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Medical Comorbidities Are Independent Preoperative Risk Factors for Surgical Infection After Total Joint Arthroplasty

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Abstract

Background Surgical site infection (SSI) after total joint arthroplasty (TJA) is a major cause of morbidity. Multiple patient comorbidities have been identified as SSI risk factors including obesity, tobacco use, diabetes, immunosuppression, malnutrition, and coagulopathy. However, the independent effect of multiple individual patient factors on risk of subsequent periprosthetic infection is unclear.

Questions/purposes The purposes of this study are (1) to collect data on several preestablished infection risk factors in addition to SSI-related data on a large TJA cohort; and (2) to use multivariate modeling on previously established patient risk factors to determine independent preoperative predictors of SSI.

Methods We reviewed records of patients undergoing TJA from January 1, 2010, to July 30, 2012. Confirmation of SSI followed published guidelines for superficial, deep, and periprosthetic. A total of 29 culture-positive SSIs (1.5% total) and 1846 controls were identified. The prevalence of known patient-specific infection risk factors was determined for both infected cases and healthy control subjects followed by multiple regression analysis to determine independent risk.

Results Isolated organisms consisted of methicillin-resistant *Staphylococcus aureus* (MRSA; 34.5%) followed by gram-negative rods (31.0%). After adjusting for anatomic site, independent risk factors for infection include: revision surgery (odds ratio [OR], 2.28; confidence interval [CI], 1.26–3.98), super obesity (body mass index > 50 kg/m^2; OR, 5.28; CI, 1.38–17.1), diabetes mellitus (OR, 1.83; CI, 1.02–3.27), tobacco abuse (OR, 2.96; CI, 1.65–5.11), MRSA colonization or infection (OR, 4.17; CI, 1.63–9.66), and current or prior bone cancer (OR, 3.86; CI, 1.21–12.79).

Conclusions Multiple patient comorbidities independently contribute to infection risk after TJA. Preoperative TJA infection risk stratification may be feasible and should be investigated further.

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

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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Introduction

Total joint arthroplasty (TJA) is a common procedure with up to 800,000 cases being performed annually in the United States [16, 27]. Infection after TJA remains a major cause

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Table 1. Definition of surgical site infection

Superficial wound infection [11, 22]	Deep wound infection [11, 22]	Organ space (periprosthetic infection) [11, 22, 26]
Within 30 days of surgery	Within 1 year of surgery	Within 1 year of surgery
Infection involves only skin and subcutaneous tissue of the incision and patient has at least one of the following [11]:	The infection involves deep soft tissues (eg, fascial and muscle layers) of the incision and patient has at least one of the following [11]:	At least one of the following criteria are met [26]:
1. Purulent drainage from the superficial incision	1. Purulent drainage from the deep incision but not from the organ/space component of the surgical site	1. A sinus tract communicating with the prosthesis; or
2. Organisms isolated from an aseptically obtained culture of fluid or tissue from the superficial incision	**2. A deep incision spontaneously dehisces or is deliberately opened by a surgeon and is culture-positive** or not cultured and the patient has at least one of the following signs or symptoms: fever (> 38 °C) or localized pain or tenderness; a culture-negative finding does not meet this criterion	**2. A pathogen is isolated by culture from two separate tissue or fluid samples obtained from the affected prosthetic joint; or**
3. At least one of the following signs or symptoms of infection: pain or tenderness, localized swelling, redness, or heat, and **superficial incision are deliberately opened by surgeon, and are culture-positive** or not cultured; a culture-negative finding does not meet this criterion.	3. An abscess or other evidence of infection involving the deep incision is found on direct examination, during reoperation, or by histopathologic or radiologic examination	**3. Four of the following six criteria exist:**
4. Diagnosis of superficial incisional SSI by the surgeon or attending physician	4. Diagnosis of a deep incisional SSI by a surgeon or attending physician	a. Elevated serum erythrocyte sedimentation rate (ESR) or serum C-reactive protein (CRP) concentration
		b. Elevated synovial white blood cell (WBC) count
		c. Elevated synovial eutrophil percentage (PMN%)
		d. Presence of purulence in the affected joint
		e. Isolation of a microorganism in one culture of periprosthetic tissue or fluid
		f. Greater than five neutrophils per high-power field in five high- power fields observed from histologic analysis of periprosthetic tissue at 400 times magnification

Only culture-positive patients were included in the surgical site infection cohort and therefore met at least one bolded criterion in the appropriate infection category; SSI = surgical site infection.

of patient morbidity with a prevalence of 0.5% to 3% [5, 21]. Surgical site infection (SSI) in the context of TJA, as defined by the Centers for Disease Control and Prevention (CDC), is superficial wound infection within 30 days of the date of surgery or within 1 year of surgery for deep wound or periprosthetic (organ space) infections (Table 1) [4, 22].

Infection rates in the TJA population are dependent on intrinsic patient factors [21]. Obesity is a particularly problematic patient risk factor for SSI in the TJA population with a markedly increased risk noted with increasing body mass index (BMI) [6, 21, 23]. Patients with a BMI greater than 50 kg/m^2 reportedly have an 18.3 times higher odds of infection compared with BMI lower than 50 kg/m^2 [21]. Diabetes mellitus is also associated with SSI in patients undergoing arthroplasty [12, 13], although the degree of attributable risk for infection independent of obesity is difficult to establish [6, 30]. These risks may increase morbidity and mortality while also adding the burden of increased cost [15, 18]. Additional patient risk factors include, but are not limited to, tobacco use, poor dentition, immunosuppression, methicillin-resistant *Staphylococcus aureus* (MRSA) colonization, malnutrition, inflammatory disease, and coagulopathy [5, 6, 18, 21, 23, 25].

A major barrier to incorporating SSI risk assessment into clinical practice for joint replacement surgeons is the lack of research assessing the independent effects of multiple patient factors on overall preoperative infection risk. Several studies report multivariate models for SSI risk after TJA, but they include both operative and preoperative variables and therefore have limited use in a preoperative setting [3, 7, 29]. These studies demonstrate that multivariate models are capable of predicting SSI status, but they do not assess whether SSI risk can be adequately determined by preoperative patient risk factors alone. Two studies that focus on preoperative infection risk assessment had mixed results [13, 17]. Lai et al. examined medical comorbidities grouped by organ system and found that diabetes (odds ratio [OR], 3.0; confidence interval [CI], 1.1–14.4; $p = 0.041$) and genitourinary conditions (OR, 2.87; CI, 0.94–8.0; $p = 0.066$) were independent SSI risk factors after primary TJA [17]. A major limitation of this grouping strategy is that no distinction is made between diagnoses that may have differing effects on host susceptibility to infection (for example, hepatic cirrhosis versus esophageal reflux). Conversely, Jamsen et al. used a more focused approach and examined obesity, diabetes, and hyperglycemia as

preoperative risk factors and found that obesity (OR, 6.4; CI, 1.7–24.6) and diabetes (OR, 2.3; CI, 1.1–4.7) but not hyperglycemia (OR, 2.3; CI, 0.60–8.5) were independently associated with SSI [13]. This approach also has its shortcomings, because the performance of their prediction model is limited by only considering a few risk factors.

The purposes of this study are (1) to collect data on several established preoperative infection risk factors in addition to SSI-related data on a large TJA cohort; and (2) to use multivariate modeling on previously established patient risk factors to determine independent preoperative predictors of SSI.

Patients and Methods

We retrospectively reviewed all 1875 patients who underwent TJA at our institution from January 1, 2010, to July 30, 2012. The study population consisted of 1640 primary surgeries and 235 revision surgeries. Included joints were limited to the hip, knee, shoulder, and elbow (Table 2). A total of 29 (1.5% total; CI, 1.1–2.3; 1.4% primary; CI, 2.0% revision) cases developed SSIs with positive microbial cultures: 15 THAs (11 primary, four revision), 13 TKAs (12 primary, one revision), and one primary total shoulder. Additionally, 4.3% (CI, 3.5–5.4) of patients (29 culture-positive patients and 55 other patients) had an SSI-associated diagnosis within 1 year of TJA. No patients were recalled specifically for this study; all data were obtained from medical records.

Although multiple criteria have been proposed for diagnosing SSI (Table 1) [11, 22, 26], for the purpose of this study, we required positive microbial cultures for SSI confirmation in addition to the minimum criteria in those studies. Our definitions of superficial incisional and deep incisional infection were consistent with current CDC guidelines [11, 22]. For our definition of organ space infection, we relied on the criteria outlined by Parvizi et al. in the most recent Musculoskeletal Infection Society guidelines [26]. All bacterial isolates were recorded (Table 3) in addition to the number of days from the joint arthroplasty until clinical signs of infection.

Table 2. Procedure-specific case volume

Procedure	Number of cases (% of total)
Primary hip	648 (35)
Primary knee	645 (34)
Primary shoulder	320 (17)
Revision hip	125 (6.7)
Revision knee	66 (3.5)
Revision upper extremity	44 (2.3)
Primary elbow	27 (1.4)
Total	1875

To identify all patients who potentially met criteria for infection, an International Classification of Diseases, 9th Revision (ICD-9) code-based query was submitted to the hospital system medical records department. The entire arthroplasty population was first categorized by date of procedure and the associated ICD-9-Clinical Modification procedure code. All patients were then identified who had an ICD-9 diagnosis code assigned within 365 days of the procedure that may be associated with SSI, including codes for osteomyelitis (730.00–730.99), septic arthritis (711.0), SSI (998.3 and 998.5), cellulitis (682), and infection or inflammatory reaction resulting from the joint implant or other hardware (996.66 or 996.67). This search revealed a total of 84 patients who met our initial criteria. We excluded 55 patients because they did not have a total joint infection, leaving a total of 29 infected subjects and 1862 uninfected control subjects.

Patient data were abstracted from the electronic medical record database using a similar query-based protocol. Patient demographic information collected on the same admission as the total joint surgery was obtained in addition to height, weight, and BMI. We then categorized patients by BMI as underweight (BMI < 18.5 kg/m^2), normal (BMI 18.5–24.9 kg/m^2), overweight (BMI 25–29.9 kg/m^2), obese (BMI 30–39.9 kg/m^2), morbidly obese (BMI 40–40.9 kg/m^2), or super obese (BMI 50 + kg/m^2). All medical diagnoses in the patient's chart before the day of surgery were then reviewed for patient-specific infection risk factors previously reported in the literature, including tobacco use, current or history of bone cancer, diabetes mellitus, hepatitis B or C, HIV, and history of *staphylococcus* infection or colonization.

Descriptive data were first generated for the entire sample. Of the 29 culture-positive SSIs, we determined the proportion of bacterial isolates (Table 3). A survival curve was created with data from the 29 culture-positive patients based on time to either SSI confirmation (Fig. 1). We tested BMI for normal distribution using a Kolmogorov-Smirnov goodness-of-fit test, and a receiver operator curve was generated for BMI as a predictor of infection status. For BMI categories (overweight BMI 25.0–29.9 kg/m^2; obese BMI 30.0–39.9 kg/m^2; morbidly obese BMI 40.0–49.9 kg/m^2; and superobese BMI $\geq$ 50 kg/m^2) and all remaining categorical risk factors, a chi-square test was used to test distribution frequency among patients with SSI versus control subjects, and ORs were calculated with 95% CIs. Finally, for all patients who underwent knee, hip, or shoulder TJA ($N = 1807$), all categorical variables associated with SSI in our descriptive analysis were considered for inclusion in a nominal logistic regression model to predict SSI status. We controlled for operative factors by adjusting for primary

Table 3. Microbial isolates

Causative organism	Count (% of total)
MRSA	10 (35)
Gram-negative rods	9 (31)
MSSA	4 (14)
Streptococcus	2 (7)
Multiple organisms	2 (7)
Coagulase-negative *staphylococcus*	1 (3.4)
Clostridium innocuum	1 (3.4)
Enterococcus faecalis	1 (3.4)
SSI category	
Superficial incisional	8 (28)
Deep incisional	10 (35)
Organ space (periprosthetic)	11 (38)
Medical comorbidity	
Overweight and obese	24 (83)
Diabetes mellitus	10 (35)
Fracture	8 (28)
Malignancy	8 (28)
Tobacco abuse	7 (24)

MRSA = methicillin-resistant *Staphylococcus aureus*; MSSA = methicillin-susceptible *S aureus*; SSI = surgical site infection.

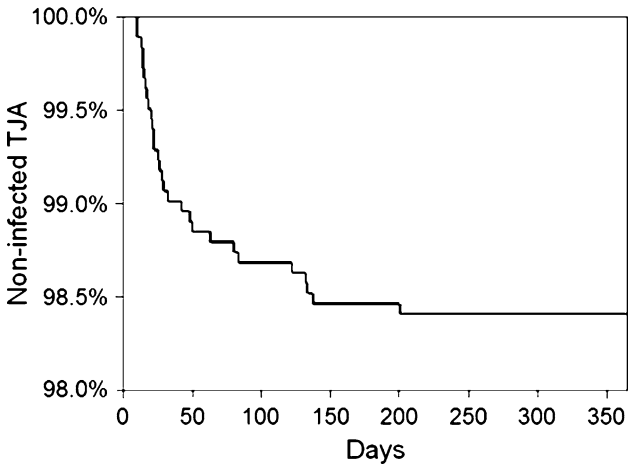

Fig. 1 Rates of 1-year infection-free implant survival are shown (N = 1876). The observed 1-year incidence of culture positive SSIs was 1.6% (CI, 1.1–2.3).

versus revision status and site of surgery. We performed all analyses with a statistical software package (JMP 9.0.0; SAS Institute Inc, Cary, NC, USA).

Results

Of the 29 culture-positive infections, superficial infections occurred in eight (28%), deep infections in 10 (34%), and

Table 4. Infection risk factor

Risk factor	Odds ratio (confidence interval)	p value
Current tobacco use	3.00 (1.78–5.06)	< 0.001
Current or history of bone cancer	12.85 (4.64–35.59)	< 0.001
Diabetes mellitus	2.44 (1.55–3.82)	< 0.001
Hepatitis B	7.34 (0.96–56.1)	0.027
Hepatitis C	5.59 (2.21–14.19)	< 0.001
MRSA colonization or prior infection	7.34 (2.85–18.91)	< 0.001
MSSA colonization or prior infection	8.64 (3.75–19.89)	< 0.001
Staphylococcal colonization or prior infection	6.52 (3.41–12.51)	< 0.001
Underweight (BMI < 18.5 kg/m^2)	1.90 (0.26–13.7)	0.56
Overweight (BMI 25.0–29.9 kg/m^2)	0.60 (0.24–1.50)	0.24
Obese (BMI 30.0–39.9 kg/m^2)	0.84 (0.51–1.41)	0.52
Morbid obesity (BMI 40.0–49.9 kg/m^2)	1.28 (0.61–2.65)	0.51
Super obesity (BMI 50 + kg/m^2)	15.69 (5.97–41.21)	< 0.001
Obesity hypoventilation syndrome	10.2 (1.17–88.5)	0.01

MRSA = methicillin-resistant *Staphylococcus aureus*; MSSA = methicillin-susceptible *S aureus*; BMI = body mass index.

Table 5. Receiver operator table for BMI and surgical site infection

Cutoff	Probability of future SSI	Sensitivity	Specificity
BMI 60 kg/m^2	30.0%	3.7%	99.8%
BMI 55 kg/m^2	20.5%	3.7%	99.5%
BMI 50 kg/m^2	13.2%	18.5%	98.1%
BMI 45 kg/m^2	8.6%	22.2%	96.0%
BMI 40 kg/m^2	5.3%	29.6%	89.3%
BMI 35 kg/m^2	3.3%	51.8%	77.0%
BMI 30 kg/m^2	2.0%	77.7%	53.4%

BMI = body mass index; SSI = surgical site infection.

Table 6. Independent infection risk factors

Independent risk factor	Adjusted odds ratio (confidence interval)	p value
Revision surgery	2.28 (1.26–3.98)	0.005
Lower extremity surgery	2.15 (0.98–5.7)	0.057
Super obesity	5.28 (1.38–17.1)	0.009
Diabetes mellitus	1.83 (1.02–3.27)	0.048
Tobacco abuse	2.96 (1.65–5.11)	< 0.001
MRSA colonization or prior infection	4.17 (1.63–9.66)	0.002
Current or history of bone cancer	3.86 (1.21–12.79)	0.041

MRSA = methicillin-resistant *Staphylococcus aureus.*

periprosthetic infections in 11 (38%). Isolated organisms consisted of MRSA (35%), gram-negative rods (31%), methicillin-sensitive *S aureus* (14%), *Streptococcus* sp (7%), multiorganism (7%), *Staphylococcus* coagulase-negative (3.4%), *Clostridium innocuum* (3.4%), and *Enterococcus faecalis* (3.4%) (Table 3). Overweight and obese status was by far the most prevalent risk factor among patients with SSI (24 of 29 [83%]) followed by diabetes (10 of 29 [34%]), fracture (eight of 29 [28%]), and current or prior bone cancer (eight of 29 [28%]) (Table 4). Although all BMI categories up to and including morbid obesity (BMI 40–49.9 kg/m^2) had nonsignificant differences between patients with SSI and control subjects ($p > 0.24$ for categories underweight through morbidly obese), categorization of super obesity (BMI > 50 kg/m^2) differed ($p < 0.001$) between cohorts and had an OR of 16 (CI, 6–41) (Table 4). When BMI was considered as a continuous variable to predict infection status ($R^2 = 0.079$, $p < 0.001$; limited to patients with available BMI data, $n = 947$), the area under the resulting receiver operator curve was 0.71, a BMI of 45 kg/m^2 had an 8.6% probability of SSI (96% specificity), and a BMI of 60 kg/m^2 had a 30% probability (99.8% specificity) (Table 5). We noted a difference between patients with SSI and healthy control subjects with regard to current or past bone cancer ($p < 0.001$; OR, 13; CI, 5–37), hepatitis B ($p = 0.027$; OR, 7; CI, 1.0–56), history of staphylococcal colonization or serious infection ($p < 0.001$; OR, 7; CI, 3.4–13), hepatitis C ($p < 0.001$; OR, 6; CI, 2.2–14), current tobacco use ($p < 0.001$; OR, 3.0; CI, 1.8–5), and diabetes mellitus ($p < 0.001$; OR, 2.4; CI, 1.6–3.8) (Table 4). Additionally, obesity-related hypoventilation syndrome was more common among patients with SSI ($p = 0.01$; OR, 10; CI, 1.2–89). No patient with HIV ($N = 10$, prevalence 0.5%) went on to develop an SSI.

After adjusting for operative factors including primary versus revision status (adjusted OR, 2.28; CI, 1.26–3.98; $p = 0.005$) and anatomic site of surgery (hip or knee versus shoulder, adjusted OR, 2.15; CI, 0.98–5.7; $p = 0.057$; hip versus knee, $p = 0.58$), we identified five independent patient risk factors for infection in our nominal logistic regression model (whole model $R^2 = 0.10$, $p < 0.001$, Bayesian information criterion = 633, $n = 1807$). These factors include super obesity (BMI > 50 kg/m^2; adjusted OR, 5.28; CI, 1.38–17.1), diabetes mellitus (adjusted OR, 1.83; CI, 1.02–3.27), tobacco abuse (adjusted OR, 2.96; CI, 1.65–5.11), MRSA colonization or prior infection (adjusted OR, 4.17; CI, 1.63–9.66), and current or prior bone cancer (OR, 3.86; CI, 1.21–12.79) (Table 6). A receiver operator curve of the output from the nominal logistic regression model had moderate to good performance at predicting infection status (area under the curve = 0.71).

Discussion

Several studies have assessed the independent effect of multiple individual patient factors on preoperative infection risk [3, 7, 13, 17, 29]. Several [3, 7, 29] provide robust multivariate SSI prediction models, but their reliance on both operative and preoperative factors limits their use in a preoperative setting. The few studies that only consider preoperative factors in their risk models either use an overly general strategy for grouping patient comorbidities [17] or only consider a small number of risk factors [13]. Therefore, we have collected data on a larger number of specific, established preoperative infection risk factors in addition to SSI-related data on a large TJA cohort and applied multivariate statistical methods to determine independent preoperative predictors of SSI.

Our retrospective study is subject to a number of limitations. First, like with all medical record reviews, confounding can be introduced by lack of proper documentation. For example, many diagnoses that are relevant to SSI risk or variables such as BMI may not have been adequately documented during hospital encounters for unrelated complaints. This type of confounding will often differentially bias effect sizes toward zero, and we may therefore be underestimating the true effect of our reported risk factors on infection rates. Second, although infection rates and prevalence of bacterial isolates identified in our work are consistent with the literature [9, 32], we relied on positive cultures for definitive confirmation of SSI, which is not an absolute requirement of current SSI diagnostic criteria [11, 22, 26]. We could not assess for differences in risk factors between culture-negative and -positive SSIs, and our results may therefore not be applicable to culture-negative cases, which may represent as many as 20% of all confirmed infections [28]. Third, 2.1% (39 of 1846) of our healthy control subjects ($N = 39$) and eight of 29 of our patients with SSI were orthopaedic oncology patients, and therefore our findings might not reflect those from institutions without oncologic practices. Fourth, although the large subset of preestablished infection risk factors considered in our multivariate model allows for a more rigorous adjustment of effect size to determine independent risk than other recent studies (Table 7), our data set is not exhaustive because our medical diagnosis code-based approach does not allow for consideration of all known infection risk factors.

Our unadjusted analyses agreed with prior reports associating several patient factors, particularly extreme obesity, hepatitis, history of bone cancer, and history of *staphylococcus* infection or colonization with SSI risk after TJA. Obesity-related data are an important contribution to the surgical infection literature, because obesity itself is

Table 7. Comparative estimates of SSI risk due to obesity, diabetes, and tobacco abuse

Study	Increased BMI		Diabetes	Tobacco abuse	Malignancy
	BMI cutoff (kg/m^2)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)
Current study	> 50.0	5.3 (1.4–17.1)	1.8 (1.02–3.3)	3.0 (1.7–5.1)	3.9 (1.2–12.8)
Berbari et al. (1998) [3]	> 30.0	0.9 (0.7–1.2)*	2.3 (1.2–4.8)*	N/A	3.1 (1.3–7.2)
Lai et al. (2007) [17]	> 30.0	1.8 (0.60–5.4)*	3.9 (1.06–14.4)	N/A	N/A
Dowsey and Choong (2009) [7]	> 30.0	2.2 (0.64–8.1)	6.9 (2.4–19.6)	2.3 (0.44–12.2)	N/A
	> 40.0	9.0 (1.6–50.6)			
Iorio et al. (2012) [12]	N/A	N/A	4.0 (2.1–7.9)*	N/A	N/A
			8.6 (2.7–27.6)*,‡		
Jamsen et al. (2010) [13]	> 40.0	6.4 (1.7–24.6)	2.3 (1.1–4.7)	N/A	N/A
			1.55 (0.51–4.7)‡		
Pulido et al. (2008) [29]	> 40.0	3.2 (1.6–6.5)	N/S	N/A	N/A
Andrew et al. (2008) [1]	30.0–40.0, > 40.0	NS*,†	N/A	N/A	N/A

*Unadjusted estimates; †no difference in infection rates among BMI < 30.0 kg/m^2, BMI 30.0–40.0 kg/m^2, and BMI > 40.0 kg/m^2 ($p = 0.011$ chi-square test); ‡comparison of insulin-dependent and noninsulin-dependent diabetics; BMI = body mass index; CI = confidence interval; N/A = not applicable; NS = nonsignificant.

overrepresented among patients undergoing arthroplasty. Obesity rates generally decline after age 60 years [8], yet at least half of patients undergoing TKA and one-third of patients undergoing THA are obese [2, 23], which is comparable to the current US average adult obesity prevalence of 36% [24]. Our findings regarding obesity are consistent with previous studies noting a markedly increased infection risk at extremes of weight [20, 21, 23, 31, 34]. In particular, it appears that patients who meet the categorical definition of super obesity (BMI > 50 kg/m^2) have a particularly elevated infection risk [21]. Finally, our treatment of BMI as continuous data appeared to be more responsive than categorical definitions for infection risk. In particular, the diagnosis of morbid obesity is often made for any patient with a BMI > 40 kg/m^2, but based on our study and previous reports in the arthroplasty literature [21], a fairly dramatic increase in infection risk occurs well beyond that threshold value. Although categorical definitions are convenient, it may be prudent to move toward describing obesity with a specific BMI in patients with extreme body weight. The high OR reported for current or prior bone malignancy such as sarcoma or metastatic cancer was expected, because the use of megaprosthetics in orthopaedic oncology has been reported to have infection rates of approximately 18% [10]. However, the association between a history of *staphylococcus* infection or colonization and future infection rates was surprising, because the infection or colonization in many cases was documented as much as 10 years before surgery. This association appeared to be regardless of methicillin resistance, although prior studies have noted a markedly elevated infection risk among MRSA carriers versus methicillin-sensitive *S aureus* carriers [14]. Finally, the associations of hepatitis, diabetes, and tobacco use with infection are consistent with previous reports [7, 19, 33].

Our multivariate analysis identifies several independent SSI risk factors and is an important contribution to the TJA literature. An important factor clinicians must consider when comparing risk estimates across studies is how thoroughly the investigators adjusted for concomitant risk factors. For example, Andrew et al., Lai et al., and Berbari et al. find no association between obesity and SSI rates with their crude (unadjusted) estimates, but Dowsey et al., Jamsen et al., and the current study all find an association with our adjusted estimates (Table 7) [1, 3, 7, 13, 17]. Not only do we establish independent infection risk for multiple patient-specific factors, but we provide adjusted estimates of effect size that will allow clinicians to more readily interpret infection risk in patients with multiple medical conditions. For example, it has been difficult to discern the independent effect of frequently comorbid conditions such as diabetes and obesity on infection risk [7, 30]. We establish that after adjusting for obesity, conditions such as obesity hypoventilation syndrome are nonsignificant risk factors, whereas diabetes mellitus is independently associated with SSI but with a smaller effect size than suggested by unadjusted estimates. Conversely, we establish that the independent association of tobacco abuse on infection rates is very similar to unadjusted rates. Finally, our findings indicate preoperative infection risk assessment based on patient factors may be clinically feasible. Although qualitative clinical algorithms are convenient, the most reliable method of predicting infection risk is to use a quantitative, multivariate formula to capture the additive

effect of independent factors on overall infection risk. Our regression model is based on a limited number of previously reported patient risk factors and has moderate to good performance at predicting infection status. However, consideration of a broader number of potential yet unreported SSI risk factors by mining data from existing patient medical records could conceptually produce a more robust prediction model. Further research is indicated in this promising area.

In conclusion, we have created a comprehensive data set of known SSI risk factors and infection outcomes on a large cohort of patients undergoing TJA. We establish comparability of SSI rates, causative organisms, and association of patient factors with infection risk at our institution to data reported in the recent SSI literature. In our multivariate analysis, we establish that several patient-specific risk factors, particularly extreme obesity, prior staphylococcal infection or colonization, hepatitis infection, and current or prior bone cancer, are independently associated with culture-positive SSIs. Our findings allow clinicians to more effectively consider the effect of multiple patient comorbidities on overall infection risk after TJA. Accordingly, preoperative infection risk stratification for patients undergoing TJA may be feasible and should be investigated further.

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