REGIONAL DIFFERENCES IN RATES OF TOTAL KNEE ARTHROPLASTY

AMONG U.S. MEDICARE BENEFICIARIES

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ABSTRACT

Background. Rates of total knee arthroplasty (TKA) among Medicare beneficiaries vary widely across the United States. Whether this variation is due to differences in patient characteristics or to differences in physician practice is unknown.

Methods. We examined rates of primary TKA among Medicare beneficiaries age 65 to 89 years in 2011 – 2015 among 306 Health Referral Regions, defined by the Dartmouth Atlas of Health Care. To adjust for differences in patient characteristics, we used Medicare claims data and census data related to residential location to estimate the probability of TKA based on a beneficiary’s demographic and socioeconomic features, knee symptoms and risks for knee osteoarthritis, and comorbid conditions. We used these estimates to generate the expected number of primary TKA in each Health Referral Region, which we compared to the observed number. We then compared the observed/expected ratios to measures of access to care and physician practice patterns across Health Referral Regions.

Results. Because observed/expected ratios based on expected rates that were adjusted for differences in age, sex, and race/ethnicity demonstrated residual confounding by race/ethnicity, we performed race-stratified analyses. Among white beneficiaries, adjustment for demographic, socioeconomic, and clinical characteristics reduced the variation in observed/expected ratios among Health Referral Regions by X%, compared to adjustment for age and sex alone. However, substantial variation remained, with observed/expected ratios that ranged from X in Newark NJ to X in Idaho Falls ID. Ratios above 1.2 were primarily located in the upper Midwest, Great Plains, and mountain west, while ratios below 0.8 were more common in large urban centers. Observed/expected ratios were higher in more rural areas, and were directly related to orthopedic surgeon density. Rates of primary TKA among beneficiaries with dementia, peripheral vascular disease, and leg ulcers were also higher in Health Referral Regions with high observed/expected ratios, as were rates among younger beneficiaries with no comorbidities. Among black beneficiaries, observed/expected ratios in 42 Health Referral Regions ranged from X to X.

Conclusions. Substantial regional variation in rates of primary TKA remained among Medicare beneficiaries after adjustment for patient characteristics. Regions with higher rates had more orthopedic surgeons per capita and higher rates of TKA among patients who had relative contraindications to TKA.

Total knee arthroplasty (TKA) is a highly effective treatment for patients with chronic knee pain and functional limitations, most often due to osteoarthritis, that is not responsive to more conservative interventions [1-3]. More than 243,000 primary TKA procedures were performed among Medicare beneficiaries in 2010 [4]. Rates in Medicare beneficiaries doubled between 1991 and 2010, and are projected to escalate over the coming decades [1,5].

Rates of TKA vary widely across the United States [6]. As early as 1988, rates of TKA among Medicare beneficiaries were noted to be more than four times higher in some midwestern and western states than in other regions [7]. This geographic variation has endured, raising questions about relative overuse or underuse of TKA in different regions [8-11]. Although patient preferences play a major role in the decision to have TKA, differences in physician practice patterns have been implicated as a source of regional variations in surgery rates [12-15]. Prior studies did not control for patient-related factors other than age, sex, and race, and did not examine if regional differences in TKA rates were associated with access to care or potential correlates of overuse or underuse.

We examined rates of primary TKA in Medicare beneficiaries in 2011 – 2015 to address three questions: do rates vary by region after accounting for differences in the prevalence of knee osteoarthritis and its major risk factors, comorbidities, and socioeconomic status? Do rates vary with measures of access to care, including use of outpatient care and the availability of orthopedic surgeons? And, to address appropriateness, do rates also vary by region among patients with clinical contraindications to TKA?

METHODS

Data source. In this retrospective cohort study, we computed the annual incidence of primary TKA among Medicare beneficiaries using 100% Medicare Part A and Part B fee-for-service claims from 2011 to 2015. Data on inpatient hospitalizations included up to 25 possible diagnosis codes and 25 procedure codes for surgeries and other interventions. Data on outpatient claims included up to 13 possible diagnosis codes per visit. International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes were used for diagnoses and procedures for all visits except those in the last quarter of 2015, when ICD-10-CM codes were used. We used five years of data to provide stable estimates of TKA rates.

The study protocol was approved by the local institutional review board. Data were made available by the Centers for Medicare and Medicaid Services (CMS) through a data use agreement.

Patients and outcome. We included all Medicare beneficiaries age 65 to 89 years who lived in one of the 50 U.S. states or District of Columbia, were enrolled in Parts A and B, and were not enrolled in Medicare Advantage plans. We excluded persons younger than 65 because they likely had selected health conditions that permitted early Medicare eligibility, and excluded persons 90 or older because this age group is overrepresented in the Midwest. Rates of primary TKA are low in persons age 90 or older [7]. Follow-up ended if the beneficiary reached age 90, or at the time of death or enrollment in Medicare Advantage.

Among these beneficiaries, we identified all instances of primary TKA in the hospitalization files using the corresponding procedure codes (ICD-9-CM 81.54; ICD-10-CM 0SRC or 0SRD). During the study years, TKA was still largely performed as an inpatient procedure in Medicare beneficiaries [16]. We computed annual incidences of primary TKA by Hospital Referral Region (HRR), based on the Dartmouth Atlas for Health Care [11]. HRRs are 306 tertiary medical care regions that represent local referral patterns for major surgeries. Each HRR has at least one hospital that performed both cardiovascular surgery and neurosurgery and has a minimum population of 120,000. We used linkages provided by CMS to map each beneficiary’s zip code of residence to one of the 306 HRRs [17].

We abstracted data on patient-related factors that were thought potentially related to the likelihood of TKA to use as adjustments for regional differences in TKA rates. Demographic characteristics included age, sex, and race/ethnicity (white, black, Hispanic, Asian, and other). We identified beneficiaries as having knee osteoarthritis (ICD-9-CM 715.X6; ICD-10-CM M17) or knee symptoms (ICD-9-CM 719.X6; ICD-10-CM M2506, M2526, M2536, M2546, M2556, M2566, M2576, M2586) based on outpatient visit diagnosis codes. Because knee osteoarthritis may be under-recorded in claims, we also included three area-level risk factors for knee osteoarthritis: obesity, smoking, and occupational physical activity [18]. We used county-level data on the prevalence of obesity and current smoking from 2011 in the Behavioral Risk Factor Surveillance System, and used county-to-HRR crosswalks to estimate obesity and smoking prevalence in HRRs. [19-21]. Similarly, we used county-level data from the U.S. Census 2011-2015 summary files to estimate the proportion of the population age 16 or older engaged in physically demanding occupations (construction, installation, building maintenance, firefighting, and farming) in each HRR [22].

Willingness to consider TKA may be affected by the presence of comorbidities. Therefore, for each beneficiary we identified the presence or absence of 20 comorbid conditions, based on inpatient and outpatient claims updated annually, using CMS Chronic Conditions Warehouse definitions: recent acute myocardial infarction; recent atrial fibrillation; ever ischemic heart disease; ever congestive heart failure; ever stroke; ever peripheral vascular disease; recent skin ulcer; ever chronic obstructive pulmonary disease; recent diabetes mellitus; recent chronic kidney disease; ever cirrhosis or other chronic liver disease; ever HIV/AIDS; ever dementia; recent depression; ever hematological malignancy; ever breast cancer; ever lung cancer, ever colorectal cancer; ever prostate cancer; and ever endometrial cancer [23].

TKA is less common among persons of low socioeconomic status [24]. We categorized a beneficiary as poor if they received government subsidies for medical insurance premiums. We also used an area-level measure of socioeconomic status, based on seven income, education, and housing characteristics of the zip code of residence from the 2010 U.S. Census [25]. Z scores for each measure (number of standard deviations above or below the national average) were computed for each zip code, and summed to derive the area-based socioeconomic score. A zip code that was at the national average on all measures would have a score of 0.

We next examined four measures potentially related to access to TKA. We classified beneficiaries as living in a rural area if their zip code of residence was outside an urban center or cluster in the 2010 U.S. Census [19,26]. We used the annual number of knee visits to any provider as a measure of access to outpatient care. Because the degree of local market penetration by managed care plans can influence the care provided to patients insured by fee-for-service plans, we used CMS data on the proportion of Medicare beneficiaries enrolled in Medicare Advantage plans in each county and year to compute weighted averages of Medicare Advantage penetration in each HRR [27,28]. We also counted the number of surgeons in each HRR that performed primary TKA among Medicare beneficiaries in the study years, based on the National Provider Identifier of the operating surgeon. We divided this number by the population of each HRR as a measure of TKA surgeon density. We used this measure, rather than the number of orthopedic surgeons, because nationally only one-half of orthopedic surgeons perform arthroplasties [29].

Statistical analysis. The outcome was primary TKA. To compare the incidence of TKA among HRRs, we first used data from all HRRs to estimate expected rates of TKA based on the characteristics of all beneficiaries. We then compared the observed rates of TKA in each HRR to the expected rates as an Observed/Expected ratio (OER). To derive the expected rates, we used Poisson models to estimate each beneficiary’s probability of TKA, based on a given set of covariates, and summed these probabilities among all beneficiaries in an HRR. In the initial model, we included only age (in five categories: 65-69 years, 70-74 years, 75-79 years, 80-84 years, and 85-89 years), sex, race/ethnicity, and age-sex interactions as covariates. In the full model, we also included indicator variables for knee osteoarthritis, each of the 20 comorbid conditions, and being poor, as well as the area-level measures of the proportion of residents who were obese, smokers, or had physically demanding occupations, and area-level socioeconomic status. We then divided the observed number of TKA by the expected number to obtain the OER in each HRR. We specified separate models for each study year,

computed the expected number of TKA per year, then summed over the 5 years. How comparable were estimates across years? [Estimated rate ratios had a median coefficient of variation of 6% over the 5 years across the 45 parameters estimated in each model, with all but one having a Why not use repeated/hierarchical models? [Repeated/hierarchical models are useful in this context for obtaining appropriate standard error estimates of the parameters; they do not change the estimates themselves. We are really interested in the predicted rate of a TKA for each individual and not the standard error of that estimate, so using separate cross-sectional models results in virtually the same estimates with much lower computational overhead and convergence issues.] An OER of 1.0 would indicate a HRR in which the observed rate of TKA was the same as the expected rate.

To determine the degree to which beneficiary characteristics other than age, sex, and race/ethnicity affected rates of TKA among HRRs, we compared the distribution of RRs based on the full model to OERs based on the initial demographic-only model. We examined correlations between OERs based on the full model and the four measures of access to TKA: the percent of beneficiaries that lived in rural areas, the annual number of outpatient visits for knee complaints, the percent of beneficiaries in a Medicare Advantage plan, and TKA surgeon density.

To examine if the characteristics of beneficiaries who received TKA differed among beneficiaries in HRRs with high OER or low OERs, we computed OERs after stratifying the sample into quartiles based on the expected probability of TKA (ranging from very low probability to highest probability). In this analysis, we sought to determine how stable the OER of a given HRR was across beneficiary subgroups with different estimated probabilities of TKA. We also computed the rate of TKA among beneficiaries with either dementia, peripheral vascular disease, or leg ulcers, which are relative contraindications to TKA, and correlated these rates with the OER across HRRs [30]. Similarly, we computed the rate of TKA among beneficiaries age 65 to 69 who had no comorbidity, as a group of healthier persons, and correlated these rates with the OER. Lastly, we examined if the number of TKAs per surgeon varied across HRRs, to assess if rates were associated a few high-volume surgeons.

We used SAS programs (version 9.4, SAS Institute, Cary NC) for analysis.

RESULTS

In 2011, there were 239,950 primary TKA among 28,808,011 beneficiaries, while in 2015, there were 262,013 primary TKA among 30,177,710 beneficiaries. When the expected rate of TKA was based on adjustment for age, sex, and race/ethnicity, the OER varied widely among HRRs (Supplemental figure 1). The highest OER of 1.72 was in Idaho Falls, ID, while the lowest OER of 0.52 was in Bronx, NY. HRRs with the highest OERs had predominantly white populations, while HRRs with the lowest OERs had large ethnic minority populations (Supplemental table 1). Despite adjustment of the expected rates for race/ethnicity, correlations remained between the OER and the racial composition of the HRR, indicating residual confounding (Supplemental figure 2). Therefore, subsequent analyses used race-specific models. Because whites comprised 84.6% of the sample, our analyses focused on associations among white beneficiaries.

Among whites, the clinical characteristics of beneficiaries varied widely among HRR. For example, the percent of poor beneficiaries ranged from 2.1% to 35.6%, and the percent with dementia ranged from 6.0% to 18.6% (Supplemental table 2). Adjustment for indicators of knee osteoarthritis, 20 comorbidities, and socioeconomic status resulted in OERs that were somewhat less divergent across HRRs, but substantial regional variation remained (Supplemental figure 3 and Supplemental table 3). Several HRR in the upper Midwest, Great Plains, and mountain west had high OERs, while HRR in the New York City region and south Florida had low OERs (Figure 1 and Supplemental table 4).

HRRs that included more rural residents had higher OER than those that were less rural (Figure 2). HRRs whose residents had fewer outpatient visits for knee complaints also had higher OER than those whose residents had more visits. There was no association between the OER and the proportion of Medicare Advantage beneficiaries in an HRR, while HRRs with more TKA surgeons per capita had higher OERs than those with fewer surgeons.

The associations of OER with rurality and outpatient visit frequency suggested that limited geographic access to care may contribute to high OERs. To test this, we separately computed OERs for the urban centers and outlying areas of 9 HRRs (3 with high OERs (Salt Lake City, Wichita, Lincoln NE), 3 with average OERs (Albuquerque, Phoenix, Bakersfield), and 3 with low OERs (San Antonio, Syracuse, Lexington KY) (Table 1). In each HRR but Lexington KY, the OER in the outlying area was higher than the OER in the urban center, suggesting an association with geographic access to care. Outlying-urban differences were greatest in the three high OER regions (Salt Lake City, Wichita, and Lincoln NE). OERs in the urban centers of these regions were all higher than 1.0, indicating higher than expected rates in these cities compared to the rest of the country.

HRRs with high OERs tended to have high OERs among beneficiaries with very low estimated probabilities of TKA as well as among beneficiaries with higher probabilities of TKA, while HRRs with low OERs tended to have low OERs across the range of estimated probability of TKA (Figure 3). This pattern suggests that a broader spectrum of beneficiaries received TKA in HRRs with high OERs, regardless of the estimated probability of surgery, and that beneficiaries and surgeons in low OER HRRs were more discriminating. Consistent with this finding, rates of TKA among beneficiaries with dementia, peripheral vascular disease, and leg ulcers were higher in the HRRs with high OERs, as were rates of TKA among 65 to 69 year-olds with no comorbidity (Figure 4).

The number of TKA surgeons per HRR ranged from 48 to 1047. The annual number of TKA performed varied widely, but the number and range of TKAs per surgeon was similar in high OER regions as in other regions (Supplemental figure 4).

Analyses in blacks, Hispanics, and Asians was limited by low representation across HRRs. Only six HRR included at least 15,000 Hispanic beneficiaries, which corresponded to the lowest white HRR population in our study. Forty-two HRRs included at least 15,000 black beneficiaries. OERs among blacks in these HRRs ranged from 0.70 to 1.2 (Supplemental table 5). OERs in blacks and whites in these regions were positively correlated, and generally higher among blacks (Figure 5).

DISCUSSION

In this analysis of Medicare beneficiaries in 2011 – 2015, we found a pattern of regional variation in rates of primary TKA similar to that first described in 1988, with higher than expected rates largely concentrated in areas from the upper Midwest to the mountain west, and lower than expected rates in many large metropolitan areas [7]. We identified several sources of variation in these rates, most importantly race/ethnicity and measures of access to TKA.

Ethnic minorities, particularly black Americans, are one-half to one-quarter as likely to have TKA than whites, even among Medicare beneficiaries and veterans, for whom financial and administrative barriers to TKA should be lessened [9,10]. Lack of familiarity with TKA, expectations regarding benefits, and risk aversion contribute to less utilization [13]. Large differences in use of TKA between ethnic minority beneficiaries and white beneficiaries meant that regions with large minority populations would always register low rates of TKA, necessitating a race/ethnicity-stratified analysis.

Among white beneficiaries, OERs tended to be higher in more rural HRRs, and

REFERENCES

1. Ethgen O, Bruyere O, Richy F, Dardennes C, Reginster JY. Health-related quality of life in total hip and total knee arthroplasty: a qualitative and systematic review of the literature. J Bone Joint Surg Am 2004;86:963-74.

2. Zhang W, Moskowitz RW, Nuki G, Abramson S, Altman RD, Arden N, Bierma-Zeinstra S, Brandt KD, Croft P, Doherty M, Dougados M. OARSI recommendations for the management of hip and knee osteoarthritis, Part II: OARSI evidence-based, expert consensus guidelines. Osteoarthritis Cartilage 2008;16:137-62.

3. Daigle ME, Weinstein AM, Katz JN, Losina E. The cost-effectiveness of total joint arthroplasty: a systematic review of published literature. Best Pract Res Clin Rheumatol 2012; 26:649-58.

4. 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 2012; 308:1227-36.

5. 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 2007; 89:780-5.

6. Birkmeyer JD, Reames BN, McCulloch P, Carr AJ, Campbell WB, Wennberg JE. Understanding of regional variation in the use of surgery. Lancet 2013;382:1121-9.

7. Peterson MG, Hollenberg JP, Szatrowski TP, Johanson NA, Mancuso CA, Charlson ME. Geographic variations in the rates of elective total hip and knee arthroplasties among Medicare beneficiaries in the United States. J Bone Joint Surg 1992;74:1530-9.

8. Katz BP, Freund DA, Heck DA, Dittus RS, Paul JE, Wright J, Coyte P, Holleman E, Hawker G. Demographic variation in the rate of knee replacement: a multi-year analysis. Health services research. Health Serv Res 1996;31:125-40.

9. 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 2003; 349:1350-9.

10. 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 2005;87:1222-8.

11. The Dartmouth Institute for Health Policy and Clinical Practice. The Dartmouth Atlas of Health Care. <http://www.dartmouthatlas.org>. Accessed November 28, 2017.

12. Hawker GA, Wright JG, Coyte PC, Williams JI, Harvey B, Glazier R, Wilkins A, Badley EM. Determining the need for hip and knee arthroplasty: the role of clinical severity and patients’ preferences. Med Care 2001;39:206-16.

13. Mota RE, Tarricone R, Ciani O, Bridges JF, Drummond M. Determinants of demand for total hip and knee arthroplasty: a systematic literature review. BMC Health Services Res 2012; 12:225.

14. Wright JG, Hawker GA, Bombardier C, Croxford R, Dittus RS, Freund DA, Coyte PC. Physician enthusiasm as an explanation for area variation in the utilization of knee replacement surgery. Med Care 1999;37:946-56.

15. Mulley AG. Inconvenient truths about supplier induced demand and unwarranted variation in medical practice. BMJ 2009;339:b4073.

16. Courtney PM, Froimson MI, Meneghini RM, Lee G-C, Della Valle CJ. Can total knee arthroplasty be performed safely as an outpatient in the Medicare population? J Arthroplasty 2018; 33:S28-S31.

17. Centers for Medicare and Medicaid Services. Medicare Geographic Variation Public Use Files [internet]. 2017 [cited 2017 October 10]; Available from: <https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/Medicare-Geographic-Variation/GV_PUF.html>

18. Blagojevic M, Jinks C, Jeffery A, Jordan KP. Risk factors for onset of osteoarthritis of the knee in older adults: a systematic review and meta-analysis. Osteoarthritis Cartilage 2010; 18:24-33.

19. Missouri Census Data Center. MABLE/Geocorr14: Geographic Correspondence Engine [internet]. 2107 [cited 17 October 2017]; Available from: http://mcdc.missouri.edu/websas/geocorr14.html

20. Dwyer-Lindgren L, Freedman G, Engell RE, Fleming TD, Lim SS, Murray CJ, Mokdad AH. Prevalence of physical activity and obesity in US counties, 2001–2011: a road map for action. Popul Health Metr 2013;11:7.

21. Dwyer-Lindgren L, Mokdad AH, Srebotnjak T, Flaxman AD, Hansen GM, Murray CJ. Cigarette smoking prevalence in US counties: 1996-2012. Popul Health Metr 2014;12:5.

22. United States Census Bureau. 2011 American Community Survey 5 year summary files. Data set [internet]. 2017 [cited 2017 November 8]; Available from: <https://factfinder.census.gov/faces/nav/jsf/pages/download_center.xhtml>

23. Centers for Medicare and Medicaid Services. Chronic Conditions Data Warehouse [internet]. 2017 [cited 2018 Feb 26]; Available from: <https://www.ccwdata.org/web/guest/condition-categories>

24. Hanchate AD, Zhang Y, Felson DT, Ash AS. Exploring the determinants of racial and ethnic disparities in total knee arthroplasty: health insurance, income, and assets. Med Care 2008; 46:481-8.

25. Ward MM. Socioeconomic status and the incidence of ESRD. Am J Kidney Dis 2008; 51:563-72.

26. Francis ML, Scaife SL, Zahnd WE, Cook EF, Schneeweiss S. Joint replacement surgeries among Medicare beneficiaries in rural compared with urban areas. Arthritis Rheumatol 2009; 60:3554-62.

27. Baicker K, Chernew ME, Robbins JA. The spillover effects of Medicare managed care: Medicare Advantage and hospital utilization. J Health Econ 2013;32:1289-300.

28. Centers for Medicare and Medicaid Services. Medicare Advantage/Part D Contract and Enrollment Data [internet]. 2017 [cited 2017 October 30]; Available from: <https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/MCRAdvPartDEnrolData/index.html>

29. Fehring TK, Odum SM, Troyer JL, Iorio R, Kurtz SM, Lau EC. Joint replacement access in 2016: a supply side crisis. J Arthroplasty 2010; 25:1175-81.

30. Cross WW 3rd, Saleh KJ, Wilt TJ, Kane RL. Agreement about indications for total knee arthroplasty. Clin Orthop Relat Res 2006; 446:34-9.

36. Wilson S, Marx RG, Pan TJ, Lyman S. Meaningful thresholds for the volume-outcome relationship in total knee arthroplasty. J Bone Joint Surg Am 2016; 98:1683-1690.

Table 1. Observed/expected ratios (OER) for primary total knee arthroplasty rates among white Medicare beneficiaries in the urban centers or outlying areas of selected Health Referral Regions. Regions selected were those with a large geographic area, an urban center with a population of 100,000 or more, and an OER at the low, middle, or high end of the distribution.

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| --- | --- | --- | --- | --- | --- |
| Health Referral Region | Percent of beneficiaries living in the urban center | Overall OER | OER urban center | OER outlying area | OER Difference |
| Lexington KY | 14.7 | 0.81 | 0.81 | 0.81 | 0 |
| Syracuse | 12.0 | 0.84 | 0.72 | 0.85 | 0.13 |
| San Antonio | 48.6 | 0.86 | 0.72 | 1.00 | 0.28 |
| Albuquerque | 38.3 | 0.97 | 0.87 | 1.04 | 0.17 |
| Bakersfield | 35.8 | 1.01 | 0.93 | 1.06 | 0.13 |
| Phoenix | 55.1 | 1.04 | 0.95 | 1.15 | 0.20 |
| Wichita | 25.3 | 1.43 | 1.13 | 1.55 | 0.41 |
| Lincoln NE | 35.2 | 1.57 | 1.35 | 1.70 | 0.35 |
| Salt Lake City | 12.7 | 1.64 | 1.28 | 1.69 | 0.41 |

FIGURE LEGENDS

Figure 1. Observed/expected ratios for rates of primary total knee arthroplasty among white Medicare beneficiaries age 65 to 89 in 2011-2015, by Health Referral Region. Expected rates were based on models that adjusted for age, sex, presence of knee symptoms, area-based measures of obesity, smoking, and physically demanding occupations, 20 comorbid conditions, poverty, and area-based socioeconomic score. Ratios greater than 1.0 indicate higher than expected rates of total knee arthroplasty, while ratios less than 1.0 indicate lower than expected rates.

Figure 2. Associations between the percent of beneficiaries living in rural areas, the number of outpatient visits for knee complaints, the percent of beneficiaries in Medicare Advantage plans, and the number of surgeons performing total knee arthroplasties per 10,000 beneficiaries and the observed/expected ratio for rates of primary total knee arthroplasty among white Medicare beneficiaries in each Health Referral Region.

Figure 3. Observed/expected ratios for rates of primary total knee arthroplasty in each Health Referral Region among white Medicare beneficiaries, stratified by expected probability of total knee arthroplasty. Expected probabilities were stratified into quartiles from very low (on the left) to highest (on the right), and quartile-specific observed/expected ratios were computed for each region.

Figure 4. Associations between rates of primary total knee arthroplasty among white Medicare beneficiaries with either dementia, peripheral vascular disease, leg ulcers, or who were age 65 to 69 with no comorbidities and the observed/expected ratio for rates of total knee arthroplasty by Health Referral Region.

Figure 5. Association between the observed/expected ratios for rates of primary total knee arthroplasty between black Medicare beneficiaries and white Medicare beneficiaries.