Demographic, Comorbidity, and Episode-of-Care Differences in Primary Total Knee Arthroplasty

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Background: Understanding time trends in age, demographic characteristics, and comorbidities is especially critical to highlight the effects on clinical practice change, outcomes, and the value of total knee arthroplasty (TKA). Therefore, the purpose of this study was to identify trends in the demographic characteristics, comorbidities, and episode-of-care outcomes for patients who underwent TKA from 2008 to 2018.

Methods: The National Surgical Quality Improvement Program (NSQIP) was queried to identify patient demographic characteristics, comorbidities, and episode-of-care outcomes in patients who underwent primary TKA from 2008 to 2018 (n = 350,879). Trends for continuous variables were analyzed using analysis of variance, and categorical variables were analyzed using chi-square tests.

Results: From 2008 to 2018, there was no clinically important difference in age, body mass index (BMI), and percentage of patients with BMI of >40 kg/m2 and no clinically important difference in chronic obstructive pulmonary disease (3.5% in 2008 and 3.2% in 2018), congestive heart failure within 30 days (0.3% in both 2008 and 2018), and acute renal failure (0.1% in 2008 and <0.1% in 2018) among patients undergoing TKA. However, modifiable comorbidities, including smoking status (9.5% in 2008 and 7.7% in 2018; $p < 0.001$), hypertension (71.0% in 2008 and 63.7% in 2018; $p < 0.001$), and anemia (16.2% in 2008 and 9.7% in 2018; $p < 0.001$), functional status, and overall morbidity and mortality probability have improved, with no clinically important difference in the percentage of diabetes (19.0% in 2008 and 18.1% in 2018). The hospital length of stay (mean [and standard deviation], 3.8 ± 2.2 days in 2008 and 2.1 ± 2.0 days in 2018; $p < 0.001$) and 30-day readmission (4.6% in 2011 and 3.0% in 2018; $p < 0.001$) decreased, with a significant increase in home discharge (65.6% in 2011 and 87.8% in 2018; $p < 0.001$).

Conclusions: The overall patient health status improved from 2008 to 2018, with improvement in the modifiable comorbidities of smoking status, malnutrition, hypertension, and anemia; the functional status; and the overall morbidity and mortality probability, with no clinically relevant change in patient age; patient BMI; percentage of patients with BMI of >40 kg/m2; or patients with diabetes mellitus, chronic obstructive pulmonary disease, congestive heart failure within 30 days, or acute renal failure. Our findings may be a reflection of a global shift toward value-based care focusing on patient optimization prior to arthroplasty, quality of care, and improved outcomes. The results of our study highlight the potential increase in TKA procedural value, which is paramount for health-care policy changes in today's incentivized, value-based, health-care environment.

Providing value-based care by improving quality of care while decreasing expenditure has evolved as the central goal for health-care organizations and clinicians[1]. This is especially relevant in elective total joint arthroplasty (TJA), as primary total knee arthroplasty (TKA) is one of the most commonly performed surgical procedures in the United States[2-5]. Although nearly 500,000 TKAs were performed in the United States in 2009[6], a recent study projected growth to >1.2 million procedures by 2030[2]. The implication of this exponential increase in TKA volume is especially relevant in today's political debate with regard to health-care system cost containment policies to mitigate the increased burden[2]. Several studies have similarly described time-trend utilization and outcomes after primary TKA[6-8], but have only focused on procedural volume.

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However, it is equally important to understand whether patient complexity has also changed over time, especially during value-based health-care reform. Evaluating patient characteristics is critical in assessing whether perioperative patient optimization has improved modifiable patient risk factors, particularly because the focus has shifted to this from 2008 to 2018. It is essential to concomitantly determine whether optimizing patient risk factors adds value to TKA by improving outcomes and decreasing cost by mitigating adverse events including extended hospital length of stay, readmission, and mortality.

Although prior studies provided preliminary insight into time trends in age and comorbidities, they focused on only Medicare patients or trends from >10 years ago[6,9]. Medicare study findings may not be generalizable, as over one-third of patients who undergo a TKA are <65 years of age[10], with younger patients projected to represent the majority of patients who undergo TKA by 2030[11]. Time-trend studies specifically evaluating patients' characteristics such as demographic characteristics, including body mass index (BMI), medical comorbidities, baseline functional status, perioperative details, and episode-of-care outcomes, which have all been associated with TKA results, have not been comprehensively evaluated from 2008 to 2018, to our knowledge. A better assessment of how important patient characteristic determinants are progressing can allow improved understanding of patient outcomes after TKA and its associated value to the health-care system over time. Therefore, the purpose of this study was to identify differences in the demographic characteristics, comorbidities, and episode-of-care outcomes for patients undergoing TKA from 2008 to 2018 using the most current national data.

We hypothesized that patient health and episode-of-care outcomes from 2008 to 2018 improved overall because of an increased focus on patient perioperative optimization and outpaced demographic and comorbidity changes in the general population reported by the U.S. Centers for Disease Control and Prevention (CDC) and the U.S. Department of Health and Human Services (HHS)[12-14].

Materials and Methods

Database

The American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) database was utilized. The 2018 version of the database contained 274 variables from 722 institutions[15]. The data are collected and are maintained by surgical clinical reviewers at each hospital site and undergo regular quality assurance. The database captures perioperative variables, including demographic characteristics, comorbidities, laboratory data, intraoperative variables, and 30-day outcomes.

Study Population

The Current Procedural Terminology (CPT) code 27447 was used to identify primary TKA (n = 351,587) from 2008 to 2018. To avoid potential coding errors, patients with an American Society of Anesthesiologists (ASA) classification of 5 (n = 12) were first excluded, followed by patients with any form of systemic sepsis (n = 681), and, finally, ventilator-dependent patients (n = 15). This left 350,879 patients for analysis.

Outcomes of Interest

The outcomes of interest were divided into patient-centric variables and episode-of-care variables. The patient-centric variables included age, BMI as a continuous variable and as the percentage with >40 kg/m^2, sex, race, estimated morbidity and mortality probability, ASA classification, functional status, diabetes mellitus, current smoking (within the past year), dyspnea, history of chronic obstructive pulmonary disease, ascites, congestive heart failure within 30 days, use of hypertension medication, acute renal failure, hemodialysis, metastatic cancer, an open wound or wound infection, use of corticosteroids, weight loss of >10% within 6 months, bleeding disorders, anemia, transfusion within 72 hours of TKA, and malnutrition.

The morbidity and mortality probability variables are created by the ACS NSQIP through hierarchal regression. The morbidity and mortality probabilities variables are native to the ACS NSQIP created for prediction through hierarchal regression. The variables contained with the equation are ASA classification, albumin, dyspnea, ethnicity, hypertension, creatinine, inpatient status, chronic obstructive pulmonary disease, white blood-cell count, bleeding disorders, BMI, age, diabetes, aspartate aminotransferase (AST) or serum glutamic-oxaloacetic transaminase (SGOT), current smoking, functional status, sodium, hematocrit, sex, wound classification, congestive heart failure, platelet count, open wound, disseminated cancer, work relative value units, emergency surgery, partial thromboplastin time, and weight loss of >10%. However, the weights of each variable and other specifics with regard to the model are not reported by the ACS. For this study, the morbidity and mortality probabilities were used as a surrogate for overall health. The anemia variable was created using the preoperative hematocrit laboratory value, with female patients with a hematocrit of <35.5% and male patients with a hematocrit of <38.5% considered anemic[16]. Notably, the hematocrit laboratory value was available for 334,059 patients (95.2%). Malnutrition was specified using the albumin preoperative laboratory value, with <3.5 g/dL considered malnourished[17]. Notably, the albumin laboratory value was available for 179,687 patients (51.2%). Appendix 1 contains year breakdowns of the number of patients for variables with missing data.

The episode-of-care variables included operative times, length of stay, home discharge, 30-day readmission, and 30-day mortality. Thirty-day readmission and home discharge were only collected in the NSQIP database from 2011 onward. Notably, patients discharged to a facility that had served as their residence were considered to have a home discharge.

Data Analysis

All data analysis was performed using SPSS Statistics 23 for Mac (IBM). Differences for continuous variables were analyzed using analysis of variance (ANOVA), and categorical variables

were analyzed using chi-square or Monte Carlo tests where applicable. An α value of <0.05 was considered significant.

Results

Demographic Characteristics

Although the change in age was significant because of the large sample size, it was not clinically important, as the mean age (and standard deviation) was 67.2 ± 10.0 years in 2008 and 67.2 ± 9.3 years in 2018. Similarly, there was a significant ($p < 0.001$) but clinically irrelevant increase in mean BMI as a continuous variable from 32.9 ± 7.4 kg/m^2 in 2008 to 33.0 ± 6.5 kg/m^2 to 2018. As a categorical variable, the number of patients with a BMI of >40 kg/m^2 decreased from 15.5% in 2008 to 14.0% in 2018. Additionally, there was nearly a 5% decline in the portion of female patients undergoing TKA, from 66.0% in 2008 to 61.3% in 2018 ($p < 0.001$). A complete list of differences is available in Table I.

Comorbidities

Overall patient health improved from 2008 to 2018, as seen in an increase in independent functional status (96.1% in 2008 to 98.5% in 2018; $p < 0.001$) and a decrease in current smoking within 1 year (9.5% in 2008 to 7.7% in 2018; $p < 0.001$), in patients with dyspnea with moderate exertion (10.5% in 2008 to 4.8% in 2018; $p < 0.001$), in those using hypertension medication (71.0% in 2008 to 63.7% in 2018; $p < 0.001$), in those with bleeding disorders (3.4% in 2008 to 1.8% in 2018; $p < 0.001$), and in those with anemia (16.2% in 2008 to 9.7% in 2018; $p < 0.001$). Furthermore, estimated morbidity (4.33% in 2012 and 2.33% in 2018; $p < 0.001$) and mortality probabilities (0.13% in 2012 and 0.10% in 2018; $p < 0.001$) also decreased. Conversely, patients who were taking corticosteroids increased (1.9% in 2008 and 3.4% in 2018; $p < 0.001$).

Episode of Care

Both TKA operative time (100.6 minutes in 2008 and 89.8 minutes in 2018; $p < 0.001$) and hospital length of stay (3.8 days in 2008 and 2.1 days in 2018; $p < 0.001$) decreased. Home discharge increased dramatically from 65.6% in 2011 to 87.8% in 2018 ($p < 0.001$). Thirty-day readmission fell from 4.6% in 2011 to 3.0% in 2018 ($p < 0.001$). There was no change in 30-day mortality from 2008 to 2018 (0.1% in 2008 and 0.1% in 2018; $p = 0.289$) (Table II).

Discussion

Because a large part of the national federal budget is allocated for TJA, there have been substantial changes in reimbursement distribution from federal agencies[6]. After noting the cost-effectiveness of several private bundled models[18,19], the Centers for Medicare & Medicaid Services (CMS) launched the episode-based Bundled Payments for Care Improvement (BPCI) initiative in 2013 and Comprehensive Care for Joint Replacement (CJR) in 2015[20]. To our knowledge, there have been few time-trend patient demographic studies evaluating changes during the bundled payment model implementation era. Therefore, the purpose of this study was to identify differences in the demographic characteristics, comorbidities, and episode-of-care outcomes for patients undergoing TKA from 2008 to 2018 using the most current national data. Our findings demonstrated that overall patient health improved from 2008 to 2018, including modifiable comorbidities such as smoking status, malnutrition, hypertension, and anemia; functional status; and overall morbidity and mortality probability, with no clinically relevant change in patient age, patient BMI, percentage of patients with BMI of >40 kg/m^2, or patients with diabetes mellitus, chronic obstructive pulmonary disease, congestive heart failure within 30 days, or acute renal failure. Additionally, the overall episode-of-care outcomes improved, with a decrease in hospital length of stay and 30-day readmission, and a considerable increase in home discharge.

Although there was a 5% decrease in female patients undergoing TKA, female patients (66% to 61%) still comprised a majority of patients undergoing arthroplasty. Female patients have been well reported in the literature as having a higher incidence of TKA compared with male patients[6-8,21-25]. During a 40-year study period from 1969 to 2008, Singh et al.[21] found that there was a significantly higher incidence ($p < 0.001$) of TKA among female patients in each decade (129.3 [95% confidence interval (CI), 123.9 to 134.8] per 100,000 person-years for female patients and 104.0 [95% CI, 98.2 to 109.8] per 100,000 person-years for male patients). The 2018 American Joint Replacement Registry (AJRR) annual report also found 61% of primary TKAs occurring in female patients[26]. However, this percentage may have been underreported because the AJRR collection is based on voluntary reporting. In a large prospective, longitudinal cohort study, Collins et al.[23] found that non-Caucasian patients had a lower rate of TKA compared with Caucasian patients, similar to our study, even after adjustment for baseline knee osteoarthritis radiographic severity, pain, BMI, number of comorbidities, age, sex, and education. Interestingly, Collins et al. also noted that female sex was associated with a greater rate of TKA than male sex in younger patients (<65 years) but not in older patients. The relation between age, sex, and other demographic characteristics was outside the scope of this study. Future time-trend patient demographic studies should focus on the association between age, sex, ethnicity, and comorbidities.

Our findings of shorter length of stay, lower 30-day readmission rates, and increased home discharge may be explained by the initial effects of the BPCI and CJR implementation results. Although length of stay was trending down and home discharge was trending up prior to 2013, both variables demonstrated greater changes after 2015 (2 years after the BPCI began and the same year that the CJR began). Initial bundled payment studies have uniformly shown a decreased overall length of stay, decreased readmissions, increased home discharge, and decreased overall cost of an episode of care within 1 to 3 years of implementation[20,27,28].

Several time-trend studies have also shown an overall increase in patient complexity and comorbidities over the past few decades[7,21,29,30]. Crowninshield et al.[25] obtained U.S. population data from the CDC, the U.S. Census Bureau, HHS, the U.S. Bureau of Labor Statistics, and the U.S. Department of

TABLE I Patient-Centric Variable Trends in TKAs*

Variable	2008 (N = 2,648)	2009 (N = 4,664)	2010 (N = 7,074)	2011 (N = 13,624)	2012 (N = 22,430)
Age† *(yr)*	67.2 ± 10.0	67.1 ± 10.1	67.3 ± 10.0	66.7 ± 10.0	67.0 ± 9.8
BMI† *(kg/m²)*	32.9 ± 7.4	32.8 ± 7.2	32.9 ± 7.3	32.6 ± 7.3	32.9 ± 7.0
BMI >40 kg/m²§,#	409 (15.5%)	665 (14.4%)	1,047 (14.9%)	1,913 (14.1%)	3,279 (14.7%)
Female sex§	1,749 (66.0%)	2,996 (64.2%)	4,481 (63.7%#)	8,407 (62.2%#)	14,095 (62.8%)
Race§					
Native American	20 (0.8%)	37 (0.8%)	44 (0.6%)	49 (0.4%)	60 (0.3%)
Asian	54 (2.0%)	74 (1.6%)	90 (1.3%)	336 (2.5%)	465 (2.1%)
African American	218 (8.2%)	329 (7.0%)	462 (6.5%)	842 (6.2%)	1,460 (6.5%)
Native Hawaiian or Pacific Islander	1 (<0.1%)	15 (0.3%)	8 (0.1%)	48 (0.4%)	38 (0.2%)
Not reported	230 (8.7%)	217 (4.7%)	443 (6.3%)	1,595 (11.8%)	2,529 (11.3%)
Caucasian	2,125 (80.6%)	3,992 (85.6%)	6,027 (85.6%)	10,754 (79.5%)	17,878 (79.7%)
Estimated mortality probability†	NA	NA	NA	NA	0.13% ± 0.15%
Estimated morbidity probability†	NA	NA	NA	NA	4.33% ± 1.6%
ASA classification§,**					
1	47 (1.8%#)	87 (1.9%#)	114 (1.6%)	308 (2.3%)	525 (2.3%)
2	1,262 (47.8%#)	2,251 (48.4%#)	3,412 (48.2%)	6,857 (50.3%)	11,723 (52.3%)
3	1,267 (48.0%#)	2,240 (48.2%#)	3,420 (48.3%)	6,227 (45.7%)	9,826 (43.8%)
4	66 (2.5%#)	73 (1.6%#)	110 (1.6%)	219 (1.6%)	343 (1.5%)
None assigned	0 (0.0%#)	0 (0.0%#)	18 (0.3%)	13 (0.1%)	13 (0.1%)
Functional status§					
Independent	2,545 (96.1%)	4,497 (96.4%)	6,734 (95.7%)	13,186 (97.5%)	22,023 (98.2%)
Partially dependent	102 (3.9%)	166 (3.6%)	327 (4.6%)	291 (2.2%)	341 (1.5%)
Totally dependent	1 (<0.1%)	1 (<0.1%)	12 (0.2%)	7 (0.1%)	21 (0.1%)
Unknown	0 (0.0%)	0 (0.0%)	1 (<0.1%)	140 (1.0%)	45 (0.2%)
Diabetes§					
Insulin-dependent	119 (4.5%)	185 (4.0%)	279 (3.9%)	586 (4.3%)	946 (4.2%)
Non-insulin-dependent	384 (14.5%)	662 (14.2%)	977 (13.8%)	1,805 (13.2%)	2,991 (13.3%)
Current smoker, within 1 year§	252 (9.5%)	392 (8.4%)	577 (8.2%)	1,127 (8.3%)	1,842 (8.2%)
Dyspnea§					
At rest	12 (0.4%)	11 (0.2%)	19 (0.3%)	41 (0.3%)	56 (0.2%)
Moderate exertion	277 (10.5%)	452 (9.7%)	564 (8.0%)	957 (7.0%)	1,549 (6.9%)
Diagnosis of chronic obstructive pulmonary disease§	92 (3.5%)	195 (4.2%)	242 (3.4%)	456 (3.3%)	810 (3.6%)
Ascites§	0 (0.0%)	2 (<0.1%)	0 (0.0%)	2 (<0.1%)	2 (<0.1%)
Congestive heart failure within 30 days§	9 (0.3%)	7 (0.2%)	6 (0.1%)	32 (0.2%)	60 (0.3%)
Use of hypertension medication§	1,880 (71.0%)	3,269 (70.1%)	4,906 (69.4%)	9,124 (67.0%)	14,780 (65.9%)
Acute renal failure§	2 (0.1%)	1 (<0.1%)	6 (0.1%)	2 (<0.1%)	8 (<0.1%)
Dialysis§	5 (0.2%)	11 (0.2%)	11 (0.2%)	17 (0.1%)	24 (0.1%)
Disseminated cancer§	4 (0.2%)	9 (0.2%)	14 (0.2%)	8 (0.1%)	26 (0.1%)
Open wound or wound infection§	15 (0.6%)	16 (0.3%)	33 (0.5%)	105 (0.8%)	117 (0.5%)
Use of corticosteroids§	49 (1.9%)	145 (3.1%)	159 (2.2%)	355 (2.6%)	714 (3.2%)
Weight loss >10% in last 6 mo§	5 (0.2%)	11 (0.2%)	15 (0.2%)	32 (0.2%)	35 (0.2%)
Bleeding disorder§	91 (3.4%)	129 (2.8%)	163 (2.3%)	366 (2.7%)	561 (2.5%)
Anemia§,#	408 (16.2%)	685 (15.5%)	981 (14.9%)	1,697 (13.3%)	2,853 (13.2%)
Transfusion in prior 72 hr§	0 (0.0%)	0 (0.0%)	14 (0.2%)	6 (<0.1%)	16 (0.1%)
Malnutrition§,#	78 (5.6%)	127 (6.1%)	146 (4.7%)	266 (4.3%)	511 (4.7%)

*NA = not available. †The values are given as the mean and the standard deviation. ‡Significant at $p < 0.05$. §The values are given as the number of patients, with the percentage in parentheses. #There were missing data for these variables; therefore, the denominator used to obtain these percentages does not equal the group total. **The ASA classification is as follows: 1 indicates no disturbance, 2 indicates mild disturbance, 3 indicates severe disturbance, and 4 indicates life-threatening. ††Monte Carlo simulation.

TABLE I (*continued*)

2013 (N = 29,812)	2014 (N = 35,976)	2015 (N = 48,825)	2016 (N = 58,887)	2017 (N = 62,311)	2018 (N = 64,628)	P Value
66.9 ± 9.6	66.1 ± 9.7	66.4 ± 9.6	66.7 ± 9.4	66.9 ± 9.3	67.2 ± 9.3	<0.001†
32.9 ± 7.1	33.1 ± 7.0	33.2 ± 6.9	33.1 ± 6.8	33.0 ± 6.6	33.0 ± 6.5	<0.001†
4,410 (14.8%)	5,616 (15.7%)	7,671 (15.7%)	8,780 (15.0%)	8,943 (14.4%)	8,980 (14.0%)	<0.001†
18,688 (62.7%)	22,268 (61.9%)	29,991 (61.4%)	36,203 (61.5%)	38,065 (61.1%)	39,628 (61.3%)	<0.001†
						<0.001†
195 (0.7%)	222 (0.6%)	245 (0.5%)	267 (0.5%)	342 (0.5%)	328 (0.5%)	
661 (2.2%)	797 (2.2%)	995 (2.0%)	1,172 (2.0%)	1,312 (2.1%)	1,342 (2.1%)	
1,960 (6.5%)	2,761 (7.7%)	3,907 (8.0%)	4,494 (7.6%)	4,884 (7.8%)	5,008 (7.8%)	
118 (0.4%)	122 (0.3%)	173 (0.4%)	257 (0.4%)	235 (0.4%)	223 (0.3%)	
3,102 (10.4%)	3,904 (10.9%)	6,312 (12.9%)	9,210 (15.6%)	10,122 (16.2%)	12,464 (19.3%)	
23,776 (79.8%)	28,170 (78.3%)	37,193 (76.2%)	43,487 (73.8%)	45,416 (72.9%)	45,263 (70.0%)	
0.13% ± 0.14%	0.12% ± 0.13%	0.11% ± 0.13%	0.11% ± 0.13%	0.11% ± 0.13%	0.10% ± 0.13%	<0.001†
3.21% ± 1.12%	2.91% ± 1.11%	2.78% ± 1.06%	2.61% ± 0.98%	2.41% ± 0.90%	2.33% ± 0.92%	<0.001†
						<0.001†
612 (2.1%)	786 (2.2%)	983 (2.0%)	1,080 (1.8%)	1,087 (1.7%)	1,089 (1.7%)	
15,332 (51.4%)	18,023 (50.1%)	23,787 (48.7%)	28,046 (47.6%)	29,818 (47.9%)	30,890 (47.8%)	
13,375 (44.9%)	16,548 (46.0%)	23,240 (47.6%)	28,620 (48.6%)	30,286 (48.6%)	31,505 (48.7%)	
462 (1.5%)	588 (1.6%)	780 (1.6%)	1,071 (1.8%)	1,033 (1.7%)	1,053 (1.6%)	
31 (0.1%)	31 (0.1%)	35 (0.1%)	70 (0.1%)	87 (0.1%)	91 (0.1%)	
						<0.001†
29,220 (98.0%)	35,189 (97.8%)	47,977 (98.3%)	57,970 (98.4%)	61,410 (98.6%)	63,771 (98.5%)	
341 (1.1%)	462 (1.3%)	560 (1.1%)	609 (1.0%)	585 (0.9%)	627 (1.0%)	
16 (0.1%)	18 (0.1%)	20 (<0.1%)	15 (<0.1%)	20 (<0.1%)	23 (<0.1%)	
235 (0.8%)	307 (0.9%)	268 (0.5%)	293 (0.5%)	296 (0.5%)	207 (0.3%)	
						0.01†
1,273 (4.3%)	1,626 (4.5%)	2,231 (4.6%)	2,575 (4.4%)	2,674 (4.3%)	2,771 (4.3%)	
3,924 (13.2%)	4,897 (13.6%)	6,704 (13.7%)	8,255 (14.0%)	8,621 (13.8%)	8,950 (13.8%)	
2,542 (8.5%)	3,201 (8.9%)	4,284 (8.8%)	4,925 (8.4%)	4,975 (8.0%)	4,945 (7.7%)	<0.001†
						<0.001†
50 (0.2%)	56 (0.2%)	80 (0.2%)	117 (0.2%)	134 (0.2%)	111 (0.2%)	
1,746 (5.9%)	1,909 (5.3%)	2,764 (5.7%)	3,036 (5.2%)	3,182 (5.1%)	3,111 (4.8%)	
1,046 (3.5%)	1,310 (3.6%)	1,789 (3.7%)	2,079 (3.5%)	2,046 (3.3%)	2,088 (3.2%)	<0.001†
7 (<0.1%)	7 (<0.1%)	7 (<0.1%)	12 (<0.1%)	8 (<0.1%)	8 (<0.1%)	0.656 (0.644 to 0.668)††
67 (0.2%)	93 (0.3%)	158 (0.3%)	185 (0.3%)	180 (0.3%)	215 (0.3%)	0.002†
19,596 (65.7%)	23,422 (65.1%)	31,938 (65.4%)	38,018 (64.6%)	40,195 (64.5%)	41,177 (63.7%)	<0.001†
4 (<0.1%)	11 (<0.1%)	11 (<0.1%)	9 (<0.1%)	15 (<0.1%)	21 (<0.1%)	0.032†
49 (0.2%)	59 (0.2%)	81 (0.2%)	88 (0.1%)	110 (0.2%)	101 (0.2%)	0.573
24 (0.1%)	35 (0.1%)	42 (0.1%)	76 (0.1%)	53 (0.1%)	94 (0.1%)	0.001†
84 (0.3%)	71 (0.2%)	81 (0.2%)	90 (0.2%)	93 (0.1%)	74 (0.1%)	<0.001†
1,098 (3.7%)	1,418 (3.9%)	1,687 (3.5%)	2,173 (3.7%)	2,142 (3.4%)	2,219 (3.4%)	<0.001†
36 (0.1%)	41 (0.1%)	40 (0.1%)	60 (0.1%)	64 (0.1%)	71 (0.1%)	<0.001†
860 (2.9%)	829 (2.3%)	996 (2.0%)	1,203 (2.0%)	1,126 (1.8%)	1,190 (1.8%)	<0.001†
3,380 (11.8%)	3,976 (11.5%)	4,635 (10.0%)	5,295 (9.5%)	5,640 (9.5%)	5,930 (9.7%)	<0.001†
18 (0.1%)	20 (0.1%)	17 (<0.1%)	22 (<0.1%)	163 (<0.1%)	25 (<0.1%)	<0.001†
556 (3.7%)	749 (4.2%)	1,112 (4.5%)	1,268 (4.2%)	1,439 (4.3%)	1,516 (4.3%)	<0.001†

TABLE II Episode-of-Care Outcome Trends in TKAs*

Variable	2008 (N = 2,648)	2009 (N = 4,664)	2010 (N = 7,074)	2011 (N = 13,624)	2012 (N = 22,430)
30-day mortality†	3 (0.1%)	5 (0.1%)	14 (0.2%)	22 (0.2%)	23 (0.1%)
30-day readmission†,†	NA	NA	NA	546 (4.6%)	866 (3.9%)
Home discharge†,†	NA	NA	NA	8,904 (65.6%)	15,196 (67.8%)
Length of stay# *(days)*	3.8 ± 2.2	3.6 ± 2.6	3.5 ± 5.5	3.4 ± 5.1	3.4 ± 5.5
Operative time# *(min)*	100.6 ± 38.5	97.9 ± 37.7	95.5 ± 39.7	96.5 ± 39.6	94.9 ± 39.1

*NA = not available. †The values are given as the number of patients, with the percentage in parentheses. †There were missing data for these variables, so some of the denominators used to determine these percentages were not the same as the group total. §Significant at $p < 0.05$. #The values are given as the mean and the standard deviation.

Commerce and found that, compared with several prior decades, patients who were then undergoing TJA were nearly 20% heavier, were more physically active, were 3 times more likely to have higher post-high school education, and lived 25% longer. In a population-based study, Oh et al.[29] used the all-payer California Healthcare Cost and Utilization Project database from 2007 and 2010 and found that patients undergoing TKA were progressively younger with a higher prevalence of depression or drug or alcohol abuse and had more medical comorbidities as measured by the Charlson Comorbidity Index. However, unlike their results, our findings of overall improved patient health with similar percentages of medical comorbidities differed from the aforementioned time-trend studies, although our study did not explore psychological and social comorbidities. Furthermore, our study looked at specific medical comorbidities in conjunction with an associated comorbidity index (ASA classification) rather than the Charlson Comorbidity Index alone, which likely provided a more comprehensive trend analysis.

Our findings of overall improved patient health with a similar percentage of medical comorbidities differed from the aforementioned time-trend studies. Furthermore, health-care regulation, including emphasis on primary care, preventive medicine, and health improvement of the general population, has garnered attention over the past 10 years. National Prevention Strategy (NPS) programs and personalized preventive care have provided patients with guidelines on attainable means for leading a healthier lifestyle and improving preexisting comorbidities[31,32]. Recent CDC and HHS time-trend data on the general population from 2007 to 2018 reported that the percentage of smokers has declined significantly, with a mean decrease of 0.8 percentage point per year from 19.7% to 14.1%, with the most decline in younger people (<65 years) and no clear trend seen in older individuals (≥65 years). Given that the mean age was >65 years in our study, our findings of a significant decrease in smoking status may be, although conjectural, the effect of improved patient perioperative optimization. CDC and HHS reports also demonstrated a prominent rise in overall obesity (10% rise in male patients and 8% rise in female patients), diabetes (10.3% rise in patients >65 years old), and acute renal failure rates[33] both in male and female patients of all age groups, with no clear trend in hypertension rates, from 2000 to 2016[12-14]. Individual functional limitations in all age groups have remained relatively unchanged from 2010 to 2017[12-14]. Although the CDC and HHS data do not present a multitude of comorbidity information as the NSQIP database does, our results potentially demonstrated overall greater patient health improvement compared with the general U.S. population.

Although speculative, our finding may also be another example of the downstream effect of the U.S. Affordable Care Act (2010), BPCI (2013), and CJR (2015). The Affordable Care Act and CMS's bundled model programs, which alter traditional approaches by increased emphasis on integrated multidisciplinary care with a patient-centered approach, have been shown to improve care coordination and quality[28]. Although the BPCI and CJR are only for Medicare patients (≥65 years), the implementation of alternative payment models caused a national paradigm shift in the overall mentality and a multidisciplinary approach toward patients undergoing arthroplasty with the goal of mitigating patients' risk factors through early detection and management of medical comorbidities preoperatively. This proactive approach may have helped to optimize patients' global health by improving modifiable comorbidities and risk factors.

There are concerns that bundled payments may restrict care for patients at a higher risk for complications due to greater comorbidities[34], including patients of lower socioeconomic status[35]. However, recent studies have shown that patients with greater medical comorbidities deemed to be at higher risk for adverse events were undergoing elective primary arthroplasty at similar rates prior to bundled programs[36]. Our finding of increasingly healthy patients undergoing TKA from 2008 to 2018 may theoretically align with the ideology of bundled programs that forces multidisciplinary medical team alliances to prevent the exclusion of high-risk patients by providing joint replacement pathways through risk mitigation and optimization. Additionally, Courtney et al.[35] reviewed 4,168 primary TKAs and total hip arthroplasties and found patients in the lowest socioeconomic group, defined on the basis of the median household income of the patient's ZIP code, to have longer lengths of stay, higher non-home discharges, and increased 90-day readmissions compared with patients with higher socioeconomic status. Our time-trend patient demographic study did not explore socioeconomic status.

TABLE II (*continued*)

2013 (N = 29,812)	2014 (N = 35,976)	2015 (N = 48,825)	2016 (N = 58,887)	2017 (N = 62,311)	2018 (N = 64,628)	P Value
31 (0.1%)	43 (0.1%)	45 (0.1%)	63 (0.1%)	59 (0.1%)	58 (0.1%)	0.289
995 (3.3%)	1,141 (3.2%)	1,628 (3.3%)	1,876 (3.2%)	1,934 (3.1%)	1,922 (3.0%)	<0.001§
20,797 (69.8%)	26,046 (72.4%)	37,110 (76.0%)	47,481 (80.7%)	52,547 (84.3%)	56,756 (87.8%)	<0.001§
3.2 ± 2.2	3.0 ± 2.5	2.8 ± 2.6	2.6 ± 2.4	2.4 ± 2.2	2.1 ± 2.0	<0.001§
93.9 ± 39.1	94.3 ± 38.5	93.4 ± 38.6	90.9 ± 36.4	90.2 ± 35.4	89.8 ± 35.0	<0.001§

This study had limitations. First, this retrospective registry study was exclusively dependent on the validity of the data collected and the CPT code imputed. However, the NSQIP database prospectively collects perioperative data on hundreds of thousands of patients across hundreds of national hospitals and provides a vigorous tool to better understand and improve outcomes[37]. Second, the number of hospitals has been increasing (211 hospitals in 2008 to 722 institutions in 2018), which may have skewed the overall data. Third, the NSQIP does not record numerous variables pertinent to arthroplasty outcomes, including surgical approach, sequential compared with truly concurrent simultaneous surgical procedures, surgeon experience, and hospital volume. Fourth, this study did not evaluate different age subgroups to see if there was a difference in demographic characteristics, comorbidities, or outcomes in younger or elderly patients. Fifth, although a detailed list of medical comorbidities was investigated, this study did not focus on social and psychological comorbidities that have been known to influence TKA outcomes[38,39]. Finally, coding errors are known limitations of large, prospective, national databases. However, despite the numerous variables and limitations, this NSQIP database study from 2008 to 2018 helps to illustrate demographic and comorbidity changes in patients undergoing primary TKA that can be compared with time trends in the general population as indicated by CDC and HHS data. The results of our study highlight the potential increase in TKA procedural value that is paramount for health-care policy changes in today's incentivized value-based health-care environment.

Health-care policy changes have increased motivation to deliver value-based care that focuses on improving the quality of health outcomes while decreasing expenditure. In the time period from 2008 to 2018, the percentage of certain comorbidities among patients undergoing TKA did not change. However, modifiable comorbidities including smoking status, hypertension, and anemia; functional status; and overall morbidity and mortality probability have improved, without a clinically important difference in the percentage of diabetes. The hospital length of stay and 30-day readmission decreased, with a significant increase in home discharge. Future time-trend studies should evaluate patient psychological comorbidity trends along with age subgroup analysis to determine if further attention is warranted in certain patient populations to continue to improve TKA results and outcomes.

Appendix

eA Supporting material provided by the authors is posted with the online version of this article as a data supplement at jbjs.org (http://links.lww.com/JBJS/G253). ■

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