REGIONAL DIFFERENCES IN RATES OF TOTAL KNEE ARTHROPLASTY

AMONG U.S. MEDICARE BENEFICIARIES

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ABSTRACT

Objective.

Methods.

Results.

Conclusions.

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 [1-4]. Among Medicare beneficiaries, TKA is second only to cataract extractions as the most common operation, with more than 380,000 procedures performed in 2012, at an aggregate cost of over $3 billion [5,6]. Rates of TKA in Medicare beneficiaries doubled between 1991 and 2010, and are projected to escalate further over the coming decades [1,7].

Despite increasing use, geographic variation in rates of TKA across the United States have persisted [8]. 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 [9]. This geographic variation has endured, raising questions about relative overuse or underuse of TKA in different regions [10-13]. Although patient preferences play a major role in the decision to have TKA, differences in physician practice patterns have been implicated in regional variations in surgery rates [14-17].

Prior studies did not adjust for patient-related factors other than age, sex, and race, and did not examine 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 regional differences in access to care, including use of outpatient care and the availability of orthopedic surgeons? And, to address appropriateness, are the characteristics of patients who receive TKA different in in high-use compared to low-use regions?

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 [18]. Rates of primary TKA are low in persons age 90 or older [9]. 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 [19]. We computed annual incidences of primary TKA by Hospital Referral Region (HRR) from the Dartmouth Atlas for Health Care [13]. HRRs are 306 tertiary medical care regions that are based on 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 [20].

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 that vary by region: obesity, smoking, and occupational physical activity [21]. 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 prevalences in HRRs. [22-24]. 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 [25].

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 and 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 [26].

TKA is less common among persons of low socioeconomic status [27,28]. We categorized a patient as poor if they received government subsidies for insurance premiums. We also used an area-level measure of socioeconomic status, based on seven economic characteristics of patient’s zip code of residence from the 2010 U.S. Census [29]. The z scores (i.e. number of standard deviations above or below the national average) for each measure are 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 also examined four measures thought to be 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 [22,30]. 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 [31-33]. 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, as opposed to the number of orthopedic surgeons, because nationally only one-half of orthopedic surgeons perform joint arthroplasties [34].

Statistical analysis. The outcome was primary TKA, which could include more than one event per beneficiary. 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 proportions 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 of TKA, based on the beneficiaries in each HRR, to obtain the OER. We specified separate models for each study year, and averaged the five estimates of OER for use in analysis. How comparable were estimates across years? Why not use repeated/hierarchical models? An OER of 1.0 would indicate a HRR in which the observed rate of TKA was the same as the expected rate, while in HRR with OER greater than 1.0, the observed rate exceeded the expected rate.

To determine the degree to which patient 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 also examined correlations between OERs based on the full model and the four measures of access to TKA: the percent of HRR beneficiaries that lived in rural areas, the annual number of outpatient visits for knee complaints, the percent of HRR beneficiaries in a Medicare Advantage plan, and TKA surgeon density.

To examine if the characteristics of patients 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 if the OER of a given HRR was similarly high among beneficiaries with a very low probability of TKA and those with a higher probability of TKA. We also computed the rate of TKA among beneficiaries with dementia, peripheral vascular disease, or leg ulcers, which are relative contraindications to TKA, and correlated these rates with the OER across HRRs [35]. Similarly, we computed the rate of TKA among beneficiaries age 65 to 69 who had no comorbidity, as a group of healthy persons, and correlated these rates with the OER. Lastly, we examined the number of TKAs per surgeon in each HRR to determine if rates were influenced by a few high-volume surgeons or many low volume surgeons. Surgeons were classified based on their annual number of TKA as low-volume (1-12), medium-volume (13-59), high-volume (60-145) or very high-volume (> 145). Higher surgeon volumes have been associated with fewer TKA complications [36].

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

RESULTS

In 2011, there were X TKA among X beneficiaries in the study, while in 2015, there were X TKA among X 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-map). The highest OER of 1.86 was in Idaho Falls, ID, while the lowest OER of 0.63 was in Newark, NJ. HRRs with the highest OER were predominantly white, while HRRs with the lowest OERs had large proportions of ethnic minorities (Supplemental table 1). Despite adjustment of the expected rates for race/ethnicity, significant 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 to generate the expected number of TKA. Because whites comprised X% of the sample, our analyses focused on associations among whites.

Among whites, the clinical characteristics of beneficiaries varied widely among HRR, with for example, the percent of poor beneficiaries ranging from X% to X%, and those with dementia ranging from X% to X% (Supplemental table 2). Adjustment for indicators of knee osteoarthritis, comorbidities, and socioeconomic status resulted in OERs that were somewhat less divergent, with 10th and 90th percentiles of X and X, compared to X and X for OERs based on age and sex-adjustment (Supplemental figure 3 and Supplemental table 3). However, substantial regional variation in OERs remained after adjustment for patient characteristics, with high OER in several HRR in the upper Midwest and mountain west, and low OER in the New York City region and south Florida (Figure 1 and Supplemental table 4).

HRRs that included more rural residents had generally 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 such visits. There was no association between the OER and the proportion of Medicare Advantage beneficiaries in an HRR. In contrast, HRRs with more TKA surgeons per capita had higher OERs than those with fewer surgeons per capita.

HRRs with high OERs tended to have high OERs among patients with very low estimated probabilities of TKA as well as those with higher estimated probabilities of TKA, while HRRs with low OERs tended to have low OERs across quartiles of estimated probability of TKA (Figure 3). This pattern suggests that HRRs with high OERs were less discriminating in performing TKA across a spectrum of beneficiaries with varying likelihood of TKA, and that HRRs with low OERs were universally more discriminating. Consistent with this interpretation, rates of TKA among beneficiaries with dementia, peripheral vascular disease, and leg ulcers were higher in HRRs with high OERs, as were rates among healthy 65 to 69 year-olds (Figure 4).

The number of TKA surgeons per HRR ranged from X to X. Most surgeons regardless of HRR performed between X and X TKA annually (Figure 5). Look for thresholds at 60.

We limited the analysis of blacks and Hispanics to those HRRs that had at least 15,000 black or Hispanic Medicare beneficiaries to provide stable OER estimates. This number corresponded to the lowest HRR population in the analysis of whites. Among blacks, there was comparatively little variation in OERs among the X HRRs studied, with a range from 0.X to X (Supplemental table 5). Among Hispanics, OERs ranged from X to X among the X HRRs that were examined (Supplemental table 5). HRRs with high OERs in whites also tended to have higher OERs among blacks and Hispanics (Figure 5). However, there was no association between TKA surgeon density in an HRR and the OER among blacks or Hispanics (Figure 5).

DISCUSSION

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FIGURE LEGENDS

Figure 1. Observed-to-expected ratios for rates of total knee arthroplasties among white Medicare beneficiaries age 65 to 89 in 2011-2015, by Health Referral Region. 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 in the and the observed-to-expected ratio for rates of total knee arthroplasty among white Medicare beneficiaries in each Health Referral Region.

Figure 3. Observed-to-expected ratios for rates of 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-to-expected ratios were computed for each region.

Figure 4. Associations between rates of 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-to-expected ratio for rates of total knee arthroplasty by Health Referral Region.

Figure 5. Association between the observed-to-expected ratios for rates of total knee arthroplasty between white and black, and white and Hispanic, Medicare beneficiaries. Associations between the observed-to-expected ratios for rates of total knee arthroplasty in black and Hispanic Medicare beneficiaries and the number of surgeons performing total knee arthroplasties per 10,000 beneficiaries in the Health Referral Region.