SPECIAL ARTICLE

Racial, Ethnic, and Geographic Disparities in Rates of Knee Arthroplasty among Medicare Patients

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ABSTRACT

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BACKGROUND

There are large variations in the use of knee arthroplasty among Medicare enrollees ac-
cording to race or ethnic group and sex. Are racial and ethnic disparities more pro-
nounced in some regions than in others, and if so, why?

METHODS

We used all Medicare fee-for-service claims data for 1998 through 2000 to determine
the incidence of knee arthroplasty according to Hospital Referral Region, sex, and race
or ethnic group. A total of 430,726 knee arthroplasties were performed during the
three-year study period.

RESULTS

At the national level, the annual rate of knee arthroplasty was higher for non-Hispanic
white women (5.97 procedures per 1000) than for Hispanic women (5.37 per 1000) and
black women (4.84 per 1000). The rate for non-Hispanic white men (4.82 procedures
per 1000) was higher than that for Hispanic men (3.46 per 1000) and more than double
that for black men (1.84 per 1000). The rates were significantly lower for black men
than for non-Hispanic white men in nearly every region of the country (P<0.05). For the
Hispanic population and for black women, racial or ethnic disparities at the national
level were due in part to geographic differences rather than to differences in the rates
for different racial and ethnic groups within geographic areas. Residential segregation
and low income levels contributed to racial and ethnic disparities in arthroplasty rates.

CONCLUSIONS

In the Medicare population, the rate of surgical treatment for osteoarthritis of the knee
varies dramatically according to sex, race or ethnic group, and region. These variations
underscore the importance of geography and sex in determining racial or ethnic barri-
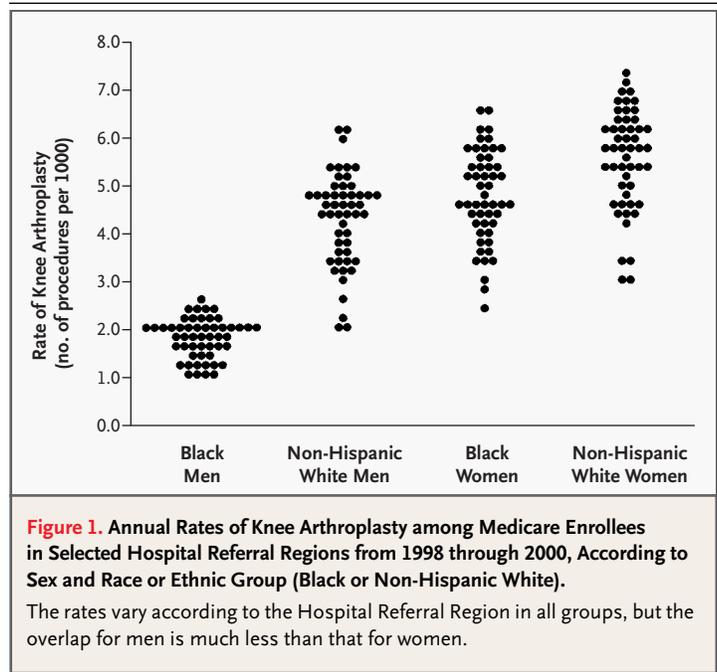ers to health care.

KNEE ARTHROPLASTY IS AN EFFECTIVE alternative to medical management for the relief of pain and improvement of function in patients with moderate-to-severe articular disease of the knee.[1-3] The indications for this surgical procedure continue to broaden as methods of fixation improve and survival of the components increases, and its use is growing at a rapid rate among Medicare enrollees.[4] The use of knee arthroplasty varies according to sex and race or ethnic group, with lower rates among men, blacks,[4,5] and Hispanics.[6] The differences between the sexes have been attributed to the higher rate of osteoarthritis among women.[7,8] However, since rates of osteoarthritis are generally higher among blacks and Hispanics than among whites,[9-11] the possibility of racial barriers must be considered.

The rates of knee arthroplasty also vary substantially among regions.[4,12] Regional variations in the rates of discretionary surgery are commonly considered to reflect differences in local medical opinion concerning the value of these procedures.[4] Little is known about regional patterns of racial disparities in knee arthroplasty and the importance of local factors in explaining such differences. To what extent are national rates of arthroplasty lower among blacks or Hispanics because they live in regions where the overall rate of knee arthroplasty is lower? To what extent are racial or ethnic differences the consequence of lower income levels or residential segregation?

METHODS

STUDY POPULATION

We used all data for Medicare beneficiaries enrolled in fee-for-service programs or non–risk-bearing health maintenance organizations from 1998 through 2000 to calculate rates of knee arthroplasty classified as code 81.54 (total knee replacement) of the *International Classification of Diseases, Ninth Revision, Clinical Modification*, which does not include reoperations. Data bases, including the Denominator File (used to determine the number of beneficiaries in a region), were provided by the Centers for Medicare and Medicaid Services. Arday et al. have found that the Medicare designations for black and Hispanic enrollees closely reflect self-reported racial or ethnic identity.[13] However, the sensitivity of the Hispanic designation is low; fewer than half of self-identified elderly Hispanic people are coded as such

Figure 1. Annual Rates of Knee Arthroplasty among Medicare Enrollees in Selected Hospital Referral Regions from 1998 through 2000, According to Sex and Race or Ethnic Group (Black or Non-Hispanic White).

The rates vary according to the Hospital Referral Region in all groups, but the overlap for men is much less than that for women.

in the Medicare claims data.[13] Three racial or ethnic groups were defined: black, Hispanic, and non-Hispanic white (or "white"). No provisions are available in Medicare data for multiple racial or ethnic identifications.

STUDY DESIGN

We used the Hospital Referral Region as the geographic variable in the study; the *Dartmouth Atlas of Health Care* identifies 306 such regions.[14] A Hospital Referral Region is a region served by a hospital or group of hospitals that offers cardiovascular and neurosurgical procedures, so that each Hospital Referral Region includes at least one tertiary care hospital. All ZIP Codes in the United States were assigned to Hospital Referral Regions on the basis of the migration patterns of hospital use among the elderly population. For example, if a person who lived in the Lebanon, New Hampshire, Hospital Referral Region traveled to Boston for a knee arthroplasty, the procedure would be credited to the Lebanon, not the Boston, Hospital Referral Region.[4]

The unit of analysis was the rate of knee arthroplasty according to sex, race or ethnic group, and Hospital Referral Region. Since there are 2 sexes, 3 racial or ethnic groups, and 306 Hospital Referral Regions, the number of separate observations was $2 \times 3 \times 306$, or 1836. The observations were analyzed

Table 1. Rates of Knee Arthroplasty among Black and Non-Hispanic White Medicare Enrollees in Selected Hospital Referral Regions, 1998–2000.*

Region	Blacks	Non-Hispanic Whites
	procedures per 1000	
Rates among men		
No significant difference		
Bronx, N.Y.†	1.3	2.1
Significantly lower for blacks		
Birmingham, Ala.	2.1	4.3
Little Rock, Ark.	1.8	4.7
Los Angeles, Calif.	1.7	3.2
Washington, D.C.	1.7	4.5
Atlanta, Ga.	2.1	4.2
Chicago, Ill.	1.3	3.0
New Orleans, La.	1.2	4.4
Shreveport, La.	1.3	3.8
Baltimore, Md.	2.2	5.0
Detroit, Mich.	1.6	5.3
Jackson, Miss.	1.0	3.4
St. Louis, Mo.	1.9	5.9
Camden, N.J.	1.3	3.4
Newark, N.J.	1.0	2.0
East Long Island, N.Y.	1.4	2.6
Manhattan, N.Y.	1.0	2.0
Charlotte, N.C.	2.5	4.8
Durham, N.C.	1.4	4.4
Greenville, N.C.	1.9	5.1
Raleigh, N.C.	2.0	4.4
Cleveland, Ohio	1.9	4.8
Philadelphia, Pa.	2.3	4.0
Charleston, S.C.	2.2	5.4
Columbia, S.C.	1.8	4.9
Memphis, Tenn.	1.0	3.4
Dallas, Tex.	1.5	4.4
Houston, Tex.	1.7	4.5
Norfolk, Va.	2.0	4.8
Richmond, Va.	2.1	4.8

Table 1. (Continued.)

Region	Blacks	Non-Hispanic Whites
	procedures per 1000	
Rates among women		
No significant difference		
Birmingham, Ala.	5.6	5.8
Little Rock, Ark.†	5.3	6.1
Los Angeles, Calif.	5.0	4.7
Camden, N.J.	4.2	4.4
Newark, N.J.†	2.4	3.1
Bronx, N.Y.	3.9	3.4
East Long Island, N.Y.	3.3	3.3
Manhattan, N.Y.†	3.4	2.9
Charlotte, N.C.	5.9	5.9
Durham, N.C.†	5.1	5.9
Greenville, N.C.	6.2	6.6
Raleigh, N.C.	5.9	5.8
Charleston, S.C.	5.8	6.4
Columbia, S.C.	5.8	5.8
Norfolk, Va.†	4.7	5.8
Significantly lower for blacks		
Washington, D.C.	4.4	5.6
Atlanta, Ga.	4.5	5.3
Chicago, Ill.	2.9	4.5
New Orleans, La.	3.4	5.4
Shreveport, La.	3.5	5.3
Baltimore, Md.	5.4	6.7
Detroit, Mich.	3.7	6.5
Jackson, Miss.	3.7	5.0
St. Louis, Mo.	4.6	7.2
Cleveland, Ohio	4.5	6.1
Philadelphia, Pa.	4.5	5.4
Memphis, Tenn.	3.0	4.4
Dallas, Tex.	4.5	6.2
Houston, Tex.	4.2	5.7
Richmond, Va.	4.6	6.2

* The listed Hospital Referral Regions are the 30 with the largest population of black Medicare enrollees. They are listed alphabetically by state. Comparisons were made with the use of a 95 percent confidence interval with a Bonferroni correction ($P<0.0017=0.05/30$) to adjust for the possibility that in multiple comparisons, the null hypothesis may be rejected by chance.

† In this region the null hypothesis was not rejected with use of the Bonferroni-corrected P value. However, the null hypothesis was rejected with use of the conventional P value of 0.05, without adjustment for multiple hypothesis testing.

as continuous at the level of the Hospital Referral Region, rather than at the individual level, for computational reasons (since there were 80.5 million person-years of data) and to allow the use of linear regression methods. A small fraction of patients (6.6 percent) underwent two knee arthroplasties during the three-year period; these events were treated independently in the statistical analysis.

Sampling error among small groups of Hispanics and blacks can create the appearance of variation in surgical rates, even if none exists.[15] We restricted the graphic analysis to Hospital Referral Regions for which the expected number of surgical procedures is at least 25 (of which there are 51 regions for blacks and 14 regions for Hispanics), so that the 95 percent confidence intervals for reported rates would not exceed plus or minus 1.7 procedures per 1000 persons. For multiple comparisons of racial or ethnic differences according to the Hospital Referral Region, hypothesis testing was performed with use of the Bonferroni correction (the P value divided by the total number of pairwise comparisons) to correct for the chance that in multiple comparisons, the null hypothesis would be rejected in a few regions by chance alone.[16] All rates are adjusted for differences in age composition among Hospital Referral Regions by the use of indirect standardization, which involves multiplying the appropriate national rate by the ratio of the crude rate to the predicted rate for the Hospital Referral Region.[17]

The first hypothesis was that observed disparities in national rates might be a consequence of the region where black or Hispanic Medicare enrollees lived rather than the result of treatment differences within hospitals or regions. To test this hypothesis, we first performed a regression analysis at the level of the Hospital Referral Region (separately according to sex) of the rates for blacks and non-Hispanic whites ($306 \times 2 = 612$) and for Hispanics and non-Hispanic whites ($306 \times 2 = 612$), in which the independent variable was race or ethnic group. When the regression was weighted by the Medicare population, the resulting coefficient for the black or Hispanic categorical variable was simply the overall national difference in rates.[18] The regression was then estimated after adjustment for the Hospital Referral Region, so that the new coefficient for the black or Hispanic categorical variable can be interpreted as the "within–Hospital Referral Region" racial or ethnic difference in surgical rates. If elderly people who were black or Hispanic had lower rates

of arthroplasty because they lived in regions where whites had lower rates of arthroplasty, the adjusted coefficient on race and ethnic group would shrink toward zero in these models adjusted for the Hospital Referral Region. The results were similar when the more flexible Blinder–Oaxaca approach was used.[19-21]

In considering potential causes of regional variation in racial or ethnic disparities, we also hypothesized that the degree of residential segregation and differences in household income could explain variations in access to care.[22-24] The index of dissimilarity measures the hypothetical fraction of blacks (or whites) who would have to move from their neighborhoods to other neighborhoods in order to attain perfect integration, in which the fraction of blacks in each neighborhood would be equal to the regional average.[25,26] The index ranges from 0.0, for the case in which every Census block is fully integrated, to 1.0, for the case in which all blocks are entirely segregated, and is calculated on the basis of the 2000 Census at the level of Metropolitan Statistical Areas.[27] There were 232 Metropolitan Statistical Area–Hospital Referral Region matches for the dissimilarity index for blacks (with 9 Metropolitan Statistical Areas assigned to more than 1 Hospital Referral Region). A Hospital Referral Region was considered to have a high or low level of residential segregation if its dissimilarity index for blacks was above or below the sample median. Data from the 2000 Census were used to determine the median household income for black and Hispanic households according to the Metropolitan Statistical Area,[28] with 235 Metropolitan Statistical Areas matched to Hospital Referral Regions. Each Hospital Referral Region was stratified according to whether the median income for blacks was above or below the sample median.
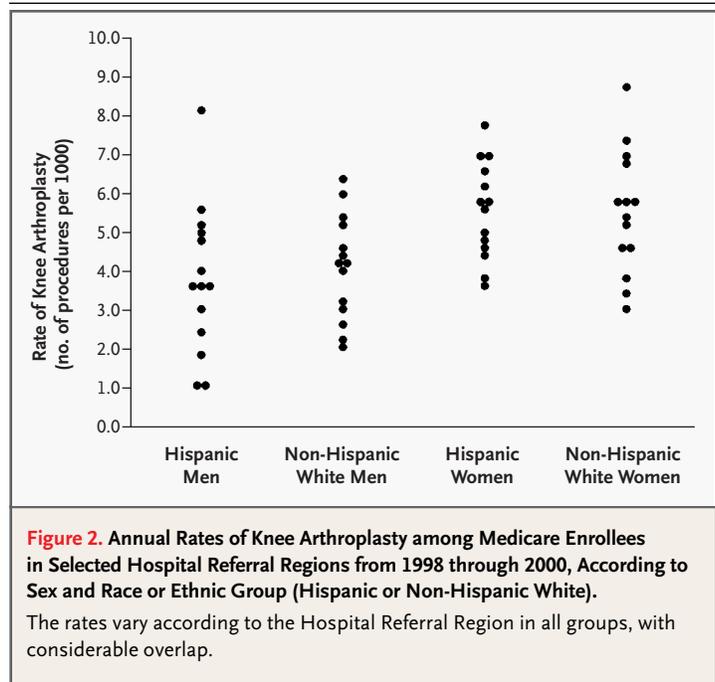
To determine whether racial or ethnic differences were affected by income or residential segregation, we estimated the interaction of differences in arthroplasty rates between blacks and other groups with the income category (high or low) and segregation category (high or low) for blacks. This analysis tested the hypothesis that a high income or a low degree of segregation might attenuate existing disparities in arthroplasty rates. We also estimated separately the interaction of differences in arthroplasty rates between Hispanic and other groups with the Hispanic income category (high or low). The dissimilarity index, a measure of residential segregation, is not available for the Hispanic population.

RESULTS

A total of 430,726 knee arthroplasties (performed in 403,251 persons in a sample of 80.5 million person-years) were reported in the Medicare claims data from 1998 through 2000. Among women, the national rates were higher for whites (5.97 procedures per 1000 women) than for Hispanics (5.37 per 1000) and blacks (4.84 per 1000) (P<0.001). Among men, the gap was more pronounced: the rate for whites (4.82 procedures per 1000 men) was higher than that for Hispanics (3.46 per 1000) and more than double the rate for blacks (1.84 per 1000, P< 0.001). Because the patterns of utilization were so different for men and women, sex-specific analyses were performed.

Figure 1 shows the regional dispersion in rates according to sex and race or ethnic group among blacks and non-Hispanic whites, with each circle representing one of 51 Hospital Referral Regions. Among men, there was very little overlap in the distribution of rates between blacks and whites. Table 1 shows arthroplasty rates according to race or ethnic group among men and women for the 30 Hospital Referral Regions with the largest black populations. In 29 of the 30 Hospital Referral Regions, the rates were significantly lower for black men than for white men. In contrast, Figure 1 shows more overlap in rates between black women and white women than in rates between black men and white men. Table 1 shows that the rates were significantly lower for black women than for white women in half (15) of the Hospital Referral Regions. In the remaining 15 regions where arthroplasty rates for black and white women did not differ significantly, according to analysis with use of the Bonferroni correction, 7 regions had rates that were equal or higher for black women than for white women, and 8 had rates that were lower. (Results are also shown with a conventional P value [P<0.05] that does not correct for multiple hypothesis testing.)

Figure 2 shows the regional dispersion in rates according to sex and race or ethnic group among Hispanics and non-Hispanic whites for the 14 Hospital Referral Regions with sufficiently large numbers of Hispanic men and women. For both men and women, the overlap was considerable. In San Antonio, Texas (the region studied by Escalante et al.[6]), Houston, Miami, New York (Manhattan), and the Bronx, the arthroplasty rates for Hispanic men were significantly lower than those for non-Hispanic white men (Table 2). For women, there was just

Figure 2. Annual Rates of Knee Arthroplasty among Medicare Enrollees in Selected Hospital Referral Regions from 1998 through 2000, According to Sex and Race or Ethnic Group (Hispanic or Non-Hispanic White).

The rates vary according to the Hospital Referral Region in all groups, with considerable overlap.

one region where the null hypothesis was rejected: New York (Manhattan), where rates for Hispanic women were greater than those for non-Hispanic white women (P<0.001) (Table 2). No other differences in rates were significant after the Bonferroni correction.

Figure 3 shows the role of geographic variation in racial and ethnic differences in national knee arthroplasty rates. The rates were 4.82 procedures per 1000 for white men and 1.84 per 1000 for black men at the national level, a difference of 2.98 per 1000. Figure 3 also shows the difference after correction for the Hospital Referral Region of residence. Among black men, the difference declined slightly, to 2.50 per 1000 (95 percent confidence interval, 2.62 to 2.39), 84 percent of the national difference. The national difference between black women and white women was 1.13 per 1000; after correction for the Hospital Referral Region of residence, the difference was reduced to 0.70 per 1000 (95 percent confidence interval, 0.83 to 0.56), 62 percent of the national difference.

Among men, the difference at the national level between the rates for Hispanics and those for non-Hispanic whites was 1.36 per 1000. After adjustment for the Hospital Referral Region of residence, the difference for Hispanic men fell to 0.89 per 1000 (95 percent confidence interval, 1.10 to 0.67), 65

Table 2. Rates of Knee Arthroplasty among Hispanic and Non-Hispanic White Medicare Enrollees in Selected Hospital Referral Regions, 1998–2000.*

Region	Hispanics	Non-Hispanic Whites
	procedures per 1000	
Rates among men		
No significant difference		
Fresno, Calif.	5.2	4.3
Los Angeles, Calif.	3.7	3.2
San Diego, Calif.	4.0	4.2
Chicago, Ill.	3.0	3.0
Albuquerque, N.M.	3.5	3.9
El Paso, Tex.	4.8	4.2
Corpus Christi, Tex.	5.6	5.4
Harlingen, Tex.	5.0	6.0
McAllen, Tex.†	8.1	6.3
Significantly lower for Hispanics		
Miami, Fla.	1.8	2.7
Bronx, N.Y.	1.1	2.1
Manhattan, N.Y.	1.1	2.0
Houston, Tex.	2.3	4.5
San Antonio, Tex.	3.5	5.2
Rates among women		
Significantly higher for Hispanics		
Manhattan, N.Y.	4.4	2.9
No significant difference		
Fresno, Calif.	5.7	5.2
Los Angeles, Calif.†	5.6	4.7
San Diego, Calif.	6.5	5.8
Miami, Fla.	3.9	3.8
Chicago, Ill.	4.5	4.5
Albuquerque, N.M.	5.0	5.5
Bronx, N.Y.	3.6	3.4
Corpus Christi, Tex.	6.9	7.0
El Paso, Tex.†	6.9	5.8
Harlingen, Tex.	6.1	7.3
Houston, Tex.	4.8	5.7
McAllen, Tex.	7.7	8.8
San Antonio, Tex.†	5.8	6.7

* Comparisons were made with the use of a 95 percent confidence interval and a Bonferroni correction (P<0.0036=0.05/14) to adjust for the possibility that in multiple comparisons, the null hypothesis may be rejected by chance.

† In this region the null hypothesis was not rejected with use of the Bonferroni-corrected P value. However, the null hypothesis was rejected with use of the conventional P value of 0.05, without adjustment for multiple hypothesis testing.

percent of the national difference. Among women, the difference was 0.60 per 1000; after adjustment for the Hospital Referral Region of residence, the difference fell to 0.03 per 1000 (95 percent confidence interval, 0.25 to 0.19), just 5 percent of the national difference.

Higher income and a lower level of residential segregation appeared to mitigate the effects of racial or ethnic differences, although not equally for both sexes. Among black men, living in regions with incomes at or above the median for blacks, as compared with regions with incomes below the median for blacks, was associated with a slightly diminished difference in arthroplasty rates (2.42 vs. 2.79 per 1000, P=0.003). Among Hispanic women in regions with incomes at or above the median for Hispanics, the rate (0.35 per 1000) was higher than that for white women; by contrast, the rate among Hispanic women in lower-income regions (0.45 per 1000) was lower than that among white women (P=0.001). Among black women, living in a region with a low level of residential segregation was associated with a smaller difference in arthroplasty rates (0.46 per 1000) than living in a region with a high level of segregation (1.05 per 1000, P<0.001).

DISCUSSION

A recent study by the Institute of Medicine called attention to the pervasive differences in treatments and in outcomes between blacks and nonblacks,[29] but relatively little attention was paid to the role of geography in these disparities. Previous studies have not always been able to consider racial disparities according to region and sex, because of limitations in sample size.[30] Our study, drawing on 80.5 million person-years of observation in the Medicare population, suggests that patterns of differences in the use of knee arthroplasty differ fundamentally according to sex, race or ethnic group, and region.

In some regions, the rate for black women was significantly lower than that for white women, whereas in other regions, the rates were roughly equal. There was substantial variation both within and between regions; for example, the rate for black women in Greenville, North Carolina (6.2 procedures per 1000), was twice as high as that for white women in Manhattan (2.9 procedures per 1000). Roughly 35 percent of the national differences in arthroplasty rates for black women and 95 percent of the national differences for Hispanic women are explained by

the fact that black and Hispanic women are more likely to live in regions with lower rates for all races and ethnic groups. Schneider et al. found, analogously, that nearly half the differences between blacks and whites in the rates of breast-cancer screening, use of beta-blockers, and eye examinations among patients with diabetes were explained by the fact that black patients belonged to lower-quality health plans rather than by differences in the quality of care for blacks and whites within the plans.[31] Finally, our study showed that higher degrees of residential racial segregation (among black women) and low income (among Hispanic women and black men) were associated with larger differences in arthroplasty rates.[22,23]

Arthroplasty rates were consistently lower among black men than among white men in nearly every Hospital Referral Region, and in some regions, such as Jackson, Mississippi, and Detroit, the rates for black men were less than one third those for white men. One cannot explain these persistent differences on the basis of financial or geographic barriers alone, since the pattern was not apparent for black women living in the same neighborhoods. The pattern in arthroplasty rates is also quite different from the much better documented difference in rates of cardiac surgery, for which racial disparities have been found among both men and women and in a variety of settings.[31-36] In contrast to our study, Schulman et al. found that only black women were less likely to be referred for cardiac catheterization and that there was no significant difference between black men and white men.[37,38]

One important limitation of our study is that equality of rates does not necessarily mean that the health care system is free of bias. Variation in arthroplasty rates could be explained, for example, by differences in underlying health status. Previous studies have suggested an increase by a factor of 1.5 to 2.0 in the incidence of osteoarthritis in women,[8,10] a difference that is not matched by correspondingly higher arthroplasty rates.[8] Hirsch et al. found that among women over the age of 60 years, 38 percent of non-Hispanic whites, 61 percent of non-Hispanic blacks, and 44 percent of Mexican-Americans had radiologic signs of knee osteoarthritis; the corresponding proportions of men were 31 percent, 43 percent, and 39 percent.[9] It is difficult to define the appropriate null hypothesis of racial or ethnic equality without adjusting for the underlying incidence of disease.[39] Another limitation of
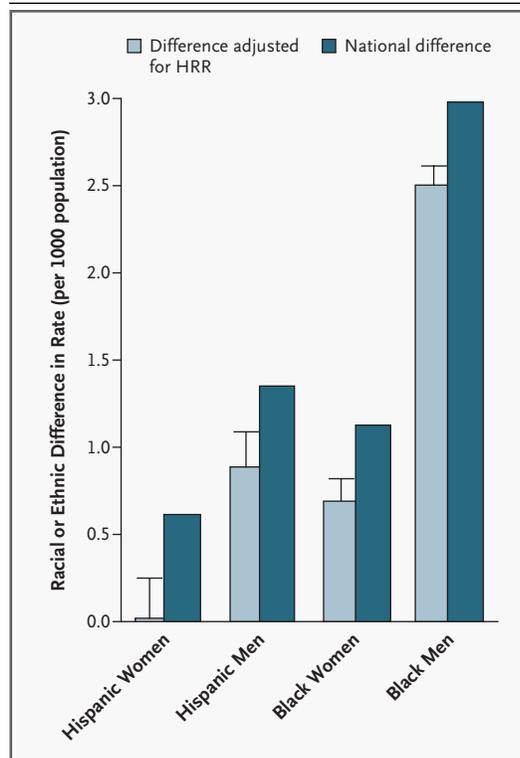

Figure 3. Racial or Ethnic Differences in Rates of Knee Arthroplasty among Medicare Enrollees at the National Level and with Adjustments for the Hospital Referral Region (HRR).

The differences are for the subgroups shown as compared with non-Hispanic white men and women. The I bars indicate 95 percent confidence intervals for the adjusted estimates (306×2=612 observations). Rates at the national level were calculated with infinitesimal sampling error. For black women and Hispanic men and women, the smaller magnitude of the difference in arthroplasty rates after adjustment for the region of residence shows that these subgroups tended to live in regions where the rates for non-Hispanic whites were lower than the national average. However, for black men, the region of residence had little effect on overall racial differences in the rate of knee arthroplasty.

our study is the difficulty of detecting racial or ethnic differences in rural areas with small numbers of black or Hispanic Medicare patients.

How much of the regional variation in knee arthroplasty can be explained by differences in the rates of underlying disease? Hawker et al. compared two regions in Canada — one with high rates of hip and knee arthroplasty and one with low rates — and found differences in potential need of at most 27 percent, depending on how need was defined.[40]

Although health status is likely to explain part of the observed variation in our study, it is unlikely to account entirely for the overall differences among regions.

Another possible cause of variation in arthroplasty rates is differences in patients' preferences. Although arthroplasty has been shown to be a superior alternative to medical management for improving function and decreasing pain in patients with osteoarthritis of the knee,[1-3,41] it carries a small risk of death or long-term complications, which may include infection, neurologic injury, and the need for reoperation. Patients' preferences should therefore have a role in determining rates of knee arthroplasty according to sex, race or ethnic group, and region. Previous research has shown that black patients are less willing than white patients to undergo risky cardiac surgery, largely because they are less familiar with the procedures.[36] Blacks also report less confidence in the efficacy of knee or hip replacement,[42] suggesting that lack of information about risks and benefits,[43] compounded by general distrust of the health care system,[44] is a partial determinant of the observed lower operation rates.

These studies raise the question, already posed in the literature on regional variation in rates of health care interventions, "Which rate is right?"[45]

Presumably, the right rate would be achieved if the procedure were performed in every patient who could clinically benefit from it and who wanted it done. But how do clinicians determine what patients really want? Katz has distinguished between choices "guided by informed decisions" and choices "limited by truncated opportunities or historical circumstances,"[46] and that distinction seems appropriate here.

Although efforts to erase disparities at the local level will have important benefits, particularly among black men, even perfect equality in rates of knee arthroplasty according to race or ethnic group at the local level will not eradicate all disparities at the national level. Finally, ensuring that patients are well informed about the potential benefits and costs of surgery and are allowed to make choices free of economic or geographic barriers to care is an important step in solving the problem of disparities in rates of knee arthroplasty.[47,48]

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