Patient Risk Factors Do Not Impact 90-Day Readmission and Emergency Department Visitation After Total Ankle Arthroplasty

Implications for the Comprehensive Care for Joint Replacement (CJR) Bundled Payment Plan

Daniel Cunningham, MD, MHSc, Vasili Karas, MD, MS, James DeOrio, MD, James Nunley, MD, Mark Easley, MD, and Samuel Adams, MD

Investigation performed at Duke University, Durham, North Carolina

Background: The Comprehensive Care for Joint Replacement (CJR) model provides bundled payments for in-hospital care and care within 90 days following discharge for Medicare beneficiaries undergoing lower-extremity joint replacement involving the hip, knee, or ankle (total hip arthroplasty, total knee arthroplasty, or total ankle arthroplasty [TAA]). The study hypothesis was that patient comorbidities are associated with readmissions, emergency department (ED) utilization, and subspecialist wound-healing consultation, which are examples of costly contributors to postoperative health-care spending.

Methods: The medical records for 1,024 patients undergoing TAAs between June 2007 and December 2016 at a single academic center in the southeastern United States were reviewed for the outcomes of readmissions, ED visitations, and subspecialist wound-healing consultation within the 90-day post-discharge period. All patients undergoing TAA ($n = 1,365$) were eligible. Of the 1,037 patients who consented to participation in the study and underwent TAA, 1,024 (98.7%) completed the study. Medical comorbidities according to the Elixhauser and Charlson-Deyo comorbidity indices that were present prior to TAA were recorded. Univariate and multivariable tests of significance were used to relate patient and operative characteristics to outcomes.

Results: Four hundred and ninety-six (48.4%) of the 1,024 patients were female, and 964 (94.1%) were white/Caucasian, with an average age (and standard deviation) of 63 ± 10.5 years. Hypertension, obesity, solid tumor, depression, rheumatic disease, cardiac arrhythmia, hypothyroidism, diabetes mellitus, and chronic pulmonary disease had a prevalence of $>10\%$. Fifty-three (5.2%) of the 1,024 patients were readmitted for any cause. Thirty-six (3.5%) of the 1,024 returned to the ED but were not admitted to the hospital. Readmission or ED visitation was most commonly for a wound complication, followed by deep venous thrombosis (DVT) and pulmonary embolism (PE) evaluation, while urgent medical evaluations composed the majority of non-TAA-related ED visitations. No patient comorbidities were significantly associated with 90-day readmission, ED visitation, or wound complications in multivariable models.

Conclusions: Patient comorbidities were not associated with 90-day hospital readmissions or ED visitation for patients undergoing TAA. Readmissions were dominated by evaluation of wound compromise as well as DVT and PE. These data suggest that there may be considerable differences between TAA and total hip arthroplasty or total knee arthroplasty that cause surgeons to question the inclusion of TAA in CJR bundled payment models.

Level of Evidence: Prognostic Level IV. See Instructions for Authors for a complete description of levels of evidence.

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The Comprehensive Care for Joint Replacement (CJR) model provides bundled payments for in-hospital care and care within 90 days following discharge for U.S. Medicare beneficiaries undergoing lower-extremity joint replacement (total hip, knee, or ankle arthroplasty). The financial burden of perioperative adverse events among value-based care models is shifted to the provider and/or hospital system responsible for the episode of care. Although the timing and breadth of CJR implementation are in flux, private insurance is also shifting away from fee-for-service to value-based purchasing of episodes of care¹.

Readmissions, emergency department (ED) utilization, and subspecialist wound-healing consultation are examples of costly contributors to 90-day post-discharge spending. Total hip arthroplasty and total knee arthroplasty have been reported to have a 5.3% to 9.7% 90-day readmission rate associated with nonwhite race, male sex, increased body mass index (BMI), presence of >2 medical comorbidities, increased length of hospital stay, and discharge to inpatient rehabilitation²⁻⁴.

Comparatively little is known about factors that influence readmission rates after total ankle arthroplasty (TAA). Zaidi et al. reported a 30-day post-discharge readmission rate of 2.2% for primary TAA in the United Kingdom National Joint Registry, with approximately one-third of readmissions related to wound infection and one-quarter related to medical issues⁵. However, the relationship between 30-day readmissions and patient risk factors was not reported. Zhou et al. reported a 30-day readmission rate of 2.7% that was associated with male sex, history of community-acquired pneumonia, and increased comorbidity burden⁶. Additionally, LaMothe et al. reported a TAA 90-day readmission rate of 6.9% that was associated with increased length of stay following the index procedure and elevated Charlson-Deyo comorbidity index⁷. However, the specific risk factors contributing to readmission were not reported in these studies. With the convergence of increasing TAA utilization^{6,8}, patient comorbidity⁹, and value-based payment models, understanding risk factors specific to 90-day post-discharge readmission, ED utilization, and subspecialist wound-healing consultation is critical to refining patient-selection strategies and operative planning. The study hypothesis was that patient comorbidities are associated with readmissions, ED utilization, and subspecialist wound-healing consultation.

Materials and Methods

Study Design, Variables, and Data Sources

This study is part of an institutional review board-approved, single-center, prospective, observational study evaluating the functional outcome and satisfaction of patients undergoing TAA for tibiotalar osteoarthritis between June 13, 2007, and December 15, 2016 (ClinicalTrials.gov identifier: NCT01986244). In this study of prospectively enrolled patients, records were retrospectively reviewed to determine patient and operative factors associated with hospital readmission, ED visitation, and subspecialist wound-healing consultation within 90 days of discharge following the index procedure, consistent with the CJR bundled-payment plan time frame. Unplanned office visits alone did not

count toward the primary outcomes of readmission, ED visitation, and subspecialist wound-healing consultation. The minimum patient age was 18 years. Other than patient age, there were no exclusion criteria. Outcomes were recorded through a review of patient records and telephone calls and were further divided into TAA-related or non-TAA-related. This study was designed and reported in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) statement¹⁰.

Age was defined as the age at the time of the index operation. Sex was defined on the basis of patients' self-reported sex. Because of the high proportion of white race in the study population, race was defined in a binary fashion, as either white or nonwhite. BMI was defined in the standard fashion using patients' height and weight recorded before or as close to the index operation as possible. The American Society of Anesthesiologists (ASA) score was determined by reviewing records from the anesthesiology department. Smoking status was defined as active, prior, or never smoker. Prior surgery on the ipsilateral ankle was determined through a review of patient records. The involved ankle was noted as left, right, or bilateral. Some patients underwent replacement of both ankles, at separate operative dates. In these cases where medical comorbidities could have changed in the intervening time frame, operations were analyzed as if they had been performed on separate patients. The implant manufacturer was noted. Any additional procedure (removal of hardware, lateral ligament reconstruction, Achilles tendon lengthening, etc.), length of hospital stay, and complete 90-day post-discharge in-office follow-up were recorded.

The major comorbidity indices, Elixhauser¹¹ and Charlson-Deyo¹², were used to identify patient risk factors. These indices were developed to predict hospital length of stay, hospital charges, in-hospital death, and 1-year mortality. Elixhauser and Charlson-Deyo comorbidities were recorded using previously established diagnosis code sets¹³ that had been listed in patient records up to the date of surgery and supplemented with a review of records. The Charlson-Deyo comorbidity index was calculated in a manner previously described¹⁴. Briefly, the score is the sum of multiple key comorbidities. Higher scores indicate greater patient comorbidity. Certain comorbidities, such as metastatic cancer, have greater values (6 points) than other comorbidities, such as peripheral vascular disease (1 point), do. Finally, 1 additional point is added for each decade of life >40 years.

Missing Data

Since patients were routinely asked about their intervening medical care, such as readmission, ED visitation, and subspecialist wound-healing consultation, while in regular follow-up, patients with incomplete 90-day post-discharge follow-up may have had unreported episodes of care. To increase sensitivity to these potential unreported episodes of care, patients with incomplete in-office 90-day follow-up were contacted via telephone or e-mail to determine whether they had had a hospital readmission, ED visitation, or additional medical consultation within 90 days post-discharge. Length of hospital stay, BMI,

Study Enrollment Flow Diagram

Fig. 1

Consolidated Standards of Reporting Trials (CONSORT) flow diagram showing study enrollment.

ASA score, and smoking status could not be obtained for some patients because of inadequate patient records. In these cases, missing data are noted in the tables.

Bias

One potential source of bias included the use of comorbidity data that had been formally coded by the time of patients' index procedures. To reduce this bias and increase sensitivity to potential uncoded patient comorbidities, history and physical-examination notes, pre-anesthesia testing notes, and discharge summaries were reviewed for additional uncoded comorbidities. Additionally, all postoperative notes within 90 days post-discharge were closely reviewed for any record of readmission, ED visitation, or wound-healing consultation to the authors' institution or outside hospitals.

Statistical Analysis

Descriptive statistics, including means with standard deviations (SDs) or proportions and percentages, were displayed for baseline data. Continuous variables (age, BMI, ASA score, number of additional procedures, length of hospital stay, and Charlson-Deyo comorbidity index) were assessed for normality with use of the Shapiro-Wilk test. Age was the only continuous variable that was normally distributed. BMI was normally distributed after log-transformation; however, the other variables remained non-normally distributed despite log-transformation and square-root transformation. Comorbidity index, ASA score, and length of hospital stay in days were analyzed in a binary fashion to determine whether they were >2 . The number of additional procedures was analyzed in a binary fashion on the basis of whether there were any additional procedures. Univariate statistical analyses were first

performed to determine the relationship of patient and operative factors on each of the following binary outcomes: all-cause 90-day post-discharge readmission; 90-day readmission that would not be excluded from CJR bundled payments; any TAA-related readmission or ED visitation; and any wound complication necessitating readmission, ED visitation, or outpatient wound-healing consultation. Statistical tests on these categorical outcomes included chi-square analysis for categorical inputs and Student *t* tests for continuous inputs with use of JMP Pro (version 13.0.0; SAS Institute). *P* values of <0.05 were considered significant. Because none of the variables analyzed in transformed or binary fashion were statistically associated with outcomes, only the continuous results are shown. When >1 factor was significantly associated with 1 of the outcomes in univariate analysis, multivariable main-effect outcome models were constructed. On the basis of studies involving total hip arthroplasty and total knee arthroplasty, multivariable main effect models that incorporated age, sex, race, BMI, Charlson-Deyo comorbidity index, ASA score, any additional procedures at implantation, prior surgery, and current smoking were used to evaluate the effect of each comorbidity with $>3\%$ prevalence on all study outcomes.

Results

Of 1,365 TAAs performed at this institution during the study time period (June 13, 2007, to December 15, 2016), 1,037 TAA patients were enrolled in a prospective database collecting patient factors, operative variables, and outcomes. Of these 1,037 patients, 95% (986) returned to this institution for follow-up within and beyond the 90-day post-discharge time period. The remaining 51 patients either had no follow-up or had <90 -day post-discharge follow-up at our institution.

TABLE I Baseline Patient and Operative Characteristics

Patient or Operative Characteristic*	Mean $\pm$ SD or Proportion (%)
Age (yr)	63 $\pm$ 10.5
Female sex	496 (48.4%)
White race	964 (94.1%)
BMI (n = 1,003) (kg/m ²)	29.8 $\pm$ 5.7
ASA score (n = 1,000)	2.4 $\pm$ 0.5
Current smoking (n = 851)	35 (4.1%)
Prior ankle surgery	578 (56.4%)
Right ankle	557 (54.4%)
Any additional procedure at implantation	710 (69.3%)
No. of additional procedures at implantation	1.4 $\pm$ 1.4
Charlson-Deyo comorbidity index	3.1 $\pm$ 1.9
Infinity	129 (12.6%)
Inbone	394 (38.5%)
Salto Talaris	261 (25.5%)
STAR	254 (24.8%)
Length of stay (n = 1,023) (days)	1.4 $\pm$ 0.8
In-office follow-up <90 days post-discharge	38 (3.7%)
Hypertension, uncomplicated	601 (58.7%)
Obesity	278 (27.1%)
Solid tumor, without metastasis	245 (23.9%)
Depression	226 (22.1%)
Rheumatoid arthritis or collagen vascular diseases	205 (20.0%)
Cardiac arrhythmias	151 (14.7%)
Hypothyroidism	137 (13.4%)
Diabetes without chronic complication	130 (12.7%)
Chronic pulmonary disease	124 (12.1%)
Deficiency anemia	102 (10.0%)
Valvular disease	101 (9.9%)
Coagulopathy	71 (6.9%)
Peptic ulcer disease, excluding bleeding	52 (5.1%)
Cerebrovascular disease	52 (5.1%)
Other neurological disorders	46 (4.5%)
Peripheral vascular disorders	45 (4.4%)
Myocardial infarction	38 (3.7%)
Renal disease	35 (3.4%)
Fluid and electrolyte disorders	34 (3.3%)
Mild liver disease	28 (2.7%)
Congestive heart failure	27 (2.6%)
AIDS or HIV	2 (0.2%)
Alcohol abuse	21 (2.1%)
Psychoses	18 (1.8%)
Diabetes, complicated	11 (1.1%)
Pulmonary circulation disorders	8 (0.8%)
continued	

TABLE I (continued)

Patient or Operative Characteristic*	Mean $\pm$ SD or Proportion (%)
Lymphoma	6 (0.6%)
Hypertension, complicated	7 (0.7%)
Weight loss	7 (0.7%)
Blood-loss anemia	6 (0.6%)
Drug abuse	3 (0.3%)
Dementia	3 (0.3%)
Hemiplegia or paraplegia	2 (0.2%)
Metastatic solid tumor	2 (0.2%)
Paralysis	2 (0.2%)
Moderate or severe liver disease	1 (0.1%)
*Unless otherwise noted, n = 1,024 patients. BMI = body mass index, ASA = American Society of Anesthesiologists, STAR = Scandinavian Total Ankle Replacement, AIDS = acquired immunodeficiency syndrome, and HIV = human immunodeficiency virus.	

Patients with incomplete 90-day post-discharge follow-up were contacted to identify any readmission, ED visitation, and subspecialist wound-healing consultation. Of these 51 patients, 38 were successfully contacted, for a study population of 1,024 patients with complete 90-day follow-up. Figure 1 displays the Consolidated Standards of Reporting Trials (CONSORT) study-enrollment flow diagram.

Table I shows the demographics, operative characteristics, and comorbidities for the study population. Patients had a mean age of 63 years, a mean BMI of 29.8 kg/m², and a mean ASA score of 2.4. Forty-eight percent were female, 94% were white, and 4% were current smokers. Fifty-six percent had had prior ankle surgery. Inbone prostheses (I and II; Wright Medical Group) represented 38% of the implants, while Salto Talaris (Integra LifeSciences) and Scandinavian Total Ankle Replacement (STAR; Stryker) each represented approximately 25% of the implants. Infinity prostheses (Wright Medical Group) represented the remaining 13% of prostheses. Sixty-nine percent of patients had ≥ 1 additional procedure, such as removal of hardware, lateral ligament reconstruction, or Achilles tendon lengthening, performed at the time of TAA. The mean length of the hospital stay was 1.4 days. The mean Charlson-Deyo comorbidity index was 3.1 points. Uncomplicated hypertension was the most common comorbidity (59%), followed by obesity (27%), a solid tumor (24%), depression (22%), rheumatoid arthritis or collagen vascular disease (20%), cardiac arrhythmia (15%), hypothyroidism (13%), diabetes mellitus without chronic complication (13%), chronic pulmonary disease (12%), and deficiency anemia (10%). The remaining comorbidities had a prevalence of <10% in the study population.

Hospital Readmissions

Fifty-three patients (5.2%) were admitted to the hospital for any cause in the 90-day post-discharge period. Figure 2 shows

Fig. 2

All-cause 90-day post-discharge hospital readmissions divided into TAA-related and non-TAA-related causes. Several patients were readmitted on multiple separate occasions, and the total number of readmissions is listed below each category. DVT = deep venous thrombosis, and PE = pulmonary embolism.

Fig. 3

All-cause 90-day post-discharge ED visitation for patients without any subsequent readmission is divided into TAA-related and non-TAA-related causes. One patient visited the ED for both TAA-related and non-TAA-related reasons, so the total number of cause-specific ED visitations is greater than the total number of patients who had any 90-day post-discharge ED visitation without readmission ($n = 36$). Also, 1 patient had 2 TAA-related visits. The total number of visits is also displayed. DVT = deep venous thrombosis, and PE = pulmonary embolism.

the distribution of causes of admission for these patients. All readmissions were separated into TAA-related and non-TAA-related. Of these 53 patients with any readmission in the 90-day post-discharge period, 36 (68%) were readmitted for TAA-related causes. The most common cause for TAA-related re-

admission was a wound complication (often for irrigation and debridement, plastic-surgery coverage, and/or antibiotics). Other common TAA-related readmissions were for deep venous thrombosis or pulmonary embolism work-up, hardware complications (periprosthetic fracture, revision following nonunion, or removal of hardware associated with pain), and pain control.

Non-TAA-related readmissions were further split into planned and unplanned. Planned readmissions in this series were exclusively composed of elective orthopaedic procedures, while unplanned readmissions were related to urgent general surgical or medical causes, such as cholecystitis, acute coronary syndrome, and pneumonia. Some patients were readmitted for multiple separate causes within the 90 days following discharge. For this reason, the TAA-related and non-TAA-related readmissions total 54 (as compared with 53) and the TAA-related causes total 42 (as compared with 37).

Emergency Department Visitation Not Necessitating Readmission

Thirty-six patients (3.5%) returned to the ED for management but were not admitted to the hospital (Fig. 3). Twenty-seven (75%) of these patients made ED visits that were TAA-related. Deep venous thrombosis and pulmonary embolism work-up dominated the causes of TAA-related ED visitation, although wound complications were also prevalent. One patient declined to come to the clinic for a regularly scheduled follow-up visit, for unclear reasons, and was evaluated in the ED.

Fig. 4

Breakdown of readmissions, ED visitations, and subspecialist consultation for wound-healing complications ($n = 56$). To avoid double-counting patients, only the highest level of care for each patient within 90 days post-discharge was noted on the figure. For example, a patient may have been followed by the division of plastic surgery on an outpatient basis for delayed wound-healing, been evaluated in the ED as part of an admission work-up, and then been admitted for operative management of the wound. In cases such as these, the patient would only be counted in the readmission category.

TABLE II Results of Multivariable Significance Testing with Models That Incorporated Age, Sex, Race, BMI, ASA Score, Prior Surgery, Any Additional Procedures at Implantation, and Length of Stay for Patients with Complete Data on Each of Those Metrics *

Comorbidity	90-Day Readmission			90-Day CJR Readmission			TAA-Related Readmission or ED Visit			Wound Complication		
	Yes (N = 53)	No (N = 934)	P Value†	Yes (N = 45)	No (N = 942)	P Value†	Yes (N = 64)	No (N = 923)	P Value†	Yes (N = 56)	No (N = 931)	P Value†
Hypertension, uncomplicated	28 (52.8%)	561 (60.1%)	0.22	24 (53.3%)	565 (60.0%)	0.25	37 (57.8%)	552 (59.8%)	0.53	32 (57.1%)	557 (59.8%)	0.91
Obesity	13 (24.5%)	264 (28.3%)	0.99	11 (24.4%)	266 (28.2%)	0.93	21 (32.8%)	256 (27.7%)	0.40	18 (32.1%)	259 (27.8%)	0.28
Solid tumor, without metastasis	13 (24.5%)	227 (24.3%)	0.66	11 (24.4%)	229 (24.3%)	0.85	15 (23.4%)	225 (24.4%)	0.31	12 (21.4%)	228 (24.5%)	0.21
Depression	11 (20.8%)	207 (22.2%)	0.58	9 (20.0%)	209 (22.2%)	0.53	17 (26.6%)	201 (21.8%)	0.50	14 (25.0%)	204 (21.9%)	0.94
Rheumatoid arthritis or collagen vascular diseases	13 (24.5%)	184 (19.7%)	0.69	10 (22.2%)	187 (19.9%)	0.93	14 (21.9%)	183 (19.8%)	0.92	17 (30.4%)	180 (19.3%)	0.112
Cardiac arrhythmias	10 (18.9%)	134 (14.3%)	0.60	8 (17.8%)	136 (14.4%)	0.82	11 (17.2%)	133 (14.4%)	0.67	10 (17.9%)	134 (14.4%)	0.46
Hypothyroidism	7 (13.2%)	126 (13.5%)	0.80	5 (11.1%)	128 (13.6%)	0.47	7 (10.9%)	126 (13.7%)	0.51	6 (10.7%)	127 (13.6%)	0.57
Diabetes, without chronic complication	4 (7.5%)	123 (13.2%)	0.16	3 (6.7%)	124 (13.2%)	0.141	7 (10.9%)	120 (13.0%)	0.30	4 (7.1%)	123 (13.2%)	0.102
Chronic pulmonary disease	7 (13.2%)	110 (11.8%)	0.87	6 (13.3%)	111 (11.8%)	0.80	11 (17.2%)	106 (11.5%)	0.33	7 (12.5%)	110 (11.8%)	0.80
Valvular disease	3 (5.7%)	98 (10.5%)	0.11	3 (6.7%)	98 (10.4%)	0.20	6 (9.4%)	95 (10.3%)	0.55	8 (14.3%)	93 (10.0%)	0.47
Deficiency anemia	7 (13.2%)	90 (9.6%)	0.68	7 (15.6%)	90 (9.6%)	0.35	7 (10.9%)	90 (9.8%)	0.83	4 (7.1%)	93 (10.0%)	0.32
Coagulopathy	4 (7.5%)	66 (7.1%)	0.96	4 (8.9%)	66 (7.0%)	0.78	5 (7.8%)	65 (7.0%)	0.93	3 (5.4%)	67 (7.2%)	0.58
Cerebrovascular disease	3 (5.7%)	49 (5.2%)	0.74	1 (2.2%)	51 (5.4%)	0.22	4 (6.3%)	48 (5.2%)	0.89	6 (10.7%)	46 (4.9%)	0.15
Peptic ulcer disease, excluding bleeding	3 (5.7%)	48 (5.1%)	0.98	2 (4.4%)	49 (5.2%)	0.75	4 (6.3%)	47 (5.1%)	0.89	1 (1.8%)	50 (5.4%)	0.21
Other neurological disorders	3 (5.7%)	43 (4.6%)	0.81	2 (4.4%)	44 (4.7%)	0.86	3 (4.7%)	43 (4.7%)	0.86	4 (7.1%)	42 (4.5%)	0.45
Peripheral vascular disorders	3 (5.7%)	41 (4.4%)	0.95	3 (6.7%)	41 (4.4%)	0.64	5 (7.8%)	39 (4.2%)	0.33	5 (8.9%)	39 (4.2%)	0.165
Myocardial infarction	1 (1.9%)	34 (3.6%)	0.32	1 (2.2%)	34 (3.6%)	0.45	1 (1.6%)	34 (3.7%)	0.23	2 (3.6%)	33 (3.5%)	0.67
Renal disease	4 (7.5%)	28 (3.0%)	0.085	3 (6.7%)	29 (3.1%)	0.166	5 (7.8%)	27 (2.9%)	0.10	3 (5.4%)	29 (3.1%)	0.50
Fluid and electrolyte disorders	1 (1.9%)	31 (3.3%)	0.39	1 (2.2%)	31 (3.3%)	0.54	2 (3.1%)	30 (3.3%)	0.70	2 (3.6%)	30 (3.2%)	0.85

*N = 987 of 1,024 eligible patients. ED = emergency department. †A p value of <0.05 indicates significance.

Urgent medical evaluations made up the bulk of non-TAA-related ED visits without any subsequent 90-day post-discharge readmission.

Wound Complications

Wound complications included concern for infection or delayed healing. Readmissions for wound complications were dominated by the need for assisted wound closure in the setting of presumed infection or delayed wound-healing. Similarly, 7 patients had removal or exchange of hardware following a periprosthetic infection. Notably, 1 patient needed a below-

the-knee amputation secondary to infection. The plastic-surgery division was consulted for outpatient management of wounds in 21 patients. Six patients presented for evaluation at the ED for infection concerns relating to a wound involving the operative ankle. One patient presented at the ED for cellulitis at the tibial tubercle guide-pin site (Fig. 4).

Association Between Patient and Operative Factors and Outcomes

As shown in Tables II and III, there were no significant associations between individual comorbidities that had a prevalence

TABLE III Results of Multivariable Significance Testing with Models That Incorporated Age, Sex, Race, BMI, ASA Score, Prior Surgery, Any Additional Procedures at Implantation, Length of Hospital Stay, and Current Smoking for Patients with Complete Data on Each of Those Metrics*

Comorbidity	90-Day Readmission			90-Day CJR Readmission			TAA-Related Readmission or ED Visit			Wound Complication		
	Yes (N = 46)	No (N = 787)	P Value†	Yes (N = 38)	No (N = 795)	P Value†	Yes (N = 53)	No (N = 780)	P Value†	Yes (N = 46)	No (N = 787)	P Value†
Hypertension, uncomplicated	23 (50%)	469 (59.6%)	0.064	19 (50%)	473 (59.5%)	0.072	31 (58.5%)	461 (59.1%)	0.39	25 (54.3%)	467 (59.3%)	0.60
Obesity	12 (26.1%)	221 (28.1%)	0.95	10 (26.3%)	223 (28.1%)	0.96	19 (35.8%)	214 (27.4%)	0.39	16 (34.8%)	217 (27.6%)	0.30
Solid tumor, without metastasis	11 (23.9%)	184 (23.4%)	0.52	9 (23.7%)	186 (23.4%)	0.64	11 (20.8%)	184 (23.6%)	0.144	9 (19.6%)	186 (23.6%)	0.12
Depression	11 (23.9%)	174 (22.1%)	0.96	9 (23.7%)	176 (22.1%)	0.98	17 (32.1%)	168 (21.5%)	0.109	14 (30.4%)	171 (21.7%)	0.45
Rheumatoid arthritis or collagen vascular diseases	12 (26.1%)	161 (20.5%)	0.69	9 (23.7%)	164 (20.6%)	0.91	12 (22.6%)	161 (20.6%)	0.96	15 (32.6%)	158 (20.1%)	0.076
Cardiac arrhythmias	9 (19.6%)	120 (15.2%)	0.78	7 (18.4%)	122 (15.3%)	0.99	9 (17%)	120 (15.4%)	0.94	8 (17.4%)	121 (15.4%)	0.72
Hypothyroidism	7 (15.2%)	107 (13.6%)	0.95	5 (13.2%)	109 (13.7%)	0.69	5 (9.4%)	109 (14%)	0.23	5 (10.9%)	109 (13.9%)	0.47
Diabetes, without chronic complication	4 (8.7%)	109 (13.9%)	0.15	3 (7.9%)	110 (13.8%)	0.135	7 (13.2%)	106 (13.6%)	0.35	4 (8.7%)	109 (13.9%)	0.159
Chronic pulmonary disease	7 (15.2%)	94 (11.9%)	0.68	6 (15.8%)	95 (11.9%)	0.59	11 (20.8%)	90 (11.5%)	0.14	7 (15.2%)	94 (11.9%)	0.93
Valvular disease	2 (4.3%)	83 (10.5%)	0.072	2 (5.3%)	83 (10.4%)	0.136	4 (7.5%)	81 (10.4%)	0.29	6 (13%)	79 (10%)	0.78
Deficiency anemia	7 (15.2%)	75 (9.5%)	0.39	7 (18.4%)	75 (9.4%)	0.138	7 (13.2%)	75 (9.6%)	0.41	4 (8.7%)	78 (9.9%)	0.6
Coagulopathy	4 (8.7%)	60 (7.6%)	0.94	4 (10.5%)	60 (7.5%)	0.73	5 (9.4%)	59 (7.6%)	0.87	3 (6.5%)	61 (7.8%)	0.72
Cerebrovascular disease	3 (6.5%)	42 (5.3%)	0.82	1 (2.6%)	44 (5.5%)	0.25	4 (7.5%)	41 (5.3%)	0.89	6 (13%)	39 (5%)	0.069
Peptic ulcer disease, excluding bleeding	3 (6.5%)	43 (5.5%)	0.99	2 (5.3%)	44 (5.5%)	0.77	4 (7.5%)	42 (5.4%)	0.79	1 (2.2%)	45 (5.7%)	0.24
Other neurological disorders	3 (6.5%)	38 (4.8%)	0.71	2 (5.3%)	39 (4.9%)	0.98	3 (5.7%)	38 (4.9%)	0.96	4 (8.7%)	37 (4.7%)	0.27
Peripheral vascular disorders	3 (6.5%)	35 (4.4%)	0.90	3 (7.9%)	35 (4.4%)	0.59	4 (7.5%)	34 (4.4%)	0.60	4 (8.7%)	34 (4.3%)	0.38
Myocardial infarction	1 (2.2%)	23 (2.9%)	0.56	1 (2.6%)	23 (2.9%)	0.74	1 (1.9%)	23 (2.9%)	0.42	2 (4.3%)	22 (2.8%)	0.97
Renal disease	4 (8.7%)	27 (3.4%)	0.183	3 (7.9%)	28 (3.5%)	0.30	5 (9.4%)	26 (3.3%)	0.132	3 (6.5%)	28 (3.6%)	0.47
Fluid and electrolyte disorders	1 (2.2%)	27 (3.4%)	0.38	1 (2.6%)	27 (3.4%)	0.53	2 (3.8%)	26 (3.3%)	0.75	2 (4.3%)	26 (3.3%)	0.88

*N = 833 of 1,024 eligible patients. ED = emergency department. †A p value of <0.05 indicates significance.

of >3% and the outcomes of all-cause 90-day readmission, CJR-included readmission, TAA-related ED visitation or readmission, or wound complications in multivariable main-effect models that incorporated baseline and operative factors. Table III includes current smoking in the multivariable analyses.

Univariate analyses are shown in Tables E-1 through E-4 in the Appendix. The presence of congestive heart failure (10.7% with wound complication versus 2.2% without wound complication; $p = 0.003$) and absence of peptic ulcer disease

(0% with wound complication versus 5.1% without wound complication; $p = 0.017$) were each associated with wound complications in univariate analysis while the presence of drug abuse (3.1% with wound complication versus 0.1% without wound complication; $p = 0.006$) was associated with TAA-related readmissions or ED visitation. Several comorbidities had a higher prevalence in the group with wound complications, although the differences in comorbidity prevalence did not reach significance: peripheral vascular disease

(8.9% versus 3.6%), cerebrovascular disease (10.7% versus 4.8%), or rheumatic diseases (30.4% versus 19.4%). Interestingly, uncomplicated diabetes mellitus had a lower prevalence in patients who had wound complications (7.1%) compared with patients who did not have wound complications (13.0%), although this difference was not significant.

Discussion

In an evolving era of value-based payment plans, understanding root causes of health-care overspending in the perioperative time period is becoming important to orthopaedic surgeons. To our knowledge, this is the first study to attempt to identify risk factors leading to 90-day hospital readmission and ED visitation among patients undergoing TAA. In our series with 1,024 TAA patients, the 90-day post-discharge readmission rate was 5.2%. Of these readmissions, TAA-related readmissions totaled 3.5% of patients while 4.4% had a readmission that would count toward the bundle. Although LaMothe et al. and Zhou et al. determined that higher Charlson-Deyo comorbidity index and increased length of hospital stay were associated with 90-day readmission, neither of these factors were significantly associated with any of our study outcomes^{6,7}. The current study further analyzed specific comorbidities and determined that none of the Elixhauser and Charlson-Deyo comorbidities were significantly associated with the outcomes of all-cause 90-day post-discharge readmission, TAA-related 90-day post-discharge readmission and ED visitation, or CJR-included readmissions in univariate or multivariable analysis.

Wound complications made up the largest percentage of TAA-related readmissions, and 5.5% of patients had a wound complication necessitating readmission, ED visitation, or outpatient wound-healing consultation. These findings are consistent with the findings of Zaidi et al., who determined that approximately one-third of 30-day readmissions were related to wound infection⁵. Work-up for deep venous thrombosis and pulmonary embolism was the second most common reason for ED visitation. While diabetes, rheumatic disease, history of smoking, and prior surgery have been previously associated with wound complications after total knee arthroplasty¹⁵, only the presence of congestive heart failure and absence of peptic ulcer disease were significantly associated with an increased rate of wound complications in univariate analysis, and no comorbidities with >3% prevalence were significantly associated with wound complications in multivariable models adjusted for baseline and operative factors.

Although there is a plausible link between congestive heart failure and poor wound-healing related to decreased tissue oxygenation¹⁶, a biological link between the absence of peptic ulcer disease and wound complications is less clear. Other vascular risk factors were 2 to 3 times more common among patients with wound complications, but the differences were not significant. Surprisingly, diabetes was underrepresented among patients who had wound complications when compared with patients who did not have wound complications.

This study had limitations. First, hospital readmissions, ED visits, and wound complications were viewed as surrogates for costly post-discharge care. Decisions guiding patient readmission, ED visitation, and subspecialist wound consultation reflect institutional norms that may or may not be replicated in other practice settings. Further, there are other factors that likely contribute considerably to bundled-payment costs, such as in-hospital care and discharge disposition, which this study did not analyze. Cost data could further highlight any potential relationships between patient and operative factors and costly outcomes. Second, although records were reviewed for readmissions, ED visits, and wound-healing consultations, there may have been unreported episodes of care. This underreporting could lead to inappropriately low estimates of complications and reduced power. Further, 51 of the 1,024 patients had incomplete 90-day postoperative follow-up and were asked to recall whether they had had any hospital readmission, ED visitation, or subspecialist wound consultation. This type of data collection exposes the study to recall bias. A further limitation of this study is that we included patients regardless of payer status and implant type. This reduces the ability to directly apply the results of this study to patients eligible for CJR, since implant type and payer status may be different. However, 519 (50.7%) of the 1,024 patients were ≥65 years old, and all patients received modern, third-generation TAA components. Lastly, although to our knowledge this is the largest single-institution study to date to analyze the relationship between specific patient and operative factors and clinically relevant 90-day post-discharge outcomes, the overall complication rate was relatively low, which limits power to detect small changes in outcomes.

In conclusion, this large series of TAAs demonstrates that patient and operative characteristics were not clearly linked to 90-day hospital readmissions, ED visits, or wound complications. Modulating TAA bundled payments on the basis of comorbidities associated with total hip arthroplasty and total knee arthroplasty may not be advisable. While questions remain surrounding the timing and scope of implementing a bundled payment model, this study demonstrates that wound complications and concern for deep venous thrombosis and pulmonary embolism were the most common reasons for 90-day hospital readmission and ED visitation after TAA. Advancements in wound-healing therapies and prevention of, and screening for, deep venous thrombosis and pulmonary embolism could be important targets for improving value-based care.

Appendix

eA Tables showing associations between all-cause 90-day post-discharge readmission and baseline, operative, and patient characteristics and comorbidities; 90-day non-excluded CJR readmissions and baseline, operative, and patient characteristics and comorbidities; TAA-related 90-day post-discharge readmission or ED visitation and baseline, operative, and patient characteristics; and wound complications necessitating readmission, ED visitation, or wound-healing consultation and baseline, operative, and patient characteristics and comorbidities

are available with the online version of this article as a data supplement at jbj.org (<http://links.lww.com/JBJS/E826>). ■

Daniel Cunningham, MD, MHSc¹
Vasili Karas, MD, MS²
James DeOrio, MD¹
James Nunley, MD¹
Mark Easley, MD¹
Samuel Adams, MD¹

¹Department of Orthopaedic Surgery, Duke University, Durham, North Carolina

²Department of Orthopaedic Surgery, Rush University Medical Center, Chicago, Illinois

ORCID iD for D. Cunningham: [0000-0003-4192-4202](https://orcid.org/0000-0003-4192-4202)

ORCID iD for V. Karas: [0000-0003-4464-1179](https://orcid.org/0000-0003-4464-1179)

ORCID iD for J. DeOrio: [0000-0003-1231-8203](https://orcid.org/0000-0003-1231-8203)

ORCID iD for J. Nunley: [0000-0002-3825-7536](https://orcid.org/0000-0002-3825-7536)

ORCID iD for M. Easley: [0000-0003-2995-3908](https://orcid.org/0000-0003-2995-3908)

ORCID iD for S. Adams: [0000-0003-1020-1167](https://orcid.org/0000-0003-1020-1167)

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