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# Cardiovascular Disease in Total Knee Arthroplasty: An Analysis of Hospital Outcomes, Complications, and Mortality

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**Background:** Cardiovascular comorbidities have been identified as a significant risk factor for adverse outcomes following surgery. The purpose of this study was to investigate its prevalence and impact on postoperative outcomes, hospital metrics, and mortality in patients undergoing total knee arthroplasty (TKA). Our hypothesis was that patients with cardiovascular comorbidities would have worse outcomes, greater postoperative complication rates, and increased mortality compared to patients without cardiovascular disease.

**Methods:** In this retrospective study, data from the National Inpatient Sample database from 2011 to 2020 were queried for patients who underwent TKA with preexisting cardiac comorbidities, including congestive heart failure (CHF), coronary artery disease (CAD), valvular dysfunction, and arrhythmia. Multivariate logistic regression analyses compared hospital metrics (length of stay, costs, and adverse discharge disposition), postoperative complications, and mortality rates while adjusting for demographic and clinical variables. All statistical analyses were performed using R studio 4.2.2 and Stata MP 17 and 18 with Python package.

**Results:** A total of 385,585 patients were identified. Those with preexisting CHF, CAD, valvular dysfunction, or arrhythmias were found to be older and at higher risk of adverse outcomes, including prolonged length of stay, increased hospital charges, and increased mortality ($p < 0.001$). Additionally, all preexisting cardiac diagnoses led to an increased risk of postoperative myocardial infarction, acute kidney injury (AKI), and need for transfusion ($p < 0.001$). The presence of valvular dysfunction, arrhythmia, or CHF was associated with an increased risk of thromboembolic events ($p < 0.001$). The presence of CAD and valvular dysfunction was associated with an increased risk of urologic infection ($p < 0.001$).

**Conclusions:** This study demonstrated that CHF, CAD, valvular dysfunction, and arrhythmia are prevalent among TKA patients and associated with worse hospital metrics, higher risk of perioperative complications, and increased mortality. As our use of TKA rises, a lower threshold for preoperative cardiology referral in older individuals and early preoperative counseling/intervention in those with known cardiac disease may be necessary to reduce adverse outcomes.

**Keywords:** *Knee, Arthroplasty, Complications, Risk stratification, Cardiology*

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Total knee arthroplasty (TKA) is an effective intervention for knee arthritis and significantly improves function and quality of life.[1] The number of TKAs performed annually has been projected to rise by 673% from 2005 to 2030.[2] As the use of TKA expands, increased efforts have been made to identify risk factors associated with adverse out-

comes.[3,4] Cardiovascular disease is the leading cause of global mortality and is identified as a significant risk factor for adverse outcomes in patients undergoing surgery.[3,4] Specifically for TKA, preexisting cardiac disease is noted as a risk factor for postoperative cardiac and thromboembolic events, and subsequently a higher risk of readmission and mortality.[4-6] Additionally, heart failure has been associated with an increased risk of prolonged length of stay (LOS), readmission, and postoperative complications following TKA.[4] Despite these findings, our understanding of the role of cardiovascular disease in TKA is limited.[3-7] The nomenclature used for the designation of a cardiac diagnosis is inconsistent in the literature, which may draw our understanding of its epidemiology into question.[3-7] At present, there are no studies that utilize multivariate analysis to assess the influence of other prevalent cardiac diseases such as coronary artery disease (CAD), valvular dysfunction, or arrhythmias on outcomes following TKA. Understanding the impact of cardiac comorbidities on TKA outcomes is essential for the optimization of postoperative outcomes and reduction of complications. It is also important to identify if specific cardiac conditions predispose patients to poorer outcomes and increased perioperative risk. Doing so may help achieve more accurate risk assessments and guide optimization measures before TKA. The aim of this study was to determine the prevalence of cardiac diseases (congestive heart failure [CHF], CAD, valvular dysfunction, and arrhythmias) in a large TKA cohort and to assess the effects of these specific comorbidities on perioperative hospital metrics (i.e., LOS, costs, and adverse discharge disposition), mortality, and postoperative complications. It was hypothesized that (1) cardiac disease would be prevalent in patients undergoing TKA and (2) its presence would lead to an increased risk of adverse outcomes, including prolonged stay, increased mortality, and increased medical/surgical complications.

## METHODS

Data extracted from National Inpatient Sample (NIS) are not linked to any patient identifiers. This study was deemed exempt from full Institutional Review Board review by the University of Texas Health Science Center at San Antonio (HSC20150408N). The data set used and analyzed during the current study are available in the National Inpatient Sample database between 2011 and 2020.

### Study Design and Variables

The patient cohort was extracted from the NIS database (2011–2020), which includes a 20% stratified sample of discharges from community hospitals in the United States. A total of 385,585 patients were identified. Inclusion criteria were those who underwent TKA based on current procedural terminology procedure codes and were diagnosed with cardiac disease based on International Classification of Diseases, 10th Revision (ICD-10) codes (Fig. 1). Cardiovascular disease encompasses many diagnoses. Each diagnosis group in this study (CHF, CAD, valvular dysfunction, and arrhythmia) encompassed multiple specific diagnoses (i.e., arrhythmia encompasses atrial fibrillation, atrial flutter, and sinus tachycardia). The decision to focus on these diagnosis groups is based on reference to prior orthopedic studies and global health data demonstrating that they constitute the majority of all cardiac diseases.[4-8] Exclusion criteria included those with a history of TKA before admission. Data on patient demographics, including age, sex, race, payer status, hospital location, and patient comorbidities were obtained.[3,5-7,9,10] Hospital variables including LOS, total charges, and discharge disposition were obtained.[9-15] Lastly, perioperative complications were collected.[3-8,10-15]

### Statistical Analysis

Multivariate logistic regression analyses were conducted to compare mortality, complications, and length of hospital stay between patients with different cardiac diseases undergoing TKA. Covariates in the analysis included age, sex, race, health insurance, hospital location, and the presence of cardiac risk factors. The analysis of hospital charges was controlled for factors that influence the cost of care, including but not limited to comorbidities, complications, and hospital LOS. Likewise, regression models were controlled for various comorbidities and demographic factors when evaluating the variables of interest. Standard statistical techniques, including *t*-tests, Fisher's exact test, or chi-square with Kendall Tau for categorical variables, and Wilcox on rank-sum tests for non-normally distrib-

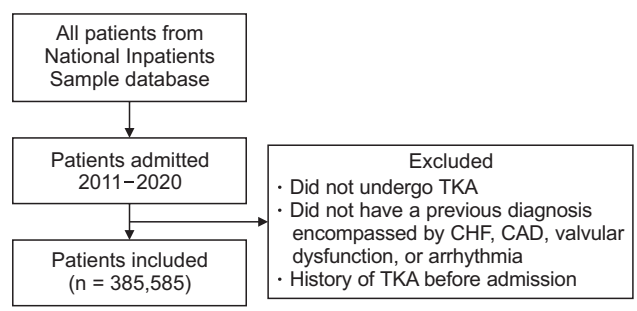


**Fig. 1.** Patient selection criteria. TKA: Total Knee Arthroplasty, CHF: congestive heart failure, CAD: coronary artery disease.

uted continuous variables, were used to evaluate statistical models. Statistical significance was defined as $p < 0.05$. All statistical analyses were performed using R studio 4.2.2 and Stata MP 17 and 18 with Python package (StataCorp.).

## RESULTS

A total of 385,585 patients were identified. Of these patients, 6,836 (1.7%) had CHF, 40,351 (10.4%) had CAD, 7,194 (1.87%) had a valvular disorder, and 22,114 (5.74%) had an arrhythmia, whereas 309,090 patients (80.16%) did not have a cardiovascular diagnosis at time of TKA, who comprised the control group (Table 1). With regard to age, those with CHF, CAD, a valvular disorder, or arrhythmia were on average older than the control group (Table 1). Respectively, the mean ages (years) were 72.64, 71.13, 71.22, and 71.26 years in each cardiac diagnosis group versus 64.13 years for the control group ($p < 0.001$). In all cardiac diagnosis groups, the greatest proportion of patients was older than 90 years. With regard to race, 42,629 patients (11.06%) were identified as Black or Hispanic; for Blacks specifically, a significantly greater proportion had a diagnosis of CHF versus no cardiac diagnosis ($p < 0.001$). With regard to payer status, patients with cardiac comorbidities were more likely to have Medicare as payer type (CHF: 78.86%, CAD: 73.79%, valvular: 71.73%, arrhythmia: 71.83%, control: 50.12%) and overall less likely to have private insurance (CHF: 14.74%, CAD: 20.89%, valvular: 24.56%, arrhythmia: 24.00%, control: 40.6%), although this was not noted to be statistically significant.

**Table 1.** Demographics of Patients with Cardiac Comorbidities Undergoing Total Knee Arthroplasty

| Variable | Total | Control | CHF | CAD | Valve | Arrhythmia | *p*-value |
|---|---|---|---|---|---|---|---|
| Number | 385,585 | 309,087 (80.16) | 6,839 (1.77) | 40,351 (10.46) | 7,194 (1.87) | 22,114 (5.74) | - |
| Age (yr) | 65.6 ± 11.2 | 64.1 ± 11.2 | 72.6 ± 10.0 | 71.1 ± 9.3 | 71.2 ± 10.3 | 71.3 ± 9.5 | < 0.001 |
| Age category (yr) | | | | | | | < 0.001 |
| < 55 | 2,100 (0.54) | 2,064 (0.67) | 4 (0.06) | 10 (0.02) | 8 (0.11) | 14 (0.06) | |
| 55–75 | 27,146 (7.04) | 25,968 (8.40) | 114 (1.67) | 540 (1.34) | 168 (2.34) | 356 (1.61) | |
| 75–90 | 138,949 (36.04) | 122,439 (39.61) | 1,316 (19.25) | 8,851 (21.94) | 1,577 (21.92) | 4,766 (21.55) | |
| ≥ 90 | 217,386 (56.38) | 158,613 (51.32) | 5,404 (79.03) | 30,950 (76.70) | 5,441 (75.63) | 16,978 (76.77) | |
| Sex | | | | | | | < 0.001 |
| Female | 213,457 (55.36) | 178,938 (57.90) | 3,280 (47.97) | 15,079 (37.37) | 5,066 (70.42) | 11,094 (50.17) | |
| Male | 172,091 (44.64) | 130,116 (42.10) | 3,558 (52.03) | 25,270 (62.63) | 2,128 (29.58) | 11,019 (49.83) | |
| Rural/urban | | | | | | | < 0.001 |
| Rural | 28,225 (7.33) | 22,288 (7.22) | 556 (8.14) | 3,302 (8.19) | 417 (5.80) | 1,662 (7.52) | |
| Urban | 356,857 (92.67) | 286,376 (92.78) | 6,273 (91.86) | 37,009 (91.81) | 6,771 (94.20) | 20,428 (92.48) | |
| Payer | | | | | | | < 0.001 |
| Medicaid | 19,663 (5.11) | 17,566 (5.69) | 294 (4.30) | 1,207 (2.99) | 137 (1.91) | 459 (2.08) | |
| Medicare | 210,830 (54.75) | 154,688 (50.12) | 5,388 (78.86) | 29,739 (73.79) | 5,151 (71.73) | 15,864 (71.83) | |
| Private insurance | 141,881 (36.85) | 125,389 (40.63) | 1,007 (14.74) | 8,421 (20.89) | 1,764 (24.56) | 5,300 (24.00) | |
| Comorbidity | | | | | | | |
| CKD | 25,830 (6.70) | 15,205 (4.92) | 2,231 (32.62) | 5,359 (13.28) | 780 (10.84) | 2,255 (10.20) | < 0.001 |
| Obesity (BMI ≥ 30 kg/m$^2$) | 90,877 (23.57) | 70,947 (22.95) | 2,267 (33.15) | 10,340 (25.63) | 1,593 (22.14) | 5,730 (25.91) | < 0.001 |
| Diabetes | 59,155 (15.34) | 41,055 (13.28) | 2,220 (32.46) | 11,167 (27.67) | 947 (13.16) | 3,766 (17.03) | < 0.001 |

Values are presented as number (%) or mean ± standard deviation. Reported *p*-values correspond to significant variables.
CHF: congestive heart failure, CAD: coronary artery disease, CKD: chronic kidney disease, BMI: body mass index.

**Table 2.** Hospital Variables of Patients with Cardiac Comorbidities Undergoing Total Knee Arthroplasty

| Hospital variable | Total | Control | CHF | CAD | Valve | Arrhythmia | *p*-value |
|---|---|---|---|---|---|---|---|
| Length of stay (day) | 2.041 ± 1.940 | 1.944 ± 1.778 | 3.535 ± 3.612 | 2.306 ± 1.962 | 2.257 ± 1.911 | 2.372 ± 2.849 | < 0.001 |
| Total charge ($) | 64,940 ± 43,056 | 64,163.9 ± 41,888 | 81,311 ± 70,133 | 66,373 ± 41,486 | 64,685 ± 41,312 | 68,197 ± 49,781 | < 0.001 |
| Discharge disposition (adverse discharge) | 58,085 (15.07) | 39,447 (12.77) | 2,809 (41.09) | 9,314 (23.09) | 1,552 (21.58) | 4,963 (22.45) | < 0.001 |
| Mortality | 164 (0.04) | 41 (0.01) | 33 (0.48) | 48 (0.12) | 6 (0.08) | 36 (0.16) | < 0.001 |

Values are presented as mean ± standard deviation or number (%).
CHF: congestive heart failure, CAD: coronary artery disease.

**Table 3.** Hospital Variables of Patients with Cardiac Comorbidities Undergoing Total Knee Arthroplasty: Odds Ratio

| Hospital variable | CHF | | CAD | | Valvular disorder | | Arrhythmia | |
|---|---|---|---|---|---|---|---|---|
| | OR | 95% CI | OR | 95% CI | OR | 95% CI | OR | 95% CI |
| Adverse discharge | 1.942 | 1.84–2.05* | 1.369 | 1.332–1.406* | 1.177 | 1.122–1.236* | 1.573 | 1.495–1.581* |
| LOS | 1.395 | 1.371–1.42* | 1.091 | 1.081–1.101* | 1.062 | 1.045–1.08* | 1.184 | 1.173–1.195* |
| 3 Days | 1.988 | 1.888–2.093* | 1.348 | 1.317–1.38* | 1.188 | 1.138–1.241* | 1.551 | 1.513–1.59* |
| 5 Days | 2.664 | 2.49–2.851* | 1.430 | 1.369–1.494* | 1.283 | 1.19–1.383* | 1.967 | 1.884–2.053* |
| 7 Days | 3.036 | 2.772–3.326* | 1.373 | 1.285–1.466* | 1.376 | 1.236–1.532* | 2.049 | 1.922–2.183* |
| 10 Days | 3.758 | 3.264–4.325* | 1.188 | 1.062–1.328* | 1.322 | 1.107–1.58* | 2.023 | 1.821–2.248* |
| Total charges | 1.181 | 1.164–1.199* | 1.016 | 1.009–1.023* | 0.992 | 0.98–1.005 | 1.067 | 1.059–1.075* |
| Mortality | 2.426 | 1.562–3.769* | 2.060 | 1.424–2.979* | 1.433 | 0.849–2.42 | 5.453 | 3.847–7.729* |

CHF: congestive heart failure, CAD: coronary artery disease, OR: odds ratio, CI: confidence interval, LOS: length of stay.
*Indicates statistical significance.

For CHF, CAD, valvular disorder, and arrhythmia groups, LOS was prolonged compared to those without cardiac comorbidities: 3.54 days, 2.31 days, 2.26 days, and 2.37 days, respectively, vs. 1.94 days for the control ($p < 0.001$) (Table 1). Additionally, all cardiac diagnoses were associated with significantly greater odds of a prolonged LOS at all time points greater than or equal to 3 days, compared to the control group ($p < 0.001$) (Tables 2 and 3). Furthermore, those with cardiac comorbidities were found to have increased hospital charges compared to those without cardiac comorbidities. For CHF, CAD, valvular disorder, and arrhythmia, the charges were found to be $81,311, $66,373, $64,685, and $68,197, respectively, vs. $64,164 for the control group ($p < 0.001$) (Table 1). Additionally, those with cardiac comorbidities had a significantly higher risk of adverse discharge disposition, as defined by discharge to a long-term nursing home or skilled nursing facility (41.09%, 23.09%, 21.58%, 22.45%, vs. 12.77% in the control group; $p < 0.001$), and increased mortality (0.48%, 0.12%, 0.08%, 0.16%, vs. 0.01% in the control group; $p < 0.001$) (Table 1). Demographic and hospital variables are presented in Table 1.

With regard to comorbidities, those with a diagnosis of CHF, CAD, or an arrhythmia had a significantly greater likelihood of also having chronic kidney disease, diabetes, and obesity (body mass index > 30 kg/m$^2$) compared to the control group ($p < 0.001$) (Table 4). Additionally, the presence of any cardiovascular diagnosis was associated with a greater likelihood of having peripheral vascular disease, hypertension, and hyperlipidemia as comorbidities ($p < 0.001$) (Table 4). Many significant findings were noted in our analysis of postoperative complications (Table 5). Patients with any of the cardiovascular diagnoses were found to have a significantly higher risk of experiencing a myocardial infarction (MI) and acute kidney injury (AKI) and had increased rates of blood transfusion ($p < 0.001$). Those with a valvular disorder or heart failure were also found to have an increased risk of experiencing a thromboembolic

**Table 4.** Comorbidities of Patients Undergoing Total Knee Arthroplasty

| Demographics | Total | Control | CHF | CAD | Valve | Arrhythmia | *p*-value |
|---|---|---|---|---|---|---|---|
| PVD | 6,516 (1.69) | 3,420 (1.11) | 372 (5.44) | 2,044 (5.07) | 222 (3.09) | 458 (2.07) | < 0.001 |
| Hyperlipidemia | 163,821 (42.49) | 115,111 (37.24) | 4,353 (63.65) | 29,532 (73.19) | 3,874 (53.85) | 10,951 (49.52) | < 0.001 |
| Hypertension | 230,647 (59.82) | 169,054 (54.69) | 6,148 (89.90) | 34,227 (84.82) | 4,929 (68.52) | 16,289 (73.66) | < 0.001 |
| Depression | 48,357 (12.54) | 38,479 (12.45) | 1,111 (16.25) | 5,303 (13.14) | 971 (13.50) | 2,493 (11.27) | < 0.001 |
| COPD | 26,264 (6.81) | 16,827 (5.44) | 1,560 (22.81) | 5,526 (13.69) | 524 (7.28) | 1,827 (8.26) | < 0.001 |
| Tobacco use | 36,739 (9.53) | 30,716 (9.94) | 545 (7.97) | 3,803 (9.42) | 387 (5.38) | 1,288 (5.82) | < 0.001 |
| Alcohol use | 5,501 (1.43) | 4,350 (1.41) | 150 (2.19) | 597 (1.48) | 84 (1.17) | 320 (1.45) | < 0.001 |
| Diabetes | 59,155 (15.34) | 41,055 (13.28) | 2,220 (32.46) | 11,167 (27.67) | 947 (13.16) | 3,766 (17.03) | < 0.001 |
| CKD | 25,830 (6.70) | 15,205 (4.92) | 2,231 (32.62) | 5,359 (13.28) | 780 (10.84) | 2,255 (10.20) | < 0.001 |
| Obesity (BMI ≥ 30 kg/m$^2$) | 90,877 (23.57) | 70,947 (22.95) | 2,267 (33.15) | 10,340 (25.63) | 1,593 (22.14) | 5,730 (25.91) | < 0.001 |

Values are presented as number (%).
CHF: congestive heart failure, CAD: coronary artery disease, PVD: peripheral vascular disease, COPD: chronic obstructive pulmonary disease, CKD: chronic kidney disease, BMI: body mass index.

**Table 5.** Postoperative Complications of Patients with Cardiac Comorbidities Undergoing Total Knee Arthroplasty

| Variable | Total | Control | CHF | CAD | Valve | Arrhythmia | *p*-value |
|---|---|---|---|---|---|---|---|
| Total Number | 385,585 | 309,087 (80.16) | 6,839 (1.77) | 40,351 (10.46) | 7,194 (1.87) | 22,114 (5.74) | - |
| Complication | | | | | | | |
| Cerebral infarction | 207 (0.05) | 94 (0.03) | 32 (0.47) | 46 (0.11) | 12 (0.17) | 23 (0.10) | < 0.001 |
| Myocardial infarction | 421 (0.11) | 60 (0.02) | 120 (1.75) | 192 (0.48) | 10 (0.14) | 39 (0.18) | < 0.001 |
| Sepsis | 639 (0.17) | 359 (0.12) | 97 (1.42) | 89 (0.22) | 11 (0.15) | 83 (0.38) | < 0.001 |
| Postoperative infection | 175 (0.05) | 118 (0.04) | 16 (0.23) | 23 (0.06) | 5 (0.07) | 13 (0.06) | < 0.001 |
| Acute kidney disease | 55,826 (14.48) | 35,364 (11.44) | 3,144 (45.97) | 10,884 (26.97) | 1,497 (20.81) | 4,937 (22.33) | < 0.001 |
| Urological infection | 4,183 (1.08) | 2,942 (0.95) | 196 (2.87) | 553 (1.37) | 129 (1.79) | 363 (1.64) | < 0.001 |
| Pulmonary embolism | 345 (0.09) | 209 (0.07) | 31 (0.45) | 47 (0.12) | 10 (0.14) | 48 (0.22) | < 0.001 |
| Deep vein thrombosis | 420 (0.11) | 281 (0.09) | 27 (0.39) | 66 (0.16) | 7 (0.10) | 39 (0.18) | < 0.001 |
| Transfusion | 12,930 (3.35) | 8,922 (2.89) | 649 (9.49) | 1,954 (4.84) | 404 (5.62) | 1,001 (4.53) | < 0.001 |
| Wound disruption | 173 (0.04) | 121 (0.04) | 14 (0.20) | 19 (0.05) | 6 (0.08) | 13 (0.06) | < 0.001 |

Values are presented as number (%).
CHF: congestive heart failure, CAD: coronary artery disease.

event ($p < 0.001$). Additionally, those with a valvular disorder or arrhythmia were found to have an increased risk of experiencing a cerebral infarction postoperatively ($p < 0.001$). Moreover, an increased risk of urologic infection was found in those with CAD and valvular disorders ($p < 0.001$). Odds ratios were also analyzed, which displayed a significant increase in odds of many of the above postoperative complications occurring in the cardiac disease groups compared to the control group ($p < 0.001$) (Table 5). Lastly, all cardiac subtypes had significantly greater mortality rates than the control group, and CHF, CAD, and valvular disorder were each identified as significant risk factors for increased postoperative mortality.

## DISCUSSION

There is an increasing global incidence of cardiovascular disease and, as the use of TKA rises, there is concern regarding its influence on postoperative outcomes. This retrospective study found that diagnosis with a cardiac disease (CHF, CAD, a valvular dysfunction, or arrhythmia) is prevalent in patients undergoing TKA and is a risk factor for prolonged LOS, increased hospital charges, increased mortality, and significantly more postoperative medical/surgical complications.

In the United States, approximately 1.8% of the general population have CHF, 2.5% have valvular heart disease, 5% have CAD, and between 1.5%–5% of the general population have an arrhythmia.[16,17] Approximately 20% of our cohort had a cardiac diagnosis at the time of TKA. Specifically, 1.7% had CHF, 10.4% had CAD, 1.87% had a valvular disorder, and 5.74% had an arrhythmia. This has been previously studied. In a review of other NIS studies, Nham et al. noted that 3.57% of their TKA cohort had a valvular disorder and 2.48% had CHF.[15] Pugely et al.[7] also noted 3.82% and 3.4%, respectively. Both studies proved prevalence, but like much of the current literature, lacked the inclusivity of our study (i.e., CAD and arrhythmia, which composed 75% of our disease prevalence). Underreporting of comorbidities in cardiac disease patients is well-established.[18] In TKA, this is likely due to inconsistent nomenclature, with studies either referring to it broadly as heart disease or only reporting one diagnosis (i.e., CHF).[3-7,13-15,18] This can lead to underestimation and ultimately alter outcome analyses.[18] It is important for surgeons to be aware of the breadth of diagnoses and be consistent in nomenclature to have a more complete understanding of the role of cardiac disease in TKA outcomes.

Based on our study, TKA patients with any cardiac disease (CHF, CAD, a valvular dysfunction, or arrhythmia) will be, on average, significantly older compared to those without cardiac disease (Table 1). No prior study has evaluated this, but this is consistent with our understanding of the relationship between global cardiac disease burden and advanced age.[19,20] Even in asymptomatic individuals without known preexisting disease, increasing age has been identified as a risk factor for the detection of a cardiac abnormality (i.e., heart block, ectopic beat) before total joint arthroplasty.[21] Multiple studies have also linked advanced age with an increased predilection for diabetes, pulmonary disease, and adverse outcomes including prolonged LOS and mortality.[7,21-25] As the average age of patients undergoing TKA increases, one must be aware of its operative implications, which may support a more prudent preoperative clearance with a lower threshold for preoperative cardiology referral.[21]

Expenditures associated with TKA have risen. LOS is an important component of costs and the delivery of efficient care. In this study, those with cardiac disease were noted to have a significantly longer LOS compared to the control group (Tables 2 and 3). Additionally, diagnosis with CHF, CAD, valvular dysfunction, or arrhythmia was predictive of a prolonged LOS (> 3, > 5, > 7, and > 10 days) after TKA (Tables 2 and 3). The impact of cardiac disease on LOS is well-described in other fields, but limited in TKA.[26-29] For CHF, only a few studies exist, but the literature is largely consistent with our findings. Pugely et al.[7] determined that CHF led to an increase in LOS by 0.6 days following TKA. Curtis et al.[4] also noted that those with CHF had a longer LOS and higher risk for readmission following TKA. Of note, the only cardiac diagnosis analyzed in either of these studies is CHF, in contrast to the present study's analysis of other cardiac disease subtypes. We found that CHF had the highest odds of prolonged LOS (all time points) versus CAD, a valvular dysfunction, or an arrhythmia (Tables 2 and 3). Similarly, only 2 studies could be identified for arrhythmia, but our results were consistent. Culler et al.[30] and Aggarwal et al.[31] noted a significantly longer LOS in patients with ventricular tachycardia or fibrillation and atrial fibrillation. Neither study commented on other cardiac disease subtypes. To our knowledge, no other study has analyzed the impact of CAD or valvular dysfunction on LOS, but our results are not surprising given the known association between cardiac disease in general and increased LOS. The financial and clinical burden produced by prolonged LOS cannot be overstated, with literature noting increased costs, nosocomial risks, and reduction in patient satisfaction with each additional day.[32-34] In those with cardiac disease, preoperative counseling/intervention may be necessary to manage patient expectations, optimize postoperative recovery, and mitigate barriers to discharge that prolong LOS.[35]

With regard to hospital charges, our study noted that those with cardiac disease had significantly higher hospital charges than those without (Tables 2 and 3). This relationship is established in the literature for some cardiac diagnoses. Culler et al.[30] noted an increase in costs of $9,005 and $14,571 in those with CHF and ventricular tachycardia or fibrillation, respectively. Of note, our omparative analysis identified CHF as having the highest hospital charges versus CAD, valvular dysfunction, or arrhythmia. This association between cardiac disease and increased charge is multifactorial. Those with cardiac disease tend to have more comorbidities requiring greater

inpatient healthcare needs/monitoring, carry a higher risk of adverse discharge disposition as seen in our study (Table 1), leading to longer LOS and higher readmission rates.[7,21-25,32-34] As we transition toward alternative payment care models, this impact on cost cannot be ignored. With ongoing efforts to "bundle" care, the lack of adjustment for cardiac comorbidities may decrease reimbursement and disincentivize TKA use.[36,37] This high-risk population can still benefit from TKA; however, the current economic trend may pose financial barriers to care for a population that is already disadvantaged.[37]

This study found that those with cardiac disease had poorer outcomes and increased mortality compared to those without. All subtypes were significantly associated with increased risk of MI, AKI, and need for transfusion (Table 5). Occurrence of an MI is detrimental to postoperative outcomes.[14,38] Though few studies exist, Basilico et al.[38] and Menendez et al.[14] each also identified CHF, CAD, valvular dysfunction, and arrhythmia as significant risk factors for a perioperative MI. Similar to our cohort, the large NIS study by Menendez et al.[14] also found that those with CAD had the highest risk of MI among all cardiac diagnosis subtypes. MI is a serious complication and not only serves as a leading cause of perioperative mortality, but also affects patient quality of life and hospital metrics including LOS, charges, and discharge.[14,38] Given these findings, efforts to create more thorough and effective cardiac risk assessments are justified to minimize the occurrence and adverse effects of cardiac events such as MI following TKA.[39,40]

The literature also supports our findings for perioperative AKI and the need for transfusion. Jafari et al.[41] and Wu et al.[42] found that CHF, other heart problems, and CAD were significant risk factors for AKI. Regarding transfusion, Owens et al.[43] identified CHF as a significant risk factor for increased transfusion rates after TKA. Despite the paucity of research on the effect of types of cardiac disease on AKI and the need for transfusion, the adverse effects of these complications are well established. Both AKI and the need for transfusion are associated with increased infection risk, morbidity and mortality, and costs/healthcare utilization.[44-47] Lastly, our study also noted an increased risk of thromboembolic events in those with cardiac disease. This is consistent with the known association between cardiac disease and thromboembolic events, a relationship that has been well-described in the literature.[4,47-50]

As stated above, cardiac disease is a leading cause of global mortality. Given its growing prevalence and the concurrent expansion of TKA utilization, more specific data regarding its implications in TKA is needed to optimize outcomes in this patient cohort. In our study, all subtypes had a significantly higher proportion of deaths compared to the control. Additionally, CHF, CAD, and valvular disorder were all found to be significant risk factors for mortality after TKA with CHF having the highest odds ratio (OR, 5.45; 95% confidence interval [CI], 3.84–7.72) (Table 3). This link between cardiac disease and mortality is well known.[51] It is important, however, to also note that cardiac disease consistently has one of the highest ORs for mortality following TKA across multiple studies. Bhattacharyya et al.[52] found that CHF and atrial fibrillation had ORs of 2.99 (2.27–3.93) and 1.39 (1.01–1.92) for mortality, respectively. Singh and Lewallen[53] found that a prior cardiac event had the highest univariate OR of 5.6 (range, 3.3–9.4) among their mortality predictors. Lastly, Memtsoudis et al.[51] found that CHF had the highest OR with a value of 10.66 (9.30–12.20), and cardiac valvular disease had an OR of 2.51 (range, 2.05–0.08). Cardiac risk assessments have allowed for a reduction in postoperative mortality. However, as seen in our study, associated deaths persist and comprise a significant portion of postoperative complications in this cohort after TKA. It is clear that patients with cardiac disease are a high-risk population and thus, surgeons may consider adopting a lower threshold for preoperative cardiac evaluation and intervention to reduce the risk of complications.

In summary, this study demonstrated that CHF, CAD, valvular dysfunction, and arrhythmia are prevalent among TKA patients and associated with worse hospital metrics, higher risk of perioperative complications, and increased mortality. As our use of TKA rises, a lower threshold for preoperative cardiology referral in older individuals and early preoperative counseling/intervention in those with known cardiac disease may be necessary to reduce adverse outcomes.

The present study has several limitations. First, it is a database study thus subject to data collection errors. Also, though comprehensive, NIS lacks detailed case information, which limits the ability to review specific details regarding a patient's perioperative course. Furthermore, the use of this database limits access to information regarding the level of control and pharmacologic management of each patient's cardiovascular disease, which may affect analysis. Second, the retrospective nature of the study may allow for inherent bias. Third, previous studies have noted that chronic conditions are under-coded, which may directly affect our prevalence calculations and outcomes analysis.[54] Despite these limitations, to the best of our knowledge, this is the first study to observe the prevalence and effects of specific types of cardiac disease on TKA

outcomes, providing useful information that may guide preoperative assessment and medical intervention before TKA.

## CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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