



# Medicaid insurance status predicts postoperative mortality after total knee arthroplasty in state inpatient databases

Journal of **Comparative Effectiveness Research**

Stephan R Maman<sup>\*,1</sup> , Michael H Andrae<sup>1</sup>, Licia K Gaber-Baylis<sup>2</sup>, Zachary A Turnbull<sup>3</sup> & Robert S White<sup>3</sup>

<sup>1</sup>Penn State Milton S Hershey Medical Center, 500 University Drive, H187, Hershey, PA 17033, USA

<sup>2</sup>Weill Cornell Medicine Center for Perioperative Outcomes, 428 East 72nd St., Ste 800A, New York, NY 10021, USA

<sup>3</sup>Department of Anesthesiology, New York Presbyterian Hospital-Weill Cornell Medicine, 525 East 68th Street, Box 124, New York, NY 10065, USA

\*Author for correspondence: [smaman@pennstatehealth.psu.edu](mailto:smaman@pennstatehealth.psu.edu)

**Aim:** Medicaid versus private primary insurance status may predict in-hospital mortality and morbidity after total knee arthroplasty (TKA). **Materials & methods:** Regression models were used to test our hypothesis in patients in the State Inpatient Database (SID) from five states who underwent primary TKA from January 2007 to December 2014. **Results:** Medicaid patients had greater odds of in-hospital mortality (odds ratio [OR]: 1.73; 95% CI: 1.01–2.95), greater odds of any postoperative complications (OR: 1.25; 95% CI: 1.18–1.33), experience longer lengths of stay (OR: 1.09; 95% CI: 1.08–1.10) and higher total charges (OR: 1.03; 95% CI: 1.02–1.04). **Conclusion:** Medicaid insurance status is associated with higher in-hospital mortality and morbidity in patients after TKA compared with private insurance.

First draft submitted: 16 February 2019; Accepted for publication: 5 July 2019; Published online: 23 October 2019

**Keywords:** disparity • insurance • Medicaid • outcomes • perioperative • total knee arthroplasty

Having any insurance at all is likely better than being uninsured [1–3], but those who are newly insured by Medicaid still experience major disparities in healthcare outcomes compared with their privately insured counterparts [4]. Disparities have been demonstrated also in orthopedics; specifically, significant differences in postoperative mortality and morbidity are associated with socioeconomic status (SES), for primary insurance status, as summarized in our literature search (Table 1) [5–13].

Disparities in total knee arthroplasty (TKA), although less studied, are equally of great significance. TKA is a commonly performed procedure in the USA, with an estimated 700,000 cases performed annually, and an expected increase in TKA procedures to 3.48 million by 2030 [24,25]. Minorities and those of lower SES receive TKA at a lower rate and experience a higher rate of TKA-related complications [26,27].

A central goal of the Affordable Care Act (ACA) is to increase the number of individuals enrolled in health insurance through the creation of state marketplaces and Medicaid expansions. Since becoming law, it has allowed approximately 20 million nonelderly adults access health insurance [28]. But, underinsured racial/ethnic minority and lower SES patients are more frequently treated at hospitals where the procedure volume is lower; we and others hypothesize that this may explain the disparate outcomes for TKA procedures [14,29–31]. Lower SES may lead to a preferential admission to poor quality, low volume hospitals. Low volume hospitals performing TKAs have poorer outcomes, including a higher risk for infection, pulmonary embolism, revision and higher mortality rate [32–35]. Furthermore, hospitals that treat a greater proportion of African-American and Medicaid patients had higher readmission rates for total hip arthroplasty (THA) and TKA compared with those who treat a relatively lower number of these patients [36]. Social determinants of health are associated with a greater risk of hospital readmission in these populations [37–39]. Lower SES is often associated with worse health status that induces higher preoperative risk. High risk, low SES populations might benefit most from being treated in high volume and high quality institutions.

**Table 1. Review of literature: postoperative outcomes after total knee arthroplasty by primary insurance payer.**

| Study (year), Ref.                    | Data source (states, dataset)                                                | Data collection (years) | Sample size (study N)                        | Outcomes reported (mortality, complications, readmissions, LOS, costs)                   | Limitations of prior studies                                                                                    |
|---------------------------------------|------------------------------------------------------------------------------|-------------------------|----------------------------------------------|------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|
| Mistry <i>et al.</i> (2018) [14]      | NIS                                                                          | 2009–2013               | 3,217,056                                    | Use of allogenic transfusions, discharge location, LOS, postop complications, total cost | Reports differences in use of allogenic transfusions but does not report differences in outcomes between groups |
| Haghverdian <i>et al.</i> (2017) [7]  | Hospital records, skilled nursing facility physical therapy data, California | Nov 2012–July 2014      | 80                                           | LOS, distance ambulated                                                                  | Single state, small sample, limited outcomes reported, only shows Medicare vs Managed Care insurance            |
| Anthony <i>et al.</i> (2018) [8]      | National Readmission Database (from HCUP)                                    | 2013–2014               | 424,104                                      | Readmission rates, SSI                                                                   | Limited outcomes reported, no mention of race                                                                   |
| Adelanic <i>et al.</i> (2018) [9]     | SID, NY, Florida                                                             | Jan 2006–Sep 2013       | 340,577                                      | Readmission rates                                                                        | Limited outcomes comparing primary insurance status                                                             |
| Middleton <i>et al.</i> (2017) [15]   | Medicare claims data                                                         | 2012–2014               | 360,520 (mortality), 355,155 (complications) | Mortality, complications, readmissions                                                   | Only Medicare population                                                                                        |
| Welsh <i>et al.</i> (2017) [16]       | Medicare claims data                                                         | 2009–2011               | 607,169                                      | Readmissions, discharge setting                                                          | Only Medicare population                                                                                        |
| Schwarzkopf <i>et al.</i> (2015) [17] | California Hospital Discharge data                                           | 2010                    | 28,611                                       | Discharge destination                                                                    | Single state, single year, limited outcomes reported                                                            |
| El Bitar <i>et al.</i> (2015) [10]    | NIS                                                                          | 2009–2011               | 1,924,432                                    | LOS                                                                                      | Limited outcomes reported                                                                                       |
| Browne <i>et al.</i> (2014) [11]      | NIS                                                                          | 2002–2011               | 142,433                                      | Complications, cost, LOS                                                                 | Compared Medicaid vs non-Medicaid insurance types only                                                          |
| Bolognesi <i>et al.</i> (2013) [18]   | Centers for Medicare and Medicaid Services                                   | Jan 2000–Dec 2009       | 65,505                                       | LOS, all-cause mortality, rate of revision or removal                                    | Only Medicare population, outdated                                                                              |
| Singh <i>et al.</i> (2014) [19]       | MedPAR Part A                                                                | 1991–2008               | 2,684,575                                    | LOS, mortality, readmissions                                                             | Outdated, only Medicare population, only racial disparities                                                     |
| Rosenthal <i>et al.</i> (2014) [20]   | Hospital billing database                                                    | Jan 2006–April 2010     | 1695                                         | Knee Society Scores, SSI, rate of follow-up                                              | Small sample, single hospital, limited to surgeons on publication, outdated                                     |
| Lovald <i>et al.</i> (2013) [21]      | Medicare Limited Data Set                                                    | 1997–2009               | 53,829                                       | Cost, mortality, complications                                                           | Outdated, limited outcomes, only Medicare population                                                            |
| Cram <i>et al.</i> (2012) [22]        | Medicare Part A data                                                         | 1991–2010               | 3,271,851                                    | LOS, readmissions, complications                                                         | Outdated, only Medicare population                                                                              |
| Blum <i>et al.</i> (2013) [13]        | Pennsylvania Health Care Cost Containment Council data                       | 2001–2007               | 17,385                                       | Complications, mortality, revisions                                                      | Outdated, limited comparisons of primary payer type                                                             |
| Webb <i>et al.</i> (2008) [23]        | Single surgeon split practice data                                           | Jan 2002–Dec 2005       | 483                                          | SSI                                                                                      | Small sample, single provider, limited outcomes, outdated                                                       |

We performed a literature search for database and registry studies investigating social determinants of health in orthopedic surgery using the Medical Subject Headings (MeSH) used by the National Library of Medicine. The MeSH terms that used to produce the search on PubMed were: ([total knee replacement] OR [total joint arthroplasty] OR [total knee arthroplasty] OR [81.54]) AND ([health insurance] OR [payer type] OR [primary payer] OR [healthcare disparities]) AND ([mortality] OR [complications] OR [morbidity] OR [patient readmission] OR [readmission] OR [length of stay] OR [resource utilization] OR [outcomes]).

HCUP: Healthcare Cost and Utilization Project; LOS: Length of stay; NIS: National Inpatient Sample; SID: State Inpatient Database; SSI: Surgical site infection.

Few studies to date examined racial/ethnic or socioeconomic disparities in TKA outside the Medicare population [8,10–12,15,16,19,40], in particular with regards to the interaction between SES and surgical volume/quality. Our primary hypothesis is that patients with Medicaid insurance status have higher rates of postoperative mortality after TKA compared with patients with private insurance.

### Study objective & hypothesis

Herein, using the State Inpatient Databases (SID) from New York, Florida, Maryland, Kentucky (2007–2014) and California (2007–2011), we sought to examine the association between primary insurance status with patient mortality and morbidity after TKA and if hospital surgical volume serves as an effect modifier for the association between insurance status and outcomes. We predict that Medicaid insurance and uninsured patients, when compared with private insurance patients, have worse outcomes after TKA and that these outcomes are worst among patients who underwent surgery at a low surgical volume hospital. We furthermore want to explore if social determinants of health (insurance status) interact with treatment in low-volume hospitals to compound poor outcomes. Previous research examining insurance types on postoperative outcomes following TKA are presented in [Table 1](#).

### Methods

We build regression models using generalized estimating equations (GEEs) with exchangeable correlation to test our hypothesis in patients included in the SID from New York, Florida, Maryland and Kentucky who underwent primary TKA from January 2007 through December 2014 to investigate the association of insurance type with postoperative outcomes, primarily focusing on in-hospital mortality, in a mixed effects regression model. The Weill Cornell Medicine Institutional Review Board approved the study and determined that participants' informed consent was not required.

### Description of State Inpatient Database

The SID is a database compiles inpatient information from nonfederal, as well as nonpsychiatric hospitals. Each SID observation represents a unique hospital admission as our unit of analysis. Hospitalization and discharge information was extracted for the SID on patients  $\geq 18$  years of age, using 2007–2014 data from New York, Florida, Maryland and Kentucky. Additionally, 2007–2011 data for California was extracted from the SID, Healthcare Cost and Utilization Project (HCUP) database. HCUP has established measures used to ensure database quality [41].

### Data extraction

We identified patients in SID from New York, Florida, Maryland and Kentucky who underwent primary TKA from January 2007 through December 2014 using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) code 81.54. Patients were divided into two groups based on whether they had a unilateral-TKA (UTKA) or bilateral-TKA (BTKA). Records with UTKA contained ICD-9-CM code 81.54 once, whereas BTKA had this code present twice [42]. We excluded patients who underwent concomitant revision of knee replacement (ICD-9-CM 81.55) or who had more than two entries for procedure code 81.54. Additionally, records were excluded if age, gender, postoperative disposition or insurance status were absent.

The following patient variables were collected: hospital length of stay (LOS), ICD-9-CM diagnoses and procedures, insurance type or expected payer, dates of admission and discharge, and patient disposition. Additionally, the following surgical and hospital variables were collected: date and location (state) hospital where the procedure was performed, the hospital Core Based Statistical Area and hospital surgical volume. The SID marks diagnoses as present-on-admission (POA) in order to indicate co-morbidities present prior to surgery from perioperative complications.

We stratified patients into five groups based on payer type (or in some cases, expected payer): Medicare (fee-for-service as well as Managed Care patients), Medicaid (also fee-for-service as well as Managed Care patients), uninsured (including self-pay and if no-charge was reported), other (including government programs, Title V, CHAMPUS, CHAMPVA and Worker's Compensation) and private insurance (private HMOs and PPOs, commercial carriers, as well as Blue Cross).

The Elixhauser co-morbidity index was used to measure patient co-morbidities [43], only selecting those diagnoses marked as POA. We relied on the Van Walraven's method for calculating a numeric score based on this index, which we then converted into a categorical variable [44].

### Sample characteristics

The total number of observations obtained for the years 2007–2014 for New York, Maryland, Florida and Kentucky, and 2007–2011 for California, was 922,819. Within these states, 199,141 TKAs were performed in 2007 with a peak of 136,884 performed in 2010. The number of TKAs then decreased, with 95,737 performed in 2014. In

Tables 2 & 3, respectively, we contrast patient characteristics and hospital characteristics by insurance type using bivariate analysis.

### Outcome measures

Our primary outcome measure was in-hospital mortality, measured by the unadjusted rate and adjusted odds ratio (OR).

Secondary outcomes included hospital LOS and postoperative complications, measured as incidence rate ratios and ORs, respectively. The following postoperative complication groups were of interest: intraoperative/procedure related, infectious, wound, pulmonary, urinary, gastrointestinal, cardiovascular and systemic.

### Statistical methods

Patients were first stratified in cohorts by insurance type, to contrast demographic and POA co-morbidities across strata. The unadjusted rates of LOS, postoperative complications, in-hospital mortality and total charges were calculated and compared by insurance status. Analysis of variance was used to compare continuous variables, and the Pearsons Chi-squared test or Fisher's exact test were used to compare categorical variables. Variables that violated assumptions of normality were converted to nonparametric equivalents.

We fit marginal logistics regression models using GEEs with exchangeable correlation in order to measure the influence of insurance type on our primary postoperative outcome in-hospital mortality while controlling for demographic characteristics, co-morbidities and potential confounders. Clustering occurs when individual hospitals repeatedly contribute observations, and GEE models take this into account. We reported ORs with their 95% CI. Separate models were developed to analyze our primary outcome of interest (in-hospital mortality) and secondary outcomes (overall and by category post-TKA complication rates). Potential confounders were accounted for in our models, by including demographic characteristics and co-morbidities (significance indicated by  $p < 0.05$ ) and patient characteristics such as race, age, gender and insurance type. Additionally, the models included the van Walraven modified Elixhauser co-morbidity index (divided into three categories: less than zero, zero and more than zero), median household income based on patient zip code, procedure year and procedure state.

The adjusted effect of insurance type on hospital LOS was examined by fitting a generalized linear mixed model to log-transformed LOS (LOS has a non-normal distribution). We reported regression coefficients with a 95% CI, denoting significance levels using the asterisk system noted above. As with the GEEs, generalized linear mixed models take clustering into account in cases where individual hospitals repeatedly contribute observations.

In order to account for potentially unmeasured confounders, the regression models were subjected to several sensitivity analyses. We used the Wald statistic to identify the most significant covariates, and our models were re-estimated after removal of the covariate, so long as there was not a significant attenuation of the effect for Medicaid insurance ( $<10\%$  attenuation of estimated odds for each outcome) and maintained statistical significance after re-estimation. In each model, the most significant covariate was age (in years).

Statistical significance was set at an alpha of  $<0.05$ , and all p-values are two-sided. Statistical tests and analysis were conducted using SAS version 9.4 (SAS Institute, NC, USA).

## Results

### Unadjusted outcomes

Our primary outcome measure was unadjusted and adjusted in-hospital mortality by insurance type. During the time period studied, total in-hospital mortality was less than 655. By payer group, in-hospital mortality totaled 528 for Medicare patients, 17 for Medicaid and 98 for privately insured patients. The unadjusted in-hospital mortality was statistically significantly lower in privately insured patients compared with the Medicare and Medicaid population ( $p < 0.0001$ ). We tabulated the unadjusted differences in in-hospital mortality and readmission rates between primary insurance types in Table 4.

### Adjusted outcomes

The effect of primary payer status on in-hospital mortality was estimated using a logistic regression model, with results shown in Table 5. After controlling for patient characteristics, surgical factors, state and hospital type, Medicaid patients had a 73% higher odds of in-hospital mortality compared with privately insured patients (OR: 1.73; 95% CI: 1.01–2.95). Self-pay or no charge patients had higher odds of 166% (OR: 2.66; 95% CI: 1.03–

**Table 2. Demographic and medical characteristics of patients undergoing total knee arthroplasty according to primary payer group.**

| Characteristic                                              | Medicare (%)   | Medicaid (%)  | Private insurance (%) | Other (%)     | Uninsured (%) | Overall (%)     | p-value |
|-------------------------------------------------------------|----------------|---------------|-----------------------|---------------|---------------|-----------------|---------|
| Total                                                       | 542,330 (58.8) | 29,692 (3.2)  | 306,340 (33.2)        | 39,609 (4.3)  | 4848 (0.5)    | 922,819 (100.0) |         |
| Age in years                                                |                |               |                       |               |               |                 | <0.0001 |
| – Mean (standard deviation)                                 | 72.41 (7.71)   | 57.65 (9.88)  | 59.25 (7.40)          | 58.78 (8.62)  | 61.44 (10.31) | 66.92 (10.15)   |         |
| Gender                                                      |                |               |                       |               |               |                 | <0.0001 |
| – Male                                                      | 188,513 (34.8) | 7357 (24.8)   | 121,716 (39.7)        | 20,757 (52.4) | 1643 (33.9)   | 339,986 (36.8)  |         |
| – Female                                                    | 353,817 (65.2) | 22,335 (75.2) | 184,624 (60.3)        | 18,852 (47.6) | 3205 (66.1)   | 582,833 (63.2)  |         |
| Race                                                        |                |               |                       |               |               |                 | <0.0001 |
| – White                                                     | 427,932 (78.9) | 12,245 (41.2) | 238,658 (77.9)        | 27,308 (68.9) | 2968 (61.2)   | 709,111 (76.8)  |         |
| – Black                                                     | 36,277 (6.7)   | 5865 (19.8)   | 26,809 (8.8)          | 4640 (11.7)   | 706 (14.6)    | 74,297 (8.1)    |         |
| – Hispanic                                                  | 42,914 (7.9)   | 6423 (21.6)   | 18,811 (6.1)          | 4101 (10.4)   | 601 (12.4)    | 72,850 (7.9)    |         |
| – Other                                                     | 22,472 (4.1)   | 3941 (13.3)   | 13,389 (4.4)          | 1702 (4.3)    | 469 (9.7)     | 41,973 (4.5)    |         |
| – Missing                                                   | 12,735 (2.3)   | 1218 (4.1)    | 8673 (2.8)            | 1858 (4.7)    | 104 (2.1)     | 24,588 (2.7)    |         |
| Year of surgery                                             |                |               |                       |               |               |                 | <0.0001 |
| – 2007                                                      | 71,068 (13.1)  | 3124 (10.5)   | 38,815 (12.7)         | 5569 (14.1)   | 565 (11.7)    | 119,141 (12.9)  |         |
| – 2008                                                      | 73,180 (13.5)  | 3533 (11.9)   | 41,892 (13.7)         | 5446 (13.7)   | 560 (11.6)    | 124,611 (13.5)  |         |
| – 2009                                                      | 75,832 (14.0)  | 3770 (12.7)   | 43,360 (14.2)         | 5475 (13.8)   | 669 (13.8)    | 129,106 (14.0)  |         |
| – 2010                                                      | 80,683 (14.9)  | 4178 (14.1)   | 45,426 (14.8)         | 5936 (15.0)   | 661 (13.6)    | 136,884 (14.8)  |         |
| – 2011                                                      | 79,005 (14.6)  | 4628 (15.6)   | 45,289 (14.8)         | 6141 (15.5)   | 665 (13.7)    | 135,728 (14.7)  |         |
| – 2012                                                      | 52,399 (9.7)   | 2963 (10.0)   | 29,478 (9.6)          | 3427 (8.7)    | 547 (11.3)    | 88,814 (9.6)    |         |
| – 2013                                                      | 54,618 (10.1)  | 3231 (10.9)   | 30,572 (10.0)         | 3779 (9.5)    | 598 (12.3)    | 92,798 (10.1)   |         |
| – 2014                                                      | 55,545 (10.2)  | 4265 (14.4)   | 31,508 (10.3)         | 3836 (9.7)    | 583 (12.0)    | 95,737 (10.4)   |         |
| State                                                       |                |               |                       |               |               |                 | <0.0001 |
| – California                                                | 135,631 (25.0) | 7564 (25.5)   | 76,332 (24.9)         | 12,315 (31.1) | 624 (12.9)    | 232,466 (25.2)  |         |
| – Florida                                                   | 193,637 (35.7) | 4755 (16.0)   | 77,990 (25.5)         | 9057 (22.9)   | 1425 (29.4)   | 286,864 (31.1)  |         |
| – Kentucky                                                  | 42,416 (7.8)   | 3274 (11.0)   | 30,008 (9.8)          | 1871 (4.7)    | 404 (8.3)     | 77,973 (8.4)    |         |
| – Maryland                                                  | 46,769 (8.6)   | 2435 (8.2)    | 37,401 (12.2)         | 2559 (6.5)    | 389 (8.0)     | 89,553 (9.7)    |         |
| – New York                                                  | 123,877 (22.8) | 11,664 (39.3) | 84,609 (27.6)         | 13,807 (34.9) | 2006 (41.4)   | 235,963 (25.6)  |         |
| Median household income state quartile for patient zip code |                |               |                       |               |               |                 | <0.0001 |
| – First quartile                                            | 114,134 (21.0) | 11,450 (38.6) | 53,688 (17.5)         | 8639 (21.8)   | 1112 (22.9)   | 189,023 (20.5)  |         |
| – Second quartile                                           | 138,946 (25.6) | 7612 (25.6)   | 73,931 (24.1)         | 10,467 (26.4) | 1138 (23.5)   | 232,094 (25.2)  |         |
| – Third quartile                                            | 143,554 (26.5) | 5725 (19.3)   | 85,030 (27.8)         | 11,185 (28.2) | 1280 (26.4)   | 246,774 (26.7)  |         |
| – Fourth quartile                                           | 136,581 (25.2) | 3305 (11.1)   | 88,292 (28.8)         | 8392 (21.2)   | 846 (17.5)    | 237,416 (25.7)  |         |
| – Missing                                                   | 9115 (1.7)     | 1600 (5.4)    | 5399 (1.8)            | 926 (2.3)     | 472 (9.7)     | 17,512 (1.9)    |         |
| Elixhauser Index – the Van Walraven Score                   |                |               |                       |               |               |                 | <0.0001 |
| – Median (Q1; Q3)                                           | 0 (-1; 0)      | 0 (-3; 0)     | 0 (-3; 0)             | 0 (-3; 0)     | 0 (-2; 0)     | 0 (-2; 0)       |         |
| Elixhauser co-morbidities                                   |                |               |                       |               |               |                 |         |
| – Congestive heart failure                                  | 14,392 (2.7)   | 561 (1.9)     | 2633 (0.9)            | 397 (1.0)     | 68 (1.4)      | 18,051 (2.0)    | <0.0001 |
| – Valvular disease                                          | 25,232 (4.7)   | 416 (1.4)     | 7996 (2.6)            | 789 (2.0)     | 124 (2.6)     | 34,557 (3.7)    | <0.0001 |
| – Pulmonary circulation disorders                           | 4663 (0.9)     | 145 (0.5)     | 1058 (0.3)            | 145 (0.4)     | 17 (0.4)      | 6028 (0.7)      | <0.0001 |
| – Peripheral vascular disorders                             | 15,702 (2.9)   | 306 (1.0)     | 3120 (1.0)            | 442 (1.1)     | 48 (1.0)      | 19,618 (2.1)    | <0.0001 |
| – Hypertension, uncomplicated                               | 354,772 (65.4) | 18,125 (61.0) | 173,013 (56.5)        | 22,344 (56.4) | 2846 (58.7)   | 571,100 (61.9)  | <0.0001 |
| – Hypertension, complicated                                 | 33,302 (6.1)   | 871 (2.9)     | 7220 (2.4)            | 982 (2.5)     | 130 (2.7)     | 42,505 (4.6)    | <0.0001 |
| – Paralysis                                                 | 697 (0.1)      | 66 (0.2)      | 239 (0.1)             | 30 (0.1)      | <11 (<0.2)    | <1043 (0.1)     | <0.0001 |
| – Other neurological disorders                              | 13,027 (2.4)   | 866 (2.9)     | 4113 (1.3)            | 513 (1.3)     | 60 (1.2)      | 18,579 (2.0)    | <0.0001 |

Patient demographic and medical characteristics were tabulated after grouping patients based on primary insurance type. p-values refer to comparisons between primary payer groups. Continuous variables analyzed using analysis of variance; categorical variables analyzed using Pearson Chi-square test or Fisher's exact test. Percents may not sum to 100 due to rounding and missing values.

**Table 2. Demographic and medical characteristics of patients undergoing total knee arthroplasty according to primary payer group (cont.).**

| Characteristic                                     | Medicare (%)   | Medicaid (%) | Private insurance (%) | Other (%)   | Uninsured (%) | Overall (%)    | p-value |
|----------------------------------------------------|----------------|--------------|-----------------------|-------------|---------------|----------------|---------|
| – Chronic pulmonary disease                        | 80,976 (14.9)  | 6735 (22.7)  | 39,697 (13.0)         | 5667 (14.3) | 672 (13.9)    | 133,747 (14.5) | <0.0001 |
| – Diabetes, uncomplicated                          | 109,089 (20.1) | 7067 (23.8)  | 49,879 (16.3)         | 7626 (19.3) | 936 (19.3)    | 174,597 (18.9) | <0.0001 |
| – Diabetes, complicated                            | 11,418 (2.1)   | 472 (1.6)    | 3931 (1.3)            | 471 (1.2)   | 67 (1.4)      | 16,359 (1.8)   | <0.0001 |
| – Hypothyroidism                                   | 92,570 (17.1)  | 2812 (9.5)   | 38,790 (12.7)         | 3946 (10.0) | 543 (11.2)    | 138,661 (15.0) | <0.0001 |
| – Renal failure                                    | 30,715 (5.7)   | 761 (2.6)    | 6455 (2.1)            | 866 (2.2)   | 116 (2.4)     | 38,913 (4.2)   | <0.0001 |
| – Liver disease                                    | 4359 (0.8)     | 815 (2.7)    | 3411 (1.1)            | 475 (1.2)   | 61 (1.3)      | 9121 (1.0)     | <0.0001 |
| – Peptic ulcer disease excluding bleeding          | 132 (0.0)      | 16 (0.1)     | 41 (0.0)              | <11 (<0.0)  |               | <200 (0.0)     | <0.0001 |
| – AIDS/HIV                                         | 166 (0.0)      | 82 (0.3)     | 70 (0.0)              | 11 (0.0)    | <11 (<0.2)    | <340 (0.0)     | <0.0001 |
| – Lymphoma                                         | 1508 (0.3)     | 29 (0.1)     | 485 (0.2)             | 54 (0.1)    | <11 (<0.2)    | <2087 (0.2)    | <0.0001 |
| – Metastatic cancer                                | 449 (0.1)      | 46 (0.2)     | 211 (0.1)             | 21 (0.1)    | <11 (<0.2)    | <738 (0.1)     | <0.0001 |
| – Solid tumor without metastasis                   | 3140 (0.6)     | 147 (0.5)    | 1114 (0.4)            | 128 (0.3)   | 30 (0.6)      | 4559 (0.5)     | <0.0001 |
| – Rheumatoid arthritis/ collagen vascular diseases | 24,733 (4.6)   | 1763 (5.9)   | 12,067 (3.9)          | 1046 (2.6)  | 206 (4.2)     | 39,815 (4.3)   | <0.0001 |
| – Coagulopathy                                     | 7436 (1.4)     | 325 (1.1)    | 2788 (0.9)            | 374 (0.9)   | 48 (1.0)      | 10,971 (1.2)   | <0.0001 |
| – Obesity                                          | 100,662 (18.6) | 8252 (27.8)  | 84,490 (27.6)         | 9927 (25.1) | 1142 (23.6)   | 204,473 (22.2) | <0.0001 |
| – Weight loss                                      | 1034 (0.2)     | 84 (0.3)     | 295 (0.1)             | 40 (0.1)    | <11 (<0.2)    | <1464 (0.2)    | <0.0001 |
| – Fluid and electrolyte disorders                  | 17,008 (3.1)   | 790 (2.7)    | 6351 (2.1)            | 812 (2.1)   | 120 (2.5)     | 25,081 (2.7)   | <0.0001 |
| – Blood loss anemia                                | 2463 (0.5)     | 141 (0.5)    | 1059 (0.3)            | 128 (0.3)   | 19 (0.4)      | 3810 (0.4)     | <0.0001 |
| – Deficiency anemia                                | 41,169 (7.6)   | 2411 (8.1)   | 16,953 (5.5)          | 2250 (5.7)  | 284 (5.9)     | 63,067 (6.8)   | <0.0001 |
| – Alcohol abuse                                    | 3946 (0.7)     | 568 (1.9)    | 2890 (0.9)            | 456 (1.2)   | 58 (1.2)      | 7918 (0.9)     | <0.0001 |
| – Drug abuse                                       | 1898 (0.3)     | 1019 (3.4)   | 1579 (0.5)            | 328 (0.8)   | 56 (1.2)      | 4880 (0.5)     | <0.0001 |
| – Psychoses                                        | 9537 (1.8)     | 1556 (5.2)   | 4353 (1.4)            | 508 (1.3)   | 80 (1.7)      | 16,034 (1.7)   | <0.0001 |
| – Depression                                       | 56,866 (10.5)  | 4733 (15.9)  | 36,094 (11.8)         | 4457 (11.3) | 495 (10.2)    | 102,645 (11.1) | <0.0001 |

Patient demographic and medical characteristics were tabulated after grouping patients based on primary insurance type. p-values refer to comparisons between primary payer groups. Continuous variables analyzed using analysis of variance; categorical variables analyzed using Pearson Chi-square test or Fisher's exact test. Percents may not sum to 100 due to rounding and missing values.

**Table 3. Hospital characteristics for patients undergoing total knee arthroplasty according to primary payer group.**

| Characteristic                             | Medicare (%)   | Medicaid (%)  | Private insurance (%) | Other (%)     | Uninsured (%) | Overall (%)    | p-value |
|--------------------------------------------|----------------|---------------|-----------------------|---------------|---------------|----------------|---------|
| Hospital volume                            |                |               |                       |               |               |                | <0.0001 |
| – First quartile                           | 132,484 (24.4) | 13,168 (44.3) | 68,462 (22.3)         | 12,853 (32.4) | 1582 (32.6)   | 228,549 (24.8) |         |
| – Second quartile                          | 134,758 (24.8) | 7646 (25.8)   | 75,268 (24.6)         | 10,369 (26.2) | 912 (18.8)    | 228,953 (24.8) |         |
| – Third quartile                           | 139,588 (25.7) | 5632 (19.0)   | 76,807 (25.1)         | 8757 (22.1)   | 915 (18.9)    | 231,699 (25.1) |         |
| – Fourth quartile                          | 135,500 (25.0) | 3246 (10.9)   | 85,803 (28.0)         | 7630 (19.3)   | 1439 (29.7)   | 233,618 (25.3) |         |
| Core-based statistical listing designation |                |               |                       |               |               |                | <0.0001 |
| – Non-CBSA                                 | 21,524 (4.0)   | 1659 (5.6)    | 11,376 (3.7)          | 1560 (3.9)    | 232 (4.8)     | 36,351 (3.9)   |         |
| – Micropolitan statistical area            | 34,953 (6.4)   | 1896 (6.4)    | 18,570 (6.1)          | 2875 (7.3)    | 237 (4.9)     | 58,531 (6.3)   |         |
| – Metropolitan statistical area            | 484,778 (89.4) | 25,910 (87.3) | 275,464 (89.9)        | 35,041 (88.5) | 4163 (85.9)   | 825,356 (89.4) |         |
| – Missing                                  | 1075 (0.2)     | 227 (0.8)     | 930 (0.3)             | 133 (0.3)     | 216 (4.5)     | 2581 (0.3)     |         |

Hospital characteristics were tabulated after grouping by primary insurance type. First quartile hospital volume indicates the lowest patient volume. p-values refer to comparisons between primary payer groups. Categorical variables analyzed using Pearson Chi-square test or Fisher's exact test. Percents may not sum to 100 due to rounding and missing values.

CBSA: Core Based Statistical Area.

6.83). Hence, we refute the null hypothesis that there is no difference in in-hospital mortality between payer groups following TKA.

**Table 4. Outcome measures for patients undergoing total knee arthroplasty according to primary payer group.**

| Characteristic                    | Medicare (%)            | Medicaid (%)            | Private insurance (%)   | Other (%)               | Uninsured (%)           | Overall (%)             | p-value |
|-----------------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|---------|
| In-hospital death                 |                         |                         |                         |                         |                         |                         | <0.0001 |
| – Yes                             | 528 (0.1)               | 17 (0.1)                | 98 (0.0)                | <11 (<0.0)              | <11 (<0.2)              | <665 (0.1)              |         |
| – 30-day readmission <sup>†</sup> | 25,325 (5.7)            | 1492 (6.5)              | 8439 (3.6)              | 1400 (4.1)              | 146 (4.2)               | 36,802 (5.0)            | <0.0001 |
| – 90-day readmission <sup>†</sup> | 45,331 (10.2)           | 2807 (12.2)             | 17,669 (7.5)            | 2589 (7.7)              | 279 (8.0)               | 68,675 (9.3)            | <0.0001 |
| Length of stay                    |                         |                         |                         |                         |                         |                         | <0.0001 |
| – Median (Q1; Q3)                 | 3 (3; 4)                | 3 (3; 4)                | 3 (3; 4)                | 3 (3; 4)                | 3 (3; 4)                | 3 (3; 4)                |         |
| Total charges in 2016 dollars     |                         |                         |                         |                         |                         |                         | <0.0001 |
| – Median (Q1; Q3)                 | 56,107 (38,251; 76,670) | 53,573 (34,417; 76,012) | 52,848 (32,604; 73,049) | 57,362 (34,368; 81,869) | 43,243 (25,463; 64,177) | 54,952 (35,882; 75,654) |         |

In-hospital death, readmission and length of stay rates were calculated by primary insurance type. p-values refer to comparisons between primary payer groups.

<sup>†</sup> Denominator does not include those whose initial disposition was death nor those without adequate follow-up information.

In-hospital mortality is a rare event. However, our findings were corroborated (and likely mediated by) our secondary outcomes, further exploring the effect of primary payer status on patient outcomes after TKA. Compared with privately insured patients, individuals insured by Medicaid were more likely to experience any postoperative complications (OR: 1.25; 95% CI: 1.18–1.33), pulmonary complications (OR: 1.26; 95% CI: 1.16–1.36), infection-related complications (OR: 1.51; 95% CI: 1.35–1.68), intraoperative complications (OR: 1.25; 95% CI: 1.03–1.52), longer LOS (OR: 1.09; 95% CI: 1.08–1.10) and greater total charges (OR: 1.03; 95% CI: 1.02–1.04).

The hospitals in our dataset were divided into quartiles based on patient volume, with the first quartile representing the lowest volume. Of all Medicaid patients in this study, 44.3% were treated at hospitals in the first quartile. In comparison, 22.3% of privately insured patients were treated at such hospitals. In-hospital mortality was greatest for hospitals in the first quartile. Using hospitals in the first quartile as the reference, the OR for in-hospital mortality for the second quartile was (OR: 0.64; 95% CI: 0.52–0.79), (OR: 0.68; 95% CI: 0.54–0.86) for the third quartile and (OR: 0.42; 95% CI: 0.31–0.57) for the fourth quartile.

Stratifying the data by state in our sensitivity analyses led to similar inferences (data not shown). There was no significant difference in the adjusted OR for in-hospital mortality between each state and Florida, except in the case of California, which had a significantly lower odds of in-hospital mortality (OR: 0.56; 95% CI: 0.45–0.70).

We performed additional sensitivity analyses: the risk-adjusted OR for Medicaid and LOS after removing age (OR: 1.08; 95% CI: 1.07–1.10) and total charges in 2016 after removing age (OR: 1.03; 95% CI: 1.02–1.04) were still significantly greater for Medicaid compared with private insurance. Risk-adjusted ORs were again calculated after removing California, and the incidence rate ratio for Medicaid patients was still significantly greater for LOS (OR: 1.07; 95% CI: 1.06–1.09) and for total charges (OR: 1.02; 95% CI: 1.01–1.03; Table 6).

## Discussion

In our regression analysis of SID patients from New York, Florida, Maryland and Kentucky who underwent primary TKA from January 2007 through December 2014, Medicaid insurance status was associated with higher unadjusted rate and risk-adjusted odds of mortality. Corroborating our primary outcome, Medicaid patients also experience higher odds of any postoperative complications, as well as pulmonary complications, infectious complications, intraoperative complications and longer LOS compared with privately insured patients. We hypothesize that these complications mediated the higher mortality in the Medicaid population. Our findings, however, are not to suggest that being insured by Medicaid is detrimental. To the contrary, having Medicaid insurance is probably better than having no insurance at all [45–47]. Although major disparities exist in health outcomes between those insured by Medicaid and private insurance, expanding access to care through the ACA's Medicaid Expansion program is leading to a decrease in the deeply entrenched disparities in access to care between socioeconomic groups in the USA [48].

Table 5. Full regression results for risk-adjusted outcomes among patients after total knee arthroplasty.

| Outcome                                             | Length of stay                | Total charges in 2016 dollars | In-hospital mortality         | Any complications             |
|-----------------------------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| Payer status (reference = private insurance)        |                               |                               |                               |                               |
| – Medicare                                          | 1.02 (1.01–1.02) <sup>†</sup> | 1.01 (1.00–1.01) <sup>†</sup> | 1.17 (0.90–1.52)              | 1.09 (1.06–1.13) <sup>†</sup> |
| – Medicaid                                          | 1.09 (1.08–1.10) <sup>†</sup> | 1.03 (1.02–1.04) <sup>†</sup> | 1.73 (1.01–2.95) <sup>§</sup> | 1.25 (1.18–1.33) <sup>†</sup> |
| – Self-pay or no charge                             | 1.04 (1.02–1.06) <sup>†</sup> | 1.01 (0.99–1.03)              | 2.66 (1.03–6.83) <sup>§</sup> | 1.10 (0.95–1.28)              |
| Other                                               | 1.06 (1.05–1.07) <sup>†</sup> | 1.01 (1.00–1.02)              | 0.69 (0.34–1.40)              | 1.07 (1.00–1.13) <sup>§</sup> |
| Race (reference = White)                            |                               |                               |                               |                               |
| – Black                                             | 1.06 (1.05–1.07) <sup>†</sup> | 1.03 (1.02–1.03) <sup>†</sup> | 1.38 (1.04–1.82) <sup>§</sup> | 1.10 (1.06–1.15) <sup>†</sup> |
| – Hispanic                                          | 1.03 (1.02–1.03) <sup>†</sup> | 1.00 (0.99–1.00)              | 0.91 (0.65–1.27)              | 1.00 (0.95–1.05)              |
| – Other                                             | 1.03 (1.02–1.03) <sup>†</sup> | 1.01 (1.00–1.03)              | 0.89 (0.59–1.32)              | 1.08 (1.03–1.14) <sup>†</sup> |
| – Missing                                           | 1.03 (1.01–1.04) <sup>†</sup> | 0.81 (0.72–0.90) <sup>†</sup> | 1.39 (0.87–2.22)              | 0.69 (0.62–0.78) <sup>†</sup> |
| Median income level (reference = first quartile)    |                               |                               |                               |                               |
| – Second quartile                                   | 0.99 (0.99–0.99) <sup>†</sup> | 0.99 (0.99–1.00) <sup>§</sup> | 0.88 (0.70–1.10)              | 1.00 (0.97–1.03)              |
| – Third quartile                                    | 0.98 (0.98–0.99) <sup>†</sup> | 0.99 (0.99–1.00) <sup>†</sup> | 0.89 (0.72–1.11)              | 0.97 (0.95–1.00)              |
| – Fourth quartile                                   | 0.98 (0.97–0.98) <sup>†</sup> | 0.99 (0.98–0.99) <sup>†</sup> | 0.92 (0.73–1.15)              | 0.97 (0.94–1.00)              |
| – Missing                                           | 1.00 (1.00–1.01)              | 1.00 (0.99–1.01)              | 0.66 (0.35–1.24)              | 1.04 (0.96–1.11)              |
| Hospital volume (reference = first quartile)        |                               |                               |                               |                               |
| – Second quartile                                   | 0.89 (0.86–0.91) <sup>†</sup> | 0.99 (0.94–1.05)              | 0.64 (0.52–0.79) <sup>†</sup> | 0.88 (0.80–0.97) <sup>§</sup> |
| – Third quartile                                    | 0.86 (0.82–0.89) <sup>†</sup> | 0.96 (0.89–1.03)              | 0.68 (0.54–0.86) <sup>†</sup> | 0.79 (0.70–0.90) <sup>†</sup> |
| – Fourth quartile                                   | 0.86 (0.82–0.90) <sup>†</sup> | 0.88 (0.78–0.98) <sup>§</sup> | 0.42 (0.31–0.57) <sup>†</sup> | 0.79 (0.66–0.95) <sup>§</sup> |
| Number of knee procedures (reference = 1 procedure) | 1.26 (1.22–1.30) <sup>†</sup> | 1.59 (1.56–1.62) <sup>†</sup> | 2.38 (1.76–3.23) <sup>†</sup> | 1.68 (1.60–1.77) <sup>†</sup> |
| Age                                                 | 1.00 (1.00–1.00) <sup>†</sup> | 1.00 (1.00–1.00)              | 1.07 (1.06–1.08) <sup>†</sup> | 1.02 (1.02–1.02) <sup>†</sup> |
| Female                                              | 1.04 (1.03–1.04) <sup>†</sup> | 0.99 (0.99–1.00) <sup>†</sup> | 0.51 (0.44–0.59) <sup>†</sup> | 0.92 (0.89–0.94) <sup>†</sup> |
| Year (reference = 2007)                             |                               |                               |                               |                               |
| – 2008                                              | 0.97 (0.97–0.98) <sup>†</sup> | 1.03 (1.01–1.05) <sup>†</sup> | 0.91 (0.69–1.22)              | 1.39 (1.30–1.50) <sup>†</sup> |
| – 2009                                              | 0.95 (0.94–0.95) <sup>†</sup> | 1.11 (1.09–1.13) <sup>†</sup> | 0.81 (0.60–1.08)              | 1.32 (1.22–1.42) <sup>†</sup> |
| – 2010                                              | 0.92 (0.92–0.93) <sup>†</sup> | 1.14 (1.11–1.16) <sup>†</sup> | 0.92 (0.70–1.21)              | 1.25 (1.15–1.36) <sup>†</sup> |
| – 2011                                              | 0.90 (0.90–0.91) <sup>†</sup> | 1.14 (1.12–1.17) <sup>†</sup> | 0.88 (0.66–1.18)              | 1.16 (1.08–1.26) <sup>†</sup> |
| – 2012                                              | 0.89 (0.88–0.90) <sup>†</sup> | 1.19 (1.16–1.23) <sup>†</sup> | 0.67 (0.48–0.94) <sup>§</sup> | 1.05 (0.97–1.15)              |
| – 2013                                              | 0.86 (0.85–0.88) <sup>†</sup> | 1.23 (1.19–1.27) <sup>†</sup> | 0.53 (0.37–0.77) <sup>†</sup> | 0.97 (0.89–1.06)              |
| – 2014                                              | 0.81 (0.79–0.83) <sup>†</sup> | 1.26 (1.21–1.31) <sup>†</sup> | 0.51 (0.35–0.75) <sup>†</sup> | 0.85 (0.76–0.94) <sup>†</sup> |
| State (reference = Florida)                         |                               |                               |                               |                               |
| – California                                        | 0.94 (0.91–0.97) <sup>†</sup> | 1.30 (1.23–1.38) <sup>†</sup> | 0.56 (0.45–0.70) <sup>†</sup> | 0.77 (0.69–0.85) <sup>†</sup> |
| – Kentucky                                          | 0.96 (0.93–0.99) <sup>§</sup> | 0.65 (0.58–0.72) <sup>†</sup> | 1.17 (0.88–1.55)              | 1.22 (1.05–1.42) <sup>‡</sup> |
| – Maryland                                          | 0.91 (0.87–0.96) <sup>†</sup> | 0.37 (0.35–0.40) <sup>†</sup> | 0.99 (0.72–1.36)              | 1.25 (1.06–1.48) <sup>‡</sup> |
| – New York                                          | 1.09 (1.06–1.13) <sup>†</sup> | 0.59 (0.54–0.63) <sup>†</sup> | 0.85 (0.66–1.09)              | 0.87 (0.76–0.99) <sup>§</sup> |
| Elixhauser index (reference = first quartile)       |                               |                               |                               |                               |
| – Second tertile                                    | 0.95 (0.94–0.95) <sup>†</sup> | 0.96 (0.96–0.97) <sup>†</sup> | 0.62 (0.50–0.78) <sup>†</sup> | 0.63 (0.60–0.66) <sup>†</sup> |
| – Third tertile                                     | 1.05 (1.04–1.05) <sup>†</sup> | 1.03 (1.03–1.03) <sup>†</sup> | 2.12 (1.72–2.61) <sup>†</sup> | 1.21 (1.17–1.24) <sup>†</sup> |

Risk-adjusted outcomes for patients undergoing total knee arthroplasty, expressed as odds ratios with 95% CI.

<sup>†</sup>p ≤ 0.005.<sup>‡</sup>p ≤ 0.001.<sup>§</sup>p ≤ 0.05.

### Implications & significance

This is the first direct comparison between Medicaid and private insurance type, demonstrating increased mortality after TKA in underinsured patients while controlling for patient characteristics, co-morbidity, risk factor and age. This is deeply concerning, given that the data are from several state databases, including several diverse large states (California, Florida, Maryland, Kentucky and New York), drawing from a significant portion of the US populations and hence likely representing a general trend across the country.

**Table 6. Sensitivity regressions for risk-adjusted outcomes among patients after total knee arthroplasty.**

| Outcome                                                         | LOS, without age              | Total charges in 2016 dollars, without age | LOS, without California       | Total charges in 2016 dollars, without California |
|-----------------------------------------------------------------|-------------------------------|--------------------------------------------|-------------------------------|---------------------------------------------------|
| Payer status (reference = private insurance)                    |                               |                                            |                               |                                                   |
| – Medicare                                                      | 1.07 (1.06–1.07) <sup>†</sup> | 1.01 (1.00–1.01) <sup>‡</sup>              | 1.01 (1.01–1.02) <sup>†</sup> | 1.00 (1.00–1.01)                                  |
| – Medicaid                                                      | 1.08 (1.07–1.10) <sup>†</sup> | 1.03 (1.02–1.04) <sup>†</sup>              | 1.07 (1.06–1.09) <sup>†</sup> | 1.02 (1.01–1.03) <sup>†</sup>                     |
| – Self-pay or no charge                                         | 1.05 (1.02–1.07) <sup>†</sup> | 1.01 (0.99–1.03)                           | 1.04 (1.02–1.07) <sup>†</sup> | 1.01 (0.99–1.03)                                  |
| – Other                                                         | 1.05 (1.05–1.06) <sup>†</sup> | 1.01 (1.00–1.02)                           | 1.04 (1.03–1.05) <sup>†</sup> | 1.00 (0.99–1.01)                                  |
| Race (reference = White)                                        |                               |                                            |                               |                                                   |
| – Black                                                         | 1.05 (1.05–1.06) <sup>†</sup> | 1.03 (1.02–1.03) <sup>†</sup>              | 1.06 (1.05–1.07) <sup>†</sup> | 1.03 (1.02–1.03) <sup>†</sup>                     |
| – Hispanic                                                      | 1.02 (1.02–1.03) <sup>†</sup> | 1.00 (0.99–1.00)                           | 1.03 (1.02–1.04) <sup>†</sup> | 1.00 (0.98–1.01)                                  |
| – Other                                                         | 1.03 (1.02–1.04) <sup>†</sup> | 1.01 (1.00–1.03)                           | 1.02 (1.01–1.03) <sup>†</sup> | 1.01 (0.99–1.04)                                  |
| – Missing                                                       | 1.02 (1.01–1.04) <sup>†</sup> | 0.81 (0.72–0.90) <sup>†</sup>              | 1.04 (1.01–1.07) <sup>‡</sup> | 0.70 (0.59–0.84) <sup>†</sup>                     |
| Median income level (reference = first quartile)                |                               |                                            |                               |                                                   |
| – Second quartile                                               | 0.99 (0.99–1.00) <sup>†</sup> | 0.99 (0.99–1.00) <sup>§</sup>              | 0.99 (0.99–1.00) <sup>†</sup> | 1.00 (0.99–1.00)                                  |
| – Third quartile                                                | 0.99 (0.98–0.99) <sup>†</sup> | 0.99 (0.99–1.00) <sup>†</sup>              | 0.98 (0.98–0.99) <sup>†</sup> | 0.99 (0.99–1.00) <sup>†</sup>                     |
| – Fourth quartile                                               | 0.98 (0.97–0.98) <sup>†</sup> | 0.99 (0.98–0.99) <sup>†</sup>              | 0.98 (0.97–0.98) <sup>†</sup> | 0.99 (0.98–1.00) <sup>†</sup>                     |
| – Missing                                                       | 1.00 (0.99–1.01)              | 1.00 (0.99–1.01)                           | 1.01 (1.00–1.02) <sup>§</sup> | 1.00 (0.99–1.01)                                  |
| Hospital volume (reference = first quartile)                    |                               |                                            |                               |                                                   |
| – Second quartile                                               | 0.89 (0.87–0.92) <sup>†</sup> | 0.99 (0.94–1.05)                           | 0.91 (0.88–0.94) <sup>†</sup> | 0.99 (0.92–1.07)                                  |
| – Third quartile                                                | 0.86 (0.83–0.89) <sup>†</sup> | 0.96 (0.89–1.03)                           | 0.88 (0.85–0.91) <sup>†</sup> | 0.96 (0.89–1.04)                                  |
| – Fourth quartile                                               | 0.86 (0.83–0.90) <sup>†</sup> | 0.88 (0.78–0.98) <sup>§</sup>              | 0.87 (0.83–0.90) <sup>†</sup> | 0.89 (0.79–0.99) <sup>§</sup>                     |
| Number of knee procedures (reference = 1 procedure)             | 1.25 (1.21–1.30) <sup>†</sup> | 1.59 (1.56–1.62) <sup>†</sup>              | 1.26 (1.21–1.32) <sup>†</sup> | 1.60 (1.57–1.63) <sup>†</sup>                     |
| Age                                                             |                               |                                            |                               |                                                   |
| Female                                                          | 1.04 (1.03–1.04) <sup>†</sup> | 0.99 (0.99–1.00) <sup>†</sup>              | 1.03 (1.03–1.04) <sup>†</sup> | 0.99 (0.99–1.00) <sup>†</sup>                     |
| Year (reference = 2007)                                         |                               |                                            |                               |                                                   |
| – 2008                                                          | 0.97 (0.97–0.98) <sup>†</sup> | 1.03 (1.01–1.05) <sup>†</sup>              | 0.98 (0.97–0.98) <sup>†</sup> | 1.03 (1.01–1.05) <sup>‡</sup>                     |
| – 2009                                                          | 0.95 (0.94–0.95) <sup>†</sup> | 1.11 (1.09–1.13) <sup>†</sup>              | 0.96 (0.95–0.96) <sup>†</sup> | 1.10 (1.07–1.12) <sup>†</sup>                     |
| – 2010                                                          | 0.92 (0.92–0.93) <sup>†</sup> | 1.14 (1.11–1.16) <sup>†</sup>              | 0.94 (0.93–0.95) <sup>†</sup> | 1.13 (1.10–1.16) <sup>†</sup>                     |
| – 2011                                                          | 0.90 (0.89–0.91) <sup>†</sup> | 1.14 (1.12–1.17) <sup>†</sup>              | 0.92 (0.91–0.93) <sup>†</sup> | 1.14 (1.11–1.17) <sup>†</sup>                     |
| – 2012                                                          | 0.89 (0.88–0.90) <sup>†</sup> | 1.19 (1.16–1.23) <sup>†</sup>              | 0.90 (0.89–0.92) <sup>†</sup> | 1.18 (1.15–1.22) <sup>†</sup>                     |
| – 2013                                                          | 0.86 (0.85–0.88) <sup>†</sup> | 1.23 (1.19–1.27) <sup>†</sup>              | 0.87 (0.86–0.89) <sup>†</sup> | 1.22 (1.18–1.27) <sup>†</sup>                     |
| – 2014                                                          | 0.81 (0.79–0.83) <sup>†</sup> | 1.26 (1.21–1.31) <sup>†</sup>              | 0.82 (0.80–0.84) <sup>†</sup> | 1.25 (1.20–1.30) <sup>†</sup>                     |
| State (reference = Florida)                                     |                               |                                            |                               |                                                   |
| – California                                                    | 0.94 (0.91–0.97) <sup>†</sup> | 1.30 (1.23–1.38) <sup>†</sup>              |                               |                                                   |
| – Kentucky                                                      | 0.95 (0.92–0.99) <sup>‡</sup> | 0.65 (0.58–0.72) <sup>†</sup>              | 0.96 (0.93–1.00) <sup>§</sup> | 0.66 (0.59–0.73) <sup>†</sup>                     |
| – Maryland                                                      | 0.91 (0.87–0.95) <sup>†</sup> | 0.37 (0.35–0.40) <sup>†</sup>              | 0.91 (0.87–0.95) <sup>†</sup> | 0.38 (0.35–0.40) <sup>†</sup>                     |
| – New York                                                      | 1.10 (1.06–1.13) <sup>†</sup> | 0.59 (0.54–0.63) <sup>†</sup>              | 1.10 (1.06–1.13) <sup>†</sup> | 0.59 (0.54–0.63) <sup>†</sup>                     |
| Elixhauser index (reference = first quartile)                   |                               |                                            |                               |                                                   |
| – Second tertile                                                | 0.95 (0.95–0.96) <sup>†</sup> | 0.96 (0.96–0.97) <sup>†</sup>              | 0.95 (0.94–0.95) <sup>†</sup> | 0.96 (0.96–0.97) <sup>†</sup>                     |
| – Third tertile                                                 | 1.06 (1.05–1.06) <sup>†</sup> | 1.03 (1.03–1.03) <sup>†</sup>              | 1.05 (1.04–1.05) <sup>†</sup> | 1.03 (1.02–1.03) <sup>†</sup>                     |
| Sensitivity analysis comparing our initial regression analyses. |                               |                                            |                               |                                                   |
| <sup>†</sup> p ≤ 0.005.                                         |                               |                                            |                               |                                                   |
| <sup>‡</sup> p ≤ 0.001.                                         |                               |                                            |                               |                                                   |
| <sup>§</sup> p ≤ 0.05.                                          |                               |                                            |                               |                                                   |
| LOS: Length of stay                                             |                               |                                            |                               |                                                   |

Beyond describing and lamenting disparate outcomes driven by social determinants of health, we need to explore potential mechanisms with a view to design and implement effective countermeasures [49]. We suspected that hospital volume may be an important mediator, which could explain the observed disparities between Medicaid and private insurance patients. Racial/ethnic minorities and Medicaid patients are less likely to be treated at high-volume hospitals when compared with White, privately insured patients [31,50,51]. Patients treated at low-volume hospitals have an increased risk for readmission following TKA [40], and other studies show that high-volume

surgeons and institutions have lower rates of complications and mortality following orthopedic surgery [52–54]. Our study corroborates this exploratory hypothesis, in that LOS, in-hospital mortality and the odds of any complication were greater in the hospitals in the first quartile for hospital volume when compared with greater volume hospitals. The differences in mortality and complication rates between payer groups demonstrated in our study may in part be due to the fact that Medicaid patients are largely treated at low-volume hospitals. This generated a new exploratory hypothesis that hospital volume and quality interact with high risk and lower SES to compound morbidity and mortality after major joint replacement, a hypothesis that should be investigated and confirmed in subsequent studies. Additional factors that may contribute to poorer outcomes for Medicaid patients include proximity of patient home to hospitals, longer waiting period for surgical appointments and lower baseline range of motion and function, and such factors should be investigated as well.

Mediated for example through (implicit) bias, the racial makeup of Medicaid patients may play a role in the disparities presented in this study. Overall health insurance coverage in 2016 for non-Hispanic Whites was 93.7%, while for Blacks coverage was 89.5%, Asians 92.4% and Hispanics 84.0% [55]. In terms of Medicaid coverage, Blacks make up 34.1% of the insured population, Hispanics make up 31.1%, and Whites makes up 16.9% as of 2015 [56]. A systematic review showed that racial and ethnic minority groups are at a greater risk for postoperative complications and mortality compared with White patients for spinal and joint replacement procedures [57,58].

Of note, the Hospital Readmissions Reduction Program, under the ACA, has since 2012 reduced payments for Inpatient Prospective Payment System hospitals with excess 30-day readmissions [59]. Such penalization may disproportionately affect hospitals that treat racial/ethnic minority groups and patients of lower SES, since the Hospital Readmissions Reduction Program model does not differentiate hospitals based on the SES of the patient population [60]. Instead, the Center for Medicare and Medicaid Services policies could promote the preferential admission of the highest risk patients in the high-quality and high-volume institutions.

### Comparison with the existing literature

We believe this is the most up-to-date, largest recent study examining the affect of insurance type on patient mortality following TKA. Previous studies on TKA focused on disparities in Medicare patients only, were outdated, did not group by insurance type, or were mainly concerned with racial/ethnic disparities (Table 1). Our sample size is large and was extracted from several diverse states, thus allowing us to control for many potential confounding variables.

Our hypothesis, formulated *a priori*, that Medicaid insurance status is associated with a higher rate of post-operative mortality following TKA when compared with privately insured patients, builds on previous studies investigating disparities between Medicaid patients and privately insured patients undergoing other orthopedic interventions [2,11,12].

Nevertheless, the present study corroborates previous research examining disparities in surgical outcomes depending on insurance status [61], including in orthopedic operations [10–12,23]. LaPar *et al.* conducted a large retrospective analysis of 893,658 patients from the Nationwide Inpatient Sample database, examining the role of primary payer status on outcomes in several surgical procedures, including 230,000 THAs, and found that those insured by Medicaid had higher odds of unadjusted mortality, higher costs and greater LOS compared with private insurance patients [62]. Our study of 922,819 cases similarly found that in-hospital mortality, LOS and total cost were higher for Medicaid patients.

### Strength & weaknesses of our analysis

One strength of our study comes from its generalizability. The HCUP dataset is a large, diverse sample that we extracted from several of the most populated states, allowing us to draw useful conclusions that can be generalized to the rest of the country. Since our study takes a large number of patient and hospital factors into account, the results can be applied broadly. Conversely, the results should not be construed to implicate bias by any individual or discrimination in any institution. Instead, further investigation at the provider and institutional level is warranted in order to expose the mechanisms driving patient disparities based on insurance type in our healthcare delivery system [49].

The results maintained statistical significance when controlling for state, hospital characteristics and patient demographics in our sensitivity analyses. The results also maintained significance independent of inclusion and exclusion of potential confounders, modeling choices and assumptions. Stratification by state still demonstrated higher mortality in Medicaid populations. Our results are compelling and consistent, considering that Medicaid

insurance status was associated also with higher complication rates and remained so across several statistical models and sensitivity analyses. We report many p-values that are highly statistically significant ( $<0.005$ ), but we acknowledge that statistical significance is less meaningful in such a large sample, since significance is quickly reached in studies with such a large number of observations [63,64].

We acknowledge several limitations of our study. Although we attempted to control for confounding variables, we cannot exclude that confounders were unaccounted for in our analyses; these confounders could be contributing to poorer postoperative outcomes for Medicaid patients. Patient risk factors that confer poorer outcomes may be proportionally higher in the Medicaid population, such as obesity, lower level of education, lower income level and decreased English proficiency and may contribute to a higher risk of adverse outcomes in Medicaid patients [65,66]. Studies examining social determinants of health in patients undergoing orthopedic surgeries are limited, but those that have been conducted found that Medicaid patients undergoing orthopedic procedures are more likely to smoke tobacco and have a higher rate of obesity [67,68]. Our results may underestimate the rate of adverse events in patients undergoing TKA since patients are only accounted for if they present with complications to the hospital where the procedure was performed. Intraoperative information is not contained in the database, preventing us from studying whether poorer outcomes for Medicaid patients are associated with particular intraoperative events. Proper event coding in the HCUP database is dependent upon providers using particular medical terminology in free-text case notes [69], and failure to do so leads to missing and misclassified data.

Perioperative and intraoperative factors may also play a role in the disparities observed in the present study. In anesthesia, social determinants of health appear to play a role in the quality of care provided [49]. The use of regional anesthesia in primary joint arthroplasty has been shown to lead to more favorable patient outcomes [70–77,78]. No large-scale studies have been performed investigating the disparities in the use of regional techniques between racial and ethnic groups, but a study by Memtsoudis *et al.* using a database of 382,236 THA and TKA patients found that neuraxial anesthesia was used in 17% of Black patients and 25% of White patients [70]. Similarly, a study by Paterno *et al.* using the same database found that in cases of hip fractures, regional anesthesia was used more often in White patients (16%) compared with Black patients (13%) [79]. Postoperative care and pain management also contain significant disparities between racial and ethnic groups [1,65,80–82], with minorities suffering from higher pain scores [83], longer wait times to receive pain treatment [84] and obtaining lower amounts of pain medication compared with White patients [85].

## Conclusion

Patients with Medicaid insurance undergoing primary TKA in New York, Florida, Maryland, California and Kentucky may be at higher risk for perioperative mortality and morbidity than their counterparts who are privately insured, even after controlling for patient characteristics, co-morbidity, risk and age.

Medicaid patients also experienced greater odds of additional adverse clinical outcomes. Our findings were maintained across several models and sensitivity analyses. Our results suggest that patient insurance status may be a predictor of adverse postoperative outcomes, and could be considered when assessing patient risk factors prior to surgery. The disparities presented in this paper are likely not unique to TKA and may be emblematic of pervasive perioperative health system disparities. Improving access through increased rates of insurance is important, but a more sophisticated view that incorporates patient outcomes as a function of insurance type and local hospital performance is crucial in addressing health disparities.

## Future perspective

Provider (implicit) bias may play a role in the disparate outcomes observed in our population [49], although it is more difficult to clearly demonstrate this effect in more complex health interventions, delivered by multiple teams. Providers may be unaware of implicit biases that could result in disparities in care [86,87]. We believe that within 5–10 years, educating practitioners about implicit biases will become standard practice, which may help alleviate the disparities demonstrated in our study [88].

In addition to physician education, audit and feedback systems may help to provide objective, real-time reports to physicians about their patient outcomes, stratified by insurance and racial groups. Such systems are shown to be useful in influencing provider behaviors in order to improve patient outcomes [89,90]. Data collected in the electronic medical record could be delivered to an internal algorithm that calculates a performance feedback report for providers [90]. It could include patient outcomes, grouped by race/ethnicity, insurance type and median income

of the home zip code of the patient, and allow providers to make adjustments as a result of seeing the disparities in outcomes in their patients.

### Summary points

- Social determinants of health predict postoperative outcomes after joint replacement surgery.
- Medicaid insurance status predicts higher odds of in-hospital mortality after total knee arthroplasty when compared with private insurance (odds ratio: 1.73; 95% CI: 1.01–2.95).
- Medicaid patients who undergo total knee arthroplasty also suffer from higher intra- and postoperative complication rates, and face longer lengths of stay and greater total charges.
- Insurance status is a useful factor to consider in predicting postoperative outcomes.
- The mechanisms underlying the disparity between Medicaid and private insurance patients are unclear, although provider bias and hospital volume may play a role.

### Author contributions

SR Maman's contributions include conducting an exhaustive literature review, summarizing conclusions from the analyzed patient data and writing the final manuscript. MH Andreae helped in formulating conclusions from the results and developing the manuscript; RS White and ZA Turnbull developed the initial study hypothesis and retrieved the data necessary for the study; and LK Gaber-Baylis performed the statistical analysis.

### Acknowledgments

The authors thank the staff members at the Center for Perioperative Outcomes for their generous support in helping with this project.

### Financial & competing interests disclosure

This research was supported in part by the CTSA Grant 5 TL1 TR002016-03 from the National Center for Advancing Translational Sciences (NCATS), a component of the NIH, and by the Penn State Donald E. Martin Professorship in Anesthesia and Pain Medicine. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH. The authors have no other relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript apart from those disclosed.

No writing assistance was utilized in the production of this manuscript.

### Ethical conduct of research

The Weill Cornell Medicine Institutional Review Board approved the study and determined that participants' informed consent was not required.

### References

Papers of special note have been highlighted as: • of interest

1. Freburger JK, Holmes GM, Ku L-JE, Cutchin MP, Heatwole-Shank K, Edwards LJ. Disparities in post-acute rehabilitation care for joint replacement. *Arthritis Care Res.* 63(7), 1020–1030 (2011).
2. Christopher AS, McCormick D, Woolhandler S, Himmelstein DU, Bor DH, Wilper AP. Access to care and chronic disease outcomes among Medicaid-insured persons versus the uninsured. *Am. J. Public Health* 106(1), 63–69 (2016).
3. Magge H, Cabral HJ, Kazis LE, Sommers BD. Prevalence and predictors of underinsurance among low-income adults. *J. General Intern. Med.* 28(9), 1136–1142 (2013).
4. Stone ML, LaPar DJ, Mulloy DP *et al.* Primary payer status is significantly associated with postoperative mortality, morbidity, and hospital resource utilization in pediatric surgical patients within the United States. *J. Pediatric Surg.* 48(1), 81–87 (2013).
- **This retrospective study examines the importance primary payer status in predicting postoperative outcomes.**
5. Schoenfeld AJ, Tipirneni R, Nelson JH, Carpenter JE, Iwashyna TJ. The influence of race and ethnicity on complications and mortality after orthopedic surgery. *Med. Care* 52(9), 842–851 (2014).
6. Li X, Veltre DR, Cusano A *et al.* Insurance status affects postoperative morbidity and complication rate after shoulder arthroplasty. *J. Shoulder Elbow Surg.* 26(8), 1423–1431 (2017).
7. Haghverdian BA, Wright DJ, Schwarzkopf R. Comparison of postarthroplasty functional outcomes in skilled nursing facilities among Medicare and Managed Care beneficiaries. *Arthroplast. Today* 3(4), 275–280 (2017).

8. Anthony CA, Peterson RA, Sewell DK *et al.* The seasonal variability of surgical site infections in knee and hip arthroplasty. *J. Arthroplast.* 33(2), 510–514.e1 (2018).
9. Adelani MA, Keller MR, Barrack RL, Olsen MA. The impact of hospital volume on racial differences in complications, readmissions, and emergency department visits following total joint arthroplasty. *J. Arthroplast.* 33(2), 309–315.e20 (2018).
10. El Bitar YF, Illingworth KD, Scaife SL, Horberg JV, Saleh KJ. Hospital length of stay following primary total knee arthroplasty: data from the Nationwide Inpatient Sample database. *J. Arthroplast.* 30(10), 1710–1715 (2015).
11. Browne JA, Novicoff WM, D'Apuzzo MR. Medicaid payer status is associated with in-hospital morbidity and resource utilization following primary total joint arthroplasty. *J. Bone Joint Surg. Am.* 96(21), e180–1–6 (2014).
12. Xu HF, White RS, Sastow DL, Andrae MH, Gaber-Baylis LK, Turnbull ZA. Medicaid insurance as primary payer predicts increased mortality after total hip replacement in the state inpatient databases of California, Florida and New York. *J. Clin. Anesth.* 43, 24–32 (2017).
- **This retrospective study shows how Medicaid patients have higher risk of in-hospital mortality after total hip arthroplasty.**
13. Blum MA, Singh JA, Lee G-C, Richardson D, Chen W, Ibrahim SA. Patient race and surgical outcomes after total knee arthroplasty: an analysis of a large regional database. *Arthritis Care Res.* 65(3), 414–420 (2013).
14. Mistry JB, Gwam CU, Naziri Q *et al.* Are allogeneic transfusions decreasing in total knee arthroplasty patients? National Inpatient Sample 2009–2013. *J. Arthroplast.* 33(6), 1705–1712 (2018).
15. Middleton A, Lin Y-L, Graham JE, Ottenbacher KJ. Outcomes over 90-day episodes of care in Medicare fee-for-service beneficiaries receiving joint arthroplasty. *J. Arthroplast.* 32(9), 2639–2647.e1 (2017).
16. Welsh RL, Graham JE, Karmarkar AM *et al.* Effects of postacute settings on readmission rates and reasons for readmission following total knee arthroplasty. *J. Am. Med. Dir. Assoc.* 18(4), 367.e1–367.e10 (2017).
17. Schwarzkopf R, Ho J, Snir N, Mukamel DD. Factors influencing discharge destination after total hip arthroplasty. *Geriatr. Orthop. Surg. Rehabil.* 6(3), 215–219 (2015).
18. Bolognesi MP, Greiner MA, Attarian DE *et al.* Unicompartmental knee arthroplasty and total knee arthroplasty among Medicare beneficiaries, 2000 to 2009. *J. Bone Joint Surg.* 95(22), e174 (2013).
19. Singh JA, Lu X, Rosenthal GE, Ibrahim S, Cram P. Racial disparities in knee and hip total joint arthroplasty: an 18-year analysis of national medicare data. *Ann. Rheum. Dis.* 73(12), 2107–2115 (2014).
20. Rosenthal BD, Hulst JB, Moric M, Levine BR, Sporer SM. The effect of payer type on clinical outcomes in total knee arthroplasty. *J. Arthroplast.* 29(2), 295–298 (2014).
21. Lovald ST, Ong KL, Lau EC, Schmier JK, Bozic KJ, Kurtz SM. Mortality, cost, and health outcomes of total knee arthroplasty in Medicare patients. *J. Arthroplast.* 28(3), 449–454 (2013).
22. Cram P, Lu X, Kates SL, Singh JA, Li Y, Wolf BR. Total knee arthroplasty volume, utilization, and outcomes among Medicare beneficiaries, 1991–2010. *JAMA* 308(12), 1227 (2012).
23. Webb BG, Lichtman DM, Wagner RA. Risk factors in total joint arthroplasty: comparison of infection rates in patients with different socioeconomic backgrounds. *Orthopedics* 31(5), 445 (2008).
24. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J. Bone Joint Surg. Am.* 89(4), 780–785 (2007).
25. Weinstein AM, Rome BN, Reichmann WM *et al.* Estimating the burden of total knee replacement in the United States. *J. Bone Joint Surg. Am.* 95(5), 385–392 (2013).
26. Skinner J, Weinstein JN, Sporer SM, Wennberg JE. Racial, ethnic, and geographic disparities in rates of knee arthroplasty among Medicare patients. *N. Engl. J. Med.* 349(14), 1350–1359 (2003).
27. Mahomed NN, Barrett J, Katz JN, Baron JA, Wright J, Losina E. Epidemiology of total knee replacement in the United States Medicare population. *J. Bone Joint Surg. Am.* 87(6), 1222 (2005).
28. Ueroi N, Finegold K, Gee E. Health insurance coverage and the Affordable Care Act, 2010–2016, in ASPE issue brief. *ASPE, Department of Health and Human Services* 2016. (2016).
29. Zhang W, Lyman S, Boutin-Foster C *et al.* Racial and ethnic disparities in utilization rate, hospital volume, and perioperative outcomes after total knee arthroplasty. *J. Bone Joint Surg. Am.* 98(15), 1243–1252 (2016).
30. SooHoo NF, Zingmond DS, Ko CY. Disparities in the utilization of high-volume hospitals for total knee replacement. *J. Natl Med. Assoc.* 100(5), 559–564 (2008).
- **This retrospective study shows Medicaid insurance and Black, Hispanic and Asian race/ethnicity are predictors for receiving total knee replacement in low-volume hospitals.**
31. Liu JH, Zingmond DS, McGory ML *et al.* Disparities in the utilization of high-volume hospitals for complex surgery. *JAMA* 296(16), 1973 (2006).
32. SooHoo NF, Zingmond DS, Lieberman JR, Ko CY. Primary total knee arthroplasty in California 1991 to 2001. *J. Arthroplast.* 21(2), 199–205 (2006).

33. Jeschke E, Citak M, Günster C *et al.* Are TKAs performed in high-volume hospitals less likely to undergo revision than TKAs performed in low-volume hospitals? *Clin. Orthopaed. Rel. Res.* 475(11), 2669–2674 (2017).
34. Katz JN, Barrett J, Mahomed NN, Baron JA, Wright RJ, Losina E. Association between hospital and surgeon procedure volume and the outcomes of total knee replacement. *J. Bone Joint Surg. Am.* 86-A(9), 1909–1916 (2004).
- **Uses Medicare claims data to show how patients who undergo knee replacement at higher volume hospitals have lower risk of perioperative complications.**
35. Hervey SL, Purves HR, Guller U, Toth AP, Vail TP, Pietrobon R. Provider volume of total knee arthroplasties and patient outcomes in the HCUP-Nationwide Inpatient Sample. *J. Bone Joint Surg. Am.* 85-A(9), 1775–1783 (2003).
36. Suter LG, Vellanky S, Li S-X, Strait K, Eddy E, Okai M. *Medicare Hospital Quality Chartbook 2012: Performance Report on Outcome Measures.* Centers for Medicare & Medicaid Services, MD, USA, (2012).
37. McHugh MD, Brooks Carthon JM, Kang XL. Medicare readmissions policies and racial and ethnic health disparities: a cautionary tale. *Policy Polit. Nurs. Pract.* 11(4), 309–316 (2010).
38. Palmer RC, Ismond D, Rodriguez EJ, Kaufman JS. Social determinants of health: future directions for health disparities research. *Am. J. Public Health* 109(S1), S70–S71 (2019).
39. Jeffries N, Zaslavsky AM, Diez Roux AV *et al.* Methodological approaches to understanding causes of health disparities. *Am. J. Public Health* 109(S1), S28–S33 (2019).
40. D'Apuzzo M, Westrich G, Hidaka C, Jung Pan T, Lyman S. All-cause versus complication-specific readmission following total knee arthroplasty. *J. Bone Joint Surg. Am.* 99(13), 1093–1103 (2017).
41. HCUP Quality Control Procedures. Healthcare Cost and Utilization Project (HCUP) (2016). [www.hcup-us.ahrq.gov/db/quality.jsp](http://www.hcup-us.ahrq.gov/db/quality.jsp)
42. Memtsoudis SG, Ma Y, González Della Valle A *et al.* Perioperative outcomes after unilateral and bilateral total knee arthroplasty. *Anesthesiology* 111(6), 1206–1216 (2009).
43. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. *Med. Care* 36(1), 8–27 (1998).
44. Walraven C van, Austin PC, Jennings A, Quan H, Forster AJ. A modification of the Elixhauser Comorbidity Measures into a point system for hospital death using administrative data. *Med. Care* 47(6), 626–633 (2009).
45. Cole MB, Galárraga O, Wilson IB, Wright B, Trivedi AN. At federally funded health centers, Medicaid expansion was associated with improved quality of care. *Health Affairs* 36(1), 40–48 (2017).
46. Finkelstein A, Taubman S, Wright B *et al.* The Oregon Health Insurance Experiment: evidence from the first year. *Q. J. Econ.* 127(3), 1057–1106 (2012).
47. Sommers BD, Gunja MZ, Finegold K, Musco T. Changes in self-reported insurance coverage, access to care, and health under the Affordable Care Act. *JAMA* 314(4), 366 (2015).
48. Meyer PA, Yoon PW, Kaufmann RB. Centers for Disease Control and Prevention (CDC). Introduction: CDC Health Disparities and Inequalities Report – United States, 2013. *MMWR Suppl.* 62(3), 3–5 (2013).
49. Andreae MH, Gabry JS, Goodrich B, White RS, Hall C. Antiemetic prophylaxis as a marker of health care disparities in the National Anesthesia Clinical Outcomes Registry. *Anesth. Analg.* 126(2), 588–599 (2018).
50. Epstein AJ, Gray BH, Schlesinger M. Racial and ethnic differences in the use of high-volume hospitals and surgeons. *Arch. Surg.* 145(2), 179 (2010).
51. Al-Refaie WB, Muluneh B, Zhong W *et al.* Who receives their complex cancer surgery at low-volume hospitals? *J. Am. Coll. Surg.* 214(1), 81–87 (2012).
52. Katz JN, Barrett J, Mahomed NN, Baron JA, Wright RJ, Losina E. Association between hospital and surgeon procedure volume and the outcomes of total knee replacement. *J. Bone Joint Surg. Am.* 86-A(9), 1909–1916 (2004).
53. Katz JN, Losina E, Barrett J *et al.* Association between hospital and surgeon procedure volume and outcomes of total hip replacement in the United States Medicare population. *J. Bone Joint Surg. Am.* 83-A(11), 1622–1629 (2001).
54. Ravi B, Jenkinson R, Austin PC *et al.* Relation between surgeon volume and risk of complications after total hip arthroplasty: propensity score matched cohort study. *BMJ* 348(may23 1), g3284–g3284 (2014).
55. Barnett JC, Berchick ER. Health insurance coverage in the United States: 2016. *Current Population Reports* 60–260 (2017).
56. CDC. Health, United States, 2015 with special feature on racial and ethnic health disparities (2015). <https://www.cdc.gov/nchs/data/hus/hus15.pdf>
57. Schoenfeld AJ, Tipirneni R, Nelson JH, Carpenter JE, Iwashyna TJ. The influence of race and ethnicity on complications and mortality after orthopedic surgery. *Med. Care* 52(9), 842–851 (2014).
58. Nwachukwu BU, Kenny AD, Losina E, Chibnik LB, Katz JN. Complications for racial and ethnic minority groups after total hip and knee replacement: a review of the literature. *J. Bone Joint Surg. Am.* 92(2), 338–345 (2010).
59. Center for Medicare & Medicaid Services. Readmissions Reduction Program (HRRP) (2018). <https://www.cms.gov/medicare/medicare-fee-for-service-payment/acuteinpatientpps/readmissions-reduction-program.html>

60. McIlvennan CK, Eapen ZJ, Allen LA. Hospital readmissions reduction program. *Circulation* 131(20), 1796–1803 (2015).
61. Manoso MW, Cizik AM, Bransford RJ, Bellabarba C, Chapman J, Lee MJ. Medicaid status is associated with higher surgical site infection rates after spine surgery. *Spine* 39(20), 1707–1713 (2014).
62. LaPar DJ, Bhamidipati CM, Mery CM *et al.* Primary payer status affects mortality for major surgical operations. *Ann. Surg.* 252(3), 544–550 (2010).
- **This retrospective study examined the role of Medicaid and Uninsured payer status in a range of major operations, not only joint replacement.**
63. Lin M, Lucas HC, Shmueli G. Research commentary – too big to fail: large samples and the p-value problem. *Information Syst. Res.* 24(4), 906–917 (2013).
64. Raw RM, Todd MM, Hindman BJ, Mueller R. The overpowered mega-study is a new class of study needing a new way of being reviewed. *Anesthesiology* 120(1), 245–246 (2014).
65. Andrae MH, White RS, Chen KY, Nair S, Hall C, Shaparin N. The effect of initiatives to overcome language barriers and improve attendance: a cross-sectional analysis of adherence in an inner city chronic pain clinic. *Pain Med.* 18(2), 265–274 (2016).
66. Funk LM, Suza A, Mikami DJ, Needleman BJ. Two-year outcomes for Medicaid patients undergoing laparoscopic Roux-en-Y gastric bypass: a case-control study. *Obes. Surg.* 24(10), 1679–1685 (2014).
67. Martin CT, Callaghan JJ, Liu SS, Gao Y, Warth LC, Johnston RC. Disparity in total joint arthroplasty patient comorbidities, demographics, and postoperative outcomes based on insurance payer type. *J. Arthroplast.* 27(10), 1761–1765 (2012).
68. Warth LC, Callaghan JJ, Wells CW *et al.* Demographic and comorbid disparities based on payer type in a total joint arthroplasty cohort: implications in a changing health care arena. *Iowa Orthopaed. J.* 31, 64–68 (2011).
69. Cleary R, Beard R, Coles J *et al.* Comparative hospital databases: value for management and quality. *Qual. Safety Health Care* 3(1), 3–10 (1994).
70. Memtsoudis SG, Sun X, Chiu Y-L *et al.* Perioperative comparative effectiveness of anesthetic technique in orthopedic patients. *Anesthesiology* 118(5), 1046–1058 (2013).
71. Opperer M, Danninger T, Stundner O, Memtsoudis SG. Perioperative outcomes and type of anesthesia in hip surgical patients: an evidence based review. *World J. Orthoped.* 5(3), 336 (2014).
72. Turnbull Z, Sastow D, Giambrone G, Tedore T. Anesthesia for the patient undergoing total knee replacement: current status and future prospects. *Local Regional Anesth.* 10, 1–7 (2017).
73. Pugely AJ, Martin CT, Gao Y, Mendoza-Lattes S, Callaghan JJ. Differences in short-term complications between spinal and general anesthesia for primary total knee arthroplasty. *J. Bone Joint Surg. Am.* 95(3), 193–199 (2013).
74. Atchabahian A, Schwartz G, Hall CB, Lajam CM, Andrae MH. Regional analgesia for improvement of long-term functional outcome after elective large joint replacement. *Cochrane Database Syst. Rev.* (8), CD010278 (2015).
75. Andrae M, Andrae D. Regional anaesthesia to prevent chronic pain after surgery: a Cochrane systematic review and meta-analysis †. *Brit. J. Anaesth.* 111(5), 711–720 (2013).
76. Weinstein EJ, Levene JL, Cohen MS *et al.* Local anaesthetics and regional anaesthesia versus conventional analgesia for preventing persistent postoperative pain in adults and children. *Cochrane Database Syst. Rev.* 4, CD007105 (2018).
77. Andrae MH, Andrae DA. Local anaesthetics and regional anaesthesia for preventing chronic pain after surgery. *Cochrane Database Syst. Rev.* 10, CD007105 (2012).
78. Levene JL, Weinstein EJ, Cohen MS, *et al.* Local anesthetics and regional anesthesia versus conventional analgesia for preventing persistent postoperative pain in adults and children: A Cochrane systematic review and meta-analysis update. *J Clin Anesth.* 55(Aug), 116–127 (2019).
79. Patorno E, Neuman MD, Schneeweiss S, Mogun H, Bateman BT. Comparative safety of anesthetic type for hip fracture surgery in adults: retrospective cohort study. *BMJ* 348, g4022 (2014).
80. Shaparin N, White R, Andrae M, Hall C, Kaufman A. A longitudinal linear model of patient characteristics to predict failure to attend an inner-city chronic pain clinic. *J. Pain* 15(7), 704–711 (2014).
81. Andrae MH, Nair S, Gabry JS, Goodrich B, Hall C, Shaparin N. A pragmatic trial to improve adherence with scheduled appointments in an inner-city pain clinic by human phone calls in the patient's preferred language. *J. Clin. Anesth.* 42, 77–83 (2017).
82. Andrae MH. Contextualizing and individualizing truth-telling about pain in a tough and unjust world. *AJOB Neurosci.* 9(3), 190–192 (2018).
83. McNeill JA, Sherwood GD, Starck PL. The hidden error of mismanaged pain: a systems approach. *J. Pain Symp. Manag.* 28(1), 47–58 (2004).
84. Epps CD, Ware LJ, Packard A. Ethnic wait time differences in analgesic administration in the emergency department. *Pain Manag. Nursing* 9(1), 26–32 (2008).
85. Dominick KL, Bosworth HB, Dudley TK, Waters SJ, Campbell LC, Keefe FJ. Patterns of opioid analgesic prescription among patients with osteoarthritis. *J. Pain Pall. Care Pharmacother.* 18(1), 31–46 (2004).

86. Cooper LA, Roter DL, Carson KA *et al.* The associations of clinicians' implicit attitudes about race with medical visit communication and patient ratings of interpersonal care. *Am. J. Public Health* 102(5), 979–987 (2012).
87. White-Means S, Zhiyong Dong Z, Hufstader M, Brown LT. Cultural competency, race, and skin tone bias among pharmacy, nursing, and medical students. *Med. Care Res. Rev.* 66(4), 436–455 (2009).
88. Green AR, Carney DR, Pallin DJ *et al.* Implicit bias among physicians and its prediction of thrombolysis decisions for black and white patients. *J. General Intern. Med.* 22(9), 1231–1238 (2007).
- **Presents evidence of physician (unconscious) implicit bias, and how such bias may play a role in treatment decisions.**
89. Jamtvedt G, Young JM, Kristoffersen DT, O'Brien MA, Oxman AD. Audit and feedback: effects on professional practice and health care outcomes. *Cochrane Database Syst. Rev.* CD000259 (2006).
90. Bentz C, Bayley B, Bonin K *et al.* Provider feedback to improve 5A's tobacco cessation in primary care: a cluster randomized clinical trial. *Nicotine Tobacco Res.* 9(3), 341–349 (2007).