

## Original Research

## Regional Differences in Primary Total Knee Arthroplasty Utilization, Physician Reimbursement, and Patient Characteristics

Vikram S. Gill, BS<sup>a, b, \*</sup>, Jack M. Haglin, MD, MS<sup>a</sup>, Sailesh V. Tummala, MD<sup>a</sup>, Georgia Sullivan, MS<sup>a, b</sup>, Mark J. Spangehl, MD<sup>a</sup>, Joshua S. Bingham, MD<sup>a</sup>

<sup>a</sup> Department of Orthopedic Surgery, Mayo Clinic, Phoenix, AZ, USA

<sup>b</sup> Mayo Clinic Alix School of Medicine, Phoenix, AZ, USA

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## ABSTRACT

**Background:** The primary purpose of this study was to evaluate how utilization, physician reimbursement, and patient populations have changed for primary total knee arthroplasty (TKA) from 2013 to 2021 at both a regional and national level within the Medicare population.

**Methods:** The Medicare Physician and Other Practitioners database was queried for all episodes of primary TKA between years 2013 and 2021. TKA utilization per 10,000 beneficiaries, inflation-adjusted physician reimbursement per TKA, and patient demographics of each TKA surgeon were extracted each year. Data were stratified geographically, and Kruskal-Wallis tests were utilized.

**Results:** Between 2013 and 2021, TKA utilization per 10,000 beneficiaries increased at the greatest rate in the Northeast (+15.1%). In 2021, TKA utilization was highest in the Midwest (97.6/10,000;  $P < .001$ ). The Midwest had the greatest decline in average physician reimbursement per TKA between 2013 and 2021 (−26.3%) and the lowest average reimbursement (\$988.70,  $P < .001$ ) in 2021. Alternatively, the Northeast had the smallest decline in average TKA reimbursement (−22.6%). Nationally, the average number of beneficiaries per TKA surgeon declined (−6.8%), while the average number of TKAs per surgeon (+5.7%) and average services per beneficiary (+24.3%) both increased. The average number of patient comorbidities and proportion of patients with dual Medicare-Medicaid eligibility decreased over time across all regions.

**Conclusions:** This study demonstrates that TKA utilization is increasing and average physician reimbursement per TKA is declining at varying rates across the country, with the Northeast and Midwest most affected. These findings should be addressed in policy discussions to ensure equitable arthroplasty care.

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## Introduction

Total knee arthroplasty (TKA) is becoming increasingly popular as the “baby boomer” population ages. As of 2010, the prevalence of TKA among adults 50 years of age or older was 4.55%, making it one of the most performed surgeries in the United States [1]. Rates are continuing to increase, with recent projections estimating a 24.3% increase in primary TKA utilization among the Medicare population for each 5-year period after 2020 [2]. In 2040, the number of TKAs

performed in the Medicare population alone is projected to be over 1.2 million [2]. This rapid and prominent increase in TKA utilization warrants further research to ensure the sustainability of arthroplasty care moving forward.

An ongoing decline in Medicare physician reimbursement across most orthopaedic procedures has previously been identified [3–5]. Specifically, Haglin et al [3] found primary TKA surgeon reimbursement to decline by 41.9% when adjusting for inflation between 2000 and 2019. It is important to consider these changes in the context of the Bundled Payments for Care Improvement initiative and Comprehensive Care for Joint Replacement initiative, introduced in 2013 and 2016, respectively [6,7]. These initiatives bundled arthroplasty payments to reimburse providers and hospitals based on a predetermined payment to cover the expected

\* Corresponding author. Mayo Clinic Arizona, 5777 E Mayo Blvd, Phoenix, AZ 85054. Tel.: +1 425 616 8421.

E-mail address: [gill.vikram@mayo.edu](mailto:gill.vikram@mayo.edu)

surgery and 90-day postoperative period. Therefore, the ultimate goal of these programs was to decrease Medicare expenditures while improving quality of care to patients. However, one major issue with these programs that aim to emphasize value-based payments rather than pure fee-for-service is the vast difference in patient populations and needs across different regions of the United States, which have led to worsening of disparities in TKA use [8]. Geographical differences in healthcare expenditures and reimbursement have been studied at a specialty-wide level but have not previously been evaluated specific to TKA [9,10]. Previous research has found an inverse relationship between patient complexity and arthroplasty physician reimbursement, indicating that these changes in reimbursement models may also be affecting the patient selection process for surgeons [11]. However, changes in the patient populations of arthroplasty surgeon over time have not previously been studied at scale.

The primary purpose of this study was to evaluate how primary TKA utilization, physician reimbursement per TKA, and patient populations of TKA surgeons have changed from 2013 to 2021 among the Medicare population at both a national and US 4-region level. The secondary aim was to summarize the impact of the coronavirus disease 2019 (COVID-19) pandemic on TKA utilization and reimbursement.

## Material and methods

### Data source

The publicly available “Medicare Physician and Other Practitioners – by Provider” and “Medicare Physician & Other Practitioners – by Provider and Service” data sets were queried for all years from 2013 to 2021. These data sets published by the Centers for Medicare and Medicaid Services include 100% of services billed to Medicare Part B. Services billed under Medicare Part A or Medicare Advantage are not included in this data set. The 2 data sets were linked together based on surgeon National Provider Identification. Data were filtered for Current Procedural Terminology code 27447 (primary TKA). Episodes billed by nonphysicians were excluded to ensure comparability. Surgeons who bill less than 10 annual TKAs were also excluded for patient privacy purposes. The “Medicare Geographic Variation” database, also published by Centers for Medicare and Medicaid Services, was used to assess the number of Medicare beneficiaries in each state for each year.

### Data extraction

The following information was extracted for each surgeon: number of TKAs each year, average Medicare physician reimbursement per TKA, number of unique services performed, total number of Medicare beneficiaries served, total number of billable services, and average number of billable services per beneficiary. All reimbursement values refer to individual physician reimbursement, not hospital reimbursement. Services include any Current Procedural Terminology codes billed by a surgeon, including office visits and other procedures, such as injections and total hip arthroplasty. Unique services refer to the number of unique Current Procedural Terminology codes billed to Medicare in a given year by a surgeon. Surgeon address was extracted and used to stratify surgeons into regions (Northeast, South, Midwest, and West) based on US Census guidelines and into commuting areas (Metropolitan, Micropolitan, Small Town, and Rural) based on the US Department of Agriculture Economic Research Reserve’s rural-urban commuting area codes [12]. The following information regarding each surgeon’s Medicare beneficiaries was also extracted for each year: average age, percent female, percent non-Hispanic White,

percent with dual Medicare–Medicaid eligibility, and average hierarchical condition category (HCC) risk score. The HCC risk score is a measure of a patient’s comorbidity profile and is normalized to 1.0, with higher numbers representing higher comorbidities [13].

### Data analyses

TKA utilization was assessed as TKA volume per 10,000 Medicare beneficiaries. All monetary data were adjusted for inflation to year 2021 dollars based on the US Consumer Price index. Descriptive statistics were used to report utilization per 10,000 Medicare beneficiaries, procedural volume, average reimbursement, and patient characteristics for each year. Differences between regions and rural-urban commuting areas were compared utilizing Kruskal-Wallis tests. All data processing and analyses were performed using R (version 4.2.3), with a *P* value less than .05 indicating significance.

This retrospective database study was exempt from institutional review board approval due to the use of deidentified patient information.

## Results

### 2013 to 2021 trends

From 2013 to 2021, a total of 2,415,802 TKAs were billed to Medicare. Between 2013 and 2021, TKA utilization per 10,000 beneficiaries increased by 6.4% nationally, with the largest increase in the Northeast (+15.1%) and a decrease in the West (−3.3%) (Fig. 1, Table 1). The number of TKAs per surgeon increased from 37.0 to 39.1, with the largest increase in the Northeast (35.1–39.4) (Table 1). The number of TKAs performed in metropolitan areas increased by 1.4%, while a decline was seen in all other areas (Table 2).

Average inflation-adjusted TKA physician reimbursement decreased by 24.0% from 2013 to 2021 nationally, with the greatest decline in the Midwest (−26.3%) and the smallest decline in the Northeast (−22.6%) (Fig. 2, Table 1). Physician reimbursement per TKA declined the most in metropolitan areas (−24.2%) (Table 2).

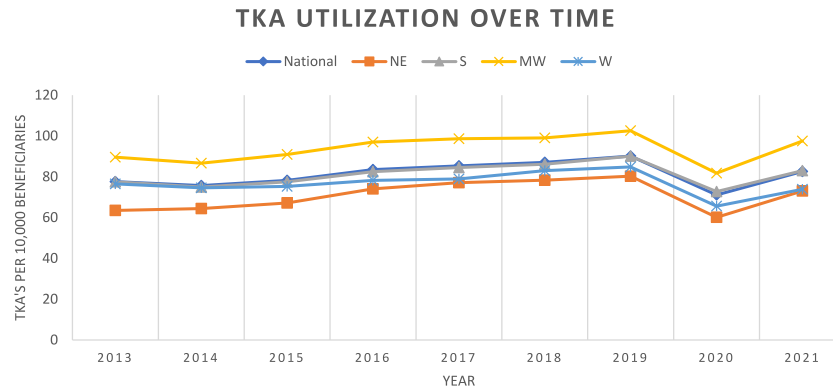
Between 2013 and 2021, the average number of beneficiaries per TKA surgeon decreased by 6.8% nationally. Prominent decreases were seen in the South and Midwest, while an increase was seen in the West (+1.9%). An increase in average services per beneficiary and a decrease in the number of unique services performed were seen across all regions. The average HCC risk score among the patient population of included arthroplasty surgeons declined by 6.8% nationally (Table 1).

### Regional differences in 2021

TKA utilization per 10,000 beneficiaries in 2021 was highest in the Midwest (97.6/10,000) and lowest in the Northeast (73.1/10,000). Alternatively, average reimbursement was highest in the Northeast (\$1091.39) and lowest in the Midwest (\$988.70). Surgeons in the South, on average, had the most beneficiaries (518.0), performed the most services per beneficiary (10.0), performed the most unique procedures (78.8), and had patients with the most comorbidities (HCC: 1.10) compared to all other regions (*P* < .001) (Table 1).

### Rural-urban differences in 2021

TKA physician reimbursement in 2021 was highest in metropolitan (\$1021.22) and rural areas (1012.82), and lowest in small town (\$960.48) and micropolitan (\$977.85) areas (*P* < .001). Surgeons in micropolitan areas had patients with the most



**Figure 1.** Medicare primary total knee arthroplasty utilization from 2013 to 2021.

comorbidities (HCC: 1.09) and performed the most unique services (87.0). Other differences in patient populations between rural-urban commuting areas are noted in [Table 2](#).

#### State differences in 2021

In 2021, the states with the highest TKA utilization per 10,000 Medicare beneficiaries were South Dakota (161.2/10,000), North Dakota (139.8/10,000), and Kansas (138.9/10,000). The states with the lowest utilization were Hawaii (27.7/10,000), Vermont (41.1/10,000), and Maine (55.6/10,000) ([Fig. 3](#)). The states with the greatest reimbursement were Alaska (\$1318.74), New York (\$1172.58), and Washington D.C (\$1144.90). States with the lowest reimbursement were Mississippi (\$898.06), Maine (\$920.38), and Arkansas (\$922.14) ([Fig. 4](#)). The states with the highest average HCC were Washington D.C (1.20) and Michigan (1.18), while the states with the lowest were Alaska (0.89) and Wyoming (0.90).

#### COVID-19

Between 2019 and 2020, TKA utilization declined by 21.1% nationally. This was the only instance during the study period where utilization declined from 1 year to the next. The decline was greatest in the Northeast (−25.1%) and least in the South (−19.2%). Alternatively, average reimbursement per TKA increased from 2019 to 2020 by 0.2% nationally (\$1129.68–\$1131.64). This increase in reimbursement was greatest in the Northeast (+1.1%) and West (+0.6%), while minimal change was seen in the South (+0.02%) and a decline was seen in the Midwest (−0.2%).

#### Discussion

The main findings of this study are (1) TKA utilization within the Medicare population is increasing nationally, with the most prominent increase in the Northeast; (2) average physician reimbursement per TKA is decreasing nationally, with the greatest decline in the Midwest; and (3) Medicare patient populations of TKA surgeons were smaller in quantity, healthier, less often had Medicaid eligibility, and more often were from metropolitan areas in 2021 compared to 2013.

This study identified an increase in primary TKA utilization of 6.4% nationally between 2013 and 2021. This is a notably slower rate of increase compared to a previous study by Cram et al that found per-capita TKA utilization to increase by 99.2% between 1991 and 2010 [14]. This slower rate of increase could partly be attributed to the COVID-19 pandemic reducing outpatient procedure rates in 2020 and 2021, which is evidenced by the fact that our study found TKA utilization to increase by 16.1% between 2013 and

2019, before declining by 8.4% between 2019 and 2021. Alternatively, this could be a continuation of a trend identified in the early 2010s that increases in joint arthroplasty utilization is slowing down [14,15]. The regional differences found in our study align well with other studies which similarly identified the Midwest region to be a “hot spot” for TKA utilization [16–20]. Despite the Midwest having the highest utilization per capita of TKA, our study found utilization to increase at the greatest rate in the Northeast. This could be due to regional differences in patient willingness and mindsets toward surgery, which have previously been demonstrated for arthroplasty in Canada [21]. This could also be a result of differences in physician beliefs about clinical indications for surgery, as has been previously demonstrated for cardiac and gastrointestinal procedures [22,23]. Alternatively, this could be because the Northeast was found to have the oldest patients, which may subsequently lead to an increased demand for TKA. Interestingly, our study found the West to be the only region where utilization decreased between 2013 and 2021. This was also likely due to the COVID-19 pandemic, as TKA utilization in the West increased by 10.9% between 2013 and 2019, before drastically declining between 2019 and 2021. However, even between 2013 and 2019, TKA utilization increased at the slowest rate in the West. Previous studies have identified the West to have the greatest physician shortage which may be manifesting as an inability to keep up with TKA demand [24,25]. This hypothesis is supported by the fact that despite a decrease in TKA utilization, the number of TKAs per surgeon increased by over 10% in the West, which was a greater rate of increase than the Midwest and South.

Haglin et al [3] identified a national decline in average Medicare primary TKA physician reimbursement of 13.3% from 2000 to 2019, and a 41.9% decrease when adjusting for inflation. Similarly, Lopez et al [26] found primary TKA physician reimbursement to decline by 9.4% between 2012 and 2017. The decline in reimbursement of 24.0% between 2013 and 2021 identified in this study was more prominent than those studies. However, our study identified a decline of 15.3% between 2013 and 2020, before an unprecedented decline in reimbursement of 10.2% was found between 2020 and 2021. One potential reason for this is that the bump in reimbursement between 2019 and 2020 due to the COVID-19 pandemic may have temporarily masked the overall downward trend in reimbursement. This was likely a sequela of the Coronavirus Aid, Relief, and Economic Securities Act, which appropriated billions of dollars for healthcare provider reimbursement to make up for lost revenues [27]. Our study found reimbursement to decline at the greatest rate and be the lowest in 2021 in the Midwest. Reimbursement declined at the slowest rate and was highest in 2021 in the Northeast. The finding that physician reimbursement per TKA is highest in the Northeast and West, and lowest in the Midwest and

**Table 1**  
Regional differences in primary total knee arthroplasty.

Variable	2013						2021					
	USA	NE	S	MW	W	P value	USA	NE	S	MW	W	P value
Surgeons	7028	1105	2627	1947	1349	n/a	6503 (-7.5%)	1027 (-7.1%)	2467 (-6.1%)	1761 (-9.6%)	1248 (-7.5%)	n/a
TKA Utilization per 10,000	77.63	63.45	77.56	89.59	76.46	n/a	82.58 (+6.4%)	73.06 (+15.1%)	83.00 (+7.0%)	97.57 (+8.9%)	73.90 (-3.3%)	n/a
TKAs per Surgeon	37.00	35.12	39.70	36.38	34.17	n/a	39.09 (+5.7%)	39.37 (+12.1%)	40.44 (+1.9%)	38.01 (+4.5%)	37.75 (+10.5%)	n/a
Reimbursement	\$1336.24	\$1410.48	\$1303.33	\$1341.09	\$1340.74	<.001	\$1015.97 (-24.0%)	\$1091.39 (-22.6%)	\$996.52 (-23.5%)	\$988.70 (-26.3%)	\$1031.16 (-23.1%)	<.001
Average beneficiaries per surgeon	492.78	498.46	576.80	444.93	393.58	<.001	459.14 (-6.8%)	487.52 (-2.2%)	518.00 (-10.2%)	401.19 (-9.8%)	401.20 (+1.9%)	<.001
Average services per beneficiary	7.22	6.73	7.62	7.20	6.59	<.001	8.97 (+24.3%)	7.90 (+17.5%)	10.01 (+31.3%)	7.87 (+9.3%)	8.91 (+35.2%)	<.001
Unique services performed	90.87	78.70	103.93	89.97	76.71	<.001	70.37 (-22.6%)	62.11 (-21.1%)	78.76 (-24.2%)	68.53 (-23.8%)	63.19 (-17.6%)	<.001
Beneficiary average age	72.92	73.62	72.53	72.91	73.31	<.001	73.72 (+1.1%)	74.02 (+0.6%)	73.71 (+1.6%)	73.49 (+0.8%)	73.76 (+0.6%)	<.001
Beneficiary average HCC	1.16	1.18	1.17	1.17	1.13	<.001	1.08 (-6.8%)	1.08 (-8.6%)	1.10 (-5.9%)	1.10 (-6.1%)	1.04 (-8.0%)	<.001
Beneficiary average % White	86.75	89.51	85.03	90.78	82.91	<.001	86.58 (-0.2%)	87.99 (-1.7%)	85.39 (+0.4%)	90.43 (-0.4%)	83.01 (+0.1%)	<.001
Beneficiary average % female	63.76	64.55	64.12	63.72	61.98	<.001	62.05 (-2.7%)	62.94 (-2.5%)	62.14 (-3.1%)	62.11 (-2.5%)	60.88 (-1.8%)	<.001
Beneficiary average % dual Medicare and Medicaid	16.40	16.10	16.22	15.84	18.21	<.001	10.94 (-33.3%)	11.80 (-26.7%)	9.27 (-42.9%)	10.95 (-30.9%)	14.49 (-20.5%)	<.001

HCC, hierarchical condition category.

Bold values indicate a statistically significant difference between regions for a given year.

**Table 2**  
RUCA differences in primary total knee arthroplasty.

Variable	2013						2021					
	USA	Metro	Micro	Small T.	Rural	P value	USA	Metro	Micro	Small T.	Rural	P value
Surgeons	7028	5855	928	204	41	n/a	6503 (-7.5%)	5609 (-4.2%)	717 (-22.7%)	148 (-27.5%)	29 (-29.3%)	n/a
TKA volume	260,018	224,353	29,195	5404	1066	n/a	254,226 (-2.2%)	224,665 (+0.1%)	24,188 (-17.2%)	4592 (-15.0%)	781 (-26.7%)	n/a
TKAs per surgeon	37.00	38.32	31.46	26.49	26.00	n/a	39.09 (+5.7%)	40.05 (+4.5%)	33.74 (+7.2%)	31.03 (+17.1%)	26.93 (+3.6%)	n/a
Reimbursement	\$1336.24	\$1347.82	\$1263.49	\$1253.47	\$1310.46	<.001	\$1015.97 (-24.0%)	\$1021.22 (-24.2%)	\$977.85 (-22.6%)	\$960.48 (-23.4%)	\$1012.82 (-22.7%)	<.001
Average beneficiaries per surgeon	492.78	499.74	482.53	361.36	384.85	<.001	459.14 (-6.8%)	462.87 (-7.4%)	453.66 (-6.0%)	370.22 (+2.5%)	326.84 (-15.1%)	<.001
Average services per beneficiary	7.22	7.22	7.32	6.76	5.50	<.001	8.97 (+24.3%)	9.04 (+25.2%)	8.95 (+22.2%)	5.91 (-12.6%)	6.48 (+17.7%)	<.001
Unique services performed	90.87	88.74	105.70	85.70	86.51	<.001	70.37 (-22.6%)	68.23 (-23.1%)	86.96 (-17.7%)	72.34 (-15.6%)	63.86 (-26.2%)	<.001
Beneficiary average age	72.92	73.03	72.31	72.07	72.45	<.001	73.72 (+1.1%)	73.78 (+1.0%)	73.34 (+1.4%)	72.95 (+1.2%)	73.65 (+1.6%)	<.001
Beneficiary average HCC	1.16	1.17	1.15	1.10	1.07	<.001	1.08 (-6.8%)	1.08 (-7.1%)	1.09 (-5.0%)	1.03 (-6.5%)	1.03 (-4.1%)	<.001
Beneficiary average % White	86.75	86.21	90.35	88.46	96.33	<.001	86.58 (-0.2%)	85.99 (-0.3%)	91.10 (+0.8%)	89.05 (+0.7%)	93.27 (-3.2%)	<.001
Beneficiary average % female	63.76	63.86	63.41	62.42	61.25	<.001	62.05 (-2.7%)	62.19 (-2.6%)	61.37 (-3.2%)	60.22 (-3.5%)	59.62 (-2.7%)	<.001
Beneficiary average % dual Medicare and Medicaid	16.40	15.49	21.01	22.93	20.65	<.001	10.94 (-33.3%)	10.39 (-32.9%)	14.22 (-32.3%)	15.47 (-32.5%)	13.32 (-35.5%)	<.001

HCC, hierarchical condition category; Metro, metropolitan; micro, micropolitan; RUCA, rural-urban commuting area; small t., small town.

Bold values indicate a statistically significant difference between regions for a given year.

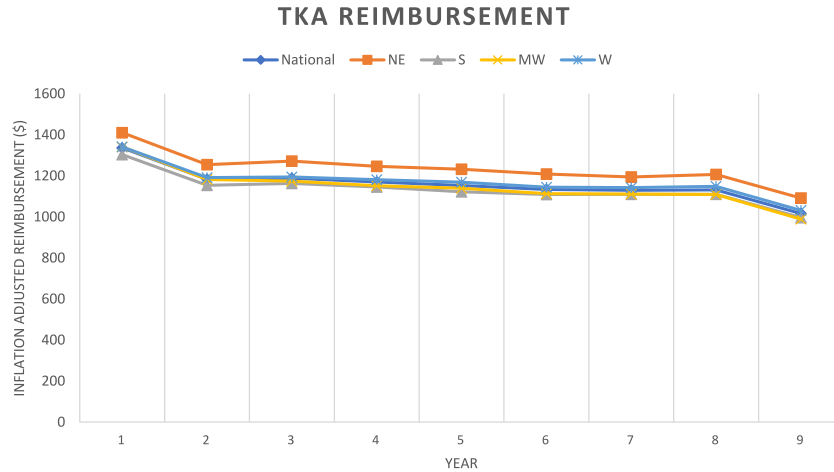


Figure 2. Average inflation-adjusted Medicare reimbursement for primary total knee arthroplasty.

South aligns with previous studies examining total hip arthroplasty, hand surgery, and shoulder surgery [28-30].

When assessing geographic differences in reimbursement, it is important to consider how Medicare physician reimbursement is determined. Medicare reimbursement for TKA is based on relative value units, which are determined and updated annually by a committee of specialists. The relative value unit amount is multiplied by a standardized conversion factor and a variable Geographic Practice Cost Index (GPCI) to determine the final reimbursement amount to the surgeon. The GPCI attempts to adjust for differences in costs of living and practice expenses across the country. Therefore, the regional differences identified in this study are likely a representation of differences in the geographical multiplier for different regions. This is consistent with the fact that the Northeast and West typically have higher cost-of-living areas and therefore likely have higher geographical multipliers [31]. However, it is important to recognize that the GPCI only stratifies the country into 112 localities, with 34 states having a single GPCI value representing the entire state [32]. This emphasizes the limited granularity of this index and the potential for inequitable reimbursement

between providers and communities. Future research should aim to better understand the extent to which GPCI accurately accounts for geographical differences in TKA reimbursement.

Although the per capita TKA utilization and number of TKAs performed per surgeon increased between 2013 and 2021, the average number of Medicare beneficiaries per surgeon declined. This discrepancy indicates either an increasing amount of bilateral TKAs or an increase in the proportion of Medicare beneficiaries that are undergoing TKA. The rate of bilateral knee osteoarthritis and the rate of patients eventually pursuing TKA of both knees is increasing [33-35]. Additionally, the present study also found that the average number of services performed per beneficiary increased by nearly 25% despite the comorbidity profiles of Medicare beneficiaries decreasing by nearly 7%. Our study also found TKA rates to be declining in nonmetropolitan areas. Together, these findings are concerning for increasingly stringent patient selection processes by surgeons. Previous studies have found surgeons to be more stringent in selecting patients based on specialization level and fear of malpractice lawsuits, which may explain increasingly stringent patient selection [36,37].

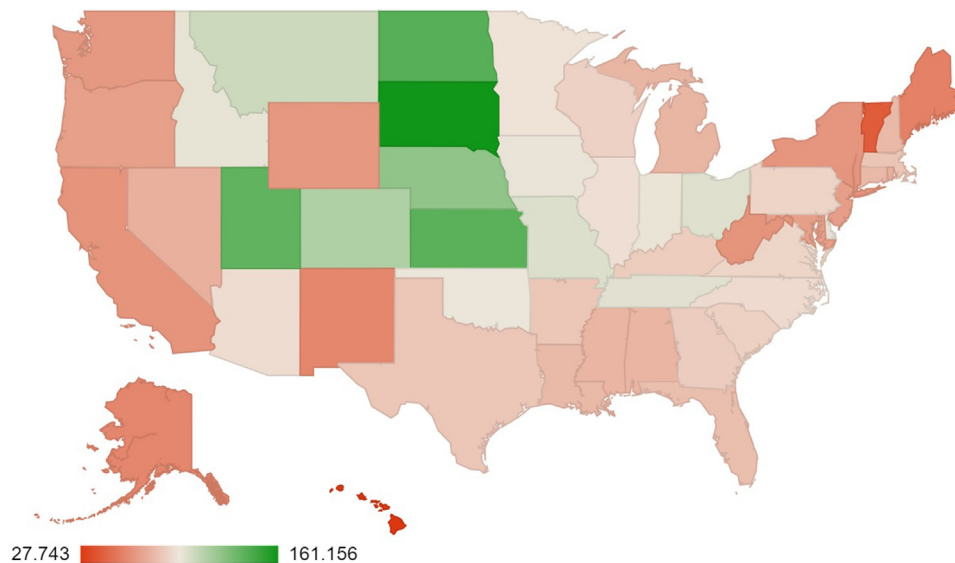
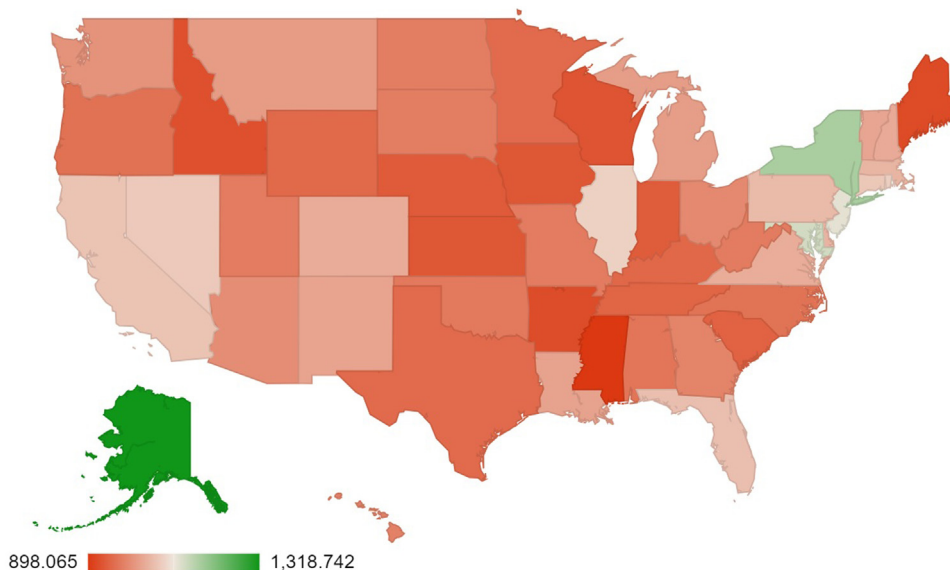


Figure 3. 2021 total knee arthroplasty utilization – by state.



**Figure 4.** 2021 total knee arthroplasty reimbursement – by state.

Additionally, the current reimbursement environment may not adequately incentivize surgeons to care for more complex or sicker patients, which could be driving this trend. However, the decline in patient comorbidities identified in this study may be an artifact of the COVID-19 pandemic, as sicker patients may have been afraid of pursuing elective surgery in 2021 [38]. Ultimately, this should continue to be researched and addressed in future policy discussions to ensure equitable and accessible arthroplasty care, moving forward.

The Northeast and West were the 2 regions with the slowest decline in reimbursement, while simultaneously having the greatest decline in patient comorbidity profiles, as measured by HCC. A recent study by Haglin et al found higher patient HCC to be associated with lower reimbursement across primary total joint arthroplasty in 2019. Our study corroborates those findings at a national level for TKA. Although Centers for Medicare and Medicaid Services does have a modifier system that allows for greater reimbursement for complicated patients where intraoperative complications arise, it is rarely approved by Medicare [39,40]. Therefore, surgeons may be financially incentivized to be more selective in choosing and accepting patients for TKA. This emphasizes the need for more robust risk stratification in determining reimbursement to ensure accessibility and economic sustainability. Our study also found the average proportion of Medicare beneficiaries with dual Medicare and Medicaid enrollment to decline nationally, with the greatest declines in the South and Midwest. This is in contrast to national trends of a slight increase in the number of Medicaid enrollees since the Affordable Care Act was enacted in 2010 [41–43]. In 2019, 17% of the traditional Medicare population were dual Medicare-Medicaid enrollees, which is a higher rate than the 13.1% rate identified for TKA surgeons in 2019 in our study [44]. Lower socioeconomic status has previously been shown to be associated with worse outcomes following TKA, so these findings further raise concern about the equity of TKA care [45,46].

This study is not without limitations. The exclusive use of a Medicare Part B database limits the generalizability of these findings to the non-Medicare population and to patients covered under Medicare Advantage. However, Medicare is the largest payor for TKAs in the United States and directly influences reimbursement rates of private insurance companies, so the results retain

significant clinical relevance [47,48]. Certain variables relevant to TKA, such as surgical outcomes, intraoperative complications, and physician expertise could not be controlled given the nature of the dataset used. With the use of a large database, there remains the risk of errors in data entry or billing. However, the effects of errors are likely minimal as a recent audit found the incorrect coding rate to be around 1% [49].

## Conclusions

This study demonstrates that TKA utilization is increasing and average physician reimbursement per TKA is declining at varying rates across the country, with the Northeast and Midwest most affected. Surgeons may also be becoming more stringent in their patient selection criteria, as the total number of unique Medicare beneficiaries per surgeon from 2013 to 2021 became smaller, and these patients became healthier and more likely to be from metropolitan areas throughout the study. These findings should be addressed in future policy discussions to ensure equitable and accessible arthroplasty care, moving forward.

## Conflicts of interest

The authors declare there are no conflicts of interest.

For full disclosure statements refer to <https://doi.org/10.1016/j.artd.2024.101454>.

## CRediT authorship contribution statement

**Vikram S. Gill:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Jack M. Haglin:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Sai-lesh V. Tummala:** Writing – review & editing, Writing – original draft, Supervision, Methodology. **Georgia Sullivan:** Writing – review & editing, Methodology, Formal analysis. **Mark J. Spanghel:** Writing – review & editing, Methodology. **Joshua S. Bingham:** Writing – review & editing, Supervision, Methodology, Conceptualization.

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