Methodological Effects on the Measurement of Repeat Hospitalizations

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ABSTRACT

OBJECTIVES: Measurement of potentially preventable readmissions (PPRs) is central to 2 policy objectives: decreasing inefficiencies in healthcare and addressing disparities in health outcomes. Rates may be determined with multiple approaches and there is no consensus on the optimal measure. We tested the proposition that inferences based on measured rates of PPRs are robust to the methodology.

STUDY DESIGN: Retrospective descriptive analysis of statewide inpatient discharge data.

METHODS: We calculated rates of PPRs for 13 conditions and 5 composite measures for hospitalizations in Massachusetts from 1997 to 2000. For each measuring index, we compared the demographics of patients with PPRs to the general Massachusetts adult population. We estimated a multivariate logistic model where the outcome variable was an indicator of whether the patient was readmitted in the following 2 years, and where the covariates were the characteristics of the patient as of their first admission.

RESULTS: We found that the rates and inferences varied across methodologies. Median income in the patient's neighborhood and insurer type had more robust relationships with PPR than race of the patient.

CONCLUSIONS: Our work explains the inconsistencies in previous studies as to the existence of a race effect on PPRs. Furthermore, it suggests that the index currently used to evaluate hospital quality by CMS may incentivize inefficient behavior by hospital administrators. We suggest an alternative measure of efficiency.

One measure of inefficiency in US healthcare is the frequency of hospitals' potentially preventable readmissions (PPRs). Between 2003 and 2004, 34% of Medicare patients discharged from a hospital were readmitted within 90 days.[1] PPRs' estimated $12 billion cost to Medicare led CMS to enact provisions in the Affordable Care Act tying a hospital's payments to its PPR rate.[2] The rate may be measured by different indexes which include or exclude admissions for a variety of medical conditions; CMS presently measures PPRs with a 3-condition composite that counts readmissions for acute myocardial infarction (AMI), congestive heart failure (CHF), and pneumonia. In October 2012, Medicare penalized more than 2000 hospitals (about 71% of those reviewed) for excessive readmissions, with fines totaling more than $280 million.[3]

Three criticisms challenge this scheme of penalizing hospitals for PPRs. First, some hospitals may be unfairly penalized because of the population they serve, such as African American or low-income communities with higher rates of initial potentially preventable hospitalizations (PPHs).[4-15] While CMS does take into account the morbidity, or general health, of a hospital's patients, they do not take into account the race/ethnicity or socioeconomic status of the population served. Second, there are no evidence-based uniform strategies to reduce readmissions,[16] which raises the question as to whether penalties will spur any meaningful change in practices. Third, no single index has been widely accepted as the standard for measuring PPRs.[17,18] This third issue is at the heart of the debate, as the lack of uniform measures precludes an informed discussion of the first 2 issues.

This paper takes a closer look at the analytical difficulty inherent in the CMS decision to evaluate hospitals by PPRs. A PPR measuring index sorts hospital admissions by medical condition, counting some admissions as potentially preventable and excluding others from the measured rate. A given index may sort conditions individually (eg, readmission for hypertension) or may group together readmissions for many different medical conditions. The latter, called composite indexes, may be general (all-cause admission) or specific (eg, a composite index that counts only readmissions for AMI, CHF, and pneumonia). Further, when analyzing readmission rates, these selection filters may apply to the medical cause of initial admission, of readmission, or both.

Measurement is further confounded by the fact that past studies examined samples that varied greatly in important demographic characteristics, including payer type (eg, public or private insurers), geographic area, and year. In some populations, PPR differs by patient race/ethnicity,[1,5,12,19-23] while other populations show no such "race effect."[24-26] **Table 1** summarizes the variation in samples, methodology, and results in key PPR studies since 2000. For this reason, we cannot say whether the variation in previous findings is due to differences in the measuring index used (eg, individual condition vs composite indexes) or to differences in the samples analyzed (eg, the sample population's demographics).

To answer this question, we examined data on all inpatient hospitalizations for individuals 18 years or older in Massachusetts from 1995 to 2002. By using the hospital data for an entire state, our results are generalizable to all hospitalizations, not just those of Medicare or the Veterans Health Administration. By taking data from a longer time span than that of previous studies, we are able to discern patterns belied by shorter time frames. Estimating the rate of PPR using the multiple measures with the same data allows us to distinguish differences that are due to the measurement rather than the characteristics of the patients. We examined Massachusetts because it was among the states with the highest penalties for excess readmissions as calculated by Medicare,[3] and in the top 10 states for all-cause PPRs.[1] Furthermore, aggregate rates of PPH indicate that these readmissions are not proportionately distributed across race/ethnicity.[27,28]

Using these data, we tested whether the effect on readmission rates of race and other demographics (eg, payer type, age, existing comorbidity, and median income in the patient's area of residence) varies depending on the methodology used to measure those rates (eg, individual or composite indexes). We find strong

Table 1. Variation in Methodologies, Sample Characteristics, and Literature Findings

ALL-CAUSE COMPOSITE		
Jencks et al (2009)[1]	National sample of Medicare recipients, 2003-2004	Higher rates of readmissions among blacks than whites
Berkowitz and Anderson (2013)[19]	National sample of Medicare recipients, 2008	Higher rates of readmissions among blacks than whites
Moore et al (2013)[24]	New York state sample of Veterans Health Network, 2011	No differences in readmission rates by race/ethnicity
Donzé et al (2013)[25]	Boston sample from an academic medical center, 2009-2010	No differences in readmission rates by race/ethnicity
SELECT-CONDITION COMPOSITES		
Friedman and Basu (2004)[5]	4-state sample for initial admission for a PQI, 1999	Higher rates of readmissions among blacks and Hispanics than among whites
ALL-CAUSE READMISSION AFTER SELECTED INITIAL CONDITIONS		
Joynt et al (2011)[20]	National sample of Medicare recipients, 2006-2008	Higher rates of readmissions among blacks than whites
INDIVIDUAL CONDITION		
Deswal et al (2004)[26]	National sample from Veterans Health Administration for heart failure, 1997-1999	No differences in readmission rates by race/ethnicity
Rathore et al (2006)[21]	National sample of Medicare recipients for heart failure, 1989-1999	Higher rates of readmissions among blacks than whites
Jiang et al (2005)[22]	5-state sample for diabetes-related complications, 1999	Higher rates of readmissions among blacks and Hispanics than among whites
Ash and Brandt (2006)[12]	Massachusetts state sample for asthma, 1997-2000	Higher rates of readmissions among blacks than whites
McHugh et al (2010)[23]	National sample of Medicare recipients for heart failure, acute myocardial infarction, and pneumonia, 2008	Higher rates of readmissions among blacks than whites for all 3; higher among Hispanics only for myocardial infarction.

PQI indicates Prevention Quality Indicator.

Table 2. Counts of Initial Admissions by PQI Condition in Massachusetts, 1997-2000

	MASSACHUSETTS ADULT POPULATION	DIABETES SHORT-TERM COMPLICATION	PERFORATED APPENDIX	DIABETES LONG-TERM COMPLICATION
Total		3789	4021	10,410
Female	52.8%	1831 (48.32)	1777 (44.19)	4857 (46.66)
Race/ethnicity				
White, non-Hispanic	83.8%	2767 (73.03)	3367 (83.74)	8534 (81.98)
Black, non-Hispanic	4.8%	604 (15.94)	158 (3.93)	872 (8.38)
Hispanic	5.6%	225 (5.94)	196 (4.87)	490 (4.71)
Other	5.8%	193 (5.09)	300 (7.46)	514 (4.94)
Age (years)				
18-39	42.1%	1269 (33.49)	1502 (37.35)	594 (5.71)
40-64	40.1%	1440 (38)	1660 (41.28)	3573 (34.32)
65-74	8.9%	442 (11.67)	454 (11.29)	2779 (26.7)
75+	8.8%	638 (16.84)	405 (10.07)	3464 (33.28)

	MASSACHUSETTS ADULT POPULATION	DEHYDRATION	BACTERIAL PNEUMONIA	URINARY TRACT INFECTION
Total		27,347	59,594	20,954
Female	52.8%	17,292 (63.23)	32,700 (54.87)	14,651 (69.92)
Race/ethnicity				
White, non-Hispanic	83.8%	24,536 (89.72)	53,639 (90.01)	18,375 (87.69)
Black, non-Hispanic	4.8%	1112 (4.07)	2109 (3.54)	913 (4.36)
Hispanic	5.6%	535 (1.96)	1502 (2.52)	707 (3.37)
Other	5.8%	1164 (4.26)	2344 (3.93)	959 (4.58)
Age (years)				
18-39	42.1%	2235 (8.17)	4195 (7.04)	2616 (12.48)
40-64	40.1%	5187 (18.97)	12,813 (21.5)	3502 (16.71)
65-74	8.9%	5061 (18.51)	11,984 (20.11)	3370 (16.08)
75+	8.8%	14,864 (54.35)	30,602 (51.35)	11,466 (54.72)

	MASSACHUSETTS ADULT POPULATION	LOWER-EXTREMITY AMPUTATION AMONG PATIENTS WITH DIABETES	ALL-PQI COMPOSITE	ACUTE COMPOSITE
Total		2971	165,613	98,054
Female	52.8%	1128 (37.97)	95,243 (57.51)	58,176 (59.33)
Race/ethnicity				
White, non-Hispanic	83.8%	2488 (83.74)	145,842 (88.06)	87,485 (89.22)
Black, non-Hispanic	4.8%	230 (7.74)	7679 (4.64)	3818 (3.89)
Hispanic	5.6%	122 (4.11)	5082 (3.07)	2589 (2.64)
Other	5.8%	131 (4.41)	7010 (4.23)	4162 (4.24)
Age (years)				
18-39	42.1%	46 (1.55)	14,525 (8.77)	8753 (8.93)
40-64	40.1%	957 (32.21)	40,054 (24.19)	20,333 (20.74)
65-74	8.9%	909 (30.6)	34,397 (20.77)	18,823 (19.2)
75+	8.8%	1059 (35.64)	76,637 (46.27)	50,145 (51.14)

NA indicates not applicable; PQI, Prevention Quality Indicator.

Proportions are in parentheses.

COPD AND ASTHMA IN OLDER ADULTS	HYPERTENSION	CONGESTIVE HEART FAILURE
32,144	2690	45,728
19,663 (61.17)	1666 (61.93)	25,614 (56.01)
28,901 (89.91)	2027 (75.35)	41,485 (90.72)
1195 (3.72)	342 (12.71)	1767 (3.86)
990 (3.08)	160 (5.95)	914 (2)
1058 (3.29)	161 (5.99)	1562 (3.42)
NA	245 (9.11)	461 (1.01)
10,867 (33.81)	988 (36.73)	6605 (14.44)
8699 (27.06)	540 (20.07)	10,339 (22.61)
12,578 (39.13)	917 (34.09)	28,323 (61.94)
ANGINA WITHOUT PROCEDURE	**UNCONTROLLED DIABETES**	**ASTHMA IN YOUNGER ADULTS**
9859	2129	3876
5063 (51.35)	1064 (49.98)	2635 (67.98)
8884 (90.11)	1626 (76.37)	2779 (71.7)
375 (3.8)	228 (10.71)	415 (10.71)
262 (2.66)	159 (7.47)	506 (13.05)
338 (3.43)	116 (5.45)	176 (4.54)
242 (2.45)	352 (16.53)	3876 (100)
3672 (37.25)	803 (37.72)	NA
2516 (25.52)	385 (18.08)	NA
3429 (34.78)	589 (27.67)	NA
CHRONIC COMPOSITE	**DIABETES COMPOSITE**	**ASTHMA COMPOSITE**
95,916	15,908	12,948
53,876 (56.17)	7419 (46.64)	9279 (71.66)
84,172 (87.76)	12,660 (79.58)	10,156 (78.44)
4916 (5.13)	1610 (10.12)	1092 (8.43)
3138 (3.27)	832 (5.23)	1143 (8.83)
3690 (3.85)	806 (5.07)	557 (4.3)
6553 (6.83)	1903 (11.96)	3876 (29.94)
24,467 (25.51)	5481 (34.45)	5053 (39.03)
21,885 (22.82)	3684 (23.16)	1752 (13.53)
43,011 (44.84)	4840 (30.42)	2267 (17.51)

evidence that the effect of some demographic factors on admission rates greatly varies depending on the measuring index used. In contrast, median neighborhood income has a consistent and statistically significant negative relationship with readmissions.

These findings present 2 important implications: first, the effects of demographic factors on PPR rates depend largely on the measuring index chosen. Second, interventions to reduce readmissions for populations at risk will be more effective if centered on income/wealth distinctions rather than on race/ethnicity.

Methods

Data

Data are from the Massachusetts Division of Health Care Finance and Policy Hospital Inpatient Discharge Database covering 1995 to 2002. Each observation is an inpatient discharge record for the patient, including dates of admission and discharge, primary and secondary diagnoses, a unique patient identifier, age, sex, race/ethnicity, zip code of residence, anticipated payer type, and an indicator of any major comorbidities. We used the US Census 1999 median household income data as a proxy for the patient's neighborhood characteristics.[29]

Methodology

We extracted records of hospital discharges (**Supplemental Information 1**) for the 13 conditions which the Agency for Healthcare Research and Quality (AHRQ) used to create Prevention Quality Indicators (PQIs): diabetes short-term complication, perforated appendix, diabetes long-term complication, chronic obstructive pulmonary disease (COPD) and asthma in older adults, hypertension, CHF, dehydration, bacterial pneumonia, urinary tract infection (UTI), angina without procedure, uncontrolled diabetes, young-adult asthma (**Supplemental Information 2**), and lower-extremity amputation among patients with diabetes. AHRQ measures PPHs using 3 different composites: acute conditions, chronic conditions, and all conditions (**Supplemental Information 3**). We created 2 additional composites: a diabetes composite (diabetes short-term complication, diabetes long-term complication, uncontrolled diabetes and lower-extremity amputation among patients with diabetes) and an asthma composite (young-adult asthma as well as COPD and asthma in older adults).

We identified the relevant records using each condition's *International Classification of Diseases, Ninth Revision, Clinical Modification* codes for primary diagnosis and the exclusion criteria developed by the AHRQ (**Supplemental Information 4**). We classified by each condition the first admission (index admission) that occurred between

Table 3. Rate of Repeat Hospitalizations for PQI Conditions in Massachusetts, 1997-2000

NUMBER OF ADMISSIONS	DIABETES SHORT-TERM COMPLICATION	PERFORATED APPENDIX	DIABETES LONG-TERM COMPLICATION	COPD AND ASTHMA IN OLDER ADULTS
1	3238 (85.46)	3960 (98.48)	7813 (75.05)	23414 (72.84)
2-3	452 (11.93)	61 (1.52)	2247 (21.59)	7135 (22.20)
≥4	99 (2.61)	NA	350 (3.36)	1595 (4.96)
NUMBER OF ADMISSIONS	**ANGINA WITHOUT PROCEDURE**	**UNCONTROLLED DIABETES**	**ADULT ASTHMA IN YOUNGER ADULTS**	**LOWER-EXTREMITY AMPUTATION AMONG PATIENTS WITH DIABETES**
1	9333 (94.66)	2028 (95.26)	3131 (80.78)	2343 (78.86)
2-3	506 (5.13)	91 (4.27)	620 (16)	617 (20.77)
≥4	20 (0.2)	10 (0.47)	125 (3.22)	11 (0.37)

COPD indicates chronic obstructive pulmonary disease; NA, not applicable; PQI, Prevention Quality Indicators.

Proportions are in parentheses.

We find strong evidence that the effect of some demographic factors on admission rates greatly varies depending on the measuring index used. In contrast, median neighborhood income has a consistent and statistically significant negative relationship with readmissions.

1997 and 2000. We defined a first admission as an admission that was not preceded within 2 years by an earlier admission for the same condition (for a single condition index) or for a condition in the same composite group (for a composite index). We defined a repeat admission as an admission for the same condition(s) defined in the index within 2 years of the first admission. For example, if a patient was admitted for diabetes short-term complication in 1998, and then diabetes long-term complication in 1999, the 1999 admission is a first admission if we are using a single condition index for diabetes long-term complication to measure PPR, but it is a repeat admission if we are using a diabetes composite index.

For each patient, we calculated the total number of hospital admissions. For example, a patient first admitted for dehydration and then admitted again within 2 years for a UTI would have an admission-number variable equal to 2 for the data point entered into the acute PQI composite; this is because both dehydration and a UTI are conditions in the acute composite index. The same patient would have an admission-number variable equal to 1 for the data point entered into the dehydration single-condition index, since that patient was hospitalized only once for dehydration.

We excluded patients with an admission in the first 2 years of our data set (1995 to 1996) from each index because we could not be sure if that admission was a first admission or a repeat admission, as we could not look back over the full preceding 2-year readmission window. We also excluded patients with first admissions for the measuring condition (or group of conditions for a composite index) during the final 2 years of our data set (2001 to 2002) since we could not look forward over the subsequent 2-year window to see if any repeat admissions followed.

For each measuring index, we compared the demographics of patients with PPRs to the general Massachusetts adult population. Then we estimated a multivariate logistic model where the outcome variable was an indicator of whether the patient was readmitted in the following 2 years, and where the covariates were the characteristics of the patient as of their first admission. These characteristics included: race (white, black, Hispanic, or other), age group (aged 18-39 years, 40-64 years, 65-74 years, 75 years and above), gender, existence of major comorbidities, and payer type (self-pay/out of pocket, Medicare/Medicaid/other government pay, or private insurance), and median neighborhood household income.

Results

First Admission and Readmission Rates

There is significant variation in the number of initial hospitalizations across conditions (**Table 2**). The most common PQI condition was bacterial pneumonia (59,594 admissions or 26% of all PQI admissions), followed closely by CHF (45,728 admissions; 20%). The second most frequent conditions were COPD and asthma (32,144; 14%), dehydration (27,347; 12%), and urinary tract infection (20,954; 9%). There is then a marked drop in frequency, with remaining conditions having 10,000 or fewer admissions (each about 2% to 4% of the total).

The racial distribution of the hospitalized population differs sig-

Table 3. Rate of Repeat Hospitalizations for PQI Conditions in Massachusetts, 1997-2000 (continued)

NUMBER OF ADMISSIONS	HYPERTENSION	CONGESTIVE HEART FAILURE	DEHYDRATION	BACTERIAL PNEUMONIA	URINARY TRACT INFECTION
1	2531 (94.09)	32053 (70.09)	24850 (90.87)	51324 (86.12)	18768 (89.57)
2-3	149 (5.54)	11348 (24.82)	2404 (8.79)	7866 (13.2)	2073 (9.89)
≥4	10 (0.37)	2327 (5.09)	93 (0.34)	404 (0.68)	113 (0.54)
NUMBER OF ADMISSIONS	**ALL-PQI COMPOSITE**	**ACUTE COMPOSITE**	**CHRONIC COMPOSITE**	**DIABETES COMPOSITE**	**ASTHMA COMPOSITE**
1	119487 (72.15)	81411 (83.03)	68062 (70.96)	12078 (75.92)	10706 (82.68)
2-3	38396 (23.18)	15626 (15.94)	22726 (23.69)	3264 (20.52)	1929 (14.9)
≥4	7730 (4.67)	1017 (1.04)	5128 (5.35)	566 (3.56)	313 (2.42)

PQI indicates Prevention Quality Indicators.

Proportions are in parentheses.

nificantly over conditions. Blacks are over-represented for all diabetes conditions, hypertension, and asthma in younger people. In fact, the proportion of black people in patients experiencing first hospitalizations is highest for diabetes short-term complication—more than triple the proportion of black people in the state's adult population. Blacks are under-represented in other individual conditions: perforated appendix, COPD and asthma in older adults, CHF, dehydration, bacterial pneumonia, and angina without procedure.

Of those first hospitalized for any PQI condition between 1997 and 2000, 28% were subsequently hospitalized. For those initially hospitalized for one of the chronic PQI conditions, 29% had a repeat hospitalization (of any type); for initial admissions for an acute PQI, 17% had a repeat admission (of any type).

The percentage of readmissions for the same PQI as initial admission varies greatly by condition. **Table 3** reports the frequency of first admissions for PQI conditions and their rates of repeat. The conditions with the lowest repeat admission rates were perforated appendix (2%) and uncontrolled diabetes (5%). The top 5 conditions for repeat admissions were CHF (30%), COPD and asthma (27%), diabetes long-term complications (25%), diabetes composite (24%), and lower-extremity amputation among patients with diabetes (21%). When PPR is measured with the 13-condition composite (all-PQI composite) the PPR rate is 28%, while it is only 17% for the acute composite and 29% for the chronic composite.

Differences in Readmission Rates by Race

To measure the change in predicted probability of readmission for a sociodemographic characteristic such as race, we estimated logistic regressions where readmission was the outcome of interest and covariates were age, gender, comorbidity, insurance type, and the individual's income level (measured by proxy). **Table 4** reports the results for the individual condition indexes; **Table 5** for composite indexes.

The rate of PPR and the effect of race on that rate vary widely over the individual PQI conditions. The probability that a black person will be readmitted is approximately 75% higher than for a white person for hypertension (odds ratio [OR], 1.753; 95% CI, 1.151-2.670), 53% higher for amputation among patients with diabetes (OR, 1.534; 95% CI, 1.119-2.103), and 22% higher for CHF (OR, 1.221; 95% CI, 1.109-1.346). In contrast, the probabilities of readmission for blacks are lower than for whites for diabetes short-term complication (OR, 0.679; 95% CI, 0.533-0.865) and for the diabetes composite (OR, 0.880; 95% CI, 0.775-0.999).

Neither the acute composite index nor the chronic composite index showed differences between blacks and whites. When using either the all-PQI composite or the asthma composite, blacks are more likely than whites to have repeat readmissions (OR, 1.059; 95% CI, 1.010-1.111; and OR, 1.437; 95% CI, 1.246-1.656, respectively). Conversely, the diabetes composite showed a lower readmission rate for blacks than for whites (OR, 0.880; 95% CI, 0.775-0.999).

The picture is similarly varied for Hispanics relative to whites. Hispanics are more likely than whites to have a repeat admission if we measure PPR with an asthma composite (OR, 1.433; 95% CI, 1.244-1.652) or with individual indexes for CHF (OR, 1.441; 95% CI, 1.242-1.673) or asthma in younger adults (OR, 1.328; 95% CI, 1.028-1.716). They are less likely than whites to have a repeat admission as measured by the diabetes composite (OR, 0.783; 95% CI, 0.659-0.929) or by the individual condition of urinary tract infection (OR, 0.697; 95% CI, 0.503-0.966). We saw no race effect for Hispanics in the all-PQI composite, the chronic composite, and the other individual conditions.

Table 4. Odds Ratios by Individual PQI Conditions

COEFFICIENT	DIABETES SHORT-TERM COMPLICATION	PERFORATED APPENDIX	DIABETES LONG-TERM COMPLICATION	COPD AND ASTHMA IN OLDER ADULTS
Race				
Black	0.679*** [0.533-0.865]	1.379 [0.517-3.680]	0.944 [0.807-1.105]	0.948 [0.815-1.103]
Hispanic	0.875 [0.590-1.297]	0.378 [0.045-3.161]	0.82 [0.638-1.055]	0.915 [0.803-1.042]
Other	0.450*** [0.269-0.754]	1.134 [0.482-2.668]	0.789** [0.632-0.987]	0.884* [0.777-1.005]
Age (years)				
18-39	2.242*** [1.829-2.748]	0.785 [0.409-1.507]	0.949 [0.769-1.171]	NA NA
65-74	0.758* [0.545-1.053]	1.031 [0.343-3.096]	0.708*** [0.621-0.806]	1.019 [0.946-1.097]
75+	0.337*** [0.220-0.517]	2.293 [0.821-6.405]	0.469*** [0.411-0.536]	0.766*** [0.707-0.831]
Gender				
Male	0.718*** [0.593-0.870]	1.235 [0.702-2.175]	1.171*** [1.070-1.281]	0.935*** [0.890-0.982]
Major comorbidity	1.058 [0.787-1.422]	0.548 [0.188-1.597]	0.96 [0.814-1.133]	0.819*** [0.720-0.931]
Payer Types				
Out of pocket	1.355** [1.020-1.800]	1.316 [0.459-3.776]	0.718** [0.544-0.947]	0.863 [0.706-1.056]
Medicaid/Medicare	1.342** [1.068-1.688]	1.511 [0.580-3.933]	1.064 [0.958-1.181]	1.361*** [1.267-1.461]
Neighborhood income	0.948* [0.902-0.996]	1.02 [0.910-1.143]	0.996 [0.971-1.022]	0.967*** [0.953-0.981]
N	3761	3991	10,317	31,900
Log lik.	−1474	−307.1	−5695.6	−18,549.8

COPD indicates chronic obstructive pulmonary disease; NA, not applicable; PQI, Prevention Quality Indicator.
The base case is a white female aged 40 to 64 years with private insurance.
The symbols ***, **, and * indicate $P < .01$, $P < .05$, and $P < .1$, respectively.
95% confidence intervals are expressed in brackets.

Effect of Income and Other Demographics

In our composite indexes, factors other than race appear to have a greater effect on PPRs. The presence of a major comorbidity and higher median neighborhood income at first admission are associated with a lower likelihood of readmission. In the all-PQI composite index, the largest effect is that of payment by Medicaid or Medicare, which increases the probability of readmission by approximately 50% (OR, 1.501; 95% CI, 1.443-1.562). This is followed in magnitude by the effect of the individual's age on likelihood of readmission: individuals aged 18 to 39 years are 34% less likely to have a PPR (OR, 0.640; 95% CI, 0.610-0.672). While the magnitudes of these effects differ between the acute composite and chronic composite, payment type and age affect probabilities the same way, regardless of the composite used.

The same factors play a role when we measure PPR by individual condition instead of by composite index. For example, payment by Medicaid or Medicare is related to a higher probability of readmission for 9 of the 13 conditions (ranging from OR, 1.287; 95% CI, 1.204-1.376 for CHF, to OR, 2.092; 95% CI, 1.167-3.751 for uncontrolled diabetes). A higher median neighborhood income is associated with a lower likelihood of readmission for the majority of conditions. However, people living in neighborhoods with above-average median income are more likely to be readmitted for hypertension (OR, 1.129; 95% CI, 1.050-1.214).

Discussion

Implications for Methodology

There is almost a 20-fold difference between the condition with the lowest readmission rate (perforated appendix) and that with the highest (CHF). These differences mean that the measuring index

	HYPERTENSION	CONGESTIVE HEART FAILURE	DEHYDRATION
	1.753*** [1.151-2.670]	1.221*** [1.109-1.346]	0.993 [0.832-1.185]
	1.132 [0.537-2.383]	1.441*** [1.242-1.673]	0.919 [0.631-1.338]
	1.741* [0.975-3.109]	0.947 [0.839-1.069]	0.972 [0.783-1.205]
	1.191 [0.720-1.971]	0.918 [0.735-1.147]	0.815** [0.683-0.974]
	0.422** [0.215-0.828]	1.031 [0.953-1.115]	0.816*** [0.708-0.940]
	0.443*** [0.255-0.767]	1.038 [0.965-1.117]	0.709*** [0.622-0.807]
	0.727* [0.509-1.038]	0.965 [0.924-1.008]	0.886*** [0.813-0.966]
	0.542 [0.177-1.659]	0.785*** [0.729-0.845]	0.874* [0.759-1.007]
	0.839 [0.466-1.475]	0.785** [0.648-0.950]	0.498*** [0.318-0.780]
	1.257 [0.792-1.995]	1.287*** [1.204-1.376]	1.369*** [1.204-1.558]
	1.129*** [1.050-1.214]	0.984*** [0.972-0.995]	0.991 [0.968-1.014]
	2654	45,367	27,117
	–580.9	–27,586.7	–8244.3

used will play a large role in the resulting PPR statistic.

A composite index of readmissions uses a weighted average of the readmission rates for individual conditions, with each weight determined by the proportion of that condition's admissions relative to those of all conditions in the composite. Thus, the effect of a single condition's readmissions on a PPR rate measured by a composite index is largely dependent on the proportion of initial admissions for that condition relative to all initial admissions. In each composite index, 1 or 2 conditions compose a large share of the initial admissions, and therefore have a significant effect on the overall rate of PPR.

For the all-PQI composite, the conditions with the greatest influence are bacterial pneumonia (36%) and CHF (28%); the acute index is dominated by bacterial pneumonia (61%), and the chronic index by COPD in adults (34%) and CHF (48%). These 3 conditions differ in their rates of readmissions (14% for bacterial pneumonia, 27% for COPD, and 30% for CHF), and in the effect of race on PPR. There is no statistically significant difference by race/ethnicity for COPD. The probability of PPR is higher for black individuals with CHF than for white individuals, while the reverse is true for bacterial pneumonia. As bacterial pneumonia and CHF differ in their condition-specific PPR rates, both the rate of PPR and the effect of race on that rate will vary depending on which of these dominant conditions are included in the measuring index.

Furthermore, conditions that do not typically result in many readmissions for the same or related conditions still impact PPR rates measured by composite index. For example, even if patients are rarely readmitted for a perforated appendix, a hospital with a high number of initial admissions for perforated appendix might have a high number of readmissions as measured by an all-PQI index simply by virtue of the fact that any subsequent admissions for a PQI after a perorated appendix will count as readmissions. We can think of the number of first admissions as establishing the size of the population for potential readmissions in any given index.

The factors affecting PPR rates—race, for example—depend largely on which measuring index is used. Because the race effect varies in direction over conditions, one might think it "averages out" in PPR rates measured by composite index. However, the race effect of the most common conditions in an index will dominate, again meaning that choice of index matters significantly for hospitals serving minority populations.

Black individuals have a statistically significantly higher probability of readmission than whites for 3 conditions: hypertension, CHF, and lower-extremity amputations among patients with diabetes. Similarly, the composite index reveals a statistically significant race effect: the probability of readmission is 5.9% higher for a black person than for a white person. This result is likely driven by CHF, a heavily weighted condition accounting for 28% of the initial admissions in the all-PQI index and 48% in the chronic composite index.

Policy Implications

Our results help to explain the variation in the literature on disparities in PPR by race/ethnicity by demonstrating that the factors associated with probability of readmissions are crucially influenced by the choice of measuring index. Specifically, the condition with the highest frequency of admission will determine whether or not a race effect exists. If the policy goal is to reduce disparities across race/ethnicities, using PPR rates for individual conditions is the only way to reveal which individuals and which conditions to target.

Racial disparities in PPR have been a topic of frequent discussion; however, our results suggest that income, not race, is the single socioeconomic factor most determinative of PPR rates. This finding suggests that the policy discussion should begin considering income as a potentially modifiable risk factor.

Linking Medicare reimbursement to PPRs reflects the popularization of economic incentives in public policy: Those hospitals with higher quality, as measured by PPR rates, receive a higher "price" for

Table 4. Odds Ratios by Individual PQI Conditions (continued)

COEFFICIENT	BACTERIAL PNEUMONIA	URINARY TRACT INFECTION	ANGINA WITHOUT PROCEDURE	UNCONTROLLED DIABETES
Race				
Black	0.871* [0.748-1.014]	1.1 [0.864-1.399]	0.933 [0.589-1.476]	0.803 [0.427-1.510]
Hispanic	1.015 [0.874-1.180]	0.697** [0.503-0.966]	1.156 [0.756-1.768]	1.108 [0.558-2.199]
Other	0.840*** [0.740-0.955]	0.831* [0.672-1.027]	0.338*** [0.150-0.758]	0.140* [0.018-1.064]
Age (years)				
18-39	0.666*** [0.589-0.753]	0.89 [0.741-1.067]	1.647* [0.995-2.726]	1.912** [1.083-3.375]
65-74	1.146*** [1.054-1.245]	0.889 [0.747-1.059]	1.054 [0.768-1.446]	0.474* [0.222-1.010]
75+	1.116*** [1.032-1.206]	0.98 [0.853-1.124]	1.361* [0.986-1.878]	0.666 [0.372-1.192]
Gender				
Male	1.181*** [1.129-1.236]	1.024 [0.926-1.132]	0.987 [0.795-1.226]	0.773 [0.494-1.209]
Major comorbidity	0.829*** [0.751-0.915]	1.046 [0.907-1.205]	1.141 [0.618-2.108]	1.642 [0.703-3.831]
Payer types				
Out of pocket	0.86 [0.700-1.057]	0.959 [0.697-1.320]	1.153 [0.682-1.951]	1.801 [0.801-4.048]
Medicaid/Medicare	1.680*** [1.534-1.840]	1.802*** [1.523-2.132]	1.589*** [1.163-2.172]	2.092** [1.167-3.751]
Neighborhood income	0.981** [0.965-0.997]	0.994 [0.972-1.017]	0.928** [0.875-0.985]	0.971 [0.863-1.092]
N	59,102	20,779	9774	2101
Log lik.	−23,513.6	−6889.8	−2007.3	−386.6

COPD indicates chronic obstructive pulmonary disease; NA, not applicable; PQI, Prevention Quality Indicator.
The base case is a white female aged 40 to 64 years with private insurance.
The symbols ***, **, and * indicate P <.01, P <.05, and P <.1, respectively.
95% confidence intervals are expressed in brackets.

their services. An administrator deciding how to allocate resources thus faces a single price for all outputs (Medicare discharges), while that price depends on the quality of a set of outputs (the small set of conditions Medicare uses to measure PPR). Such pricing should lead an administrator to shift inputs to reduce the PPRs for the condition(s) dominating the composite index if the benefit is greater than the cost of doing so. This response will reduce measured PPR, but may be inefficient if the resources spent could have been used to achieve even greater reductions in PPR for a different condition, or some greater improvement to hospital service that goes altogether unmeasured by PPR rates. These effects are consistent with the observation that certain conditions in particular are presently undertargeted: while current interventions focus on reducing readmissions for chronic heart failure and, to a lesser degree, COPD, few address the other conditions with high readmission rates.[30] If the policy goal is to encourage overall efficiency and earn the highest return for Medicare spending, the appropriate index would incentivize an overall efficient allocation of resources. To do so, we recommend a composite index of all 13 PQIs, with conditions weighted by relative cost.

Conclusions

An effective policy for improving healthcare efficiency or reducing disparities across sociodemographic groups must include a commonly accepted measure of PPRs. Medicare's current index measures admissions for only 3 conditions (and may be slightly expanded in the future), but that choice of measurement lacks a sound basis in the literature.

We examined the methodological issues in measuring PPR and discerned differences in rates and covariates that are attributable to the choice of measuring index rather than to underlying differences in the quality of hospital services. First, we demonstrated that pooling data over a range of conditions obscures differences in

ASTHMA IN YOUNGER ADULTS	LOWER-EXTREMITY AMPUTATION AMONG PATIENTS WITH DIABETES
1.236 [0.957-1.597]	1.534*** [1.119-2.103]
1.328** [1.028-1.716]	1.393 [0.845-2.297]
0.839 [0.540-1.305]	0.77 [0.502-1.179]
NA NA	0.987 [0.475-2.053]
NA NA	0.861 [0.686-1.080]
NA NA	0.789** [0.629-0.989]
0.892 [0.767-1.037]	1.204** [1.011-1.433]
1.066 [0.776-1.463]	0.604*** [0.470-0.776]
1.102 [0.894-1.358]	1.01 [0.446-2.287]
1.343*** [1.101-1.638]	1.057 [0.823-1.357]
0.950** [0.903-1.001]	1.01 [0.963-1.058]
3841	2951
–1858.2	–1502.5

PPR across individual conditions. These differences are important because a hospital's measured PPR will depend on the conditions included in the measuring index and the relative frequencies of those conditions; for this reason, tying reimbursements to the arbitrarily measured rate of PPR does not optimize efficiency. Second, we found no consistent relationship between probability of readmission and demographic predictors across the composite indexes and individual conditions. These findings explain the variation in the literature on the effect of race/ethnicity on PPR and suggest that there is no one-size-fits-all solution when designing hospital-level programs, public health interventions, or public policies.

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Table 5. Odds Ratios by PQI Composite

COEFFICIENT	ALL-PQI COMPOSITE	ACUTE COMPOSITE	CHRONIC COMPOSITE	DIABETES COMPOSITE	ASTHMA COMPOSITE
Race					
Black	1.059** [1.010-1.111]	0.964 [0.870-1.069]	1.032 [0.967-1.102]	0.880** [0.775-0.999]	1.437*** [1.246-1.656]
Hispanic	1.02 [0.945-1.100]	0.891* [0.793-1.002]	1.051 [0.974-1.135]	0.783*** [0.659-0.929]	1.433*** [1.244-1.652]
Other	0.828*** [0.782-0.877]	0.857*** [0.782-0.939]	0.858*** [0.797-0.925]	0.807** [0.675-0.964]	1.078 [0.826-1.408]
Age (years)					
18-39	0.640*** [0.610-0.672]	0.696*** [0.643-0.754]	0.812*** [0.756-0.873]	0.985 [0.867-1.119]	1097* [0.978-1.231]
65-74	1.193*** [1.146-1.241]	1.107*** [1.041-1.178]	1.108*** [1.056-1.162]	0.857*** [0.764-0.960]	0.709*** [0.602-0.836]
75+	1.229*** [1.179-1.282]	1.216*** [1.153-1.281]	1.052** [1.001-1.105]	0.575*** [0.518-0.639]	0.548*** [0.462-0.651]
Gender					
Male	1.031*** [1.009-1.053]	1.050*** [1.015-1.087]	0.973* [0.945-1.003]	1.080** [1.006-1.160]	0.833*** [0.746-0.931]
Major comorbidity	0.897*** [0.858-0.937]	0.894*** [0.838-0.955]	0.903*** [0.853-0.957]	0.917 [0.812-1.037]	0.821* [0.653-1.033]
Payer types					
Out of pocket	0.948 [0.887-1.012]	0.815*** [0.707-0.939]	0.924* [0.846-1.010]	0.835** [0.713-0.977]	1.062 [0.902-1.251]
Medicaid/ Medicare	1.501*** [1.443-1.562]	1.666*** [1.568-1.771]	1.436*** [1.368-1.507]	1.158*** [1.052-1.275]	1.384*** [1.239-1.547]
Neighborhood income	0.974*** [0.966-0.982]	0.990* [0.979-1.001]	0.978*** [0.970-0.987]	0.99 [0.972-1.009]	0.940*** [0.914-0.967]
N	164,217	97,232	95,117	15,770	12,842
Log lik.	−95,639.3	−43,625	−56,908.6	−8637.8	−5800

PQI indicates Prevention Quality Indicator.

The base case is a white female aged 40 to 64 years with private insurance.

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eAppendix. Supplemental Information

1. Admission records of patients younger than 18 years were excluded from this analysis. AHRQ has indicators specific to pediatric health.
2. This indicator includes only patients younger than 40 years. Asthma in adults 40 years and older is combined with COPD by AHRQ to eliminate the diagnostic uncertainty between these 2 conditions in older patients. See Expanding the use of AHRQ Prevention Quality Indicators, November 7, 2009, p 20. (http://www.qualityindicators.ahrq.gov/Downloads/Modules/PQI/PQI_Summary_Report.pdf)
3. Acute conditions include dehydration, bacterial pneumonia, and UTI, and chronic conditions encompass all remaining conditions except perforated appendix. PQI for perforated appendix is excluded from these 3 PQI composites because the denominator of admission rate of this condition is based on discharge (population at risk), while the denominator of admission rate for all other conditions is based on total area population.
4. For example, hypertension is defined by a list of primary diagnosis codes and exclusion criteria. These exclusion criteria include transfer from another hospital, skilled nursing facility, or intermediate care facility; and diagnosis code for stage I-IV kidney disease. Technical specifications of each PQI indicator are available at http://www.qualityindicators.ahrq.gov/Modules/PQI_TechSpec.aspx. Although most of the listed conditions are specified by using the primary diagnosis code, perforated appendix is based on a list of specific diagnosis codes in any of the diagnosis fields, and lower-extremity amputation among patients with diabetes is identified by both diagnosis and procedure codes.