

# Geographic Differences in Rates of Primary Total Knee Arthroplasty in Young and Older Adults: A Comparison of 3 US States

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**ABSTRACT.** **Objective.** Rates of total knee arthroplasty (TKA) among Medicare beneficiaries (adults aged  $\geq 65$  yrs) vary across the United States, with higher rates in the Midwest and West than in the South. It is not known if a similar variation is present among younger patients, or if findings in Medicare reflect selective postponement of TKA in some regions.

**Methods.** Data on all primary TKA performed in adults aged  $\geq 20$  years in 3 states (Iowa, Utah, and Florida) in 2016 were obtained from state inpatient databases. Rates of TKA were computed based on population census data. Age-, sex-, and race-standardized rates were compared between Iowa and Florida, and between Utah and Florida, among adults aged 20–64 years and adults aged  $\geq 65$  years.

**Results.** There were 10,074, 8954, and 43,908 primary TKAs in Iowa, Utah, and Florida, respectively. Standardized rates were higher in Iowa and Utah than in Florida among both adults aged 20–64 years (Iowa:Florida rate ratio [RR] 1.89, 95% CI 1.79–1.99; Utah:Florida RR 2.31, 95% CI 2.18–2.45) and those aged  $\geq 65$  years (Iowa:Florida RR 1.41, 95% CI 1.35–1.47; Utah:Florida RR 1.77, 95% CI 1.70–1.85). Results were similar in sensitivity analyses limited to White patients, urban residents, and those with a diagnosis of knee osteoarthritis.

**Conclusion.** TKA rates were higher in Iowa and Utah than in Florida among both younger adults and those aged  $\geq 65$  years, indicating that geographic differences are not specific to elderly patients.

*Key Indexing Terms:* age, regional variation, total knee arthroplasty

Rates of many surgical procedures, including total knee arthroplasty (TKA), vary by geographic region.<sup>1</sup> In the United States, rates of TKA are generally higher in the Midwest and Mountain West than in the South and on the East or West Coasts.<sup>2,3,4,5</sup> We recently reported that primary TKA rates in areas of Utah and Iowa were 58–75% and 31–66% higher than the national average, respectively, whereas rates in Florida were lower than the national average, after adjustment for the prevalence of knee osteoarthritis (OA) and its risk factors, comorbidities, and socio-demographic features.<sup>6</sup> The presence of large regional differences implies variation in clinical decision making, possibly related to determining appropriate candidates for TKA and the optimal timing of surgery, and raises the question of whether TKA may be inappropriately overused in some regions or underused in other regions.

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All prior US studies of regional differences in TKA use have been based on data from Medicare, the publicly funded health insurance program for elderly Americans.<sup>2,3,4,5,6</sup> This raises the question of whether regional disparities merely reflect age-related differences in accessing TKA, or if true geographic differences in TKA use exist. For example, regions with high TKA rates among older individuals may be areas where more people postpone TKA until Medicare eligibility, resulting in a relative inflation of rates among Medicare beneficiaries.<sup>7</sup> Conversely, areas with low rates among older individuals may have high rates among younger persons, which either through the depletion of eligible patients or diversion of surgical capacity, reduces the number of older patients who can receive primary TKA in these regions. Persons younger than 65 years now comprise  $\geq 40\%$  of new TKA recipients and represent the fastest growing population receiving this procedure.<sup>8,9</sup>

Determining whether true geographic differences in TKA rates exist, and if the results of Medicare-based studies are biased, requires the study of population-based samples that include persons of all ages. I used hospitalization data from 3 states that represent areas with high and low TKA rates in Medicare data to compare rates of primary TKA in both younger (20–64 yrs) and older ( $\geq 65$  yrs) adults.

## METHODS

I examined state inpatient databases for 2016 from 2 states with high relative rates of TKA (Iowa and Utah) and 1 state with low rates of TKA (Florida),

based on previous analyses of Medicare data.<sup>6</sup> These states were specifically chosen because their comparison allowed testing whether the differences in TKA rates that were present in older patients were also present among younger patients. State inpatient databases include data on all hospitalizations in nonfederal community hospitals, including private and publicly owned hospitals but excluding those operated by the US government (ie, Department of Veterans Affairs hospitals). Data were obtained from the Healthcare Cost and Utilization Project under a data use agreement.<sup>10</sup> These limited datasets omit all direct identifiers, and their use is therefore exempt from review by an institutional review board.<sup>10</sup>

In each state database, I identified hospitalizations with primary TKA as those with an International Classification of Diseases, 10th revision (ICD-10) procedure code prefixed 0SRC or 0SRD. I excluded TKA among those aged < 20 years and those performed on nonresidents. Because unique patient identifiers were not provided, the unit of analysis was the hospitalization and not individual patients. The type of arthritis was classified as knee OA if ICD-10 M17 was listed among the hospitalization diagnosis codes, in the absence of codes for rheumatoid arthritis (M05, M06), psoriatic arthritis (L40.5), enteropathic arthritis (M07), juvenile arthritis (M08), or ankylosing spondylitis (M45) or reactive arthritis (M02), all of which were classified together as inflammatory arthritis.

I computed rates of primary TKA by age (5-year groups), sex, and race (White, Black, Hispanic of any background, and other, as reported in the data source) of the estimated 2016 population of each state, based on census data. Rates in Iowa and Utah were then standardized to the age, sex, and race distribution of the Florida population to permit direct comparisons, expressed as standardized rate ratios (RR). To determine if risks differed in younger and older patients, analyses were repeated in 2 age strata: 20–64 years and ≥ 65 years.

I performed 3 sensitivity analyses. Because use of TKA is higher among White patients than other ethnic groups, and because the populations of Iowa and Utah include a higher proportion of White individuals than that of Florida, I repeated the analysis among White patients only.<sup>4,5,6,11</sup> I also compared rates among those with a diagnosis of knee OA, because differences in the prevalence of inflammatory arthritis may affect comparisons between the younger and older strata. TKA is also more common among residents of rural areas than urban areas.<sup>12</sup> Therefore, differences in rurality may confound comparisons of rates among these states. I repeated the analysis in the subset of people living in urban areas in each state, defined as counties with a Rural-Urban Commuting Area code of 1–6 (of a 10-point scale).<sup>13</sup> This measure was developed by the U.S. Department of Agriculture and the Health Resources and Services Administration Federal Office of Rural Health Policy and rates locations based on population size and

commute distance to an urban area; this has been used previously to define rural and urban differences in TKA use.<sup>12</sup> Because only 2 counties in Florida were classified as rural by this measure, a separate analysis of rural residents was not possible.

SAS programs (version 9.4; SAS Institute) were used for analysis.

## RESULTS

There were 10,074 primary TKAs in Iowa, 8954 primary TKAs in Utah, and 43,908 primary TKAs in Florida in 2016 (Table 1). In Florida, 32.5% of TKAs were in patients aged < 65 years, compared to 44.1% in Iowa and 46.3% in Utah. Knee OA was the predominant diagnosis in each state.

Among all adults, rates of TKA were substantially higher in Iowa and Utah than in Florida, with standardized RRs of 1.56 and 1.94, respectively (Table 2). When stratified by age, RRs were higher both among patients aged 20–64 years and those aged ≥ 65 years. In Iowa, the RR was 1.89 among younger patients and 1.41 among older patients. In Utah, the RR was 2.31 among younger patients and 1.77 among older patients. Standardized rates were higher in Utah and Iowa than in Florida in all age groups > 45 years (Figure 1).

In the sensitivity analyses, the associations were similar among White patients and among those with a diagnosis of knee OA specifically (Table 2). In addition, residents of urban areas of Iowa and Utah had higher rates of TKA than residents of urban areas of Florida, among both younger and older age groups.

## DISCUSSION

Because previous studies of geographic variation in TKA rates in the US relied on Medicare data, it was unknown if these differences were specific to older patients, or if similar variations were present among younger patients. Using comparisons among 3 states, the current results indicate that the variation in TKA rates observed in Medicare-aged patients is also present in younger patients. RRs were, in fact, higher among younger patients than among those aged ≥ 65 years. Among the younger patients, rates were highest in those aged 55–64 years, as would be expected given that knee OA is the most common diagnosis leading to TKA.

Table 1. Demographic and clinical features of total knee arthroplasty recipients in 2016, by state.

|                          | Iowa, n = 10,074 | Utah, n = 8954 | Florida, n = 43,908 |
|--------------------------|------------------|----------------|---------------------|
| Mean age, yrs, mean ± SD | 66.0 ± 9.7       | 65.1 ± 9.7     | 67.9 ± 9.3          |
| Age < 65 yrs             | 4442 (44.1)      | 4149 (46.3)    | 14,280 (32.5)       |
| Age ≥ 65 yrs             | 5632 (55.9)      | 4805 (53.7)    | 29,628 (67.5)       |
| Female sex               | 6220 (61.7)      | 5239 (58.5)    | 26,642 (60.7)       |
| Race/ethnicity           |                  |                |                     |
| White                    | 9670 (96.0)      | 8337 (93.1)    | 34,674 (79.0)       |
| Black                    | 133 (1.3)        | 41 (0.5)       | 3610 (8.2)          |
| Hispanic                 | 104 (1.0)        | 165 (1.8)      | 4125 (9.4)          |
| Other                    | 167 (1.7)        | 411 (4.6)      | 1499 (3.4)          |
| Arthritis type           |                  |                |                     |
| Knee osteoarthritis      | 9484 (94.1)      | 8289 (92.6)    | 40,039 (91.2)       |
| Inflammatory arthritis   | 255 (2.5)        | 257 (2.9)      | 1784 (4.1)          |
| Other                    | 335 (3.3)        | 408 (4.5)      | 2085 (4.7)          |
| Urban residents          | 8333 (82.7)      | 8446 (94.3)    | 43,887 (99.9)       |

Values are expressed as n (%) unless otherwise indicated.

Table 2. Primary TKA rates per 100,000 population in Iowa, Utah, and Florida, overall and by age group.

|  | TKA, n | Crude Rate (95% CI) | Standardized Rate <sup>a</sup> (95% CI) | RR (95% CI)      | P*       |
|--|--------|---------------------|---|------------------|----------|
| <b>All ages</b>                        |        |                     |   |                  |          |
| Iowa                                   | 10,074 | 4.3 (4.2–4.4)       | 4.3 (4.2–4.4)                           | 1.56 (1.51–1.62) | < 0.0001 |
| Utah                                   | 8954   | 4.4 (4.3–4.5)       | 5.3 (5.2–5.5)                           | 1.94 (1.88–2.02) | < 0.0001 |
| Florida                                | 43,908 | 2.7 (2.7–2.8)       | 2.7 (2.7–2.8)                           | 1.00             |          |
| <b>Ages 20–64 yrs</b>                  |        |                     |   |                  |          |
| Iowa                                   | 4442   | 2.5 (2.4–2.6)       | 2.3 (2.1–2.4)                           | 1.89 (1.79–1.99) | < 0.0001 |
| Utah                                   | 4149   | 2.4 (2.3–2.6)       | 2.7 (2.6–2.9)                           | 2.31 (2.18–2.45) | < 0.0001 |
| Florida                                | 14,280 | 1.2 (1.1–1.2)       | 1.2 (1.1–1.2)                           | 1.00             |          |
| <b>Age ≥ 65 yrs</b>                    |        |                     |   |                  |          |
| Iowa                                   | 5632   | 11.0 (10.7–11.3)    | 10.3 (9.8–10.7)                         | 1.41 (1.35–1.47) | < 0.0001 |
| Utah                                   | 4805   | 15.0 (14.6–15.4)    | 12.9 (12.4–13.4)                        | 1.77 (1.70–1.85) | < 0.0001 |
| Florida                                | 29,628 | 7.3 (7.2–7.4)       | 7.3 (7.2–7.4)                           | 1.00             |          |
| <b>White patients, all ages</b>        |        |                     |   |                  |          |
| Iowa                                   | 9670   | 4.7 (4.6–4.8)       | 5.6 (5.5–5.8)                           | 1.53 (1.49–1.57) | < 0.0001 |
| Utah                                   | 8337   | 5.0 (4.9–5.1)       | 7.6 (7.5–7.8)                           | 2.06 (2.01–2.12) | < 0.0001 |
| Florida                                | 34,674 | 3.7 (3.6–3.8)       | 3.7 (3.6–3.8)                           | 1.00             |          |
| <b>White patients, ages 20–64 yrs</b>  |        |                     |   |                  |          |
| Iowa                                   | 4205   | 2.7 (2.6–2.8)       | 3.0 (2.9–3.1)                           | 1.81 (1.74–1.88) | < 0.0001 |
| Utah                                   | 3809   | 2.8 (2.7–2.9)       | 4.0 (3.9–4.2)                           | 2.45 (2.36–2.56) | < 0.0001 |
| Florida                                | 10,442 | 1.6 (1.6–1.7)       | 1.6 (1.6–1.7)                           | 1.00             |          |
| <b>White patients, age ≥ 65 yrs</b>    |        |                     |   |                  |          |
| Iowa                                   | 5465   | 11.0 (10.7–11.3)    | 12.1 (11.7–12.4)                        | 1.41 (1.36–1.45) | < 0.0001 |
| Utah                                   | 4528   | 15.5 (15.1–16.0)    | 15.2 (14.7–15.6)                        | 1.90 (1.84–1.97) | < 0.0001 |
| Florida                                | 24,232 | 8.0 (7.8–8.1)       | 8.0 (7.8–8.1)                           | 1.00             |          |
| <b>Knee OA, all ages</b>               |        |                     |   |                  |          |
| Iowa                                   | 9484   | 4.1 (4.0–4.2)       | 4.0 (3.9–4.2)                           | 1.61 (1.55–1.67) | < 0.0001 |
| Utah                                   | 8289   | 4.1 (3.9–4.2)       | 4.9 (4.7–5.1)                           | 1.96 (1.89–2.03) | < 0.0001 |
| Florida                                | 40,039 | 2.5 (2.4–2.5)       | 2.5 (2.4–2.5)                           | 1.00             |          |
| <b>Knee OA, ages 20–64 yrs</b>         |        |                     |   |                  |          |
| Iowa                                   | 4152   | 2.3 (2.3–2.5)       | 2.1 (2.0–2.2)                           | 1.95 (1.85–2.07) | < 0.0001 |
| Utah                                   | 3823   | 2.2 (2.1–2.3)       | 2.5 (2.3–2.7)                           | 2.36 (2.22–2.50) | < 0.0001 |
| Florida                                | 12,751 | 1.1 (1.0–1.1)       | 1.1 (1.0–1.1)                           | 1.00             |          |
| <b>Knee OA, age ≥ 65 yrs</b>           |        |                     |   |                  |          |
| Iowa                                   | 5332   | 10.4 (10.1–10.7)    | 9.7 (9.3–10.2)                          | 1.45 (1.38–1.52) | < 0.0001 |
| Utah                                   | 4466   | 14.0 (13.5–14.4)    | 11.9 (11.4–12.4)                        | 1.77 (1.70–1.86) | < 0.0001 |
| Florida                                | 27,288 | 6.7 (6.6–6.8)       | 6.7 (6.6–6.8)                           | 1.00             |          |
| <b>Urban residents, all ages</b>       |        |                     |   |                  |          |
| Iowa                                   | 8333   | 4.3 (4.3–4.5)       | 4.4 (4.2–4.6)                           | 1.59 (1.54–1.65) | < 0.0001 |
| Utah                                   | 8446   | 4.4 (4.3–4.5)       | 5.4 (5.2–5.7)                           | 1.99 (1.92–2.07) | < 0.0001 |
| Florida                                | 43,887 | 2.7 (2.7–2.8)       | 2.7 (2.7–2.8)                           | 1.00             |          |
| <b>Urban residents, ages 20–64 yrs</b> |        |                     |   |                  |          |
| Iowa                                   | 3715   | 2.5 (2.4–2.6)       | 2.3 (2.1–2.5)                           | 1.93 (1.83–2.04) | < 0.0001 |
| Utah                                   | 3901   | 2.4 (2.3–2.5)       | 2.8 (2.6–3.0)                           | 2.34 (2.21–2.49) | < 0.0001 |
| Florida                                | 14,272 | 1.2 (1.1–1.3)       | 1.2 (1.1–1.3)                           | 1.00             |          |
| <b>Urban residents, age ≥ 65 yrs</b>   |        |                     |   |                  |          |
| Iowa                                   | 4618   | 11.3 (11.1–11.7)    | 10.4 (10.0–11.0)                        | 1.43 (1.37–1.50) | < 0.0001 |
| Utah                                   | 4545   | 15.3 (14.9–15.7)    | 13.2 (12.7–13.9)                        | 1.81 (1.74–1.90) | < 0.0001 |
| Florida                                | 29,615 | 7.3 (7.2–7.4)       | 7.3 (7.2–7.4)                           | 1.00             |          |

<sup>a</sup> Standardized rates are standardized to the age (5-year group), sex, and race composition of the Florida population. \* P values vs Florida. OA: osteoarthritis; RR: rate ratio; TKA: total knee arthroplasty.

The RRs for Utah were higher than those for Iowa, which was consistent with the ranking of TKA rates in these regions in Medicare.<sup>6</sup> Findings were similar when restricted to White patients or urban residents; this was important given that greater proportions of White and rural residents may have contributed

to higher overall TKA rates in Iowa and Utah than in Florida. Results were also similar when restricted to those with knee OA, indicating that differences in the prevalence of inflammatory arthritis were not responsible for the results in the younger patients. The sensitivity analyses indicate that differences among

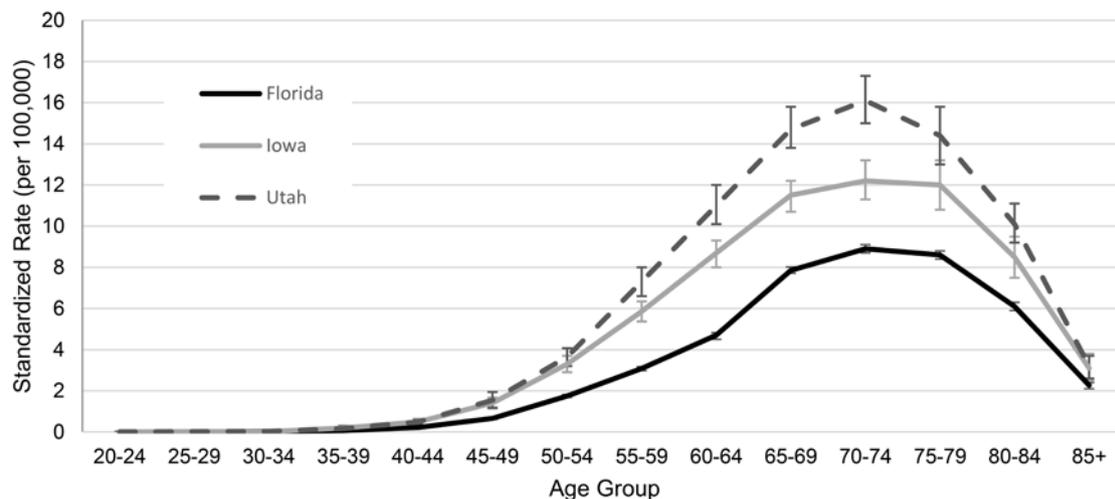


Figure 1. Standardized rates of primary total knee arthroplasty in Iowa, Utah, and Florida, by age group. Error bars represent 95% CIs.

states in population demographics or in underlying diagnoses between younger and older patients do not account for the differences in TKA rates.

The main limitation of the study was that data from only 3 states were examined, but these states were chosen because of their different rates of TKA among Medicare beneficiaries. Inclusion of additional states was limited by funding, but studying many other states with average TKA rates would not have helped address the research question. The study did not capture TKAs that might have been performed out of state, although these numbers are likely small. Only 1 year of data was examined to avoid changes related to (1) the increasing use of outpatient TKA, which are not captured in the hospitalization data and which may be more common among younger patients, and (2) the removal of TKA from the Medicare inpatient-only list in 2018. Regional differences in TKA rates were stable between 2011 and 2015, and would be expected to have remained so in 2016.<sup>6</sup> In 2016, only 3% of TKAs were performed as outpatient procedures.<sup>14</sup> Therefore, the analysis likely included almost all TKAs performed in these states.

To my knowledge, this study is the first analysis of US geographic differences in primary TKA rates to include adults of all ages. These results confirm that geographic differences in TKA rates observed among Medicare beneficiaries are also present among younger patients, and that findings among Medicare beneficiaries are not biased due to differential age-related access to TKA among regions. These findings suggest that the factors contributing to higher TKA rates in the Midwest and West are not limited to older patients but are also present among younger patients. Among these factors are the active endorsement by surgeons and the individual willingness of patients to have surgery, as well as possible limits in accessing surgery due to waitlists and capacity constraints.<sup>15,16</sup> Future research should include an in-depth examination of the factors that motivate patients and surgeons to consider TKA, including both enabling and inhibiting factors, and whether these factors vary among people living in different regions of the US.

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