The Influence of Income and Race on Total Knee Arthroplasty in the United States

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Background: The associations among income, total knee arthroplasty, and underlying rates of knee osteoarthritis are not well understood. We studied whether high-income Medicare recipients are more likely to have a knee arthroplasty and less likely to suffer from knee osteoarthritis.

Methods: Two data sources were used: (1) the 2000 United States Medicare claims data measuring the incidence of total knee arthroplasty by race, ethnicity, zip (postal) code income, and region (n = 27.5 million) and (2) the National Health and Nutrition Examination Survey (NHANES III) for individuals with an age of sixty years or more (n = 1926) with radiographic and clinical evidence of osteoarthritis. Logistic regression methods were used to adjust for covariates.

Results: At the national level, age-adjusted rates of total knee arthroplasty in the high-income quintile were no higher than those in the low-income group (odds ratio, 0.98; 95% confidence interval, 0.96 to 1.00). Within regions, access to care was better for high-income groups (odds ratio, 1.19; 95% confidence interval, 1.17 to 1.22). Racial disparities in arthroplasty were significant ($p < 0.001$); the odds ratio was 0.36 (95% confidence interval, 0.34 to 0.38) for black men and 0.45 (95% confidence interval, 0.41 to 0.49) for Asian women. There was no evidence of an income gradient for most clinical and radiographic measures of arthritis. The exception was a significant negative association between income and pain on passive motion ($p < 0.05$).

Conclusions: High-income Medicare enrollees are no less likely to have osteoarthritis than low-income enrollees but have somewhat better access to care. Racial disparities are more important than those that are attributable to socioeconomic status.

Level of Evidence: Prognostic Level II. See Instructions to Authors for a complete description of levels of evidence.

There are large disparities with regard to race and ethnicity in the use of knee replacements in the United States[1-4], but the evidence on how these rates vary by income is either several decades old[5] or leads to conflicting conclusions[1,6,7]. The association between income and health outcomes is important for two reasons. First, some studies have demonstrated that racial disparities in the prevalence of disease disappear after controlling for socioeconomic status[8,9]. It is therefore important to measure whether racial differences that have been observed in previous studies reflect in part the fact that black and Hispanic Medicare enrollees in the United States are, on the average, in lower income categories than whites are.

Second, dramatic increases in Part-B Medicare premiums for high-income households were enacted as part of the 2003 drug benefit legislation and are scheduled to begin their phase-in by 2007[10]. Currently, all Medicare enrollees pay 25% of the cost of Part-B benefits, but the goal of the current legislation is for high-income Medicare enrollees to pay as much as 80% of average Part-B benefits, more than tripling current premiums. This in part stems from the widespread view that higher-income groups utilize Medicare program benefits more intensively than lower-income groups do[11]. While some controversy remains with regard to the link between socioeconomic status and total Medicare expenditures[12,13], we focused on how income affects the use of particularly cost-effective procedures such as knee arthroplasty[14,15]. To test this hypothesis, we used a 2000 sample of nearly every enrollee in the Medicare program (n = 27.5 million) to estimate the incidence of total knee arthroplasty according to race, ethnicity, and income as measured at the zip (postal) code level.

It is difficult to make inferences about disparities in the general population without a better understanding of how the disease burden differs by income or race[4]. While there is good evidence that women, and black and Hispanic women in particular, have substantially higher rates of knee osteoarthritis[16-19], there is no evidence of such differences between income groups. In addition, there is increasing evidence that the functional aspects of disease may differ across income or education

groups, even after controlling for objective clinical measures[20]. Radiographic, clinical, and self-reported pain measures from the NHANES III (National Health and Nutrition Examination Survey) also were used to test the hypothesis that the prevalence of osteoarthritis differs by income and race. Our hypothesis was that higher-income Medicare recipients are less likely to have osteoarthritis but are more likely to have a total knee arthroplasty.

Materials and Methods

Incidence of Knee Osteoarthritis in the Medicare Claims Data

The 2000 Medicare claims data comprised every Medicare enrollee over the age of sixty-five years in the fee-for-service program. Individuals who were enrolled in a Medicare health maintenance organization were excluded. The claims data were used to construct rates of knee arthroplasty on the basis of the International Classification of Disease (ICD-9) code 81.54 (total knee replacement), which did not include revisions. These data were then matched by zip code to median income in the zip code with use of data from the 2000 Census. There are important issues in the measurement of race and ethnicity in the Medicare claims data, largely arising from the piecemeal approaches in years past when just a few racial categories were collected[21,22]. In recent years, the sample sizes of Hispanic and Asian groups have expanded, allowing for four racial or ethnic groups: black, Hispanic, Asian, and all others, who for the purposes of exposition we denote as white. The sensitivity of racial categorization was generally high, meaning that if individuals reported themselves as Hispanic, they generally were, but the specificity was lower, meaning that not all self-identified Hispanics were identified as such in the Medicare data[22].

Income was measured by matching Medicare claims by zip code to United States 2000 Census data on median income. In the regression, the logarithmic transformation of income was used. This implied that a percentage increase in income would have similar effects on health status, regardless of whether the change occurred at a low or high-income level. The income measures also were used to create income quintiles, ranging from Quintile 1 (the 20% of the Medicare population with the lowest zip code income) to Quintile 5 (the 20% of the Medicare population with the highest zip code income).

In the statistical analysis, we estimated the shape of the income gradient with use of two approaches: one that did not adjust for where the patient lived and one that did[1,23]. The former income gradient reflects the overall association in the United States between income and total knee arthroplasty utilization rates. The latter reflects "access to care," or the influence of income on total knee arthroplasty utilization rates *within* a region, for example, because of better access to local orthopaedic surgeons in higher-income neighborhoods. These two rates could differ, for example, if high-income Medicare enrollees are more likely to live in regions with higher overall rates of total knee arthroplasty for both low and high-income patients.

We used the 306 hospital referral regions from the *Dartmouth Atlas of Health Care*. A hospital referral region was defined to be a region centered on a hospital or group of hospitals that offered cardiovascular and neurosurgical procedures in 1992 and 1993, so that each hospital referral region included at least one large tertiary hospital. Nearly every zip code in the United States was assigned to a hospital referral region on the basis of the observed migration patterns of hospital use among the elderly population[24,25].

Logistic regression analysis was performed with use of STATA software (version 9.0; StataCorp, College Station, Texas), which adjusted for racial and ethnic identification, gender, five-year age categorical variables, and (in some cases) regional categorical variables. In interpreting the incidence rates of total knee arthroplasty, estimated odds ratios can be interpreted as relative risks as the underlying incidence rates were so small[26].

Prevalence of Osteoarthritis and Knee Pain in NHANES III

The NHANES III survey was conducted from 1988 through 1994 and included information on self-reported health status and the results of a physician's clinical examination of the knees for the population of individuals who were sixty years old or more. In 2001, data on radiographic measures of knee osteoarthritis for NHANES III were released by the Centers for Disease Control.

Three dependent variables were considered. The first measure was a Kellgren-Lawrence radiographic score of ≥2 for at least one knee. A score of 2 indicated minimal osteophytes, with possible joint-space narrowing, cysts, and sclerosis; a score of 3 indicated moderate osteophytes and narrowing; and a score of 4 indicated severe osteophytes with definite narrowing[27]. The second measure combined radiographic and clinical measures: a Kellgren-Lawrence score of ≥2 in at least one knee plus evidence of at least one of three clinical findings (crepitus, swelling, or maximum limitation on passive motion of <115°). The third measure, pain on passive motion, was self-reported, and we hypothesize that the response to this question may be mediated by factors such as socioeconomic status.

Independent variables were age (in five-year intervals), gender, and race. Because there were so few Hispanic and Asian respondents in the sample, we considered just three groups: black, white, and other reported racial or ethnic categories. Quartiles of body-mass index were used to allow for a nonlinear association between body-mass index and the prevalence of osteoarthritis and knee pain. In addition, the region of residence (South, Northeast, Midwest, and West) was included.

Income was reported in intervals, and for primary results it was converted to logarithmic form with use of interval midpoints. This assumption was relaxed by the use of approximate income quintiles (twentieth percentiles) defined in the NHANES data: less than $12,000, $12,000 to $18,999, $19,000 to $27,999, $28,000 to $50,000, and more than $50,000. Logistic regression was used to estimate the models with each of the three dependent variables using both population weights and sampling strata with use of the SVY and LOGISTIC com-

TABLE I Knee Arthroplasty Rates by Race, Ethnicity, and Income in the Elderly Medicare Population in 2000*

	Sample Size	Crude Rate of Total Knee Arthroplasty (Per 1000)	Odds Ratio and 95% Confidence Interval	
			Overall (Adjusting for Age, Gender, Racial or Ethnic Identification, and Income)	Access to Care (Adjusting for Age, Gender, Racial or Ethnic Identification, Income, and Region)
Income (log)			0.980 (0.964 to 0.995)	1.192 (1.168 to 1.216)
Black men	828,302	1.603	0.359 (0.339 to 0.379)	0.416 (0.394 to 0.440)
Hispanic men	179,922	3.174	0.674 (0.620 to 0.732)	0.796 (0.732 to 0.866)
Asian men	160,762	1.275	0.278 (0.242 to 0.319)	0.364 (0.317 to 0.418)
White men	10,103,053	4.463	1.000	1.000
Black women	1,351,520	4.325	1.015 (0.987 to 1.043)	1.188 (1.155 to 1.223)
Hispanic women	249,953	4.693	1.028 (0.970 to 1.089)	1.282 (1.207 to 1.361)
Asian women	216,825	2.039	0.449 (0.409 to 0.493)	0.586 (0.533 to 0.645)
White women	14,404,322	5.679	1.342 (1.326 to 1.357)	1.350 (1.334 to 1.365)

*N = 27,494,659. The national rate of total knee arthroplasty is 4.963 per 1000 enrollees. The odds ratios reported here can be interpreted as showing the relative risk that a person in a given category received a total knee arthroplasty in 2000. For example, compared with the reference group of white men, Asian men are roughly 28% as likely to have a total knee arthroplasty (without controlling for region). Age variables at five-year intervals (sixty-five to sixty-nine years, seventy to seventy-four years, seventy-five to seventy-nine years, eighty to eighty-four years, and eighty-five years or more) were included in both regressions but are not reported.

mands in STATA version 9.0, and odds ratios were converted into probabilities with use of the ADJUST command.

Results

Incidence Rates of Total Knee Arthroplasty in the Medicare Claims Data

Of the 35,035,220 total Medicare enrollees in July 2000 who were sixty-five years old or more, 6,802,284 were excluded because of enrollment in a health maintenance organization for any month during 2000 and 738,277 were excluded because they could not be linked to Census zip code data, leaving 27,494,659 individuals in the sample. In this group, there were 136,449 individuals who had at least one total knee arthroplasty in 2000, for a national rate of 4.96 per 1000 enrollees. Sample sizes for gender and for each racial or ethnic group are shown in the first column of Table I.

The incidence rates of knee arthroplasty according to income and race or ethnicity are shown in Table I. The crude rate is shown first, followed by the rate after adjusting just for race, income, gender, and age, and, finally, by the rate after adjusting for race, income, gender, age, and region. The odds ratio of total knee arthroplasty was 0.36 (95% confidence interval, 0.34 to 0.38) for black men, 0.28 (95% confidence interval, 0.24 to 0.32) for Asian men, and 0.45 (95% confidence interval, 0.41 to 0.49) for Asian women. In Table I, the reported coefficients can be interpreted as relative risks; thus, Asian women, for example, were just 45% as likely to have a total knee arthroplasty as white men. The odds ratio for black women (1.02; 95% confidence interval, 0.99 to 1.04) was lower than that for white women (1.34; 95% confidence interval, 1.33 to 1.36). Separate analyses stratified by each income quintile yielded similar results to those described above. Finally, there was little association between the rate of total knee replacement and income; the odds ratio was 0.98, a very modest association that was significant ($p < 0.05$) solely because of the large sample size.

The association between total knee arthroplasty and income was stronger after adjusting for the hospital referral region (odds ratio, 1.19; 95% confidence interval, 1.17 to 1.22). Adjusting for the hospital referral region means that the estimated association occurs solely because of variations in income within the region (for example, Beverly Hills, California versus South Central Los Angeles, California). In this type of comparison, a 10% increase in income within a region was associated with a 1.9% increased likelihood of knee arthroplasty. Figure 1 illustrates the association between income and total knee arthroplasty by income with use of two different approaches for the measurement of the income gradient: the overall effect (which adjusts for age and racial or ethnic identification but not region) and "access to care" (which includes all covariates, including the region of residence). As in the previous regression analysis, the "access to care" measure yielded a pronounced income gradient, with the highest quintile experiencing rates that were 18.5% higher than those in the lowest quintile.

Prevalence of Osteoarthritis and Knee Pain in the NHANES Sample

Of the 20,050 adults in the NHANES sample, 2589 were more than sixty years old and had radiographic evidence of knee osteoarthritis. Of these, 431 were excluded because they reported congestive heart failure, cancer, or possible active infections. In addition, respondents were excluded because of missing data on body-mass index (seven respondents), race (one respondent), radiographic measures (161 respondents), or questions about knee pain and functioning (sixty-three respondents), leaving a

TABLE II Summary Statistics from the NHANES III Survey*

Variable	Mean and Standard Deviation
Independent variables	
Age *(yr)*	70.40 ± 7.54
Race/ethnicity *(%)*	
Black	8.20 ± 27.44
Other nonwhite	3.73 ± 18.95
White	88.08 ± 32.41
Gender *(% female)*	57.34 ± 49.47
Income *(%)*	
>$35,000	32.33 ± 46.79
$15,000 to $35,000	38.54 ± 48.68
<$15,000	29.12 ± 45.44
Body-mass index	
Average	27.17 ± 5.06
South	26.02 ± 43.88
Midwest	28.42 ± 45.11
Northeast	21.98 ± 41.42
West	23.58 ± 42.46
Dependent variables	
Evidence of crepitus in at least one knee	49.81 ± 50.01
Maximum limitation on knee motion <115°	4.60 ± 20.96
Evidence of swelling in at least one knee	4.27 ± 20.23
Kellgren-Lawrence score of ≥2 in at least one knee	37.36 ± 48.39
Kellgren-Lawrence score of ≥2 and evidence of crepitus, limitation of knee motion, or swelling	24.20 ± 42.84
Pain on passive motion in at least one knee	16.22 ± 36.87

*N = 1926. The percentages in each of the three shaded areas add up to 100%. The variable "wtepfex6" was used to reweight the data to replicate characteristics of the United States population.

sample of 1926. A description of the variables and summary statistics are reported in Table II. After accounting for the population sampling weights, we found that 38% of the respondents had a Kellgren-Lawrence score of ≥2 in at least one knee, and one quarter had had both clinical and radiographic evidence of osteoarthritis (a Kellgren-Lawrence score of ≥2 and either crepitus, limitation of knee motion, or swelling in the knee).

The association between income and a diagnosis of osteoarthritis is shown in Table III. When the dependent variable was a binary value for whether the Kellgren-Lawrence score was ≥2, the odds ratio for the logarithm of income was 1.10 (95% confidence interval, 0.95 to 1.27), meaning that there was no significant association between income and the Kellgren-Lawrence score. There were differences by gender and racial group: with white men as the reference group, the odds ratio was 1.52 (95% confidence interval, 1.11 to 2.09) for white women, 3.60 (95% confidence interval, 2.33 to 5.56) for black women, and 2.20 (95% confidence interval, 1.43 to 3.38) for black men. Body-mass index was also an important risk factor for osteoarthritis ($p < 0.001$). Similar results were obtained for the more restrictive measure of osteoarthritis, that is, a Kellgren-Lawrence score of ≥2 plus evidence of crepitus, swelling, or limitation of knee movement (Table III). There was no association between this measure and income; as is shown in Figure 2, there was a slight positive association between evidence of osteoarthritis and income quintile, although the results were not significant given the limited sample size.

Pain with passive motion was also considered. In this logistic regression (results not reported), there was no significant difference in pain according to race or ethnicity. However, there was significantly greater pain with passive motion for black and white women ($p < 0.01$). Figure 2 demonstrates the strong negative association between income and knee pain with passive motion ($p < 0.05$), even after adjusting for race, gender, age, body-mass index, and region. Overall rates of knee pain ranged from 20% in the bottom income quintile to 9% in the second-highest income quintile. Knee pain also was a more sensitive indicator of osteoarthritis for high-income

TABLE III Regression Analysis: NHANES III Survey*

	Odds Ratio and 95% Confidence Interval	
	Kellgren-Lawrence Score of ≥2	Kellgren-Lawrence Score of ≥2 and Evidence of Crepitus, Swelling, or Limitation of Knee Movement
Income (log)	1.099 (0.949 to 1.273)	1.084 (0.925 to 1.269)
Men: white	1.000	1.000
Men: black	2.197 (1.427 to 3.383)	2.115 (1.348 to 3.317)
Men: other	1.820 (0.496 to 6.680)	1.801 (0.278 to 11.651)
Women: white	1.523 (1.108 to 2.094)	1.379 (0.979 to 1.942)
Women: black	3.601 (2.332 to 5.560)	3.574 (2.296 to 5.563)
Women: other	4.930 (1.300 to 18.687)	1.448 (0.516 to 4.068)
Body-mass index (quartile 1)	1.000	1.000
Body-mass index (quartile 2)	2.126 (1.391 to 3.251)	1.832 (1.144 to 2.935)
Body-mass index (quartile 3)	4.007 (2.613 to 6.144)	4.618 (2.960 to 7.203)
Body-mass index (quartile 4)	9.088 (5.867 to 14.079)	8.641 (5.524 to 13.517)
South	1.000	1.000
Northeast	0.870 (0.594 to 1.274)	0.700 (0.457 to 1.073)
Midwest	1.356 (0.972 to 1.890)	1.069 (0.739 to 1.547)
West	1.021 (0.665 to 1.568)	0.712 (0.448 to 1.133)

*The dependent variable is a Kellgren-Lawrence Score of 2, 3, or 4 or the combination of a Kellgren-Lawrence Score of 2, 3, or 4 and the presence of either crepitus, swelling, or limitation of knee motion on examination. N = 1926 for all estimates. All estimates are adjusted for population weights and sampling strata. Age variables were included in the regression but are not reported. For these two measures (a Kellgren-Lawrence score of ≥2, or a Kellgren-Lawrence score of ≥2 with evidence of crepitus, swelling, or limitation of knee movement), the estimated odds ratio cannot be interpreted as a relative risk[26].

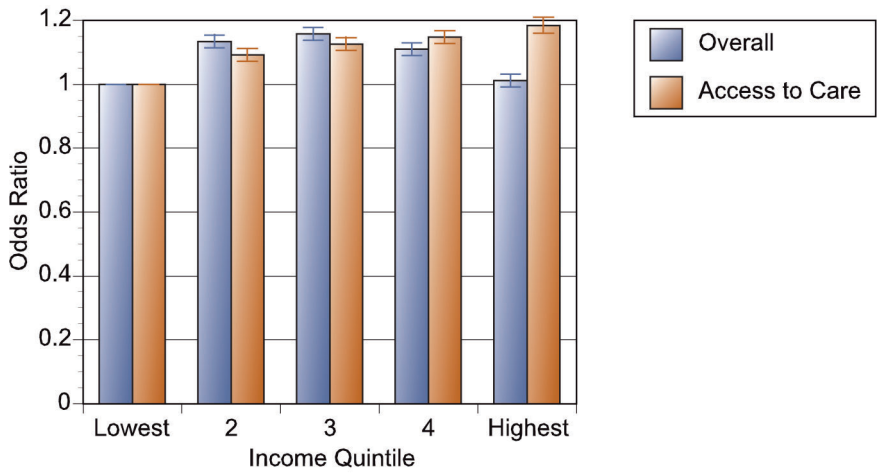

Fig. 1

Illustration showing the odds ratio of total knee replacement in the Medicare population according to income quintile. The overall odds ratio of total knee replacement is shown for each zip code income quintile in the year 2000, ranging from the lowest 20% in Quintile 1 to the highest 20% in Quintile 5. Ninety-five percent confidence intervals are also shown. The "Overall" regression shows how knee arthroplasty rates vary by income with controls for age, gender, and racial or ethnic identification. It describes a shallow inverted U shape, with slightly higher rates in the middle-income quintile (16% above the reference group) but with nearly identical rates in the bottom and top-income quintiles. The "Access to Care" regression adjusts for the previous factors but also includes the region of residence, so this can be interpreted as the effect of income within the same region. Access to care is better for higher-income households, with an 18.5% greater chance of total knee arthroplasty in the highest-income quintile.

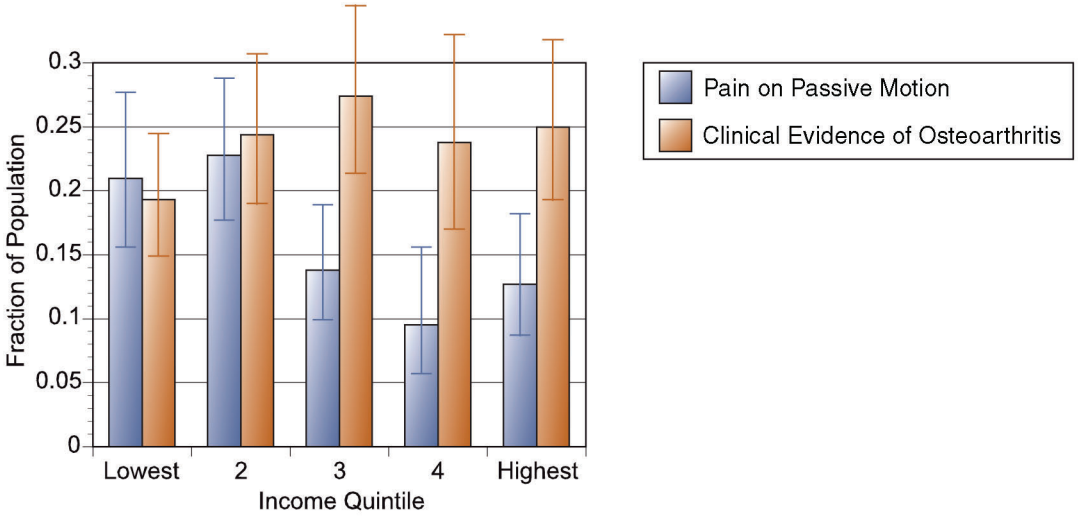

Fig. 2

Illustration showing the fraction of the population with clinical evidence of osteoarthritis and pain on passive motion according to income. Results from two separate regressions using the NHANES III data set (n = 1926) are shown. The logistic regression analysis was adjusted for population weight and strata and controls for age, gender, race, region, and body-mass index, with odds ratios converted to sample probabilities with use of the ADJUST command in STATA 9.0. Clinical evidence of osteoarthritis is defined as the presence of a Kellgren-Lawrence score of ≥2 and evidence of crepitus, swelling, or limitation of movement on examination. Ninety-five percent confidence intervals are also shown. There was no significant difference between the lowest and highest quintile with regard to clinical evidence of osteoarthritis, but there was a significant difference between the lowest and highest quintiles with regard to pain on passive motion (p = 0.04).

respondents; 78% of the respondents in the top quintile who reported pain on passive motion also were diagnosed with a Kellgren-Lawrence score of ≥2, contrasting with 66% of those in the lowest income group.

Discussion

Across the United States, there was little association between socioeconomic status and the rate of total knee arthroplasty. Nor was there an association between socioeconomic status and clinical evidence of knee osteoarthritis. This first result contrasts with those reported by Mahomed et al.[7], who found that the "dually eligible" individuals who were enrolled in both Medicare and Medicaid (presumably reflecting poverty status) were less likely to have a total knee arthroplasty. However, eligibility for Medicaid is often predicated on poor health or nursing home residence, which could by itself reduce the appropriateness of a total knee arthroplasty.

One puzzling result from the statistical analysis is why access to care is greater for high-income Medicare enrollees within a region, but the overall association between income and utilization is essentially zero. The solution to the puzzle requires an understanding of the geographic patterns of total knee arthroplasty in the United States, where there are large documented variations in utilization rates[1,25]. For example, the average rate of total knee arthroplasty for white women in Manhattan (New York City) during 1998 to 2000 was 2.9 per 1000 enrollees. In Little Rock, Arkansas, the corresponding rate was 6.6 per 1000 enrollees, and in McAllen, Texas, the rate was 8.8 per 1000 enrollees[1]. If we were to suppose that high-income residents within the regions of Manhattan, Little Rock, and McAllen were 18.5% more likely to have a total knee arthroplasty (the result that we found on the average across the United States) and we were then to compare the rates of total knee arthroplasty among high-income individuals in the United States, without adjusting for region, a different pattern would emerge: even the wealthiest residents of Manhattan would be less likely to have a total knee arthroplasty than the lower-income residents of McAllen. One measure is not better than the other; they each provide an answer to a different question[23].

The present study demonstrates that total knee replacement rates among minority groups are substantially lower than the rate for whites, and this result holds after controlling for income. Thus, observed racial disparities, which are consistent with earlier studies[16,19,28,29], are not the consequence of socioeconomic class but persist even when comparing black, Asian, or white Medicare enrollees with similar economic status. Nor can these differences be explained by variation in underlying rates of osteoarthritis as these rates were higher still among black men and women.

The work by Ibrahim et al. supports the idea that among black patients with osteoarthritis, there is much greater belief in the efficacy of physical therapy, Tylenol (acetaminophen), herbal medicine, massage, and prayer, and considerably less belief in the efficacy of surgery[30]. Less well understood is our finding that Asian men and women also have very low rates of total knee arthroplasty. One potential explanation could be the poor quality of patient-doctor interactions. One study demonstrated that Asian-American respondents (n = 621)

were far less likely than black (n = 1037), Hispanic (n = 1153), or white respondents (n = 3488) to understand what their doctor told them, and only 49% strongly agreed with the statement that the "doctor understands my background/values" as compared with rates of 60% for black respondents and 61% for white respondents[31].

Pain on passive motion is sometimes considered to be a symptom of late-stage osteoarthritis[32] and was shown in the present study to be a sensitive indicator of radiographic evidence of osteoarthritis for individuals over the age of sixty years. Unlike other clinical indicators of osteoarthritis, pain on passive motion was negatively associated with income, a result also noted in association with educational level in an earlier study[33]. This finding raises the possibility that other factors may mediate the response to passive motion. The issue of nonorganic signs has been considered in relation to lower back pain[34], but little is known about such factors in relation to osteoarthritis of the knee.

One important limitation of the present study is the use of zip code or neighborhood income instead of individual income. One advantage, however, is that zip code income avoids measurement errors in individual income responses. It also better captures housing or financial wealth, often an important source of financial support among elderly individuals. Previous researchers using data sources with both individual and zip code income have shown zip code income to be a valid measure of socioeconomic status[35].

These results have potential implications for surgical practice. They suggest that minority patients or patients with lower income levels (within a given region) are currently less likely to undergo total knee arthroplasty, despite a similar or greater prevalence of osteoarthritis. In part, lower utilization rates may reflect financial burdens for lower-income households without supplemental insurance, but even in the Canadian system, in which financial barriers are minimal, Hawker et al. found that fewer than one in five patients who were deemed medically appropriate expressed an interest in having a joint replacement, with rates among lower-income groups being even lower ($p < 0.10$)[17]. The real challenge is in creating an environment where patients are able to make well-informed decisions that overcome past biases, language barriers, and distrust of the health-care system[36], for example, with the use of decision aids to help patients to understand benefits and risks of surgery[37].

Our findings also have implications for recent legislation mandating a tripling of Part-B premiums for the highest-income Medicare enrollees. On the basis of our findings, higher Part-B premiums cannot be justified because higher-income taxpayers have better access to one common surgical procedure, total knee arthroplasty. Whether these patterns hold for other surgical procedures is not known. ■

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