration of 30 mg low-molecular-weight heparin twice daily starting on postoperative day 1, warfarin on postoperative day 1, and rivaroxaban or heparin in certain patients with nephropathy or other comorbidities.

Postoperative wound management consisted of application of a sterile dressing for a period of 1 to 3 days postoperatively with serial dressing change if needed for postoperative days 4 to 14. Patients with potential infections were identified through readmissions and review of microbiology results by our institution's infection control

department as part of routine infection surveillance. PJIs were defined as those patients meeting the Centers for Disease Control and Prevention's (CDC) National Healthcare Safety Network case definitions for deep PJI (ie, occurs within 30–90 days postoperatively, involves deep soft tissues of the incision, purulent drainage, dehiscence and fever, localized pain or tenderness) in the 1-year period after surgery and followed by the New York State Infection Control Program [3].

Patients' preoperative state including the American Society of Anesthesiologists (ASA) scores, body mass index (BMI), diabetes status, *S aureus* colonization, and history of tobacco use were recorded. When analyzing diabetes status, a positive history of diabetes mellitus or any end organ damage such as retinopathy, nephropathy, or neuropathy was noted. The search was done using the International Classification of Diseases, 9th Revision codes for these specific pathologies. Additional factors studied were age, sex, procedure type (hemiarthroplasty or THA), surgery type (primary or revision surgery), operating time (number of minutes from incision through closure), use of blood products, time of surgical procedure (same-day or nonsame-day), and surgical caseload (annual surgeon volume). Modifiable risk factors were defined as those conditions that could be treated or corrected before elective surgery (*S aureus* colonization, tobacco use, and BMI), whereas nonmodifiable factors are those that cannot be changed as a result of the emergent nature of the surgery or patient characteristics that cannot be altered before surgery.

Patients' records were retrieved from a secure electronic medical record (Integrated Clinical Information System, El Camino, CA, USA) database. Institutional review board approval was granted for retrospective review of patients' records.

Statistical Analysis

Univariate and multivariate regression analyses were conducted to determine significant patient-related and surgical predictors for the risk of postoperative deep PJIs. Variables included in the model were dichotomized and analyzed as follows: age was dichotomized as < 65 versus ≥ 65 years. Sex was dichotomized as males versus females. BMI was analyzed in two ways: < 30 versus ≥ 30 kg/m² and < 40 versus ≥ 40 kg/m². ASA score was categorized into ≤ 2 versus > 2. Diabetes complication status was dichotomized as complications present versus no complications present. History of tobacco use was dichotomized as active (tobacco use within 1 month of date of surgery) versus inactive. Procedure type was dichotomized as THA versus hemiarthroplasty, whereas surgery type was dichotomized as primary versus revision surgery. Time of surgical

procedure was dichotomized as same-day versus nonsame-day. Positive nasal screening for *S aureus* was dichotomized as yes versus no. Operating time was dichotomized as ≤ 115 minutes versus > 115 minutes. The cutoff point was based on median operating time (115 minutes [interquartile range, 91–149]). Caseload was dichotomized as < 103 versus ≥ 103 . The cutoff point was ascertained after visualization of individual surgeon infection rates. The caseload was dichotomized by the median annual individual surgeon volume of 103 THA per year. Infection rate was not included in determining high- versus low-volume surgeons.

To increase the power of the results, risk factors were combined to determine their synergistic effects in the prediction of deep PJIs. Results are reported as odds ratio (OR) and 95% confidence interval (CI). All analyses were performed using SAS Version 9.3 (SAS Institute, Cary, NC, USA) and were performed by a trained statistician (AS). Statistical significance was set at 0.05.

Results

We evaluated PJI incidence 1 year postoperatively. Forty-seven deep PJIs of varying organism species (Table 1) were identified after 3672 primary hip arthroplasties (1.3 deep PJIs per 100 procedures). Infection developed in 20 of 363 (5.5%) nonsame-day procedures and 27 of 3309 (0.8%) same-day primary hip arthroplasties. Deep PJI developed in eight (2%) of 406 revision hip arthroplasties. After controlling for the following risk factors associated with deep PJI: ASA score > 2 (OR, 4.76; 95% CI, 2.48–9.10; $p < 0.001$), BMI ≥ 40 kg/m² (OR, 3.86; 95% CI, 1.67–8.86; $p < 0.001$), operating time > 115 minutes (OR, 2.45; 95% CI, 1.33–4.49; $p = 0.002$), nonsame-day surgery (OR, 7.09; 95% CI, 3.93–12.7; $p < 0.001$), *S aureus* colonization (OR, 2.36; 95% CI, 1.13–4.88; $p = 0.02$), caseload < 103 (OR, 1.97; 95% CI, 1.09–3.56; $p = 0.02$), revision surgery (OR, 5.28; 95% CI, 2.95–9.43; $p < 0.001$), diabetes complications (OR, 6.80; 95% CI, 2.01–22.9; $p < 0.001$), and hemiarthroplasty (OR, 4.64; 95% CI, 1.72–12.4; $p = 0.008$) (Table 2), our multivariate analysis revealed that BMI ≥ 40 kg/m² (OR, 4.1; 95% CI, 1.3–12.7; $p = 0.014$), revision surgery (OR, 6.0; 95% CI, 2.5–14.0; $p < 0.001$), operating time > 115 minutes (OR, 3.3; 95% CI, 1.20–9.0; $p = 0.019$), and nonsame-day surgery (OR, 4.16; 95% CI, 1.44–12.02; $p = 0.008$) were predictors of deep PJIs (Table 2).

S aureus colonization and tobacco use were additive risk factors when combined with the significant risk factors from the multivariate analysis. BMI ≥ 40 kg/m² and active tobacco use (OR, 7.5; 95% CI, 1.69–33.4; $p = 0.03$), revision surgery and active tobacco use (OR, 7.2; 95% CI,

Table 1. Organisms found in patients with deep periprosthetic joint infections

Organism	Frequency
<i>Acinetobacter</i> spp.	2
Coagulase-negative <i>Staphylococcus</i> spp.	9
<i>Corynebacterium</i> spp.	2
<i>Escherichia coli</i>	3
<i>Enterococcus faecalis</i>	9
Group B <i>Streptococcus</i>	2
<i>Klebsiella pneumoniae</i>	3
<i>Morganella</i> spp.	1
<i>Pseudomonas aeruginosa</i>	7
<i>Proteus</i> spp.	2
<i>Staphylococcus aureus</i>	15

2.4–22.2; $p = 0.004$), and *S. aureus* colonization and revision surgery and active tobacco use (OR, 12.2; 95% CI, 1.44–103.9; $p = 0.09$) were significant predictors for deep PJIs (Table 3). There were 28 patients who had BMI ≥ 40 kg/m² with active tobacco use, 76 colonized with *S. aureus* and active tobacco use, 78 with active tobacco use who underwent revision surgery, 16 colonized with *S. aureus*, and active tobacco use who underwent revision surgery, and 30 colonized with *S. aureus*, with a BMI ≥ 30 kg/m², and active tobacco use (Table 3).

Discussion

Although the risk of infection after joint arthroplasty can never be eliminated, we believe that some of the risk

factors for these infections are potentially modifiable and if addressed before surgery may lead to a decrease in the frequency of deep PJIs. The rationale for our study was to determine which patient- or surgical-related characteristics are risk factors for development of a deep PJI after arthroplasty. We sought to quantify these risks and identify them as modifiable or nonmodifiable. In this evaluation of 3672 primary hip arthroplasties performed at a single institution, 47 infections were identified (1.3%). We found several risk factors for deep PJI: obesity (BMI ≥ 40 kg/m²), increased operating time, nonsame-day surgery (> 24 hours after admission), and revision surgery. *S. aureus* colonization and tobacco use were additive risk factors when combined with significant risk factors identified in the multivariate analysis. This is significant and may warrant consideration of surgery delay. These risk factors were noted in previous studies and were validated in our study [1, 2, 20, 22] (Table 4).

There are limitations to our study. First, this is a retrospective study and as such has its inherent weakness of data collection. Inconsistencies in data coding and retrieval from an administrative database are possible. However, every infection was verified by our hospital epidemiologist and met the criteria set forth by the CDC for deep PJIs. Additionally, all PJIs are corroborated with the state of New York Infection Data Bank. Second, the number of subjects in this specific cohort is relatively small compared with other studies; however, we feel that this is counterbalanced by the granularity and reproducibility of our data, which is corroborated with the state of New York Infection Data Bank. Third, our data include same-day elective surgeries and nonsame-day surgeries and also THA versus

Table 2. Risk factors for periprosthetic joint infections

Risk factor	Number of patients with risk factor	Univariate		Multivariate	
		Risk ratio (95% CI)	p value	Risk ratio (95% CI)	p value
Nonsame-day surgery	363	7.09 (3.93–12.77)	$< 0.001^*$	4.16 (1.44–12.02)	0.008*
Diabetes complications	39	6.8 (2.01–22.9)	$< 0.01^*$		
Revision surgery	540	5.28 (2.95–9.43)	$< 0.001^*$	4.23 (1.67–10.72)	$< 0.001^*$
ASA score > 2	1173	4.76 (2.49–9.11)	$< 0.001^*$		
Hemiarthroplasty	147	4.64 (1.72–12.4)	$< 0.01^*$		
BMI ≥ 40 kg/m ²	173	3.86 (1.68–8.87)	$< 0.001^*$	4.13 (1.3–12.88)	0.01*
Operating time > 115 minutes	1543	2.45 (1.34–4.50)	0.002*	3.38 (1.23–9.28)	0.018*
<i>Staphylococcus aureus</i> colonization	671	2.36 (1.13–4.88)	0.02*		
Caseload < 103	1659	1.97 (1.09–3.56)	0.02*		
BMI ≥ 30 kg/m ²	1105	1.75 (0.93–3.30)	0.09		
Female	1987	1.65 (0.90–3.03)	0.10		
Active tobacco use	447	1.14 (0.47–2.76)	0.78		
Age ≥ 65 years	1575	0.99 (0.55–1.76)	0.96		
Use of blood product(s)	336		0.11		

* Significant at alpha level 0.05; CI = confidence interval; ASA = American Society of Anesthesiologists; BMI = body mass index.

Table 3. Patients with multiple risk factors for deep surgical site infections

Risk factors	Number of patients with risk factor	Risk ratio (95% CI)	p value
BMI ≥ 40 kg/m ² + active tobacco use	28	7.52 (1.69–33.4)	0.04*
BMI ≥ 30 kg/m ² + active tobacco use	149	1.55 (0.35–6.89)	0.64*
<i>Staphylococcus aureus</i> colonization + active tobacco use	76	3.31 (0.74–14.82)	0.14
Revision surgery + active tobacco use	78	7.26 (2.37–22.26)	0.004*
<i>S aureus</i> colonization + revision + active tobacco use	16	12.23 (1.44–103.99)	0.09
<i>S aureus</i> colonization + BMI ≥ 30 kg/m ² + active tobacco use	30	12.76 (2.47–66.16)	0.017*

* Significant at alpha level 0.05; CI = confidence interval; BMI = body mass index.

Table 4. Results of predictive factors for periprosthetic joint infections

Publications	Number of patients	Patient-related factors
Berbari et al. [1]	924	Diabetes mellitus, extended preoperative hospital stay, rheumatoid arthritis, revision surgery, higher index arthroplasty risk factor (equivalent of ASA score)
Mangram et al. [14]	NA	Positive nasal screening for <i>Staphylococcus aureus</i> , complications associated with diabetes
Møller et al. [16]	120	Tobacco use
Ridgeway et al. [21]	24,808	Hemiarthroplasty
Muiliwijk et al. [17]	26,127	Extended preoperative hospital stay
Pulido et al. [20]	9245	Morbid obesity (BMI ≥ 40 kg/m ²), higher ASA score, simultaneous bilateral surgery
Dowsey and Choong [5]	1214	Morbid obesity (BMI ≥ 40 kg/m ²), diabetes
Marchant et al. [15]	1,000,000	Complications associated with diabetes
Yano et al. [24]	2423	Positive nasal screening for <i>S aureus</i>
Jämsen et al. [11]	NA	High ASA score, diabetes, urinary disorders, malnutrition, tobacco use

NA = not applicable; ASA = American Society of Anesthesiologists; BMI = body mass index.

hemiarthroplasty. Although this does not represent a unified surgical population, it provides an opportunity for evaluating the risk factors for deep PJIs in different procedure types for hip arthroplasty and reflects the variety of cases found in any large orthopaedic center. We do not maintain that patients undergoing elective THA and patients with hip fracture are comparable populations. Patients with hip fracture are most certainly older and have more comorbidities than the elective THA population and we did not control for medical comorbidities. However, we do feel that because the populations have those differences, they should be separated for public reporting purposes. The infection rates are higher for the nonelective patients and should be held to a different standard for reporting purposes. Fourth, although the surveillance of our patients was thorough and augmented by reports from the New York Infection Surveillance Program, which requires institutions treating a patient with PJI to notify the institution that performed the surgery, there is still the possibility that we may not have been aware of some cases treated out of state, which were not reported. Fifth, we did not look at the anesthesia method, venous thromboembolic prophylaxis regimen, or implant fixation as risk factors for infection.

Risk factors for infection can be subdivided into patient-related and nonpatient-related risk factors, some of which

are modifiable. The assumption is that treatment of modifiable factors may reduce risk, and if shown to be true, patients who undergo surgery without modification may develop preventable infections. Bozic et al. [2] in their analysis of Medicare patients defined patient-related risk factors for PJI after THA. They included rheumatologic disease, obesity, coagulopathy, and preoperative anemia. Jämsen et al. [11] also identified similar patient-related risk factors in addition to high ASA score, diabetes, urinary disorders, malnutrition, and tobacco use as significant contributors to postoperative infections. Pulido et al. [20] instituted a preoperative protocol designed to minimize risk factors for infection. Their protocol addressed urinary tract infection, autologous blood use, blood loss during surgery, and correcting preoperative anemia. Morbid obesity (BMI ≥ 40 kg/m²) has been identified as a significant risk factor for PJIs after joint arthroplasty. Pulido et al. [20] and Dowsey and Choong [5] in their analyses of 9245 primary hip and knee arthroplasties and 1214 consecutive TKAs cases, respectively, found BMI ≥ 40 kg/m² to be a significant risk factor for PJI. We validated these findings in our study for hip arthroplasties in patients with BMI ≥ 40 kg/m² (OR, 3.86; 95% CI, 1.67–8.86; $p < 0.001$). We also found that patients with BMI ≥ 40 kg/m² and active tobacco use, patients colonized with *S aureus* and

active tobacco use, revision patients with active tobacco use, revision patients colonized with *S aureus* with active tobacco use, and patients colonized with *S aureus*, BMI ≥ 30 kg/m², and active tobacco use had three to 12 times greater risks of infection as a result of the additive effects of tobacco use (Table 3). It is therefore important for patients and surgeons to quantify the magnitude of risks and combination of risk factors. Because tobacco use was also found to be a significant modifiable risk factor in previous studies [11, 16], it is worthwhile to optimize patients before surgery to decrease the chance of infection.

Several studies found diabetes mellitus to be a risk factor for infection [1, 14, 15]; however, hemoglobin A1c level has not been found to be predictive of infection [10]. In our study, however, ASA score > 2 , diabetes complications, caseload, and hemiarthroplasty were identified in the univariate analysis as significant predictors; multivariate analysis did not confirm these findings as predictive of infection risk. Morbid obesity may be a better predictor of infection than the diabetes trait alone (we did not subdivide our diabetics into insulin- and noninsulin-controlled diabetes). In our study, operating time was also found to be predictive of infection risk after hip arthroplasty (OR, 3.38; 95% CI, 1.23–9.28). Operating time may be a modifiable risk factor if preoperative planning, operating room efficiency, and surgeon education are not optimized.

Nonmodifiable factors also contribute to increased infection risk. We should consider infections that arise in patients whose risk factors are nonmodifiable as being less likely to be preventable and these infections should not be considered “never events.” Among these nonmodifiable risk factors are revision surgery and nonsame-day surgery (> 24 hours after admission). Nonsame-day surgery was a better predictor of infection risk in this study than hemiarthroplasty alone. Mulwijk et al. [17], in their analysis of the Dutch nosocomial infection surveillance network, found a significant association between PJI and preoperative stay at the hospital of longer than 2 days. Similar findings were noted by Berbari et al. [1] who showed that infected patients stayed 0.7 days longer before surgery in comparison to control subjects. In our study, we found that admission 24 hours or more before surgery increases the incidence of infection and should be avoided in those cases that are not emergent or semiurgent (OR, 7.09; 95% CI, 3.93–12.7; $p < 0.001$). Positive nasal screening for *S aureus* including methicillin-resistant *S aureus* was found to increase PJI in previous studies [14, 24]. Our data show similar findings. Ridgeway et al. [21] in an analysis of 24,808 patients (16,291 THA, 5769 hemiarthroplasty, 2550 revision, and 198 revision hemiarthroplasty cases) showed that the trauma itself is an independent risk factor for PJI and can explain the higher infection rates in patients undergoing hemiarthroplasty. Presumably exposure to

hospital-acquired organisms while in a weakened, post-traumatic state also raises the risk of infection.

Based on these findings, an institutional PJI prevention plan that includes preoperative topical antiseptics, *S aureus* screening and decolonization, a weight loss and nutrition counseling intervention program to decrease BMI as well as improve nutrition for morbidly obese patients, referral of patients with poorly controlled diabetes to an endocrinologist for perioperative glucose management, and a tobacco cessation program for active smokers (being tobacco-free for at least 4 weeks before surgery) is warranted. Møller et al. [16] have described the benefits of a tobacco cessation program for the prevention of complications in a surgical population. They conducted the first randomized clinical trial about the risk-reducing effects of smoking cessation intervention programs on patients undergoing THA or TKA. Their results supported this hypothesis and showed that preoperative smoking cessation programs begun 6 to 8 weeks before surgery reduced postoperative complications [16]. We recommend the following as is currently done at our institution. We instituted a perioperative orthopaedic surgical home program to assist with modifying risk factors for poor outcomes before TJA. We currently have hard stops for morbid obesity (BMI ≥ 40 kg/m²), active tobacco use, drug addiction, and *S aureus* colonization. If attempts are not made to address these risk factors for poor outcome at the time the patient's surgery is scheduled, the surgery is delayed until sufficient effort is made to alter their increased risk of a poor outcome. We have outlined a number of other interventions for optimization of preoperative TJA patients including fall risk, deconditioning, cardiac and stroke prevention, and venous thromboembolic risk screening in high-risk patients.

In conclusion, we found elevated BMI, revision surgery, protracted surgical time, and nonsame-day surgery to be independent risk factors for deep PJI after arthroplasty and we also found tobacco use and *S aureus* colonization to be additive risk factors. Based on this, we believe that when reporting deep PJI rates, stratification into same-day versus nonsame-day hip arthroplasty and preventable infections (when the modifiable risk factors are not addressed) versus nonpreventable infections (these risk factors are adequately addressed) may provide a more accurate assessment of performance on an institutional and individual surgeon level. Additionally, we feel that a preoperative program including behavior modification designed to educate patients about their specific risks and assist them in addressing risk factors may potentially decrease PJI rates. It may allow patients to make more informed decisions regarding their choice for surgery and encourage them to participate in programs designed to address these modifiable risk factors before surgery.

References

- Berbari EF, Hanssen AD, Duffy MC, Steckelberg JM, Ilstrup DM, Harmsen WS, Osmon DR. Risk factors for prosthetic joint infection: case-control study. *Clin Infect Dis*. 1998;27:1247–1254.
- Bozic KJ, Lau E, Kurtz S, Ong K, Rubash H, Vail TP, Berry DJ. Patient-related risk factors for periprosthetic joint infection and postoperative mortality following total hip arthroplasty in Medicare patients. *J Bone Joint Surg Am*. 2012;2:794–800.
- Centers for Disease Control and Prevention-National Healthcare Safety Networks (CDC/NHSN). 2013 Protocol Corrections, Clarification, and Additions. Available at: www.cdc.gov/nhsn/pdf/psmanual/errata2013.pdf. Accessed October 20, 2013
- de Beer J, Petrucci D, Rotstein C, Weening B, Royston K, Winemaker M. Antibiotic prophylaxis for total joint replacement surgery: results of a survey of Canadian orthopedic surgeons. *Can J Surg*. 2009;52:229–234
- Dowsey MM, Choong P. Obese diabetic patients are at substantial risk for deep infection after primary TKA. *Clin Orthop Relat Res*. 2009;467:1577–1581.
- Hacek DM, Robb WJ, Paule SM, Kudrna JC, Stamos VP, Peterson LR. Staphylococcus aureus nasal decolonization in joint replacement surgery reduces infection. *Clin Orthop Relat Res*. 2008;466:1349–1355
- Hanssen AD, Ransen J. Evaluation and treatment of infection at the site of a total hip or knee arthroplasty. *Instr Course Lect*. 1999;48:111–122
- Hooper GJ, Rothwell AG, Frampton C, Wyatt MC. Does the use of laminar flow and space suits reduce early deep infection after total hip and knee replacement? The ten-year results of the New Zealand Joint Registry. *J Bone Joint Surg Br*. 2011;93:85–90.
- Iarikov D, Demian H, Rubin D, Alexander J, Nambiar S. Choice and doses of antibacterial agents for cement spacers in treatment of prosthetic joint infections: review of published studies. *Clin Infect Dis*. 2012;55:1474–1480.
- Iorio R, Williams KM, Marcantonio AJ, Specht LM, Tilzey JF, Healy WL. Diabetes mellitus, hemoglobin A1C, and the incidence of total joint arthroplasty infection. *J Arthroplasty*. 2012;27:726–729.
- Jämsen E, Furnes O, Engesaeter LB, Kontinen YT, Odgaard A, Stefánssdóttir A, Lidgren L. Prevention of deep infection in joint replacement surgery. *Acta Orthop*. 2010;81:660–666.
- Johnson AJ, Daley JA, Zywielski MG, Delanois RE, Mont MA. Preoperative chlorhexidine preparation and the incidence of surgical site infections after hip arthroplasty. *J Arthroplasty*. 2010;25:98–102.
- Kapadia BH, Johnson AJ, Issa K, Mont MA. Economic evaluation of chlorhexidine cloths on healthcare costs due to surgical site infections following total knee arthroplasty. *J Arthroplasty*. 2013;28:1061–1065.
- Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR. Guideline for prevention of surgical site infection, 1999. Centers for Disease Control and Prevention (CDC) Hospital Infection Control Practices Advisory Committee. *Am J Infect Control*. 1999;27:97–132.
- Marchant MH Jr, Viens NA, Cook C, Vail TP, Bolognesi MP. The impact of glycemic control and diabetes mellitus on perioperative outcomes after total joint arthroplasty. *J Bone Joint Surg Am*. 2009;91:1621–1629.
- Møller AM, Villebro N, Pedersen T, Tonnesen H. Effect of preoperative smoking intervention on postoperative complications: a randomised clinical trial. *Lancet*. 2002;359:114–117.
- Muilwijk J, Walenkamp GH, Voss A, Wille JC, van den Hof S. Random effect modelling of patient-related risk factors in orthopaedic procedures: results from the Dutch nosocomial infection surveillance network 'PREZIES.' *J Hosp Infect*. 2006;62:319–326.
- Peersman G, Laskin R., Davis J, Peterson M. Infection in total knee replacement: a retrospective review of 6489 total knee replacements. *Clin Orthop Relat Res*. 2001;392:15–23.
- Poss R, Thornhill TS, Ewald FC, Thomas WH, Batte NJ, Sledge CB. Factors influencing the incidence and outcome of infection following total joint arthroplasty. *Clin Orthop Relat Res*. 1984;182:117–126.
- Pulido L, Ghanem E, Joshi A, Purtill JJ, Parvizi J. Periprosthetic joint infection: the incidence, timing, and predisposing factors. *Clin Orthop Relat Res*. 2008;466:1710–1715.
- Ridgeway S, Wilson J, Charlet A, Kafatos G, Pearson A, Coello R. Infection of the surgical site after arthroplasty of the hip. *J Bone Joint Surg Br*. 2005;87:844–850.
- Urquhart DM, Hanna FS, Brennan SL, Wluka AE, Leder K, Cameron PA, Graves SE, Cicuttini FM. Incidence and risk factors for deep surgical site infection after primary total hip arthroplasty: a systematic review. *J Arthroplasty*. 2010;25:1216–1222.
- van Kasteren ME, Mannien J, Ott A, Kullberg BJ, de Boer AS, Gyssens IC. Antibiotic prophylaxis and the risk of surgical site infections following total hip arthroplasty: timely administration is the most important factor. *Clin Infect Dis*. 2007;44:921–927.
- Yano K, Minoda Y, Sakawa A, Kuwano Y, Kondo K, Fukushima W, Tada K. Positive nasal culture of methicillin-resistant Staphylococcus aureus (MRSA) is a risk factor for surgical site infection in orthopedics. *Acta Orthop*. 2009;80:486–490.
- Zimmerli W, Trampuz A, Ochsner PE. Prosthetic-joint infections. *N Engl J Med*. 2004;351:1645–1654.