American Journal of Infection Control 000 (2019) 1−8

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major Article

Impact of patient comorbidities on surgical site infection within 90 days of primary and revision joint (hip and knee) replacement

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Key Words:
Total knee replacement
Total hip replacement
Surgical site infection
Comorbidity
Post-operative complications

Background: The frequency of primary and revision total knee and hip replacements (pTKRs, rTKRs, pTHRs, and rTHRs, respectively) is increasing in the United States due to demographic changes. This study evaluated the impact of preoperative patient and clinical factors on the risk of surgical site infection (SSI) within the 90-day period after primary and revision total joint replacements (TJR).

Methods: A retrospective observational cohort study was designed using the IBM MarketScan and Medicare databases, 2009-2015. Thirty-four comorbidities were assessed for all patients, and multivariable logistic regression models were used to evaluate factors associated with higher odds of SSI after adjusting for other patient and clinical preoperative conditions.

Results: The study included a total of 335,134 TKRs and 163,547 THRs. SSI rates were 15.6% and 8.6% after rTKR and rTHR, respectively, compared with 2.1% and 2.1% for pTKR and pTHR, respectively. Comorbidities with the greatest adjusted effect on SSI across all TJRs were acquired immunodeficiency syndrome (odds ratio [OR], 1.58; 95% confidence interval [CI], 1.06-2.34; $P = .0232$), paralysis (OR, 1.56; 95% CI, 1.26-1.94; $P < .0001$), coagulopathy (OR, 1.48; 95% CI, 1.36-1.62; $P < .0001$), metastatic cancer (1.48; 95% CI, 1.24-1.76; $P < .0001$), and congestive heart failure (OR, 1.39; 95% CI, 1.30-1.49; $P < .0001$).

Conclusions: SSI occurred most commonly among patients after revision TJR and were related to many patient comorbidities, including diabetes, congestive heart failure, and coagulopathy, which were significantly associated with a higher risk of SSI after TJR.

BACKGROUND

Osteoarthritis is associated with pain, restricted physical functioning, and limitation in activities of daily living.[1] For patients with osteoarthritis of the hip or knee, total joint replacement (TJR) may be a preferred procedure to reduce pain and improve function.[2,3] More than 600,000 knee and nearly 300,000 hip replacement procedures are performed annually in the United States.[4-7] Primary and revision TJR volumes are expected to increase substantially by 2030 following aging of the population and an increasing prevalence of arthritis and comorbid conditions.[8,9] As a result, the number of these procedures may reach 572,000 primary hip replacements, 3.48 million primary knee replacements, 90,000 revision hip replacements, and 250,000 revision knee procedures.[6]

Such trends highlight the need for solutions to cost-effectively prevent and treat surgical site infections (SSIs), one of the common complications after TJR procedures.[7,10] The reported incidence of SSI ranges from 0.5% to 8% after both primary and revision TJR.[7,9,11] Factors shown to be associated with an increased risk of SSI include patient demographics, comorbid conditions, and the type of surgical procedure.[5,7,8,10,12-16] When assessing SSI after each type of surgery, studies have shown that, compared with primary procedures, revision TJR procedures had the highest SSI rates.[5,7,15]

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Funding/support: This work was supported by Johnson & Johnson Medical Device Companies. A.S.C., J.L., and C.E.H. are employees and stockholders of Johnson & Johnson.

Conflicts of interest: CEE and DL made paid presentations for Ethicon, a Johnson and Johnson company. No others to report.

https://doi.org/10.1016/j.ajic.2019.03.030
0196-6553/

However, variability exists in published studies with respect to SSI rates and the preoperative patient characteristics that contribute to the risk of SSI.[5] This study evaluated the impact of preoperative factors, including patient comorbidities and presentation, on the risk of SSI within 90 days after primary and revision TJR of the hip and knee.

METHODS

Study design and data sources

This was a retrospective cohort study using the IBM MarketScan Commercial Claims and Encounters (CCAE) and the Medicare Supplemental and Coordination of Benefits (MDCR) databases. The CCAE contains information on individuals who are under the age of 65 and are the primary insured, spouse, or dependent. The Medicare database includes information for individuals 65 years or older who are Medicare eligible and have supplemental insurance paid for by their current or former employer. A standard extract from these databases consists of 3 files: (1) an enrollment file, which includes patient sociodemographic and health insurance payer type information; (2) a medical file, which includes detailed records for hospital in- and outpatient admissions and services across different facilities of care captured with ICD-9-CM and ICD-10-CM diagnosis and procedure codes and Common Procedural Terminology (CPT) codes; and (3) a drug file (pharmacy claims). The files are linkable, based on an encrypted patient identification number. The CCAE includes approximately 50 million patients per year covered by employee-sponsored plans, and the MDCR includes about 2 million patients per year receiving Medicare coverage and employee-paid coverage with Medicare supplemental plans. Institutional Review board approval was not necessary to conduct this study, as data within these databases are de-identified and comply with Health Insurance Portability and Accountability Act (HIPAA) regulations.

Sample selection

We identified patients in the databases who underwent total knee arthroplasty or total hip arthroplasty between 2009 and 2015 in either outpatient or inpatient settings of care. Participants were categorized into 4 subgroups based on surgical type: (1) primary total knee replacement (pTKR), (2) revision total knee replacement (rTKR), (3) primary total hip replacement (pTHR), and (4) revision total hip replacement (rTHR). Patient subgroups were identified using ICD-9-CM or CPT codes: ICD-9 81.54 or CPT-4 27440-7 for pTKR; ICD-9 00.80-4 and 81.55 or CPT-4 27486-8 for rTKR; ICD-9 81.51 or CPT-4 27130 for pTHR; and ICD-9 00.70-7 and 81.53 or CPT-4 27134 and 27137-38 for rTHR. Patients were included if they were continuously enrolled for at least 12 months before and 90 days after TJR. Patients with elective total joint procedures were retained. In contrast, those admitted through emergency rooms or treated for joint fractures were excluded. Patients were also excluded from the analysis if there was evidence of infection before primary or revision joint replacements, simultaneous (bilateral) surgery, or multiple TJR procedures within the study period.

For each patient retained in the study, the occurrence of SSI within 90 days after primary or revision TJR was identified. The presence of incisional SSI (superficial or deep) was identified using ICD codes 998.5, 686.9, 038.9, 711.05-6, or 730.05-6. For each patient, we assessed the presence of 34 patient-level preexisting conditions. Demographic characteristics including age and gender were reported. Clinical factors such as the year of TJR and place of service (ambulatory surgical center, inpatient, outpatient, or other unspecified facility) were also included.

Statistical analysis

SAS Enterprise Guide 7.1 (SAS Institute; Cary, NC) was used to prepare, manage, and analyze the data. Descriptive statistics were performed, including means and standard deviations (SDs) for all continuous variables and proportions for categorical variables. Analyses were performed for all TJR patients and separately for the 4 distinct surgical subgroups: (1) pTKR, (2) rTKR, (3) pTHR, and (4) rTHR. Multivariable logistic regression models were developed for both the overall population and each surgical subgroup to examine the effects of preoperative patient conditions (demographics and preexisting comorbid factors) and surgical characteristics (year and place of surgery) on the odds of SSI. Odd ratios (ORs), 95% confidence intervals (CIs), and *P* values were reported.

RESULTS

Patient characteristics

The study included a total of 498,681 patients who had a TJR, among whom 335,134 had knee and 163,547 had hip replacement surgery. For knee replacement procedures, pTKR (n = 320,648) and rTKR (n =14,486) represented 95.7% and 4.3% of total knee procedure volumes, respectively. Among hip replacement procedures, pTHR (n = 151,756) accounted for 92.8% and rTHR (n = 11,791) represented 7.2% of the THR sample.

Baseline patient and clinical characteristics are reported in Table 1. Mean ages (SD) in years were 64.5 (10.1) for pTKR, 66.0 (11.2) for rTKR, 63.1 (11.6) for pTHR, and 65.6 (13.5) for rTHR. Females accounted for 57.3% of the 4 groups combined. Of these procedures, 97.5% of pTKR, 98.1% of rTKR, 99.0% of pTHR, and 99.4% of rTHR were performed in inpatient settings of care. Total joint replacement procedures performed in outpatient settings, ambulatory surgery centers, and other unspecified facilities of care represented less than 2%.

Preoperative comorbid conditions by surgical group

Among patient-level factors, 34 preoperative comorbid conditions were identified; all TJR- as well as surgery-specific distributions are reported in Table 1. The 5 most frequently diagnosed comorbidities in all TJR patients were uncontrolled hypertension (59.9%), diabetes (20.5%), cardiac arrhythmia (14.9%), coagulopathy (14.8%), and hypothyroidism (14.6%). Other conditions, including depression, obesity, cardiac valvular disorders, cancer, osteoporosis, rheumatoid arthritis, smoking, peripheral vascular disease, cerebrovascular disorders, fluid and electrolyte disorders, complications of hypertension, chronic pulmonary disorders, congestive heart failure, deficiency anemia, renal failure, liver disorders, connective tissue disorders, myocardial infection, or weight loss, represented 1.0% to 11.0% of all TJR procedures.

Postoperative SSI rates

Higher rates of SSI were observed after revision TJR procedures as compared to primary TJR during the 90-day period after index surgery. SSI rates were 15.6% (2259/14,486) and 8.6% (1011/11,791) for patients who underwent rTKR and rTHR, respectively, compared to 2.1% (6830/320,648) and 2.1% (3202/151,756) after pTKR and pTHR, respectively. Figure 1 presents the SSI rates with standard errors.

Risk factors for all and specific total joint replacement procedures

Associations between risk factors and 90-day SSI after surgical procedures are reported in Table 2. In the multivariable logistic

Table 1
Baseline patient and clinical characteristics

	All procedures	pTKR	rTKR	pTHR	rTHR
Total, n	498,681	320,648	14,486	151,756	11,791
Demographics					
Age in years, mean (SD)	64.1 (10.7)	64.5 (10.1)	66.0 (11.2)	63.1 (11.6)	65.6 (13.5)
Female, %	57.3	60.1	57.7	51.8	53.7
Male, %	42.7	40.0	42.3	48.2	46.3
Source of admission, %					
Inpatient	98.0	97.5	98.1	99.0	99.4
Outpatient	1.4	1.8	1.6	0.6	0.5
Ambulatory surgery center	0.5	0.6	0.2	0.4	0.1
Unspecified facility	0.01	0.1	0.1	0.1	0.1
Year of TJR procedure, %					
2009	13.8	14.0	21.4	12.5	16.0
2010	13.7	14.0	15.23	12.9	14.3
2011	17.2	17.3	17.6	16.9	19.4
2012	18.6	18.5	16.9	19.1	18.5
2013	16.0	15.94	13.0	16.7	14.1
2014	15.8	15.6	12.4	16.7	14.0
2015	4.8	4.7	3.4	5.1	3.7
Comorbidity condition, %					
Uncontrolled hypertension	59.9	62.3	65.8	54.6	57.3
Diabetes	20.5	22.7	27.8	15.5	17.8
Cardiac arrhythmia	14.9	14.6	19.8	14.6	20.5
Coagulopathy	14.8	15.0	19.0	13.7	17.6
Hypothyroidism	14.6	15.3	15.7	13.1	14.6
Depression	11.3	11.5	14.5	10.5	13.8
Obesity	11.2	12.3	13.1	9.0	7.6
Valvular disorders	8.3	8.2	11.5	8.0	11.5
Cancer	8.1	7.9	9.6	8.3	10.2
Osteoporosis	8.1	7.0	9.8	8.5	14.4
Rheumatoid arthritis	7.6	7.1	10.6	8.3	11.8
Smoking	7.2	6.7	6.8	8.2	9.1
Peripheral vascular disease	6.8	6.6	9.5	6.7	9.5
Cerebrovascular disorders	6.2	6.2	8.6	5.8	9.2
Fluid electrolyte disorders	5.5	5.3	8.8	5.3	10.0
Hypertension complications	5.0	5.1	7.0	4.4	6.4
Chronic pulmonary disorders	4.6	4.6	7.1	4.2	7.5
Congestive heart failure	4.3	4.2	8.4	4.1	8.2
Deficiency anemia	4.3	4.3	6.9	3.9	6.4
Renal failure	3.9	3.9	6.6	3.6	6.3
Liver disorders	3.1	3.1	3.9	3.0	3.7
Connective tissue disorders	2.2	2.1	3.5	2.2	3.7
Myocardial infection	1.9	1.8	2.7	2.0	3.4
Weight loss	1.3	1.1	2.3	1.5	3.3
Peptic ulcer	1.0	1.0	1.5	1.0	1.1
Alcohol abuse	0.9	0.7	1.0	1.2	1.7
Drug abuse	0.8	0.7	1.5	0.9	1.8
Psychosis	0.7	0.7	1.4	0.7	1.7
Blood loss anemia	0.7	0.6	1.1	0.7	1.6
Lymphoma	0.6	0.5	0.8	0.7	1.2
Metastatic cancer	0.6	0.4	0.9	0.7	1.3
Dementia	0.3	0.3	0.8	0.3	1.5
Paralysis	0.3	0.2	0.6	0.3	0.7
Acquired immunodeficiency syndrome	0.1	0.1	0.1	0.3	0.2

pTHR, primary total hip replacement; *pTKR*, primary total knee replacement; *rTHR*, revision total hip replacement; *rTKR*, revision total knee replacement; *TJR*, total joint replacement; *SD*, standard deviation.

regression model performed on the entire TJR sample, risk factors that were found to be significantly associated with SSI were gender (female), preoperative comorbidities (acquired immunodeficiency syndrome [AIDS], paralysis, coagulopathy, metastatic cancer, congestive heart failure, alcohol abuse, dementia, obesity, chronic pulmonary disorders, lymphoma, fluid and electrolyte disorders, depression, psychosis, renal failure, deficiency anemia, smoking, blood loss anemia, diabetes, liver disorders, drug abuse, rheumatoid arthritis, peripheral vascular disease, uncontrolled hypertension, cardiac arrhythmia, connective tissue disorders, weight loss, cardiac valvular disorders, osteoporosis, or cerebrovascular disorders), and clinical factors (year of procedure, knee compared with hip, revision compared with primary procedure).

With regard to demographic characteristics, females had 17% lower adjusted odds of SSI compared to males ($OR_{adjusted} = 0.83$; 95% CI, 0.80-0.86; $P < .0001$). With regard to clinical factors, it was found that patients with rTJR had 5.76 times (95% CI, 5.52-6.02; $P < .0001$) higher adjusted odds of SSI as compared to those with primary total joint replacement. Also, patients with TKR procedures had 1.17 times (95% CI, 1.12-1.21; $P < .0001$) higher adjusted odds of SSI than those with THR procedures.

Figure 2A presents factors that were found to be statistically significantly associated with SSI during the 90 days after primary TKR procedures. The 5 top comorbidities that had statistically significant associations with SSI were AIDS (OR, 2.01; 95% CI, 1.02-3.95; $P = .043$), paralysis (OR, 1.62; 95% CI, 1.16-2.25; $P = .0044$), chronic pulmonary

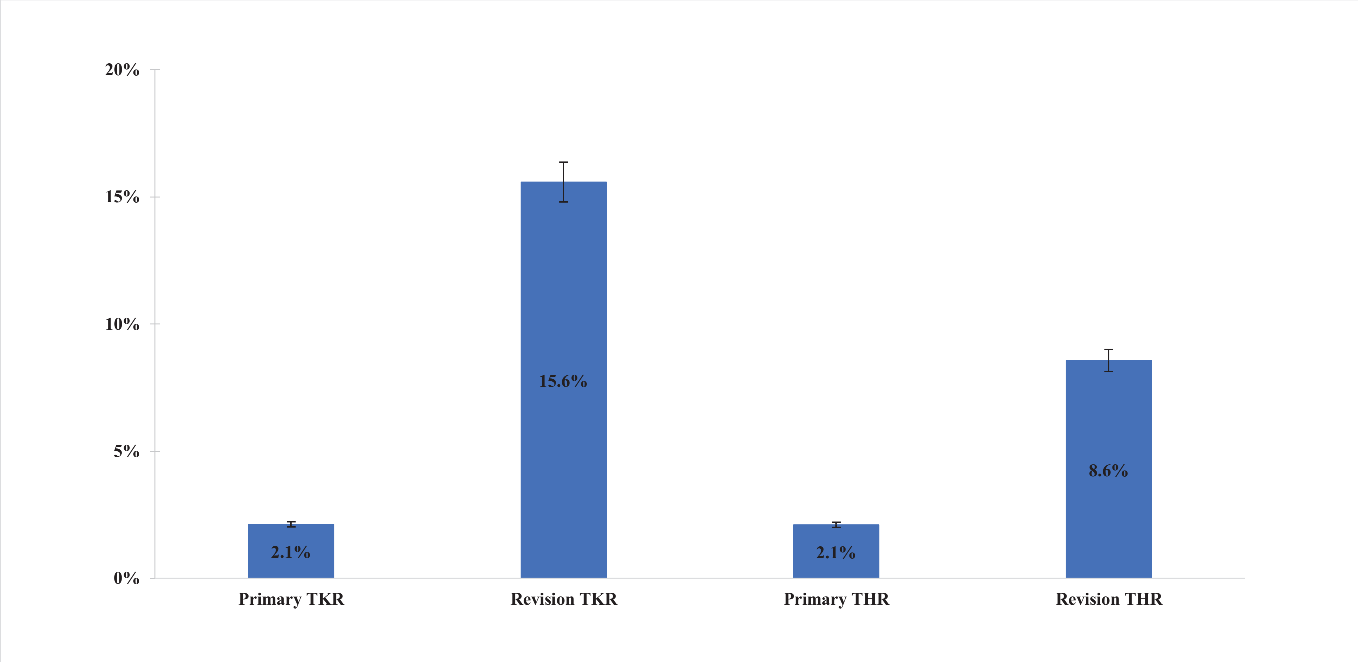

Fig 1. Surgical site infection rates within 90 days of surgery (± standard error) by type of surgery. *THR*, total hip replacement; *TKR*, total knee replacement.

disorders (OR, 1.45; 95% CI, 1.36-1.53; $P < .0001$), psychosis (OR, 1.44; 95% CI, 1.17-1.77; $P = .0005$), and coagulopathy (OR, 1.41; 95% CI, 1.24-1.61; $P < .0001$).

After rTKR (Fig 2B), the top 5 comorbidities with significant associations with SSI were AIDS (OR, 4.50; 95% CI, 1.20-6.85; $P = .0255$), dementia (OR, 2.15; 95% CI, 1.41-3.26; $P = .0003$), lymphoma (OR, 2.02; 95% CI, 1.31-3.13; $P = .0016$), metastatic cancer (OR, 1.79; 95% CI, 1.18-2.70; $P = .0061$), and connective tissue disorders (OR, 1.76; 95% CI, 1.29-2.38; $P = .0003$).

After pTHR (Fig 2c), paralysis (OR, 2.12; 95% CI, 1.47-3.06; $P < .0001$), alcohol abuse (OR, 1.58; 95% CI, 1.25-2.01; $P = .0002$), obesity (OR, 1.57; 95% CI, 1.42-1.74; $P < .0001$), diabetes (OR, 1.40; 95% CI, 1.28-1.52; $P < .0001$), and depression (OR, 1.39; 95% CI, 1.26-1.54; $P < .0001$) were the leading factors for increased risk of SSI. By contrast, after rTHR (Fig 2d), metastatic cancer (OR, 2.09; 95% CI, 1.33-3.29; $P = .0014$), congestive heart failure (OR, 1.95; 95% CI, 1.58-2.41; $P < .0001$), blood loss anemia (OR, 1.91; 95% CI, 1.31- 2.77; $P = .0008$), coagulopathy (OR, 1.73; 95% CI, 1.33-2.27; $P < .0001$), and weight loss (OR, 1.52; 95% CI, 1.13-2.04; $P = .0053$) were the leading factors for increased risk of SSI.

DISCUSSION

This study has shown that patient demographics, preexisting comorbid conditions, and clinical factors, including type of surgical procedure and anatomical site of treatment (hip or knee), were significantly associated with SSIs within 90 days of surgical procedures. SSI rates were highest among patients after revision procedures. Risk factors, including obesity, diabetes, congestive heart failure, coagulopathy, and fluid electrolyte disorders, were significantly associated with SSIs after all of the TJR procedures. Alcohol abuse (in pTKR, rTKR, and rTHR), chronic pulmonary disorder (in pTKR, rTKR, and pTHR), deficiency anemia (in pTKR, rTKR, and rTHR), uncontrolled hypertension (in pTKR, pTHR, and rTHR), metastatic cancer (in pTKR, rTHR, and rTKR), and peripheral vascular disease and renal failure (in pTKR, rTKR, and pTHR) were found to be statistically significant after each of the specific total replacement procedures listed.

Several studies have evaluated risk factors associated with the occurrence of SSI after TJR procedures. As in our study, patient-related and clinical characteristics have been recognized in many studies.[5,9,11,12,15,17-23] However, published studies do not reflect a consistent set of risk factors, may not distinguish primary from revision TJR, and adopt varying analytic methods. A quantitative comparison of our results relative to findings from existing publications is therefore challenging.

Our findings revealed that male patients were at a high risk of SSIs. This result aligns with findings from other studies.[7,14,23] However, future studies may be required to consider interactions among gender, physical activity, and socioeconomic status to further elucidate the relationship between gender and the risk of SSI after TJR. Underlying reasons for the statistical significance of procedure year as a predictor of SSI risk in our study cannot be ascertained without further investigation. Lower rates of infection in 2015 may have resulted from undetected temporal trends in patient characteristics, surgical techniques, technologies, and/or provider characteristics. Unknown or unmeasured procedural characteristics may also have influenced infection rates over time (eg, nature of fractures, quality of reduction, infection control practices).

It is well known that certain patient comorbid conditions increase the risk of SSI. We confirmed and quantified the effect of several comorbidities on SSI. Our results agree with existing reports that obesity,[8,24,25] diabetes,[5,26,27] congestive heart failure,[5,8,28,29] coagulopathy,[8,11,27,30,31] and fluid electrolyte disorders[11,32,33] are high risk factors for SSIs after all TJR procedures.

Bozic et al,[8] in a case-control study of pTHR patients, found that obesity significantly increased the risk of SSI (OR, 2.12; 95% CI, 1.08-4.16; $P = .023$). These results are similar to those observed in our study (OR, 1.35; 95% CI, 1.28-1.42; $P < .0001$). We found that diabetes significantly increased the risk of SSI during the 90-day period after TJR procedures (OR, 1.23; 95% CI, 1.18-1.28; $P < .0001$), and we also found specific effect size by type of procedure (Fig. 2A-D). Lai et al,[24] in a retrospective case-control study, reported that diabetes was associated with higher risk of SSI (OR, 3.91; 95% CI, 1.06-14.44; $P = .041$) in patients after primary hip or knee replacement procedures; however,

Table 2
Multivariable logistic regression model for overall TJR

Preoperative patient factors	Odds ratio	95% confidence interval		*P* value
Demographics				
Age	1.000	0.998	1.001	.619
Female	0.830	0.800	0.862	<.0001
Source of admission				
Inpatient versus other sources	1.066	0.929	1.223	.3637
Year of TJR procedure				
2009 versus 2015	1.401	1.27	1.546	<.0001
2010 versus 2015	1.27	1.15	1.402	<.0001
2011 versus 2015	1.196	1.085	1.318	.0003
2012 versus 2015	1.19	1.081	1.31	.0004
2013 versus 2015	1.169	1.06	1.289	.0017
2014 versus 2015	1.126	1.021	1.242	.0174
Surgical type				
Revision versus primary	5.762	5.519	6.017	<.0001
Anatomical site of TJR procedure				
Knee versus hip	1.167	1.123	1.213	<.0001
Comorbid conditions				
Acquired immunodeficiency syndrome	1.579	1.064	2.343	.0232
Paralysis	1.563	1.261	1.937	<.0001
Coagulopathy	1.480	1.357	1.616	<.0001
Metastatic cancer	1.477	1.242	1.757	<.0001
Congestive heart failure	1.389	1.299	1.485	<.0001
Alcohol abuse	1.387	1.209	1.592	<.0001
Dementia	1.354	1.114	1.644	.0023
Obesity	1.346	1.28	1.416	<.0001
Chronic pulmonary disorders	1.339	1.282	1.4	<.0001
Lymphoma	1.319	1.105	1.573	.0021
Fluid electrolyte disorders	1.313	1.234	1.397	<.0001
Depression	1.280	1.217	1.346	<.0001
Psychosis	1.277	1.106	1.474	.0008
Renal failure	1.272	1.181	1.369	<.0001
Deficiency anemia	1.265	1.179	1.357	<.0001
Smoking	1.247	1.174	1.325	<.0001
Blood loss anemia	1.233	1.056	1.44	.0082
Diabetes	1.232	1.182	1.283	<.0001
Liver disorders	1.231	1.133	1.338	<.0001
Drug abuse	1.2200	1.056	1.409	.0069
Rheumatoid arthritis	1.206	1.101	1.322	<.0001
Peripheral vascular disease	1.193	1.124	1.267	<.0001
Hypertension uncontrolled	1.179	1.133	1.227	<.0001
Cardiac arrhythmia	1.169	1.116	1.225	<.0001
Connective tissue disorders	1.156	1.034	1.292	.0105
Weight loss	1.128	1.003	1.269	.0437
Valvular disorders	1.124	1.062	1.19	<.0001
Osteoporosis	1.088	1.023	1.157	.0069
Cerebrovascular disorder	1.088	1.021	1.16	.0098
Peptic ulcer	1.067	0.92	1.236	.3908
Cancer	1.065	0.999	1.135	.0537
Myocardial infarction	1.050	0.946	1.164	.359
Hypothyroidism	0.999	0.951	1.050	.98
Hypertension complications	0.998	0.928	1.073	.9536

TJR, total joint replacement.

it is unclear if the authors of this study controlled for procedure type and anatomical site, factors that may have contributed to a wide confidence interval for this risk factor. Evehart et al[13] found similar results for the effect of diabetes (OR, 1.83; 95% CI, 1.02-3.27; $P = .048$) but did not report these separately by surgical subgroups.

In our study, it was found that congestive heart failure was associated with SSI (OR, 1.39; 95% CI, 1.30-1.49; $P < .0001$). The risk of SSI was similar after primary and revision TJR procedures (Fig. 2A-D). Our report agrees with that of Eka and Chen,[5] who, in a literature review, reported that congestive heart failure predisposes TJR patients to SSI. In a retrospective analysis accessing the association of medical comorbidities and the risk of 90-day post-TJR SSI and mortality, Bozic et al[34] reported that TKR patients with congestive heart failure had 1.28 times the adjusted risk of SSI (OR, 1.28; 95% CI, 1.13-1.46; $P < .0001$), which confirms our findings.

We found that patients with a coagulopathy were 1.48 times at risk for post-TJA SSI when compared to their counterparts without a coagulopathy (OR, 1.48; 95% CI, 1.36-1.62; $P < .0001$), which was consistent after specific TJR procedures. Poultsides et al[31] estimated a slightly higher magnitude of risk but an increased association (OR, 2.36; 95% CI, 1.99-2.79; $P < .0001$) with coagulopathy. It is unclear whether the authors evaluated the effect of coagulopathy across specific TJR procedures.

In our study, we found that patients with fluid and electrolyte disorders were at high risk of SSI, and we found a similar risk across primary and revision total knee and hip replacement procedures. Our result corroborates reports from a hospital-based study in which Poultsides et al[31] observed that patients with an imbalance of fluid and electrolytes had a 2.42 times (OR, 2.36; 95% CI, 2.21-2.65; $P < .0001$) higher risk of post-TJR SSI.

A number of authors have evaluated the respective effects of other comorbid conditions such as alcohol abuse, chronic pulmonary disorders, deficiency anemia, uncontrolled hypertension, metastatic cancer, peripheral vascular disease, and renal failure on SSI following TJR

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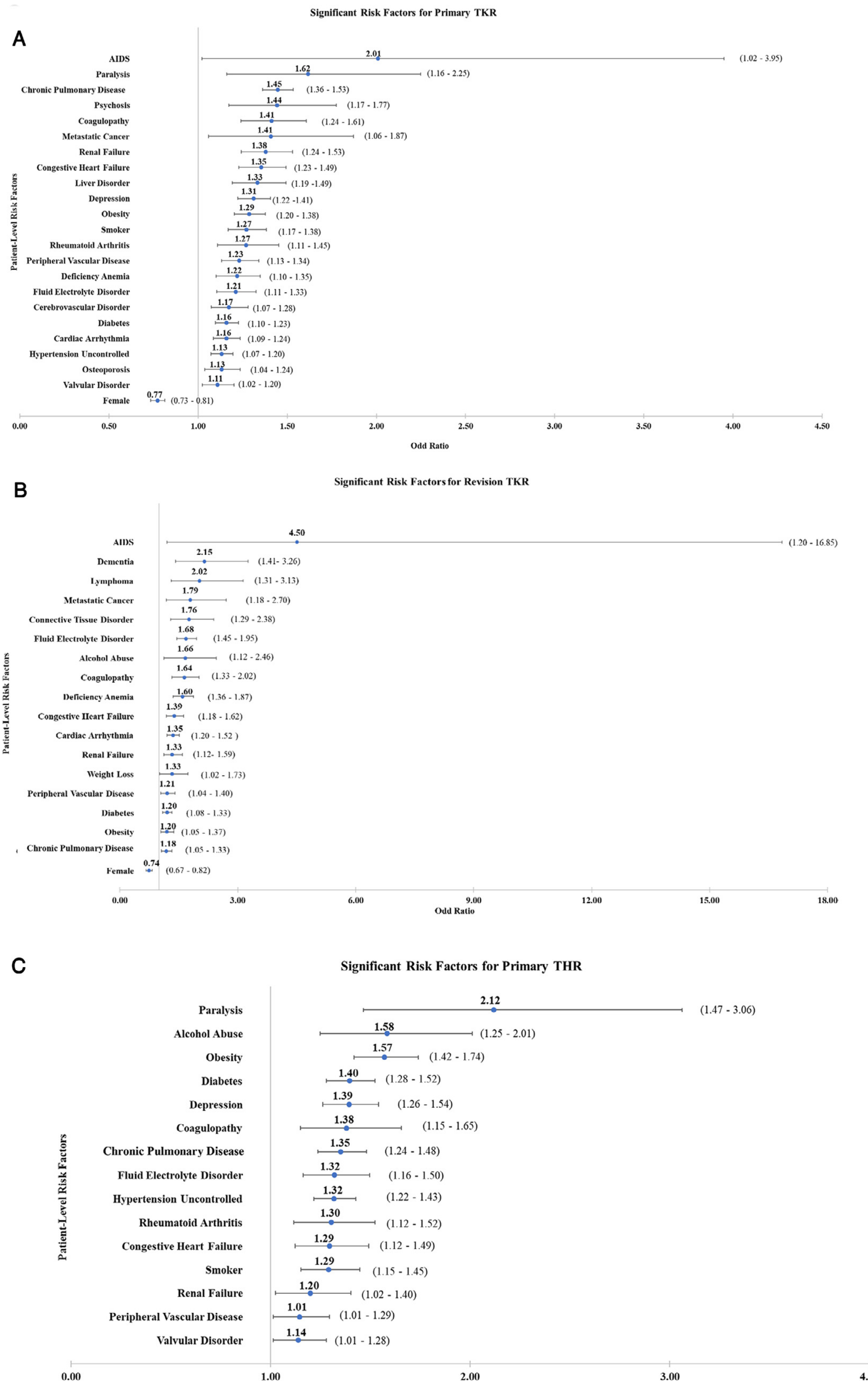

Fig 2. (A) Risk factors associated with surgical site infection (SSI) within 90 days of primary TKR. (B) Risk factors associated with SSI within 90 days of revision TKR. (C) Risk factors associated with SSI within 90 days of primary THR. (D) Risk factors associated with SSI within 90 days of revision THR. *THR*, total hip replacement; *TKR*, total knee replacement.

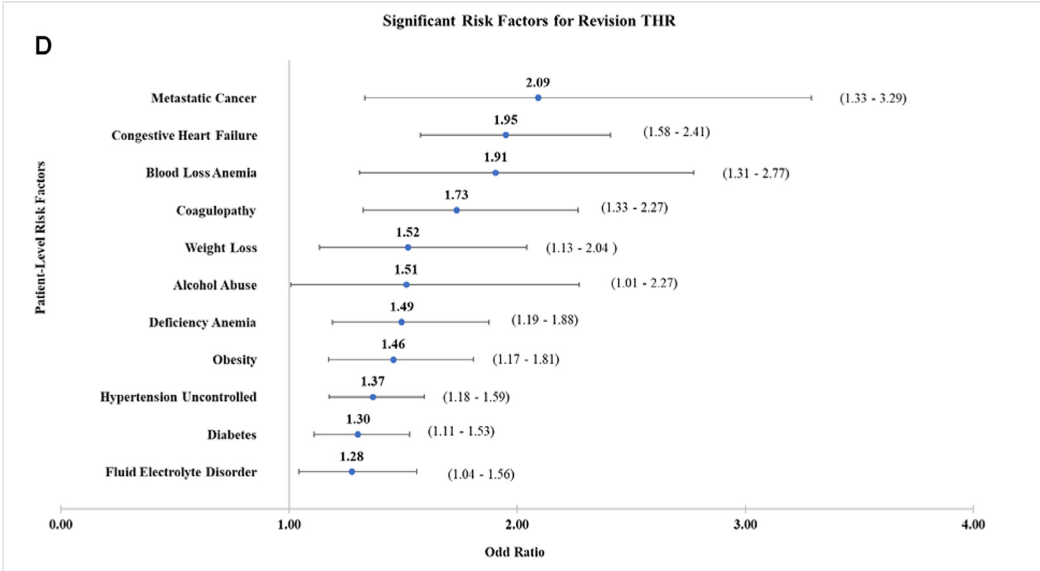

Fig 2 Continued.

procedures. We have found that patients with alcohol abuse are at higher risk of SSI following rTKR, pTHR, and rTHR but not after pTKR. This result aligns with findings by Bozic et al,[34] who reported no significant association between alcohol abuse and pTKR (OR, 1.14; 95% CI, 0.49-2.66; $P = .7569$). The authors did not report the effect on the other types of TJR procedures. When Grammatico et al[23] examined the impact after TJR, but not specific procedure type, they found a similar association (OR, 2.47; 95% CI, 1.67-3.63; $P < .001$) as we did in our study. Conversely, chronic pulmonary disorders,[9] deficiency anemia,[5,8,34] uncontrolled hypertension,[21,31] metastatic cancer,[34] peripheral vascular disease,[31,34] and renal failure[8,21,23] were evaluated in numerous studies and reported as increasing risk factors for SSI after TJR. The authors did not stratify the type of surgery, as we did in our study, but confirmed our findings with regard to these comorbidities in a broader perspective.

In this study, we found that patients after revision TJR procedures were at a 5.77 times higher risk of SSI than those after primary TJR. This result is consistent with results from several other studies[9,18,19] that have reported an increased risk after revision procedures.

Findings from a recently convened international consensus panel on orthopedic infections align well with those in this study. The panel concluded that risk factors for SSI after total joint arthroplasty include male sex, revision TJR, TKR versus THR, obesity, diabetes, congestive heart failure, alcohol abuse, chronic pulmonary disease, renal failure, anemia, peripheral vascular disease, AIDS, depression, psychosis, smoking, liver disorder, rheumatoid arthritis, cardiac arrhythmia, and cerebrovascular disease.[35]

Our study has several limitations. First, as with all retrospective, observational studies, causality cannot be inferred. Second, we were unable to control for potentially important factors, including physical function, socioeconomic status, and nutritional status. The exclusion of these and other potential predictive factors could impair the accuracy of our model estimates. Third, the use of large administrative databases inherently relies upon the accurate interpretation and completeness of information coded from clinical documentation. In particular, such databases likely lead to underestimation of patient conditions such as obesity and smoking history. Although the study showed diabetes to be a risk factor for SSI, the database did not contain information on pre-, intra-, and postoperative glucose control, which may influence outcomes. The SSI rates reported for the 4 surgical subgroups did not include risk adjustment (Fig 1); however, risk- adjusted ORs for SSI for revision versus primary procedures and knee versus hip procedures are presented (Table 2). Thirty-four patient-level preexisting conditions; demographic characteristics, including age and gender; and clinical factors, such as the year of TJR and place of service, were included in these risk-adjustment models. However, known risk factors including the American Society of Anesthesiologists classification of physical health score and operative time are unavailable in claims data and therefore could not be used for risk adjustment. Finally, the presence of SSI was identified based on ICD-9-CM diagnosis codes, without the availability of laboratory confirmation. Results have been mixed regarding the accuracy of ICD-9-CM diagnosis codes for SSI after various procedures.[36] However, administrative data using ICD-10-CM codes have shown reasonable test performance characteristics for the identification of complex SSIs after arthroplasty.[37] Future research using newer data with ICD-10 codes and laboratory confirmation is warranted to validate study findings.

The strengths of our study included the use of IBM MarketScan claim databases, which allow for longitudinal analyses of a nationally representative sample; thus, our findings are likely to be generalizable. Moreover, our multivariable analyses allowed us to control for potential confounders while establishing independent associations. Finally, the use of a large sample size allowed for a comprehensive evaluation within the 4 surgical subgroups.

CONCLUSIONS

Surgical site infection rates within 90 days of surgery were highest among patients following revision total joint replacement. Several comorbid risks, including obesity, diabetes, congestive heart failure, coagulopathy, and fluid and electrolyte disorders, were significantly associated with higher SSI rates after both primary and revision TJR procedures. Currently, 1 to 1.5 million total joint arthroplasties are performed yearly in the United States; that number is expected to increase to 4 to 4.5 million by the year 2030.[6,38] The incidence of periprosthetic joint infection, as defined by the Musculoskeletal Infection Society, ranges from 2.0% to 2.4%, suggesting that within the next 10 years we can expect to see approximately 80,000 to 90,000 new periprosthetic joint infections yearly, and 60% to 70% will be associated with total knee replacement. Although some authors have recently reported that the risk of periprosthetic joint infection has stabilized in selective patient populations, the burden of catastrophic comorbid disease in the Medicare patient population does not appear to have decreased and is likely to increase as demand for TJA increases over the next 10 years.[39,40] The fiscal impact of periprosthetic joint infections on the health care system is significant. Using a conservative projection based on current patient demographics and comorbid risks, one can estimate that by the year 2030 the cost to the health care system of managing 80,000 to 90,000 total joint infections could exceed $8 billion a year.

Knowledge of comorbid risk is essential to the development of effective evidence-based interventional strategies to improve patient outcomes. Other surgical disciplines, such as colorectal and obstetrics/gynecology, have developed effective surgical care bundles that upon implementation significantly improve patient outcomes.[41-43] The present investigation reflects the largest effort to date and identifies the number of comorbid risks in patients undergoing total joint replacement, both primary and revision. The challenge for the future will be the development of evidence-based surgical care bundles that focus on the peri-, intra-, and postoperative components of orthopedic patient care, especially in patients undergoing periprosthetic revision.

Acknowledgments

The authors thank Brian Po-Han Chen for his help in reviewing the manuscript.

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