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ORIGINAL RESEARCH

Inequities in Aortic Stenosis and Aortic Valve Replacement Between Black/African-American, White, and Hispanic Residents of Maryland

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BACKGROUND: Racial and ethnic inequities exist in surgical aortic valve replacement for aortic stenosis (AS), and early studies have suggested similar inequities in transcatheter aortic valve replacement.

METHODS AND RESULTS: We performed a retrospective analysis of the Maryland Health Services Cost Review Commission inpatient data set from 2016 to 2018. Black patients had half the incidence of any inpatient AS diagnosis compared with White patients (incidence rate ratio [IRR], 0.50; 95% CI, 0.48–0.52; $P<0.001$) and Hispanic patients had one fourth the incidence compared with White patients (IRR, 0.25; 95% CI, 0.22–0.29; $P<0.001$). Conversely, the incidence of any inpatient mitral regurgitation diagnosis did not differ between White and Black patients (IRR, 1.00; 95% CI, 0.97–1.03; $P=0.97$) but was significantly lower in Hispanic compared with White patients (IRR, 0.36; 95% CI, 0.33–0.40; $P<0.001$). After multivariable adjustment, Black race was associated with a lower incidence of surgical aortic valve replacement (IRR, 0.67; 95% CI, 0.55–0.82 $P<0.001$ relative to White race) and transcatheter aortic valve replacement (IRR, 0.77; 95% CI, 0.65–0.90; $P=0.002$) among those with any inpatient diagnosis of AS. Hispanic patients had a similar rate of surgical aortic valve replacement and transcatheter aortic valve replacement compared with White patients.

CONCLUSIONS: Hospitalization with any diagnosis of AS is less common in Black and Hispanic patients than in White patients. In hospitalized patients with AS, Black race is associated with a lower incidence of both surgical aortic valve replacement and transcatheter aortic valve replacement compared with White patients, whereas Hispanic patients have a similar incidence of both. The reasons for these inequities are likely multifactorial.

Key Words: aortic stenosis ■ racial and ethnic inequities ■ surgical aortic valve replacement ■ transcatheter aortic valve replacement

See Editorial by Edelman and Thourani

Aortic stenosis (AS) is the second most common valvular heart disease in the United States, occurring in 0.4% of the adult population.[1] Although surgical aortic valve replacement (SAVR) is the historic standard for the treatment of severe symptomatic AS, in recent years transcatheter aortic valve replacement (TAVR) has become the preferred treatment in patients at intermediate or higher risk for SAVR as a result of its minimal invasiveness, more rapid recovery, and equivalent outcomes.[2–8] Furthermore, TAVR has recently received approval from the US Food and Drug Administration for low surgical risk patients with severe AS.[9,10] National uptake of TAVR has been rapid—according to the most recently available data, more than 70 000 TAVRs have

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CLINICAL PERSPECTIVE

What Is New?

- Non-Hispanic Black and Hispanic patients aged 50 or greater in Maryland had approximately half and one-quarter the incidence of hospitalization with any diagnosis of aortic valve stenosis as compared with White patients, respectively.
- After multivariable adjustment, non-Hispanic Black race predicts a lower incidence of both surgical and transcatheter aortic valve replacement among those with aortic stenosis whereas Hispanic ethnicity does not.
- Non-Hispanic White and non-Hispanic Black patients have a similar incidence of hospitalization with any diagnosis of mitral regurgitation, but both non-Hispanic Black and Hispanic patients have a lower incidence of surgical mitral valve repair or replacement than White patients.

What Are the Clinical Implications?

- The pathophysiology of aortic valve stenosis may differ in important and clinically relevant ways according to race and ethnicity, potentially paralleling differences in aortic valve stenosis seen between men and women.
- Elucidating racial and ethnic differences in the pathophysiology of aortic valve stenosis would have important implications for its diagnosis and management, particularly in borderline severe cases when different imaging criteria may be necessary (eg, aortic valve calcium score).
- Clinicians should remain vigilant for possible racial and ethnic diagnostic and therapeutic referral biases as well as differences in healthcare-related attitudes and practices that may contribute to the observed inequities.

Nonstandard Abbreviations and Acronyms

AS	aortic stenosis
CCS	Clinical Classifications Software
HSCRC	Health Services Cost Review Commission
IRR	incidence rate ratio
SAVR	surgical aortic valve replacement
SMVR	surgical mitral valve repair/replacement
TAVR	transcatheter aortic valve replacement
TMVR	transcatheter mitral valve repair/replacement

been performed in the United States with Food and Drug Administration-approved devices from the first approval in 2011 through mid-2016.[11]

Racial and ethnic inequities in medical care are well documented in SAVR as well as in cardiology and medicine more generally, particularly with new technologies.[12–19] Early indications are that TAVR is no different; the trial of a balloon-expandable prosthesis in low-risk patients was the only pivotal TAVR trial to report the proportion of non-White patients included (8.7%).[9] Black, Hispanic, and other racial and ethnic groups comprised only 3.8%, 3.4%, and 1.5%, respectively, of patients undergoing TAVR with a Food and Drug Administration-approved device from November 2011 to June 2016, numbers markedly disproportionate to the racial and ethnic composition of the US population.[11] Although there is some evidence to support the notion that AS prevalence is less in Black/African-American patients,[20] the inequities in treatment seem too significant and the history of inequities in medicine too great to attribute racial inequities in TAVR to differences in disease prevalence alone. Notably, this is occurring in the context of the clear recognition of racial inequities in medical care and the call for action in an Institute of Medicine report more than 15 years ago.[21]

Although there is increasing recognition of racial/ethnic inequities in TAVR, the extent of the problem and its possible causes remain unclear. Prior studies in TAVR patients are few and limited in important ways. The majority of large studies have used the National Inpatient Sample, which does not allow linkage of multiple hospital admissions for the same patient.[22–24] As a result, studies of racial inequities in TAVR using National Inpatient Sample data are limited by the use of admissions rather than patients as the denominator and therefore cannot accurately estimate AS prevalence nor TAVR or SAVR incidence on a per-patient basis. Studies using other data are limited by very small sample sizes. In contrast, Maryland provides a unique opportunity to study racial/ethnic inequities in TAVR in an unselected population because of the existence of the Maryland Health Services Cost Review Commission (HSCRC) inpatient revisit data set, which contains administrative data for every inpatient hospitalization in the state and contains individual patient identifiers enabling patient-based analysis across multiple hospital visits. Therefore, we undertook the present study to determine the extent of racial/ethnic inequities in AS, SAVR, and TAVR in Maryland.

METHODS

Because of the sensitive nature of the data collected for this study, requests to access the data set from qualified researchers trained in human subjects confidentiality protocols may be sent to the Maryland HSCRC at

4160 Patterson Avenue, Baltimore, MD 21215 (phone 888-287-3229). The authors agree to provide their analysis scripts for purposes of reproducing the results or replicating the procedure upon written request to the corresponding author. This study was approved by the Johns Hopkins University School of Medicine Institutional Review Board, with a waiver of informed consent.

Data Source

All acute care hospitals in the state of Maryland are required to submit confidential patient-level administrative data for every inpatient hospitalization to the Maryland HSCRC. The HSCRC data are primarily used for analyses of the cost of health care in Maryland but are also available for research use. The "revisit" data set contains a unique patient identifier that allows each individual patient to be tracked across multiple visits and years. We used the Maryland HSCRC inpatient revisit data set for calendar years 2016 to 2018, because 2016 was the first full year for which *International Classification of Diseases, Tenth Revision, Clinical Modification* (*ICD-10-CM*) codes were available, allowing differentiation of AS from aortic regurgitation. The first author (MJC) had full access to the data and takes responsibility for the integrity of the analyses.

Outpatient and observation visits are not included in the HSCRC inpatient revisit data set but are available separately. We did not use the outpatient and observation data sets for this study because they include only visits that occurred on a hospital campus. Because a majority of outpatient visits do not occur on a hospital campus and there may be considerable racial/ethnic differences in outpatient visit locations, we felt the selection bias introduced by these data sets was likely to be too significant to be useful for this analysis.

Data Encoding

The unit of analysis for our study was the individual patient. Age was available only as a range of 5 years (50–54, 55–59, …, 85+), and the age for an individual patient with more than 1 admission in the year was determined to be the maximum range for any of that patient's hospitalizations during the time period of the study. Demographic variables consisted of race/ethnicity (non-Hispanic White, non-Hispanic Black/African American [hereinafter referred to as Black], Hispanic), sex, marital status (single, married, separated/divorced, widow/widower), primary payer (Medicare, Medicaid, commercial, charity/self-pay, other), and ZIP code. For patients with more than 1 admission, demographic variables were set to the most common category of all admissions during the time period of the study (the "mode"); those with no mode or more than 1 mode were set to missing as it was not possible to determine which was accurate. Median income for a patient was the median income for the patient's ZIP code tabulation area in 2016 according to US Census Bureau estimates.

We used discharge *ICD-10-CM* codes for all diagnoses and procedures. AS was defined as *ICD-10-CM* codes I06.0, I06.2, I35.0, I35.2, or Q23.0, mitral regurgitation (MR) was defined as *ICD-10-CM* codes I05.1, I05.2, and I34.0, and mitral stenosis was defined as *ICD-10-CM* codes I05.1, I05.2, and I34.2. Codes used for all other diagnoses were as specified by the US Agency for Healthcare Research and Quality Clinical Classifications Software (CCS) for *ICD-10-CM* (single-level diagnoses, version 2019.1).[25] Definitions for comorbidities comprised the following groups: cerebrovascular disease, CCS categories 109, 110, 111, and 112; chronic kidney disease, CCS category 158; chronic obstructive pulmonary disease, CCS category 127; congestive heart failure, CCS category 108; coronary artery disease, CCS categories 100 and 101; diabetes mellitus, CCS categories 49 and 50; hypertension, CCS categories 98 and 99; and peripheral artery disease, categories 114 and 115. Diagnoses were considered to be present if noted in any discharge diagnosis for any acute inpatient hospitalization during the time period of analysis. The TAVR procedure was defined as *International Classification of Diseases, Tenth Revision, Procedure Coding System* (*ICD-10-PCS*) codes 02RF37H, 02RF37Z, 02RF38H, 02RF38Z, 02RF3JH, 02RF3JZ, 02RF3KH, or 02RF3KZ, and the SAVR procedure consisted of *ICD-10-PCS* codes 02RF07Z, 02RF08Z, 02RF0JZ, or 02RF0KZ. *ICD-10-PCS* codes X2RF332 (TAVR) and X2RF032 (SAVR) denote "new technology" and came into use after the design of our study, and we are unable to tell if these codes were used to denote procedures done in the context of clinical research, which could be more susceptible to racial/ethnic inequities. Therefore, we performed a supplementary analysis including these codes in the TAVR and SAVR definitions. The transcatheter mitral valve repair or replacement (TMVR) procedure was defined as *ICD-10-PCS* codes 02RG37H, 02RG37Z, 02RG38H, 02RG38Z, 02RG3JH, 02RG3JZ, 02RG3KH, 02RG3KZ, 02QG3ZE, 02QG3ZZ, 02UG37E, 02UG37Z, 02UG38E, 02UG38Z, 02UG3JE, 02UG3JZ, 02UG3KE, 02UG3KZ, or 02VG3ZZ, and the surgical mitral valve repair or replacement (SMVR) procedure was defined as *ICD-10-PCS* codes 02RG07Z, 02RG08Z, 02RG0JZ, 02RG0KZ, 02QG0ZE, 02QG0ZZ, 02UG07E, 02UG07Z, 02UG08E, 02UG08Z, 02UG0JE, 02UG0JZ, 02UG0KE, 02UG0KZ, or 02VG0ZZ. Echocardiography was defined as *ICD-10-PCS* codes B245YZZ, B246YZZ, B24BYZZ, B245ZZZ, B246ZZZ, B24BZZZ, B245ZZ4, B246ZZ4, and B24BZZ4.

Statistical Analysis

Hospitalization, Diagnosis, and Procedure Incidence Rates

We included all patients who are residents of Maryland (either by home ZIP code or with known Maryland residency) aged 50 or older who underwent hospitalization at an acute inpatient facility in Maryland. Patients with more than 1 race or who were missing race data were excluded. The incidence rates of all-cause inpatient hospitalization, inpatient hospitalization with any diagnosis of AS, inpatient hospitalization with SAVR, inpatient hospitalization with TAVR, and inpatient echocardiography were calculated using the US Census Bureau population estimate (from SC-EST2017-ALLDATA6: Annual State Resident Population Estimates for 6 Race Groups by Age, Sex, and Hispanic Origin: April 1, 2010 to July 1, 2017)[26] as a midpoint population estimate for each year. US Census Bureau population estimates were not available for 2018, so we assumed linear growth in each racial/ethnic group from 2016 to 2018. Incidence rates of inpatient hospitalization with MR, SMVR, and TMVR were calculated in the same fashion; MR was included to serve as an internal "control" because it is also diagnosed by echocardiography and rates are not thought to vary by race/ethnicity, whereas SMVR and TMVR were included as similar surgical and transcatheter comparators.

We also calculated the incidence rates of SAVR and TAVR in the population of patients with any inpatient diagnosis of AS, and as a comparator, the incidence rates of SMVR and TMVR in those with any inpatient diagnosis of MR. Because date of hospitalization was available only as quarter and year, follow-up time was determined assuming that hospitalization or death occurred at the midpoint of the quarter (eg, hospitalization in quarter 1 of 2016 was considered to have happened at 0.125 years into the study). We did not have data on outpatient deaths; all patients without an inpatient death were assumed to have lived for the full 3 years of the study period for the determination of follow-up time.

Factors Associated With AS, TAVR, and SAVR

Baseline demographics and comorbidities are reported as proportions for categorical variables and median (interquartile range) for continuous variables. Categorical variables were compared with the chi-square test and continuous variables with the Kruskal–Wallis test. Multivariable negative binomial regression was used to model the association of race and other baseline factors with incidence of inpatient hospitalization with AS or MR because the outcome mean and variance were markedly different, making Poisson regression inappropriate. Univariate associations of procedures with baseline variables were determined by univariate Poisson regression with a robust variance estimator. Follow-up time was determined as noted previously. Multivariate analyses for factors associated with TAVR, SAVR, and SMVR used Poisson regression with all variables in the univariate regressions. We were unable to perform an analysis of factors associated with TMVR because of the very low incidence of TMVR. All regressions also assessed for interactions between race and age as well as between race and sex, and nonsignificant interactions were excluded from the final models. Marital status was missing for 3.0% of all hospitalized patients, 2.9% of patients with any inpatient diagnosis of AS, and 3.2% of patients with any inpatient diagnosis of MR; primary payer for 1.5%, 1.1%, and 1.5%, respectively; median household income for 3.0%, 3.4% and 3.1%, respectively; and sex for 0.02%, 0.01%, and 0.05%, respectively. Therefore, we performed supplemental analyses for AS, MR, SAVR, and TAVR using multiple imputation by chained equations with n=10 imputed data sets. All variables and interactions included in the outcome model were included in the imputation model.

All analyses were performed in Stata version 15.1 (StataCorp, College Station, TX). Poisson and negative binomial regressions used the robust variance estimator (option *vce[robust]*). Multiple imputation models used the *augment* option to avoid collinearity. Statistical significance was set at α=0.05 for all statistical comparisons except interaction effects, for which significance was set at α=0.001, and there was no correction for multiple comparisons. Note that because of concerns for the potential to identify individual patients, per the data use agreement cells containing n≤10 or those enabling the calculation of cells containing n≤10 are only reported as such.

RESULTS

Incidence of Acute Inpatient Hospitalization and AS

From January 2016 through December 2018 there were more than 1.8 million inpatient hospitalizations in Maryland. Of those, 433 078 unique patients underwent 896 274 acute inpatient hospitalizations, were Maryland residents, were aged ≥50 years, and were non-Hispanic White, non-Hispanic Black, or Hispanic and therefore constituted the study population (Figure). These were the 3 most common racial/ethnic groups in our data; other groups had numbers too small to form meaningful conclusions and therefore were excluded. Black patients had a slightly

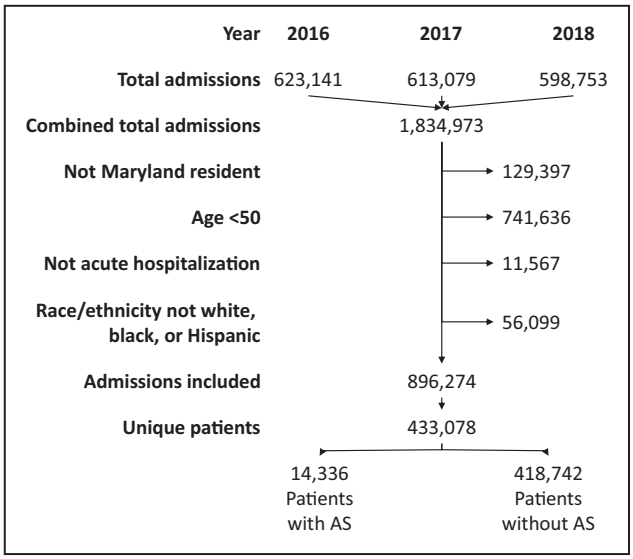

Figure 1. Selection of study cohort.
AS indicates aortic stenosis.

higher incidence of any acute inpatient hospitalization (7503 per 100 000 patient-years) compared with White patients (7367 per 100 000 person-years, incidence rate ratio [IRR], 1.02; 95% CI, 1.01–1.03; *P*<0.001; Table 1). Hispanic patients had approximately half the incidence of acute inpatient hospitalization of either White (IRR, 0.53; 95% CI 0.52–0.54 *P*<0.001) or Black patients (IRR, 0.52; 95% CI, 0.51–0.53; *P*<0.001). However, Black patients had half the incidence of hospitalization with any diagnosis of AS compared with White patients (IRR, 0.50; 95% CI, 0.48–0.52; *P*<0.001) and Hispanic patients had one quarter the incidence of hospitalization with any diagnosis of AS (IRR, 0.25; 95% CI, 0.22–0.29; *P*<0.001, Table 1). In comparison, the incidence of hospitalization with any inpatient diagnosis of MR was similar in Black and White patients (IRR, 1.00; 95% CI, 0.97–1.03, *P*=0.97) but much less in Hispanic patients compared with both White and Black patients (IRR, 0.36, 95% CI, 0.33–0.40; *P*<0.001; and IRR, 0.36; 95% CI, 0.32–0.40; *P*<0.001; respectively). Furthermore, Black patients had the highest incidence of inpatient echocardiography (498 per 100 000 patient-years), followed by White patients (381 per 100 000 patient-years) and Hispanic patients (355 per 100 000 patient-years), differences that were significant for Black compared with White patients (IRR, 1.31; 95% CI, 1.27–1.34; *P*<0.001), Hispanic compared with Black patients (IRR, 0.71; 95% CI, 0.67–0.76; *P*<0.001), and Hispanic compared with White patients (IRR, 0.93; 95% CI, 0.88–0.99; *P*=0.025). Importantly, except for White compared to Hispanic patients, these differences in the incidence of inpatient echocardiography persisted even when

Table 1. Incidence Rates and Rate Ratios of Any Inpatient Hospitalization, Inpatient Hospitalization With Any Diagnosis of Aortic Stenosis, Inpatient Hospitalization With a Primary Admitting Diagnosis of Aortic Stenosis, and Inpatient Hospitalization With Mitral Regurgitation in Patients Aged ≥50 Years in Maryland From 2016 Through 2018, According to Race/Ethnicity

	Any Hospitalization			Any Aortic Stenosis			Primary Diagnosis of Aortic Stenosis			Any Mitral Regurgitation		
	Estimate	95% CI	*P* Value	Estimate	95% CI	*P* Value	Estimate	95% CI	*P* Value	Estimate	95% CI	*P* Value
Incidence rate												
White	7367	…	…	293	…	…	55	…	…	308	…	…
Black	7503	…	…	147	…	…	19	…	…	309	…	…
Hispanic	3898	…	…	75	…	…	16	…	…	112	…	…
Incidence rate ratio												
B vs W	1.02	1.01–1.03	<0.001	0.50	0.48–0.52	<0.001	0.35	0.31–0.40	<0.001	1.00	0.97–1.03	0.97
H vs W	0.53	0.52–0.54	<0.001	0.25	0.22–0.29	<0.001	0.30	0.22–0.39	<0.001	0.36	0.33–0.40	<0.001
H vs B	0.52	0.51–0.53	<0.001	0.51	0.44–0.58	<0.001	0.84	0.61–1.13	0.24	0.36	0.32–0.40	<0.001

Incidence rates are per 100 000 person-years. B indicates black; CI, confidence interval; H, Hispanic; and W, white.

echocardiography performed during hospitalizations for SAVR or TAVR were excluded. When stratified by age, the incidence rate ratios for comparisons of hospitalizations, hospitalizations with AS, hospitalizations with MR, and inpatient echocardiography were similar to the crude combined estimates, but nearly all comparisons had evidence of an effect of differing age group structures by race (Table 2).

Predictors of AS in Inpatients

Among 433 078 Maryland residents aged 50 years or older with at least 1 acute inpatient hospitalization from 2016 to 2018, 14 336 patients (3.3%) had a diagnosis of AS (Figure, Table S1). In the entire population of hospitalized patients, Black and Hispanic patients were younger than White patients, more frequently female, and had a higher prevalence of diabetes mellitus but less frequently were married and had Medicare as the primary payer. Black and Hispanic patients had a lower prevalence of coronary artery disease compared with White patients, and Black patients more frequently had congestive heart failure (24.1%) and chronic kidney disease (29.3%). After controlling for demographic and socioeconomic characteristics as well as comorbidities, Black and Hispanic patients still had a lower incidence of any inpatient diagnosis of AS (IRR, 0.45; 95% CI, 0.42–0.49; $P<0.001$ for Black versus White; and IRR, 0.67; 95% CI, 0.58–0.78; $P<0.001$ for Hispanic versus White, Table S2) whereas the incidence of hospitalization with any diagnosis of MR was more similar across races (IRR, 1.20; 95% CI, 1.13–1.28; $P<0.001$ for Black versus White; and IRR, 0.89; 95% CI, 0.79–1.01; $P=0.77$ for Hispanic versus White). A supplemental analysis using multiple imputation to address missing data was entirely consistent with the primary analysis (data not shown).

Characteristics of Patients With AS According to Race/Ethnicity

Among the 14 336 patients hospitalized with any diagnosis of AS, 80.5% were White, 17.9% were Black, and 1.6% were Hispanic (Table 3). Notably, this was disproportional to the overall population of Maryland aged 50 years or older during the study period, which was 65.8% non-Hispanic White, 29.1% non-Hispanic Black, and 5.2% Hispanic. More Black patients were female (61.4%) compared with White (49.7%) and Hispanic patients (55.8%, $P<0.001$), and the age distribution of Black patients was shifted toward younger ages when compared with the White and Hispanic groups. Hispanic patients had the highest median income by ZIP code tabulation area (median $76 212, interquartile range $65 103–$100 037), followed by White patients ($74 201, $61 000–$96 026) and Black patients ($63 635, $45 439–$77 413). Black patients

Table 2. Incidence Rate Ratios of Any Inpatient Hospitalization, Inpatient Hospitalization With Any Diagnosis of Aortic Stenosis, and Inpatient Hospitalization With Mitral Regurgitation in Patients Aged ≥50 Years in Maryland From 2016 Through 2018, According to Race/Ethnicity and Stratified by Age

Age Group	Any Hospitalization			Aortic Stenosis			Mitral Regurgitation		
	Black vs White	Hispanic vs White	Hispanic vs Black	Black vs White	Hispanic vs White	Hispanic vs Black	Black vs White	Hispanic vs White	Hispanic vs Black
50–54	1.32	0.63	0.47	0.72	0.49	0.68	2.01	0.61	0.31
55–59	1.29	0.60	0.47	0.79	0.20	0.25	1.80	0.52	0.29
60–64	1.21	0.64	0.53	0.72	0.36	0.50	1.52	0.52	0.34
65–69	1.13	0.65	0.57	0.74	0.29	0.39	1.51	0.55	0.36
70–74	1.08	0.71	0.66	0.73	0.40	0.55	1.14	0.49	0.43
75–79	1.04	0.71	0.68	0.70	0.34	0.48	1.02	0.51	0.49
80–84	0.99	0.68	0.69	0.63	0.48	0.77	0.88	0.46	0.52
85+	0.93	0.64	0.69	0.61	0.51	0.83	0.80	0.53	0.66
P-value*	<0.001	<0.001	<0.001	0.04	0.13	0.009	<0.001	0.97	<0.001

*Mantel-Haenszel test of homogeneity.

Table 3. Demographic Characteristics and Comorbidities of Patients With Any Inpatient Diagnosis of Aortic Stenosis According to Race/Ethnicity

	All (n=14 336)	White (n=11 545)	Black (n=2560)	Hispanic (n=231)	*P* Value
Female sex*	51.9	49.7	61.4	55.8	<0.001
Age					
50–54	1.5	1.3	2.4	NR†	<0.001
55–59	3.0	2.7	4.8	NR	
60–64	5.6	5.2	7.6	6.9	
65–69	8.0	7.4	10.7	6.5	
70–74	11.8	11.4	13.6	10.8	
75–79	14.8	14.6	16.2	11.3	
80–84	18.2	18.4	17.0	20.4	
≥85	37.1	39.1	27.7	37.2	
Median household income ($)‡	72 454 (59 720–92 653)	74 201 (61 000–96 026)	63 635 (45 439–77 413)	76 212 (65 103–100 037)	<0.001
Marital status§					
Single	12.5	9.4	26.1	18.3	<0.001
Married	44.0	46.8	31.7	39.7	
Separated/divorced	8.7	8.2	10.6	10.7	
Widow/widower	34.8	35.6	31.6	31.3	
Primary payer‖					
Medicare	88.4	89.0	86.5	77.0	<0.001
Medicaid	2.6	1.9	5.1	11.7	
Commercial	8.1	8.2	7.4	NR	
Charity/self-pay	0.2	0.2	NR	NR	
Other	0.8	0.8	NR	NR	
Comorbidities					
Mitral regurgitation	11.3	11.2	11.8	13.9	0.30
Mitral stenosis	1.7	1.7	1.4	NR	0.32
Diabetes mellitus	52.5	49.7	64.5	59.7	<0.001
Coronary artery disease	68.1	68.7	66.5	58.9	0.001
Congestive heart failure	59.0	57.5	65.9	55.4	<0.001
Peripheral vascular disease	29.1	28.5	31.9	26.0	0.002
Cerebrovascular disease	20.2	19.5	23.1	17.8	<0.001
Any arterial vascular disease¶	77.9	78.1	77.7	69.7	0.009
COPD	34.5	35.1	33.5	19.5	<0.001
Chronic kidney disease	44.6	41.7	58.2	42.0	<0.001
Aortic valve replacement					
Surgical	7.5	7.9	5.3	10.8	<0.001
Transcatheter	9.7	10.3	6.9	9.5	<0.001

COPD indicates chronic obstructive pulmonary disease.

*n=14 335.

†NR="not reported" because n≤10 or because this lowest value cell would make calculation of the exact number possible for a cell with n≤10, and therefore may not be reported per the data use agreement.

‡n=13 845.

§n=13 917.

‖n=14 182.

¶Any arterial vascular disease=coronary artery disease, peripheral vascular disease, or cerebrovascular disease.

were less frequently married (31.7%) and had the highest burden of diabetes mellitus (64.5%), congestive heart failure (65.9%), cerebrovascular disease (23.1%), and chronic kidney disease (56.5%). Hispanic patients had the highest proportion of charity/self-pay, whereas White patients had the highest proportion of Medicare as the primary payer (89.0%).

The most common primary admission diagnosis for patients with any inpatient diagnosis of AS according to race/ethnicity is shown in Table S3. Although

"non-rheumatic aortic (valve) stenosis" was the most frequent primary admission diagnosis in White and Hispanic patients, it was only the third most common in Black patients.

Incidence of SAVR and TAVR

A total of 1076 patients with any inpatient diagnosis of AS underwent 1084 hospitalizations with SAVR and 1388 patients underwent 1390 hospitalizations with TAVR in 2016 to 2018; nearly all patients had a single hospitalization for either SAVR or TAVR. Among the entire population of Maryland aged 50 years and older, the incidence of SAVR was 37.3, 15.4, and 13.9 per 100 000 patient-years for White, Black, and Hispanic patients, respectively. Among patients with any inpatient diagnosis of AS, the incidence of SAVR was 2916, 1934, and 4036 per 100 000 patient-years for White, Black, and Hispanic patients, respectively, though this difference was significant only for Black compared with White patients (IRR, 0.66; 95% CI, 0.55–0.79; *P*<0.001) and Hispanic compared with Black patients (IRR, 2.09; 95% CI, 1.31–3.21; *P*=0.002). Similarly, the incidence of TAVR among the entire population was 33.9, 11.8, and 7.4 per 100 000 patient-years for White, Black, and Hispanic patients, respectively, and among patients with any inpatient diagnosis of AS was 3805, 2513, and 3553 per 100 000 patient-years for White, Black, and Hispanic patients, respectively. The difference was statistically significant in the AS population for only Black compared with White (IRR, 0.66; 95% CI, 0.56–0.77; *P*<0.001). Black patients were less likely to have a scheduled admission for SAVR, but there were no other differences in the acuity of admission according to race/ethnicity during the admission for SAVR or TAVR (Table 4).

Table 4. Status of Admission for TAVR or SAVR According to Race/Ethnicity

SAVR (n=1084)	All	White	Black	Hispanic	*P* Value
		n=922	n=137	n=25	
Emergent	14.9	13.5	NR*	NR	0.036
Urgent	4.3	NR	NR	NR	
Scheduled	79.6	81.5	68.6	NR	
Other	NR	NR	NR	NR	
Unknown	NR	NR	NR	NR	
TAVR (n=1390)		**n=1191**	**n=177**	**n=22**	
Emergent	13.5	13.9	NR	NR	0.88
Urgent	NR	NR	NR	NR	
Scheduled	82.7	82.2	84.2	NR	
Other	NR	NR	NR	NR	
Unknown	NR	NR	NR	NR	

All values are percentages. SAVR indicates surgical aortic valve replacement; and TAVR, transcatheter aortic valve replacement.

*NR="not reported" because n≤10 or because this lowest value cell would make calculation of the exact number possible for a cell with n≤10, and therefore may not be reported per the data use agreement.

By comparison, among the entire population of Maryland aged 50 years and older, the incidence of SMVR was 21.0, 12.7, and 6.1 per 100 000 patient-years and the incidence of TMVR was 1.7, 0.8, and 0.6 per 100 000 patient-years for White, Black, and Hispanic patients, respectively. Among 17 876 patients with any inpatient diagnosis of MR, the incidence of SMVR was 1601, 934 and 1013 per 100 000 patient-years for White, Black, and Hispanic patients, respectively. The difference was significant for White versus Black (IRR, 0.58; 95% CI, 0.48–0.70; *P*<0.001) but not for White versus Hispanic (IRR, 0.63; 95% CI, 0.30–1.17; *P*=0.14) or Black versus Hispanic patients (IRR, 1.08; 95% CI, 0.51–2.05; *P*=0.77). Similarly, the incidence of TMVR among those with MR was 168, 78, and 201, per 100 000 patient-years for White, Black, and Hispanic patients, respectively, and again this difference was significant for White versus Black (IRR, 0.47; 95% CI, 0.23–0.88; *P*=0.011) but not for White versus Hispanic (IRR, 1.20; 95% CI, 0.14–4.52; *P*=0.74) or Black versus Hispanic patients (IRR 2.56, 95% CI 0.28–11.49, *P*=0.26).

Outcomes of SAVR and TAVR

Inpatient death after SAVR occurred in 2.0% of admissions of White patients, and there were too few deaths of patients of Black race or Hispanic ethnicity after SAVR to report exact rates (≤10) but there was no statistically significant difference in death rates according to race/ethnicity (*P*=0.069). Total length of stay for the SAVR hospitalization was longest for Black patients (median 8 days, interquartile range [IQR] 6–14), intermediate for White patients (7 days, IQR 5–10), and shortest for Hispanic patients (6 days, IQR 4–8; *P*<0.001). Total charges during SAVR admission followed a similar pattern and were higher for Black patients (median $67 095, IQR $50 950–$92 128) than for White ($57 501, IQR $45 044–$74 760) or Hispanic patients ($50 353, IQR $38 844–$68 184, *P*<0.001).

Inpatient death after TAVR occurred in 1.1% of admissions of White patients; there were also too few deaths in patients of Black race or Hispanic ethnicity to report exact rates (≤10), but again there was no difference in death rates after TAVR by race/ethnicity (*P*=0.17). Length of stay did not vary according to race (median 2 days, IQR 2–5 for White; 3 days, IQR 2–5 for Black; and 2 days, IQR 2–3 for Hispanic; *P*=0.23). There was no difference in total charges during TAVR admission according to race/ethnicity ($71 170, IQR $62 460–84 591 for White; $70 253, IQR $61 269–$87 158 for Black; and $64 010, IQR $57 806–$73 777 for Hispanic; *P*=0.088).

Table 5. Predictors of SAVR in Patients With Any Inpatient Diagnosis of Aortic Stenosis

	Univariate			Multivariate		
	Incidence Rate Ratio	95% CI	*P* Value	Incidence Rate Ratio	95% CI	*P* Value
Race/ethnicity						
White (reference)	…	…	…	…	…	…
Black	0.66	0.55–0.79	<0.001	0.67	0.55–0.82	<0.001
Hispanic	1.38	0.93–2.05	0.11	1.23	0.82–1.85	0.32
Female sex*	0.47	0.42–0.54	<0.001	0.76	0.66–0.87	<0.001
Age						
50–54 (reference)	…	…	…	…	…	…
55–59	0.81	0.60–1.10	0.18	0.81	0.60–1.10	0.19
60–64	0.68	0.51–0.89	0.006	0.65	0.49–0.86	0.002
65–69	0.51	0.38–0.67	<0.001	0.54	0.40–0.72	<0.001
70–74	0.43	0.33–0.56	<0.001	0.50	0.37–0.67	<0.001
75–79	0.26	0.20–0.34	<0.001	0.33	0.24–0.45	<0.001
80–84	0.13	0.10–0.17	<0.001	0.18	0.13–0.25	<0.001
≥85	0.02	0.01–0.03	<0.001	0.03	0.02–0.04	<0.001
Median household income (per $10 000)†	1.00	0.98–1.03	0.82	0.99	0.96–1.01	0.31
Marital status‡						
Single (reference)	…	…	…	…	…	…
Married	1.62	1.34–1.97	<0.001	1.71	1.38–2.11	<0.001
Separated/divorced	1.33	1.03–1.71	0.031	1.41	1.08–1.84	0.010
Widow/widower	0.36	0.28–0.46	<0.001	1.21	0.92–1.59	0.17
Primary payer§						
Medicare (reference)	…	…	…	…	…	…
Medicaid	3.00	2.30–3.91	<0.001	1.14	0.84–1.56	0.41
Commercial	5.14	4.49–5.89	<0.001	1.39	1.16–1.67	<0.001
Charity/self-pay	2.01	0.63–6.48	0.24	0.78	0.22–2.80	0.70
Other	2.91	1.80–4.69	<0.001	1.49	0.89–2.50	0.13
Comorbidities						
Diabetes mellitus	1.84	1.62–2.08	<0.001	1.44	1.26–1.65	<0.001
Coronary artery disease	1.58	1.38–1.82	<0.001	1.86	1.60–2.17	<0.001
Congestive heart failure	0.49	0.44–0.56	<0.001	0.76	0.66–0.87	<0.001
Peripheral vascular disease	1.34	1.18–1.52	<0.001	1.42	1.25–1.62	<0.001
Cerebrovascular disease	0.76	0.64–0.89	0.001	0.81	0.69–0.96	0.015
COPD	0.53	0.46–0.61	<0.001	0.54	0.46–0.63	<0.001
Chronic kidney disease	0.39	0.34–0.45	<0.001	0.46	0.39–0.53	<0.001

N=13 351 for the multivariate model. CI indicates confidence interval; and COPD, chronic obstructive pulmonary disease.
*n=14 335.
†n=13 845.
‡n=13 917.
§n=14 182.

Predictors of SAVR and TAVR

Predictors of SAVR in patients with AS are shown in Table 5. By multivariate Poisson regression, Black race (IRR, 0.67; 95% CI, 0.55–0.82; *P*<0.001), female sex (IRR, 0.76; 95% CI, 0.66–0.87; *P*<0.001), older age (IRR, 0.03; 95% CI, 0.02–0.04; *P*<0.001 for age ≥85 compared with 50–54), congestive heart failure (IRR, 0.76; 95% CI, 0.66–0.87; *P*<0.001), cerebrovascular disease (IRR, 0.81; 95% CI, 0.69–0.96; *P*=0.015), chronic obstructive pulmonary disease (IRR, 0.54; 95% CI, 0.46–0.63; *P*<0.001), and chronic kidney disease (IRR, 0.46; 95% CI, 0.39–0.53; *P*<0.001) were inversely related to the incidence of

Table 6. Predictors of TAVR in Patients With Any Inpatient Diagnosis of Aortic Stenosis

	Univariate			Multivariate		
	Incidence Rate Ratio	95% CI	*P* Value	Incidence Rate Ratio	95% CI	*P* Value
Race/ethnicity						
White (reference)	…	…	…	…	…	…
Black	0.66	0.56–0.77	<0.001	0.77	0.65–0.90	0.002
Hispanic	0.93	0.61–1.42	0.75	1.08	0.70–1.67	0.72
Female sex*	0.88	0.79–0.97	0.013	1.01	0.90–1.14	0.87
Age						
50–54 (reference)	…	…	…	…	…	…
55–59	1.20	0.49–2.91	0.69	0.94	0.38–2.32	0.89
60–64	1.59	0.71–3.55	0.26	1.18	0.52–2.66	0.69
65–69	2.24	1.04–4.86	0.040	1.44	0.65–3.20	0.37
70–74	2.98	1.40–6.35	0.005	2.00	0.91–4.37	0.084
75–79	3.62	1.71–7.67	0.001	2.29	1.05–5.01	0.038
80–84	4.55	2.16–9.62	<0.001	2.78	1.27–6.07	0.010
≥85	3.20	1.52–6.74	0.002	2.02	0.92–4.41	0.078
Median household income (per $10 000)†	1.03	1.01–1.04	0.004	1.01	0.99–1.03	0.25
Marital status‡						
Single (reference)	…	…	…	…	…	…
Married	1.72	1.41–2.09	<0.001	1.35	1.11–1.66	0.003
Separated/divorced	1.17	0.90–1.54	0.24	1.02	0.77–1.34	0.91
Widow/widower	1.42	1.15–1.74	0.001	1.07	0.86–1.32	0.57
Primary payer§						
Medicare (reference)	…	…	…	…	…	…
Medicaid	0.33	0.19–0.58	<0.001	0.55	0.27–1.08	0.083
Commercial	0.65	0.52–0.81	<0.001	0.96	0.73–1.25	0.74
Charity/self-pay	0.34	0.05–2.42	0.28	0.56	0.08–3.87	0.56
Other	1.40	0.87–2.25	0.16	1.52	0.97–2.38	0.069
Comorbidities						
Diabetes mellitus	0.91	0.82–1.01	0.083	0.85	0.76–0.95	0.005
Coronary artery disease	3.01	2.59–3.50	<0.001	2.72	2.32–3.19	<0.001
Congestive heart failure	2.09	1.86–2.35	<0.001	2.00	1.76–2.27	<0.001
Peripheral vascular disease	1.31	1.18–1.47	<0.001	1.17	1.04–1.32	0.007
Cerebrovascular disease	1.06	0.93–1.21	0.38	0.98	0.85–1.12	0.73
COPD	0.89	0.80–1.00	0.052	0.74	0.66–0.84	<0.001
Chronic kidney disease	0.98	0.88–1.08	0.65	0.77	0.69–0.86	<0.001

N=13 351 for the multivariate model. CI indicates confidence interval; and COPD, chronic obstructive pulmonary disease.
*n=14 335.
†n=13 845.
‡n=13 917.
§n=14 182.

SAVR. Predictors of SAVR included being married (compared with single; IRR, 1.71; 95% CI, 1.38–2.11; *P*<0.001), having commercial insurance as the primary payer (versus Medicare; IRR, 1.39; 95% CI, 1.16–1.67; *P*<0.001), diabetes mellitus (IRR, 1.44; 95% CI, 1.26–1.65; *P*<0.001), coronary artery disease (IRR, 1.86; 95% CI, 1.60–2.17; *P*<0.001), and peripheral vascular disease (IRR, 1.42; 95% CI, 1.25–1.62; *P*<0.001). Hispanic patients had a similar incidence of SAVR compared with White patients (IRR, 1.23; 95% CI, 0.82–1.85; *P*=0.32).

Predictors of TAVR in patients with AS are shown in Table 6. By Poisson regression, Black race (IRR, 0.77; 95% CI, 0.65–0.90; *P*=0.002), diabetes mellitus (IRR, 0.85; 95% CI, 0.76–0.95; *P*=0.005), chronic obstructive pulmonary disease (IRR, 0.74; 95% CI, 0.66–0.84; *P*<0.001), and chronic kidney disease (IRR, 0.77; 95% CI, 0.69–0.86; *P*<0.001) were inversely related to the

incidence of TAVR. Predictors of TAVR included age 80 to 84 (IRR, 2.78; 95% CI, 1.27–6.074; *P*=0.010 for comparison to 50–54), being married (IRR, 1.35; 95% CI, 1.11–1.66; *P*=0.003), coronary artery disease (IRR, 2.72; 95% CI, 2.32–3.19; *P*<0.001), congestive heart failure (IRR, 2.00; 95% CI, 1.76–2.27; *P*<0.001), and peripheral vascular disease (IRR, 1.17; 95% CI, 1.04–1.32; *P*=0.007).

Supplemental analyses for predictors of SAVR and TAVR using multiple imputation to account for missing data were both entirely consistent with the primary analysis (data not shown). Additionally, after multivariable adjustment, both Black race (IRR, 0.48; 95% CI, 0.39–0.59; *P*<0.001) and Hispanic ethnicity (IRR, 0.42; 95% CI, 0.21–0.82; *P*=0.011) were associated with a lower incidence of SMVR in the population of patients with any inpatient diagnosis of MR (Table S4).

A supplemental analysis including *ICD-10-PCS* codes X2RF332 (TAVR) and X2RF032 (SAVR) resulted in the inclusion of an additional 121 TAVR hospitalizations (8.7% in excess of the 1390 original TAVR hospitalizations) and 9 SAVR hospitalizations (0.8% in excess of the 1084 original SAVR hospitalizations). Results were essentially unchanged from the primary analysis (data not shown), except that race/ethnicity was associated with TAVR hospitalization cost (median $71 638, IQR $62 663–84 617 for White; $71 370, IQR $61 398–88 538 for Black; and $61 536, IQR $56 342–73 313 for Hispanic; *P*=0.006) and there was no longer a difference in the urgency of SAVR admission.

There were 2537 patients admitted with a primary diagnosis of AS; 2152 (84.8%) were White, 335 (13.2%) were Black, and 50 (2.0%) were Hispanic. Among those patients, 817 (32.2%) underwent SAVR and 1224 (48.3%) underwent TAVR. In this population, race/ethnicity no longer predicted SAVR (IRR, 0.94; 95% CI, 0.75–1.18; *P*=0.59 for Black; and IRR, 1.09; 95% CI, 0.68–1.74; *P*=0.72 for Hispanic in multivariable Poisson regression with n=2409) or TAVR (IRR, 0.95; 95% CI, 0.80–1.14; *P*=0.60 for Black; and IRR, 0.85; 95% CI, 0.54–1.35; *P*=0.50 for Hispanic in multivariable Poisson regression with n=2409).

DISCUSSION

The main findings of our study are (1) the incidence of any inpatient diagnosis of AS in Black patients is half that of White patients despite a slightly higher incidence of all-cause inpatient hospitalization in Black patients, (2) the incidence of any inpatient diagnosis of AS in Hispanic patients is one quarter that of White patients and the incidence of all-cause inpatient hospitalization is half that of White patients, and (3) Black patients with any inpatient diagnosis of AS had a lower incidence of both TAVR and SAVR compared with their White counterparts, whereas Hispanic patients had a similar incidence of both TAVR and SAVR.

Racial and ethnic inequities have been documented in nearly all areas of medicine,[21] and in particular in cardiology[13–15] and the surgical management of AS.[12,16–19,27,28] In a single-center study of 880 patients with severe AS by echocardiography from 2004 to 2010, Yeung and colleagues found that Black patients were less likely to undergo AVR (39% versus 53%, *P*=0.02) and more likely to refuse AVR (33% versus 20%, *P*=0.04).[17] Using the National Inpatient Sample, Alqahtani et al found 11.3% of White patients and 6.7% of Blacks (*P*<0.001) admitted with an AS-related diagnosis underwent AVR from 2003 to 2014.[19] In their study of 952 patients with aortic valve stenosis, Cruz Rodriguez and colleagues found that although Black patients represented 33% of the overall patient population, they constituted only 18% of patients with aortic valve disease. Black patients were less likely to be referred to cardiac surgery (odds ratio [OR], 0.46; 95% CI, 0.31–0.67; *P*<0.001) compared with White patients, whereas there was no difference for Hispanic patients (OR, 0.90; 95% CI, 0.57–1.41; *P*=0.656).[18] Despite these marked and well-documented inequities, there is evidence that many cardiologists may be unaware of racial/ethnic inequities in their own practices.[29]

Racial/ethnic differences in AS prevalence may in part explain these inequities. Patel et al previously demonstrated a prevalence of severe AS of 0.91% in White patients and 0.29% in Black patients in a large single-center echocardiographic database, whereas Beydoun et al found a prevalence of AS of 2.62±0.02% for White patients and 1.37±0.02% for Black patients in 2012 in the National Inpatient Sample.[20,30] Alqahtani et al described an AS-related admission rate of 26 cases/100 000 patient-years for Whites and 9.5 cases/100 000 patient-years for Blacks age 50 or older in the National Inpatient Sample in 2014.[19] In the present study, we were able to estimate AS incidence with a denominator of patients rather than hospitalizations. We found that White patients had approximately twice the incidence of any inpatient diagnosis of AS compared with Black patients and 4 times that of Hispanic patients. Multivariable regression similarly suggested that Black race and Hispanic ethnicity are protective against a diagnosis of AS, despite adjustment for differences in age, comorbidities, and socioeconomic factors. In contrast, after similar multivariable adjustment, we found that Black race predicted a slightly higher incidence of any inpatient hospitalization with mitral regurgitation, but that Hispanic ethnicity did not. These results strongly suggest a true higher incidence

of AS in White patients, and our estimate of doubling of AS incidence in White patients compared with Black patients is consistent with prior studies. Furthermore, referral bias leading to lower numbers of Black patients admitted with any diagnosis of AS is unlikely to account for this difference because the proportion of Black Maryland residents undergoing acute inpatient hospitalization in Maryland was slightly greater than the proportion of White Maryland residents undergoing acute inpatient hospitalization. In addition, Black patients underwent inpatient echocardiography at higher rates than either White or Hispanic patients. In contrast, our analyses suggest that less medical care may play a role in the lower estimate of AS incidence in Hispanic patients, because they had considerably lower rates of hospitalization with AS, hospitalization with MR, and all-cause hospitalization.

The reason for a difference in AS incidence according to race/ethnicity is unclear but may relate to underlying differences in disease pathophysiology. One prior study showed a lower prevalence of bicuspid aortic valve disease in Black patients (0.17%) compared with White patients (1.1%), and another showed an association of Hispanic ethnicity with less aortic valve thickening.[31,32] Furthermore, Black race was associated with less incident aortic sclerosis (OR, 0.31; 95% CI, 0.24–0.41; $P<0.001$) and AS (OR, 0.49; 95% CI, 0.25–0.95; $P=0.035$) in the Cardiovascular Health Study but was not associated with incident aortic valve calcification or aortic valve calcium progression in the Multi-Ethnic Study of Atherosclerosis.[33,34] Interestingly, it seems paradoxical that Black patients tend to have a higher level of lipoprotein(a), which is nearly entirely genetically determined and associated with incident AS, yet still have a lower incidence of AS.[35]

Our analysis also showed that Black patients with any inpatient diagnosis of AS had a lower incidence of both SAVR and TAVR compared with White patients, whereas Hispanic patients had a similar incidence of both procedures, even after adjustment for age, comorbidities, and socioeconomic characteristics. Interestingly, the incidence of both TAVR and SAVR in the overall population of Maryland (without regard to AS presence) was lower for both Black and Hispanic patients compared with White. The fact that the difference between White and Hispanic patients in the overall population does not persist in inpatients with AS whereas the difference between White and Black patients is present in both the overall and AS populations suggests a true difference exists in SAVR and TAVR between White and Black patients. Furthermore, our finding of a similar inequity in SMVR and TMVR between White and Black or Hispanic patients in those with MR suggests that racial/ethnic inequities in treatment arise from more than differences in incidence rates. The potential reasons for the inequity between White and Black patients are unclear but likely multifactorial. A prior single-center case-control study of 67 patients with severe AS found that non-Black patients were more likely than Black patients to undergo TAVR (OR, 2.81; 91% CI, 1.01–7.85; $P=0.048$) and that every $10 000 increase in income raised the odds of TAVR by 10% ($P=0.05$), but we did not find a significant effect of median household income after adjustment for other socioeconomic characteristics. This may be partially due to the fact that we did not have income on an individual level but rather used median household income by ZIP code tabulation area. Additionally, a patient's cultural beliefs and practices may particularly influence the likelihood of treatment refusal, which has previously been shown to be significantly higher in Black patients compared with White patients (33% versus 20% for SAVR).[17] Little is known about how such beliefs may influence acceptance of TAVR in particular, which is a relatively novel and expanding therapy.

Our study did not include the severity of AS because of the use of administrative claims data. If racial/ethnic differences exist in the pathophysiology of AS, it may be that Black patients have less severe or less frequently symptomatic AS that does not require intervention. In support of this are single-health system data from Cruz Rodriguez et al suggesting that Black patients with aortic valve disease identified through retrospective medical record review have earlier-stage disease than White patients.[18] Furthermore, Yeung et al found that even in a population limited to severe AS by echocardiography, Black patients still underwent AVR less frequently than White patients (39% versus 53%, $P=0.02$).[17] Moreover, AS is primarily a disease of the elderly, and the Black patients hospitalized with any diagnosis of AS in our study were significantly younger than their White counterparts. However, Black patients remained much less likely to undergo TAVR or SAVR despite adjustment for age. Although we found no significant difference in the incidence of TAVR or SAVR according to race for patients with a primary admitting diagnosis of AS, the sample size is considerably smaller for this analysis. Therefore, it is unclear if differences in AS incidence or severity fully account for the observed treatment inequities. Certainly, further study in this area is greatly needed.

Finally, we could not measure and therefore could not control for bias on the part of the physician (referring or specialist), which may be subconscious bias or overt racism. Such bias may have contributed to our findings. A prior survey of 344 cardiologists found that 34% agreed that inequities exist in medical care in general, 33% agreed that inequities exist in cardiology, 12% agreed that inequities exist in their own hospital, and only 5% agreed that inequities exist in the care of their own patients.[29] Given the racial inequities in

SAVR and TAVR in the current study and prior studies, it seems that underrecognition of inequities is also a significant problem.

Limitations and Strengths

First and foremost, our study shares the limitations inherent to all studies using administrative data, which are collected primarily for billing purposes. We are unable to verify the veracity of the *ICD-10-CM* diagnosis or *ICD-10-PCM* procedure codes. However, we used a broad definition of AS in order to minimize the chance that we missed a significant number of patients with AS. Furthermore, we used standardized diagnosis codes to define relevant comorbidities. We also do not have information on the severity of AS nor symptom status, both of which markedly influence treatment decisions. Because AS is largely diagnosed and managed in the outpatient setting, yet definitively treated in the inpatient setting, our study of inpatient hospitalizations cannot assess for nor exclude a diagnosis or referral bias in the outpatient setting. Additionally, we may have missed Maryland residents who were hospitalized in adjacent states and the District of Columbia rather than in Maryland. Finally, patient race was obtained from administrative data; race is inherently a subjective characteristic without a clear definition, and we cannot be certain of who determined each patient's race.

Strengths of our study include the large number of patients included, the use of a per-patient rather than per-hospitalization analysis, and the use of a data set with individual data on the entire population of Maryland rather than a data set reliant on sampling of a larger population.

Conclusions

Among residents of Maryland aged 50 years or older with an acute inpatient hospitalization, any inpatient diagnosis of AS is twice as common in White patients than in patients of Black race and 4 times as common in White patients than in patients of Hispanic ethnicity. There is a marked racial inequity in the rates of SAVR and TAVR, with Black patients having a lower incidence of either procedure compared with White patients. The reasons for these inequities are doubtlessly complex and multifactorial, and further study is needed to elucidate the mechanisms and develop solutions. In particular, our findings suggest that future studies should focus on identifying possible referral biases (both for diagnosis and treatment of AS), pathophysiologic mechanisms for differences in AS incidence or progression according to race/ethnicity, and racial/ethnic differences in attitudes and beliefs toward SAVR and TAVR that may result in differential usage rates.

ARTICLE INFORMATION

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Supplementary Material

Tables S1–S4

REFERENCES

1. Nkomo VT, Gardin JM, Skelton TN, Gottdiener JS, Scott CG, Enriquez-Sarano M. Burden of valvular heart diseases: a population-based study. *Lancet*. 2006;368:1005–1011.
2. Smith CR, Leon MB, Mack MJ, Miller DC, Moses JW, Svensson LG, Tuzcu EM, Webb JG, Fontana GP, Makkar RR, et al. Transcatheter versus surgical aortic-valve replacement in high-risk patients. *N Engl J Med*. 2011;364:2187–2198.
3. Makkar RR, Fontana GP, Jilaihawi H, Kapadia S, Pichard AD, Douglas PS, Thourani VH, Babaliaros VC, Webb JG, Herrmann HC, et al. Transcatheter aortic-valve replacement for inoperable severe aortic stenosis. *N Engl J Med*. 2012;366:1696–1704.
4. Adams DH, Popma JJ, Reardon MJ, Yakubov SJ, Coselli JS, Deeb GM, Gleason TG, Buchbinder M, Hermiller J Jr, Kleiman NS, et al. Transcatheter aortic-valve replacement with a self-expanding prosthesis. *N Engl J Med*. 2014;370:1790–1798.
5. Popma JJ, Adams DH, Reardon MJ, Yakubov SJ, Kleiman NS, Heimansohn D, Hermiller J Jr, Hughes GC, Harrison JK, Coselli J, et al. Transcatheter aortic valve replacement using a self-expanding bioprosthesis in patients with severe aortic stenosis at extreme risk for surgery. *J Am Coll Cardiol*. 2014;63:1972–1981.
6. Leon MB, Smith CR, Mack MJ, Makkar RR, Svensson LG, Kodali SK, Thourani VH, Tuzcu EM, Miller DC, Herrmann HC, et al. Transcatheter or surgical aortic-valve replacement in intermediate-risk patients. *N Engl J Med*. 2016;374:1609–1620.
7. Thourani VH, Kodali S, Makkar RR, Herrmann HC, Williams M, Babaliaros V, Smalling R, Lim S, Malaisrie SC, Kapadia S, et al. Transcatheter aortic valve replacement versus surgical valve replacement in intermediate-risk patients: a propensity score analysis. *Lancet*. 2016;387:2218–2225.
8. Reardon MJ, Van Mieghem NM, Popma JJ, Kleiman NS, Sondergaard L, Mumtaz M, Adams DH, Deeb GM, Maini B, Gada H, et al. Surgical or transcatheter aortic-valve replacement in intermediate-risk patients. *N Engl J Med*. 2017;376:1321–1331.
9. Mack MJ, Leon MB, Thourani VH, Makkar R, Kodali SK, Russo M, Kapadia SR, Malaisrie SC, Cohen DJ, Pibarot P, et al. Transcatheter aortic-valve replacement with a balloon-expandable valve in low-risk patients. *N Engl J Med*. 2019;380:1695–1705.
10. Popma JJ, Deeb GM, Yakubov SJ, Mumtaz M, Gada H, O'Hair D, Bajwa T, Heiser JC, Merhi W, Kleiman NS, et al. Transcatheter aortic-valve replacement with a self-expanding valve in low-risk patients. *N Engl J Med*. 2019;380:1706–1715.

11. Alkhouli M, Holmes DR Jr, Carroll JD, Li Z, Inohara T, Kosinski AS, Szerlip M, Thourani VH, Mack MJ, Vemulapalli S. Racial disparities in the utilization and outcomes of TAVR: TVT registry report. *JACC Cardiovasc Interv*. 2019;12:936–948.
12. Groeneveld PW, Laufer SB, Garber AM. Technology diffusion, hospital variation, and racial disparities among elderly Medicare beneficiaries: 1989–2000. *Med Care*. 2005;43:320–329.
13. Sonel AF, Good CB, Mulgund J, Roe MT, Gibler WB, Smith SC Jr, Cohen MG, Pollack CV Jr, Ohman EM, Peterson ED, et al. Racial variations in treatment and outcomes of black and white patients with high-risk non-ST-elevation acute coronary syndromes: insights from CRUSADE (Can Rapid Risk Stratification of Unstable Angina Patients Suppress Adverse Outcomes With Early Implementation of the ACC/AHA Guidelines?). *Circulation*. 2005;111:1225–32.
14. Groeneveld PW, Kruse GB, Chen Z, Asch DA. Variation in cardiac procedure use and racial disparity among veterans affairs hospitals. *Am Heart J*. 2007;153:320–327.
15. Capers Q, Sharalaya Z. Racial disparities in cardiovascular care: a review of culprits and potential solutions. *J Racial Ethn Health Disparities*. 2014;1:171–180.
16. Schelbert EB, Rosenthal GE, Welke KF, Vaughan-Sarrazin MS. Treatment variation in older black and white patients undergoing aortic valve replacement. *Circulation*. 2005;112:2347–2353.
17. Yeung M, Kerrigan J, Sodhi S, Huang PH, Novak E, Maniar H, Zajarias A. Racial differences in rates of aortic valve replacement in patients with severe aortic stenosis. *Am J Cardiol*. 2013;112:991–995.
18. Cruz Rodriguez B, Acharya P, Salazar-Fields C, Horne A Jr. Comparison of frequency of referral to cardiothoracic surgery for aortic valve disease in blacks, hispanics, and whites. *Am J Cardiol*. 2017;120:450–455.
19. Alqahtani F, Aljohani S, Amin AH, Al-Hijji M, Ali OO, Holmes DR, Alkhouli M. Effect of race on the incidence of aortic stenosis and outcomes of aortic valve replacement in the United States. *Mayo Clin Proc*. 2018;93:607–617.
20. Patel DK, Green KD, Fudim M, Harrell FE, Wang TJ, Robbins MA. Racial differences in the prevalence of severe aortic stenosis. *J Am Heart Assoc*. 2014;3:e000879. DOI: 10.1161/JAHA.114.000879.
21. Institute of Medicine Committee on Understanding and Eliminating Racial and Ethnic Disparities in Health Care. In: Smedley BD, Stith AY, Nelson AR eds. U*nequal Treatment: Confronting Racial and Ethnic Disparities in Health Care*. Washington, DC: National Academies Press (US); 2003.5–6.
22. Alkhouli M, Alqahtani F, Holmes DR, Berzingi C. Racial disparities in the utilization and outcomes of structural heart disease interventions in the United States. *J Am Heart Assoc*. 2019;8:e012125.
23. Alqahtani F, Aljohani S, Almustafa A, Alhijji M, Ali O, Holmes DR, Alkhouli M. Comparative outcomes of transcatheter aortic valve replacement in African American and Caucasian patients with severe aortic stenosis. *Catheter Cardiovasc Interv*. 2018;91:932–937.
24. Hernandez-Suarez DF, Ranka S, Villablanca P, Yordan-Lopez N, Gonzalez-Sepulveda L, Wiley J, Sanina C, Roche-Lima A, Nieves-Rodriguez BG, Thomas S, et al. Racial/ethnic disparities in patients undergoing transcatheter aortic valve replacement: insights from the Healthcare Cost and Utilization Project's National Inpatient Sample. *Cardiovasc Revasc Med*. 2019;20:546–552.
25. Healthcare Cost and Utilization Project (HCUP). Clinical classifications software v2019.1 (beta version). 2018. https://www.hcup-us.ahrq.gov/toolssoftware/ccs10/ccs_dx_icd10cm_2019_1.zip. Accessed May 30, 2019.
26. United States Census Bureau. Population estimates by age, sex, race, and Hispanic origin. 2018. https://www.census.gov/newsroom/press-kits/2018/estimates-characteristics.html. Accessed April 23, 2020.
27. McNeely C, Zajarias A, Fohtung R, Kakouros N, Walker J, Robbs R, Markwell S, Vassileva CM. Racial comparisons of the outcomes of transcatheter and surgical aortic valve implantation using the Medicare database. *Am J Cardiol*. 2018;122:440–445.
28. Taylor NE, O'Brien S, Edwards FH, Peterson ED, Bridges CR. Relationship between race and mortality and morbidity after valve replacement surgery. *Circulation*. 2005;111:1305–1312.
29. Lurie N, Fremont A, Jain AK, Taylor SL, McLaughlin R, Peterson E, Kong BW, Ferguson TB Jr. Racial and ethnic disparities in care: the perspectives of cardiologists. *Circulation*. 2005;111:1264–1269.
30. Beydoun HA, Beydoun MA, Liang H, Dore GA, Shaked D, Zonderman AB, Eid SM. Sex, race, and socioeconomic disparities in patients with aortic stenosis (from a nationwide inpatient sample). *Am J Cardiol*. 2016;118:860–865.
31. Sashida Y, Rodriguez CJ, Boden-Albala B, Jin Z, Elkind MS, Liu R, Rundek T, Sacco RL, DiTullio MR, Homma S. Ethnic differences in aortic valve thickness and related clinical factors. *Am Heart J*. 2010;159:698–704.
32. Chandra S, Lang RM, Nicolarsen J, Gayat E, Spencer KT, Mor-Avi V, Hofmann Bowman MA. Bicuspid aortic valve: inter-racial difference in frequency and aortic dimensions. *JACC Cardiovasc Imaging*. 2012;5:981–989.
33. Novaro GM, Katz R, Aviles RJ, Gottdiener JS, Cushman M, Psaty BM, Otto CM, Griffin BP. Clinical factors, but not C-reactive protein, predict progression of calcific aortic-valve disease: the Cardiovascular Health Study. *J Am Coll Cardiol*. 2007;50:1992–1998.
34. Owens DS, Katz R, Takasu J, Kronmal R, Budoff MJ, O'Brien KD. Incidence and progression of aortic valve calcium in the Multi-Ethnic Study of Atherosclerosis (MESA). *Am J Cardiol*. 2010;105:701–708.
35. Thanassoulis G, Campbell CY, Owens DS, Smith JG, Smith AV, Peloso GM, Kerr KF, Pechlivanis S, Budoff MJ, Harris TB, et al. Genetic associations with valvular calcification and aortic stenosis. *N Engl J Med*. 2013;368:503–512.

SUPPLEMENTAL MATERIAL

Table S1. Demographic characteristics and comorbidities of patients with any acute inpatient hospitalization according to race/ethnicity.

	All (n =433,078)	**White (n =290,290)**	**Black (n =130,704)**	**Hispanic (n =12,084)**	**P-value**
Female sex*	53.5	52.6	55.4	53.4	<0.001
Age					
50-54	10.8	8.8	14.5	17.9	<0.001
55-59	13.1	11.4	16.4	16.0	
60-64	13.8	12.9	15.8	15.0	
65-69	14.0	13.6	14.9	13.1	
70-74	12.9	13.5	11.8	10.9	
75-79	11.2	11.9	9.7	9.3	
80-84	9.6	10.5	7.6	7.9	
≥85	14.7	17.3	9.3	10.0	
Median household income ($)[†]	72,454 (57,949-94,866)	74,994 (61,949-98,117)	63,704 (45,439-79,716)	75,730 (63,635-97,730)	<0.001
Marital status[‡]					
Single	21.7	14.6	37.4	26.0	<0.001
Married	47.5	53.0	34.7	50.7	
Separated/divorced	11.6	11.3	12.5	10.2	
Widow/widower	19.2	21.1	15.4	13.1	
Primary payer[§]					
Medicare	63.5	66.9	57.9	42.2	<0.001
Medicaid	9.2	5.7	15.8	22.7	
Commercial	24.6	25.2	23.0	26.0	
Charity/self-pay	0.9	0.5	1.4	6.7	
Other	1.8	1.7	1.9	2.4	

Comorbidities					
Aortic stenosis	3.3	4.0	2.0	1.9	<0.001
Mitral regurgitation	4.1	4.2	4.1	2.9	<0.001
Mitral stenosis	0.24	0.27	0.19	0.17	<0.001
Diabetes mellitus	40.4	36.3	49.0	46.1	<0.001
Coronary artery disease	32.3	33.8	29.8	22.6	<0.001
Congestive heart failure	21.3	20.3	24.1	14.7	<0.001
Peripheral vascular disease	12.4	12.7	12.1	7.4	<0.001
Cerebrovascular disease	11.4	10.8	12.8	9.8	<0.001
Any arterial vascular disease[‖]	42.8	43.7	41.9	32.7	<0.001
COPD[#]	22.4	23.9	20.5	9.9	<0.001
Chronic kidney disease	22.6	19.8	29.3	16.9	<0.001

*n = 432,990. [†]n = 420,051. [‡]n = 420,147. [§]n = 426,415. [‖]Any arterial vascular disease = coronary artery disease, peripheral vascular disease, or cerebrovascular disease. [#]COPD = chronic obstructive pulmonary disease.

Table S2. Multivariate predictors of any inpatient diagnosis of aortic stenosis and mitral regurgitation.

	Aortic Stenosis			Mitral Regurgitation		
	Incidence Rate Ratio	**95% CI***	**P-value**	**Incidence Rate Ratio**	**95% CI***	**P-value**
Race						
White (reference)	-	-	-	-	-	-
Black	0.45	0.42-0.49	<0.001	1.20	1.13-1.28	<0.001
Hispanic	0.67	0.58-0.78	<0.001	0.89	0.79-1.01	0.077
Female sex	0.92	0.88-0.96	<0.001	1.23	1.19-1.28	<0.001
Age						
50-54 (reference)	-	-	-	-	-	-
55-59	1.41	1.19-1.68	<0.001	1.07	0.98-1.17	0.13
60-64	2.18	1.85-2.55	<0.001	1.12	1.03-1.23	0.009
65-69	2.58	2.19-3.04	<0.001	1.25	1.14-1.37	<0.001
70-74	3.58	3.04-4.22	<0.001	1.38	1.25-1.53	<0.001
75-79	4.93	4.19-5.81	<0.001	1.53	1.37-1.70	<0.001
80-84	7.06	5.99-8.31	<0.001	1.74	1.57-1.93	<0.001
≥85	10.35	8.78-12.19	<0.001	1.87	1.69-2.07	<0.001
Median household income (per $10,000)	0.99	0.98-0.997	0.004	1.02	1.01-1.03	<0.001
Marital status						
Single (reference)	-	-	-	-	-	-
Married	1.09	1.03-1.16	0.006	0.96	0.91-1.01	0.13
Separated/divorced	1.03	0.94-1.12	0.54	0.96	0.90-1.03	0.22
Widow/widower	1.17	1.09-1.25	<0.001	0.99	0.93-1.05	0.70
Primary payer						
Medicare (reference)	-	-	-	-	-	-

Medicaid	0.90	0.79-1.02	0.10	1.10	1.01-1.20	0.033
Commercial	0.84	0.77-0.91	<0.001	1.01	0.95-1.08	0.65
Charity/self-pay	0.67	0.45-0.998	0.049	1.26	1.01-1.54	0.036
Other	0.72	0.58-0.88	0.002	0.73	0.62-0.88	<0.001
Comorbidities						
Diabetes mellitus	1.54	1.47-1.60	<0.001	1.15	1.10-1.19	<0.001
Coronary artery disease	-	-	-	3.57	3.42-3.72	<0.001
Peripheral vascular disease	-	-	-	1.59	1.52-1.67	<0.001
Cerebrovascular disease	-	-	-	1.44	1.37-1.51	<0.001
Any arterial vascular disease	3.37	3.21-3.54	<0.001	-	-	-
Chronic kidney disease	1.77	1.69-1.85	<0.001	2.06	1.98-2.15	<0.001
COPD	1.40	1.34-1.47	<0.001	1.54	1.48-1.60	<0.001
Interactions						
Black race x female sex	1.32	1.19-1.46	<0.001	-	-	-
Black race x age 70-74	-	-	-	0.77	0.68-0.86	<0.001
Black race x age 75-79	-	-	-	0.74	0.65-0.84	<0.001
Black race x age 80-84	-	-	-	0.68	0.60-0.78	<0.001
Black race x age ≥85	-	-	-	0.66	0.59-0.75	<0.001

N = 403,480. *CI = confidence interval. †COPD = chronic obstructive pulmonary disease.

Table S3. Top 10 primary admission diagnoses for patients with any inpatient diagnosis of aortic stenosis according to race/ethnicity.

	White (n = 35,516)			Black (n = 10,293)			Hispanic (n = 661)		
Rank	**Diagnosis**	**n**	**%**	**Diagnosis**	**n**	**%**	**Diagnosis**	**n**	**%**
1	I35.0 - Non-rheumatic aortic (valve) stenosis	2066	5.8	A41.9 - Sepsis, unspecified organism	500	4.9	I35.0 - Non-rheumatic aortic (valve) stenosis	55	8.3
2	A41.9 - Sepsis, unspecified organism	1967	5.5	I13.0 - Hypertensive heart and chronic kidney disease with heart failure and stage 1-4/unspecified chronic kidney disease	496	4.8	I13.0 - Hypertensive heart and chronic kidney disease with heart failure and stage 1-4/unspecified chronic kidney disease	44	6.7
3	I13.0 - Hypertensive heart and chronic kidney disease with heart failure and stage 1-4/unspecified chronic kidney disease	1431	4.0	I35.0 - Non-rheumatic aortic (valve) stenosis	345	3.4	A41.9 - Sepsis, unspecified organism	41	6.2
4	I11.0 - Hypertensive heart disease with heart failure	1298	3.7	I11.0 - Hypertensive heart disease with heart failure	328	3.2	I11.0 - Hypertensive heart disease with heart failure	21	3.2
5	I21.4 - Non-ST elevation (NSTEMI) myocardial infarction	1164	3.3	I21.4 - Non-ST elevation (NSTEMI) myocardial infarction	314	3.1	I50.23 - Acute on chronic systolic (congestive) heart failure	19	2.9
6	J18.9 - Pneumonia, unspecified organism	837	2.4	I13.2 - Hypertensive heart and chronic kidney disease with heart failure and stage 5 chronic kidney disease/ESRD	266	2.6	J18.9 - Pneumonia, unspecified organism	15	2.3
7	J44.1 - Chronic obstructive pulmonary disease with acute exacerbation	808	2.3	J44.1 - Chronic obstructive pulmonary disease with acute exacerbation	212	2.1	I21.4 - Non-ST elevation (NSTEMI) myocardial infarction	12	1.8
8	N17.9 - Acute kidney failure, unspecified	683	1.9	J18.9 - Pneumonia, unspecified organism	209	2.0	Z51.11 - Encounter for antineoplastic chemotherapy	12	1.8
9	J96.01 - Acute respiratory failure with hypoxia	615	1.7	N17.9 - Acute kidney failure, unspecified	203	2.0	N17.9 - Acute kidney failure, unspecified	11	1.7
10	N39.0 - Urinary tract infection, site not specified	545	1.5	J96.01 - Acute respiratory failure with hypoxia	199	1.9	J96.01 - Acute respiratory failure with hypoxia	11	1.7

Table S4. Predictors of SMVR in patients with any inpatient diagnosis of mitral regurgitation.

	Univariate			Multivariate		
	Incidence Rate Ratio	**95% CI***	**P-value**	**Incidence Rate Ratio**	**95% CI***	**P-value**
Race						
White (reference)	-	-	-	-	-	-
Black	0.58	0.48-0.70	<0.001	0.48	0.39-0.59	<0.001
Hispanic	0.63	0.34-1.18	0.15	0.42	0.21-0.82	0.011
Female sex[†]	0.60	0.52-0.70	<0.001	0.85	0.73-1.00	0.056
Age						
50-54 (reference)	-	-	-	-	-	-
55-59	0.97	0.72-1.31	0.86	0.93	0.69-1.27	0.66
60-64	1.12	0.85-1.49	0.42	1.02	0.76-1.37	0.89
65-69	0.77	0.57-1.03	0.074	0.84	0.61-1.16	0.29
70-74	0.63	0.47-0.85	0.002	0.67	0.47-0.95	0.027
75-79	0.46	0.33-0.63	<0.001	0.52	0.36-0.76	0.001
80-84	0.27	0.19-0.39	<0.001	0.28	0.18-0.44	<0.001
≥85	0.02	0.01-0.05	<0.001	0.03	0.01-0.07	<0.001
Median household income (per $10,000)[‡]	1.04	1.02-1.07	0.001	1.02	0.99-1.05	0.28
Marital status[§]						
Single (reference)	-	-	-	-	-	-
Married	1.63	1.33-2.00	<0.001	1.59	1.27-2.00	<0.001
Separated/divorced	1.09	0.82-1.46	0.56	1.14	0.84-1.55	0.40
Widow/widower	0.38	0.28-0.52	<0.001	0.99	0.70-1.39	0.94
Primary payer[‖]						
Medicare (reference)	-	-	-	-	-	-

Medicaid	2.07	1.59-2.69	<0.001	1.33	0.95-1.84	0.092
Commercial	3.66	3.11-4.31	<0.001	1.41	1.14-1.76	0.002
Charity/self-pay	2.13	0.95-4.78	0.065	0.96	0.38-2.39	0.93
Other	2.31	1.23-4.31	0.009	1.28	0.66-2.47	0.47
Comorbidities						
Diabetes mellitus	1.63	1.39-1.90	<0.001	1.79	1.50-2.13	<0.001
Coronary artery disease	0.76	0.65-0.88	<0.001	0.79	0.66-0.93	0.006
Congestive heart failure	0.79	0.68-0.92	0.002	1.42	1.19-1.69	<0.001
Peripheral vascular disease	0.80	0.67-0.96	0.017	1.08	0.89-1.32	0.45
Cerebrovascular disease	0.69	0.55-0.85	0.001	0.83	0.66-1.04	0.11
COPD[#]	0.52	0.44-0.62	<0.001	0.58	0.48-0.70	<0.001
Chronic kidney disease	0.44	0.37-0.52	<0.001	0.53	0.44-0.64	<0.001

N = 16,584 for the multivariate model. *CI = confidence interval. [†]n = 17,867. [‡]n = 17,314. [§]n = 17,312. [‖]n = 17,604.

[#]COPD = chronic obstructive pulmonary disease.