Articles

Demographic Variation in the Rate of Knee Replacement: A Multi-Year Analysis

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Objective. The aim of this study is to describe the practice variation of knee replacements (KRs) in the elderly ($\geq$65) over time from 1985–1990 in terms of the number of primary, bilateral, and revision KRs; the extent of large area variation in performance rates; and the degree to which demographic variables are the determinants of area rates.

Data Sources/Study Setting. Data analyzed are from every hospital in the United States that performed a KR on a Medicare patient during the study period. Data were obtained from the MEDPAR, HISKEW, and denominator files of the Medicare Statistical System.

Study Design. This is a cohort study of all Medicare beneficiaries who received a KR between 1985 and 1990. The dependent variable in the analyses was the count of the KRs performed in each area.

Data Collection/Extraction Methods. This is a population-based sample of Medicare enrollees in the United States. All hospitalizations for Medicare-reimbursed KRs were included in the initial data set. Exclusion criteria were used to identify the Medicare covered population with a definite KR. These criteria resulted in 7.3 percent exclusions and a final set of 414,079 KR hospitalizations.

Principal Findings. The number of Medicare-funded KRs increased in each of the study years corresponding to an annual rate of increase of 18.45 percent. The likelihood of receiving a KR was a function of age, gender, and race. For each year, KRs were almost twice as likely to be performed on women than on men. The odds of whites getting the surgery were over 1.5 times greater than for blacks. Even after adjusting for demographic factors, significant regional variation remained.

Conclusions. Much about area variation and the rate of growth in KR rates remains unexplained. For answers to emerge, better data and different types of studies are required.

Key Words. Practice variation, knee replacement, outcomes research, osteoarthritis

The escalation in health care costs and the push for national and state health reform has provoked societal and governmental interest in the apparent geographic variation in the frequency of performance of medical procedures and therapies. The Agency for Health Care Policy and Research (AHCPR) was established to provide a national focal point on health care variations research and the development of clinical guidelines aimed at reducing variation (Salive, Mayfield, and Weissman 1990). As early as 1973, Wennberg and Gittelsohn reported the presence of wide dispersion in the rates with which similar populations in the New England states received tonsillectomies. In the 1980s, others reported the same type of variation for certain orthopaedic procedures (Chassin, Brook, Park, et al. 1986). Variation suggests different practice styles across the country and uncertainty among physicians, patients, and the population at large about the appropriate indications for the procedures.

The absence of a nationalized registry of procedures or a national health insurance program prohibits the derivation of the variation in medical procedures for the entire U.S. population. However, the Health Care Financing Administration (HCFA) maintains a claims database for all Medicare beneficiaries, representing nearly all individuals in this country age 65 or older. Since certain procedures, such as total knee replacement (KR), are more commonly performed on elderly patients, the Medicare database provides

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a useful basis on which to examine the national variation in the use of such procedures.

Total knee replacement is believed to be the most effective major surgical treatment for knee arthritis. Patients undergoing the procedure are primarily elderly; an estimated 75 percent of all KRs in the United States are performed on Medicare beneficiaries. Chassin and colleagues reported that the mean rate of KR procedures in 1981 was 9 per 10,000 Medicare beneficiaries (Chassin, Brook, Park, et al. 1986). By 1985, Medicare expenditures on KRs exceeded 2 billion dollars per annum (McGill 1989). Peterson and colleagues estimated that the number of KRs performed on Medicare beneficiaries in 1988 exceeded 68,000 and showed that the age-adjusted Medicare KR rate varied by state more than threefold in the same year. These rates were not correlated with physician supply but were inversely related to population density (Peterson, Hollenberg, Szatrowski, et al. 1992). The aim of this study is to provide more definitive information on the practice variation of knee replacements (KRs) among Medicare beneficiaries by providing, for the first time, national estimates over time from 1985–1990 of (1) the number of primary, bilateral, and revision KRs; (2) the extent of large area variation in the rates of performance of KRs; and (3) the degree to which demographic variables are associated with the variation in the number of procedures performed and procedure rates by area.

MATERIALS AND METHODS

INCLUSION CRITERIA

Our data were drawn from the Medicare Provider Analysis and Review (MEDPAR), Health Insurance Skeleton Eligibility Write-off (HISKEW), and denominator files of the Medicare Statistical System. In addition, several data elements were validated through survey and medical records information collected in another part of the Patient Outcome Research Team (PORT) grant, of which this analysis is a part (Freund et al. 1990). MEDPAR, the file of all claims associated with hospitalizations paid in whole or in part by Medicare, was used to identify all Medicare claims from 1985–1990 indicating that a KR had been performed. We identified possible KRs through the use of the following ICD-9-CM procedure codes: (1) 81.41 (total knee replacement–primary or revision) in the years prior to 1989; (2) 81.54 (total knee replacement–primary only), a new code introduced after October 1989; and (3) 81.55 (revision knee replacement), a new code introduced after October 1989. Bilateral knee replacements were identified by searching for instances in which either two knee replacements were indicated during one hospitalization, or in which payment for DRG 471, bilateral KR, was indicated. This DRG did not exist before 1986 and has only been in wide use since 1987; therefore, data for 1985 and 1986 are unreliable. Since no procedure code existed to indicate whether an operation was a primary or revision KR until October 1989, we designed an algorithm to distinguish primary from revision KRs between 1985 and October 1989. Our strategy was to use data post-October 1, 1989 to predict those revisions from before. An in-depth examination of all hospitalizations in the last quarter of 1989 that included procedure code 8.55 revealed that the vast majority also included one of several 996 "complication" codes. We then tested empirically whether we could predict revisions according to whether or not one or more complication codes was present. This method showed that we could predict a revision KR with a sensitivity of 87.2 percent and a specificity of 93.0 percent.

EXCLUSION CRITERIA

To increase our certainty that the cases found through the search of MEDPAR were indeed KRs performed in the United States (not including Puerto Rico and the Virgin Islands), and that we had adequate information about them, we applied the following six types of exclusions: (1) patients for whom a single KR procedure was accompanied by a diagnosis indicating that the procedure was not done because of contraindication or patient preference (code V64); (2) patients for whom data were expected to be incomplete, including individuals enrolled in HMOs and patients residing outside the United States; (3) patients who were inappropriate to analyze because of health status differences, including those who had end-stage renal disease (ESRD) or were disabled at the time of enrollment; (4) patients for whom it appeared certain, based on their diagnosis codes, that the procedure was miscoded (e.g., an 81.41 was indicated when the true procedure was 31.41); (5) individuals who did not die during the index hospitalization, who were discharged home, who had an inpatient stay of three or fewer days and total charges less than $5,000 in 1989 dollars; and (6) any case where the KR was to have taken place at a psychiatric, rehabilitation, or drug treatment facility.

After identifying all claims, claims files were linked by the unique Medicare identification number to the history file (HISKEW) in order to identify the actual persons who had the KR and to retrieve their demographic characteristics. HISKEW stores all identification information on 100 percent of Medicare beneficiaries, including Medicare identification number, address, and demographic profile. To ensure confidentiality, identifying information on the files was stored in an encrypted format.

The impact of all exclusions on the constructed database was small, ranging from 7.2 percent in 1989 to 7.7 percent in 1985 of all of the Medicare claims originally identified. The single criterion that contributed the most was excluding those individuals who were eligible for Medicare due to disability instead of age 65 and over.

VALIDATION OF CLAIMS DATA

Questionnaire and hospital chart data were acquired on a sample of 1,750 individuals of whom 750 were randomly selected to represent the United States and 500 each were selected to represent Western Pennsylvania and the state of Indiana (Hawker, Paul, Katz, et al. under review). Approximately 80 percent of individuals responded to the mail survey, and 80 percent of charts were obtained from the hospitals. These data, for persons who were identified as having a KR from the Medicare claims analysis, were used to validate that the identified KR had taken place. Overall, for 97.8 percent of individuals who were identified as having a KR, we verified, by self-report on the questionnaire or by using the hospital chart, or both, that the procedure had been performed. Such information suggests small errors in the claims estimates provided here. Similarly, while race was excluded as an analysis variable by Peterson (Peterson, Hollenberg, Szatrowski, et al. 1992) because it was felt to be unreliable, our sample revealed, to the contrary, that individuals who were shown as white or African American in the claims indicated the same racial category in the survey 99 percent of the time. Individuals whose race was coded as unknown were omitted because their information was not verifiable.

Figures on the total Medicare population eligible for KR, which were used to compute rates of performance, were taken from the HCFA denominator files. Person-months of eligibility for all non-HMO-enrolled, and non-ESRD members were calculated and divided by 12 in order to obtain the number of person-years for each of the six study years. Files were linked by matching the unique Medicare identification number, which eliminated double counting of patients.

VARIABLES AND ANALYSIS STRATEGY

An integrated modeling approach was used to describe variation in rates based on demographic characteristics, year of surgery, and region of residence. That is, one modeling strategy and one set of multivariable runs were able to produce the estimates to address all of the aims regarding the numbers of KRs performed from 1985–1990 and the regional variation. Conceptually, we were interested in seeing if demographic variables explain regional differences in rates of performance. If they do not, then other factors, such as physician practice styles, access to care, and disease prevalence, must account for the variation. Rates of KRs were analyzed by age; race; gender; primary, revision, or bilateral; region; and year. For the analysis five age strata were developed that reflected the age distribution of the population and coincided with standard definitions utilized in the denominator file: 65–69, 70–74, 75–79, 80–84, and 85 and older. Race is recorded in four categories in Medicare databases, but because of the small numbers in the unknown and other categories and their lack of verifiability, only whites and African Americans were used in the analysis. In order to compare with other estimates, large areas were defined as the ten regions used by the Health Care Financing Administration. Those regions are: Region I. CT, MA, ME, NH, VT; Region II. NJ, NY; Region III. DL, DC, MD, PA, VA, WV; Region IV. AL, NC, SC, FL, GA, KY, MS, TN; Region V. IL, IN, MI, MN, OH, WI; Region VI. AR, LA, NM, OK, TX; Region VII. IA, KS, MO, NE; Region VIII. CO, MT, ND, SD, UT, WY; Region IX. AZ, CA, HI, NV; Region X. AK, ID, OR, WA. KRs were assigned to a region according to an individual's place of residence, and not where the procedure was performed. Other characteristics, such as clinical diagnoses, were available only for those receiving a KR and not for the entire population; thus, they could not be used in the analysis.

Log-linear Poisson regression was used to model the relationship between the number of KRs, a count variable, and the independent variables, age, race, gender, region, and year. The number of KRs was calculated within each of the 1,200 combinations of the five independent variables (six years, five age groups, two genders, two races, ten regions). Since the denominator of the rate, the number of Medicare person-months, was also calculated for each combination and included as an offset term on the right side of the model equation, the analysis is equivalent to modeling the performance rates. To test the assumption of the Poisson model–that variances are equal to the means–a proportional Poisson error model and an extra Poisson variance error model were fit and compared (McCullagh and Nelder 1983). The proportional Poisson error model assumes instead that the variance is proportional to, rather than equal to, the expected count. An extra Poisson variance error model includes an additional variance component in the model. The GLIM statistical package was used for estimation of all three types of models (Baker and Nelder 1978).

The Poisson model was fit stepwise, first adding all main effects and then the two-, three-, and four-way interactions of age, race, gender, region, and year. Main effects and interactions were added one by one and retained if they contributed significantly to the explanatory value of the model. The statistical significance of each effect or interaction was determined by computing and then comparing the Pearson chi-square lack of fit statistic when the interaction term(s) were included and then excluded, respectively. Since one consequence of using a very large database is to increase the ability to detect small differences, even when they are clinically unimportant, the criterion for inclusion of a main effect or interaction was set at $p < .005$. Therefore, all differences seen in the model should be both statistically significant and clinically meaningful.

A statistical model with many main effects and interactions is difficult to interpret. Therefore, the results are displayed as odds-ratios calculated directly from the estimated parameter values, rather than the parameter estimates themselves. Odds-ratios can be interpreted as the percent more or less likely that a KR is performed on someone in a given demographic, race, or geographic category holding all of the other independent variables constant. Thus, for example, all reported odds-ratios are age-adjusted, as well as adjusted for other factors.

The final model contained main effects for age, race, sex, region, and year; all ten possible two-way interactions among the five independent variables; and three-way interactions for region-age-gender and region-age-race. To examine the fit of the final model, we computed the Pearson chi-square in order to compare the proposed final model to a saturated model containing all possible interactions; the Pearson residuals and the estimated extra variance components were then examined. The Pearson chi-square lack of fit statistic was nominally significant (χ_2 = 1083/45, df = 969, p = .006), as one might expect using a large database. However, examination of residuals did not reveal any patterns indicating systematic lack of fit or cells with large residuals. The extra Poisson variance was estimated to be 0.0005. The proportional Poisson model had a similarly small estimated scale factor of 1.118. Neither altered the conclusions of the simpler pure log-linear Poisson model, which is the basis of the estimates reported in the next section.

RESULTS

TRENDS IN KRS OVER TIME

The number of Medicare-paid KRs increased in each of the study years, starting with 48,524 in 1985 and progressing to 96,720 in 1990 (Table 1). This corresponds to an 18.45 percent annual rate of increase. The age-adjusted rates also showed a steady increase from 1.92 per 1,000 in 1985 to 3.54 per 1,000 in 1990. The fraction of KRs performed as bilateral knee replacements increased from 4.4 percent to 5.3 percent between 1987 and 1990. Revision KRs increased from 5.5 percent to 7.3 percent during the period. The overall rate of KR performance doubled over the six-year period (Table 2). Age-adjusted rates (per 1,000) in 1985 were very different by race and gender (white female 2.27; African American female 1.57; white male 1.56; African American male 0.50). Although an increase over time is seen for each race and gender, the relative increases in the rates are greater in men than in women and also in African Americans than in whites (Table 2), thus narrowing the gaps between these groups with time. The increase in KR rates also differed among the regions (Table 3). Regions II and IV had the largest increases while Region X had the smallest relative increase.

EFFECT OF AGE, GENDER, AND RACE ON KR PERFORMANCE

Receiving a KR was a function of age, gender, and race. KRs were consistently more likely to be performed on individuals between 70 and 84 years of age. Overall odds-ratios show that KRs were 29 and 41 percent more likely in the 70–74 and 75–79 age groups than in the 65–69-year-old group. Achieving the age of 80 decreased the odds of a KR relative to the 70–74 and 75–79 age groups, but those in the 80–85 age group were still 17 percent more likely

Table 1: The Number of Medicare-Paid Knee Replacements by Year and Type (United States, Aged Medicare Beneficiaries)

	1985	*1986*	*1987*	*1988*	*1989*	*1990*
N (Total = 414,079)	48,524	54,787	63,377	72,491	78,185	96,721
Annual percent change		12.9%	15.7%	14.4%	7.9%	23.7%
Age-adjusted rate (per 1,000)	1.92	2.15	2.45	2.76	2.92	3.54
Percent revision	5.5	5.8	5.8	5.7	6.5	7.3
Percent bilateral	*	*	4.4	5.1	4.9	5.3

*Reliable data not available before change in DRG coding.

Table 2: Odds of Receiving Knee Replacement by Race and Gender, by Year (Odds-Ratios)

	1985	*1986*	*1987*	*1988*	*1989*	*1990*
Overall	1.00	1.13	1.32	1.50	1.79	2.00
Gender						
Male	1.00	1.14	1.35	1.57	1.75	2.12
Female	1.00	1.12	1.28	1.43	1.83	1.88
Race						
White	1.00	1.11	1.29	1.45	1.66	1.88
African American	1.00	1.15	1.34	1.55	1.91	2.12

Table 3: Annual Medicare Knee Replacement, by Region (Odds-Ratios)

Region (Regional Headquarters)	*Age† -Adjusted Rate for 1985*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*
Region I (Boston)*	1.56	1.00	1.12	1.22	1.39	1.72	1.90
Region II (New York)	0.98	1.00	1.19	1.30	1.62	1.91	2.28
Region III (Philadelphia)	1.83	1.00	1.17	1.31	1.49	1.79	2.08
Region IV (Atlanta)	1.48	1.00	1.22	1.45	1.62	1.93	2.19
Region V (Chicago)	2.31	1.00	1.09	1.31	1.49	1.73	1.97
Region VI (Dallas)	2.05	1.00	1.10	1.32	1.51	1.88	2.05
Region VII (Kansas City)	2.98	1.00	1.15	1.35	1.53	1.79	1.95
Region VIII (Denver)	3.20	1.00	1.09	1.29	1.41	1.69	1.88
Region IX (San Francisco)	2.05	1.00	1.19	1.33	1.55	1.83	1.94
Region X (Seattle)	2.70	1.00	1.00	1.29	1.40	1.62	1.77

*Headquarter city in each region in parenthesis for identification.

†Age-adjusted rate per 1,000.

to receive a KR than 65–69-year-olds. Being 85 or older caused a substantial drop in the likelihood of undergoing a KR. Being in the oldest age group was associated with a 41 percent less chance of having a KR than being in the youngest group. Also, KRs were almost twice as likely to be performed on women as on men (odds-ratio (OR) = 1.95). These differences were less pronounced in 1990 than in 1985, but were exacerbated by race. On average, KRs were over two and one-half times more likely for African American women than for men (OR = 1.66), whereas the difference was only 24 percent for white women versus white men (OR = 1.24).

Differences across race within gender also varied markedly. Procedures were performed on white men much more often than on African Americans, the odds-ratio being 2.50. The difference between white and African American women was much smaller (OR = 1.16).

REGIONAL VARIATION

Even after adjustment for demographic characteristics of the population, significant geographic differences in the rates of performance of KRs remain. Table 4 shows that the lowest adjusted rates were in Region II, while the highest rates were in Regions VIII and X. As noted earlier, the odds of obtaining the procedure increased each year in all regions but at different rates; the lowest increase from 1985 to 1990 was 77 percent in Region X, while the highest was in Region II with an increase of 128 percent (Table 3). Thus, a decrease in regional variation occurred over the six-year period. The two three-way interactions involving region were also examined further based on odds-ratios obtained from the model. Of note for the western part of the United States (Region VIII: OR = 1.01; Region IX: OR = 0.99; and Region X: OR = 0.90) are higher relative rates in men over 85 years old (approximately equal to those 65–69). Racial differences also vary by age and region. Racial differences in rates generally increased with age; they also differed markedly by region. In Regions I and X, whites were only about 15 percent more likely than African Americans to have a KR, the smallest racial differential. The largest racial differences in rates (OR greater than 2.0) were seen in Regions V, VI, and VII. Racial differences in Regions II, VIII, and IX were less than 50 percent; in Regions III and IV, whites were about 70 percent more likely to receive the procedure than African Americans.

Table 4: Odds of Receiving Knee Replacement by DHHS Region (Odds-Ratios)

Region (Regional Headquarters)	*Over All Years*
DHHS Region I (Boston)	0.85
DHHS Region II (New York)	0.56
DHHS Region III (Philadelphia)	0.89
DHHS Region IV (Atlanta)	0.79
DHHS Region V (Chicago)	1.00
DHHS Region VI (Dallas)	0.81
DHHS Region VII (Kansas City)	1.32
DHHS Region VIII (Denver)	1.65
DHHS Region IX (San Francisco)	1.21
DHHS Region X (Seattle)	1.67

DISCUSSION

Our research indicates that the number of KR operations (primary, bilateral, or revision arthroplasty) doubled during the 1985–1990 period. Several factors might account for this rather dramatic increase. It should be noted, however, that this is not an artifact of an increase in the number of overall Medicare beneficiaries, since rates have gone up approximately twofold for every demographic subgroup and the Medicare population has risen only 2 percent per year (Prospective Payment Assessment Committee 1992). Although the average age at the time of the operation has not increased, with the overall aging of the Medicare population, it is likely that the number of individuals with knee arthritis has increased. Unfortunately, no national figures are available on the prevalence of knee arthritis by year, race, or geographic location. Data from the National Health Interview Survey (NHIS) provide the number of reported conditions of arthritis in the United States from 1985 to 1990, stratified by age, race, and gender. Overall, women have a higher number of reported conditions of arthritis than men and African Americans have a higher number than whites, but these data are not specific to arthritis of the knee (National Center for Health Statistics 1985–1990). Other studies support these findings for knee osteoarthritis (OA). The literature reports that for those over 65, the female:male prevalence ratio is generally between 1.5:1 and 2:1 (Felson 1988). Controlling for age, African American women in the HANES I survey had twice the prevalence of white women for knee OA, but men did not differ by race (Anderson and Felson 1988).

That the number of revisions and KRs performed as bilaterals has increased over time, however, is not surprising. Surgical technology improves over time as does a surgeon's experience with performing a procedure. As the overall procedure improves, the likelihood of an individual revision should be reduced. However, as the prevalence of patients having KR increases, the number of revisions would be expected to increase. Many revision(s) performed during the study period, 1985–1990, are likely to be from surgeries prior to 1985 using older techniques and components. Also, as KR technology becomes more widespread, surgeons may become more likely to extend the technology to a single-stage procedure in patients with bilateral knee arthritis. Some surgeons suggest that bilateral KR is more cost-effective than two primary KRs, although there is no controlled study testing this hypothesis (Morrey, Adams, Ilstrayo, et al. 1987).

Access to orthopaedists may be an explanation of both the increase in the counts of KRs and the disparity by race. However, to test this hypothesis requires information that is not readily available. Insofar as patients generally elect surgery near to where they reside, it is important to have data on the number of referring physicians and orthopaedists performing KR per population for those areas. Our analysis is of large area data, however, so even if such data existed, they would comprise an improper unit of analysis.

Similarly, while the rate at which the counts of KRs performed on African Americans has increased, this procedure is distinctly less likely to be performed on African Americans as a whole in comparison to whites. This is the case even though, based on data from NHANES I, African American women appear to have a higher prevalence of osteoarthritis than white women, and there is no racial difference in prevalence among men (Anderson and Felson 1988). While our analyses suggest that the gap in the relative disparity in numbers may be decreasing, it is likely that African Americans, by virtue of being of lower average socioeconomic status, may lack or may have lacked access to physicians. Even though all KRs in this study were reimbursed by Medicare, Medicare still leaves substantial out-of-pocket costs to be borne by the patients. African Americans may be less able to pay their out-of-pocket expenses than whites. Virtually all studies of procedures in African American versus white populations show that African Americans always receive them less frequently, although the underlying reasons are far from understood (Anyanian, Udvarhely, Gatsonis, et al. 1993; Wenneker and Epstein 1989). Different preferences toward the risk of surgery or cultural attitudes that influence care-seeking behavior might also be additional explanations for differing rates by race (Barry et al. 1988; Fleming, Wasson, Albertsen, et al. 1993).

An additional explanation of the large increase in rates of performing KR is unmet need. As more surgeons learn to perform the surgery, more KR surgery may be performed on those who need it. Unfortunately, no adequate measure of unmet need exists. Our research has shown that the single greatest predictor of the decision to have KR is the presence of significant joint pain or functional impairment (Hawker, Paul, Katz, et al. under review). Many individuals who have their arthritis confirmed by knee x-ray report no evidence of prior problems with function (Bradley, Brandt, Katz, et al. 1991).

Research into medical technology diffusion strongly suggests that indications for use of technology change over time as physicians gain increased experience (Hillman and Schwartz 1985). Commonly used technologies such as KR are developed and introduced in academic medical centers first and usually are recommended to benefit a small group of individuals with a circumscribed list of indications. As the procedure is increasingly performed, the indications for use broaden to include individuals who are sicker either because they have more comorbidities or more severe disease. Thus, as more surgeons have learned the procedure and prostheses have improved, indications for KR may have expanded, leading to greater usage. Also, the effectiveness of the procedure may have improved through incremental reliability associated with more advanced instrumentation systems and improved prosthetic systems. While this would explain why more of the over-85 group are getting the procedure, the presence of a greater number and/or more significant comorbidities may also explain why the rate in this group is much lower than that in the others. The Medicare Statistical System stores little information on comorbidities at the time of surgery. Over the study period, the average number of diagnoses, a proxy for comorbidities, has increased from 2.58 in 1985 to 3.08 in 1989. Additionally, individuals in the over-85 group may simply have lower rates because they received their knee replacements when they were younger. Also, as the number and severity of medical comorbidities increase, patients may be less concerned with the functional limitations stemming from knee arthritis. Moreover, patients or physicians, or both, may decide that the additional risks of surgery outweigh the benefits given these patients' reduced life expectancy.

Wennberg and others have hypothesized that much of the variation in rates is due to physician behavior, reflecting different underlying philosophies about why to operate–or why not (Chassin, Brook, Park, et al. 1986; Wennberg, Barnes, and Zubkoff 1982). Physicians are thought to hold the key because, in other studies, variation in rates remains statistically unexplained after controlling for characteristics of the patient, the hospital in which they are treated, and their area of residence (Keller et al. 1990; Lu-Yao et al. 1993). Previous studies suggest that variation is lowest when physicians agree on the indications for surgery (Chassin, Brook, Park, et al. 1986; Roos 1984; Roos, Roos, and Henteleff 1977). Other research by this PORT team, however, suggests that disagreement remains among both practicing orthopaedists and primary care physicians in Ontario and Indiana with regard to some indications for surgery (Parchman, Kalasinski, Melfi, et al. 1996; Tierney, Fitzgerald, Heck, et al. 1994; Wright, Coyte, Hawker, et al. 1996). This lack of agreement on surgical indications may partially explain the high rate variation in the Medicare data. Further studies on variation in KR rates must be expanded and improved to provide better information on the severity of disease and comorbidity in population subgroups, to characterize cultural beliefs regarding use of physicians, and to directly measure access barriers. In addition, better modeling of the supply of resources and the areas themselves is warranted.

CONCLUSION

As indicated by our analyses, much about area variation and the rate of growth in KR rates remains unexplained. That area variation has minimally decreased in the United States over time means that variation is likely to remain an important concern. In similar analyses in Ontario, we found a marked decrease in small area variation over time (Wright, Coyte, Hawker, et al. 1996). For answers to emerge, better data and different types of studies than have heretofore appeared in the literature are required. There is need for understanding how referral patterns contribute to rate variation. Similarly, while data are available on the number of orthopaedists in a state or region, no such information exists on the availability of orthopaedists who actually perform KRs in smaller geographic areas, or on the number of individuals in communities with painful and functionally disabling arthritis of the knee. Completely absent from the literature are ethnographic studies of care-seeking behavior that could help illuminate many of the cultural or access factors that lead to lower rates of performance on African Americans than on whites. Until many of these variables (information on access, referrals, and physicians performing KR) are readily available, research will be unable to unravel the reasons for geographic variability.

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