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ORIGINAL RESEARCH

Racial and Ethnic Differences in the Clinical Diagnosis of Aortic Stenosis

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BACKGROUND: Racial and ethnic minority groups are underrepresented among patients undergoing aortic valve replacement in the United States. We evaluated the impact of race and ethnicity on the diagnosis of aortic stenosis (AS).

METHODS AND RESULTS: In patients with transthoracic echocardiography (TTE)-confirmed AS, we assessed rates of AS diagnosis as defined by assignment of an *International Classification of Diseases, Ninth Revision (ICD-9)* and *Tenth Revision (ICD-10)* code for AS within a large multicenter electronic health record. Multivariable Cox proportional hazard and competing risk regression models were used to evaluate the 1-year rate of AS diagnosis by race and ethnicity. Among 14 800 patients with AS, the 1-year diagnosis rate for AS following TTE was 37.4%. Increasing AS severity was associated with an increased likelihood of receiving an AS diagnosis (moderate: hazard ratio [HR], 3.05 [95% CI, 2.86–3.25]; $P<0.0001$; severe: HR, 4.82 [95% CI, 4.41–5.28]; $P<0.0001$). Compared with non-Hispanic White, non-Hispanic Black (HR, 0.65 [95% CI, 0.54–0.77]; $P<0.0001$) and non-Hispanic Asian individuals (HR, 0.72 [95% CI, 0.57–0.90], $P=0.004$) were less likely to receive a diagnosis of AS. Additional factors associated with a decreased likelihood of receiving an AS diagnosis included a noncardiology TTE ordering provider (HR, 0.92 [95% CI, 0.86–0.97]; $P=0.005$) and TTE performed in the inpatient setting (HR, 0.72 [95% CI, 0.66–0.78]; $P<0.0001$).

CONCLUSIONS: Rates of receiving an *ICD* diagnostic code for AS following a diagnostic TTE are low and vary significantly by race and ethnicity and disease severity. Further studies are needed to determine if efforts to maximize the clinical recognition of TTE-confirmed AS may help to mitigate disparities in treatment.

Key Words: aortic stenosis ■ diagnosis ■ disparities ■ echocardiography ■ race and ethnicity

See Editorial by Parikh and Kort

Racial and ethnic disparities exist in the management of patients with aortic stenosis (AS).[1–7] After the diagnosis of severe AS, Black individuals are more likely to be lost to follow-up after diagnostic transthoracic echocardiography (TTE),[8] less likely to be referred to cardiothoracic surgery,[9] and more likely to decline aortic valve replacement.[7] These observations likely contribute to the underrepresentation of Black patients among those undergoing surgical aortic valve replacement for severe AS.[4,7] Similar disparities in the treatment of severe AS have persisted since the introduction of transcatheter aortic valve implantation (TAVI), with lower rates of treatment and TAVI use among racial and ethnic minority groups than in White individuals.[3,5,6,8,10] Given the high mortality associated with untreated, symptomatic severe AS,[11] there is an unmet need to understand the factors contributing to these racial and ethnic disparities in care delivery.

Several studies have implicated differences in the biology of AS and the reduced susceptibility of some ethnic and racial groups to the development and

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CLINICAL PERSPECTIVES

What Is New?

- Rates of coding for aortic stenosis (AS) following transthoracic echocardiography–proven AS are low.
- Non-Hispanic White race and increasing AS severity were associated with an increased likelihood of receiving a diagnostic code for AS following transthoracic echocardiography.
- Non-Hispanic Black and Non-Hispanic Asian individuals were less likely to receive an AS diagnosis following diagnostic transthoracic echocardiography.

What Are the Clinical Implications?

- Disparities in rates of diagnosis for AS among various racial and ethnic groups may contribute to disparities in the treatment of clinically significant AS.

Nonstandard Abbreviations and Acronyms

AS	aortic stenosis
MG	transvalvular mean pressure gradient
TAVI	transcatheter aortic valve implantation
TTE	transthoracic echocardiography

progression of AS.[12,13] Studies using administrative data have similarly suggested a reduced prevalence of AS among Black, Hispanic, and Asian/Pacific Islander groups compared with White individuals.[4,5] Such studies, however, rely on the recognition of AS by providers and the assignment of a diagnosis billing code and may underestimate the true disease prevalence. Disparities in the rates of diagnosis of AS may contribute to the undertreatment of racial and ethnic minority groups; yet, this factor has been poorly studied. Using a comprehensive, multicenter research patient data registry supplemented with echocardiographic data, we sought to explore the potential role of race and ethnicity on rates of *International Classification of Diseases, Ninth Revision* (*ICD-9*) and *Tenth Revision* (*ICD-10*) code assignment in patients with AS detected by TTE imaging.

METHODS

Study Population

The data that support the findings of this study are available from the corresponding author upon reasonable request. Reports from TTE that took place between April 1990 and May 2020 were obtained from the Mass General Brigham Research Patient Data Registry, an administrative multicenter database spanning 2 large academic centers, Massachusetts General Hospital, and Brigham and Women's Hospital. The presence of AS on TTE was defined exclusively by transvalvular mean pressure gradient (MG), which was extracted from TTE reports using natural language processing. AS severity was defined by MG as per American College of Cardiology/American Heart Association guidelines[14] as mild AS (MG <20 mm Hg), moderate AS (MG 20–39 mm Hg), and severe AS (MG ≥40 mm Hg). Records were chronologically sorted to identify an index date for each patient (ie, the first known date where an MG was reported). Records were analyzed to identify the earliest date, if any, in which a diagnostic code for AS (*ICD-9* code: 424.1; *ICD-10* code: I35.0) was issued. Patients with an *ICD* diagnosis for AS before the date of their index TTE were excluded from this study as were patients with prior surgical aortic valve replacement/TAVI. Patients for whom other or unknown was indicated as race and ethnicity and patients under the age of 18 years were also excluded, yielding a final cohort size of 14 800. This retrospective cohort study was approved by the Mass General Brigham Institutional Review Board, and no informed consent was required.

Study Variables

The primary outcome was issuance of an AS diagnostic code within 1 year of index TTE. Independent variables used in our analysis included race and ethnicity, age, sex, primary language, residential setting, type of insurance carrier, AS severity, Combined Comorbidity Index score, ordering provider specialty, and TTE setting. Categories for race and ethnicity were self-reported by patients and included non-Hispanic White, Hispanic (all races), non-Hispanic Black or African American, and non-Hispanic Asian or Pacific Islander. Age, sex, and primary language were extracted from the electronic health record. Patient comorbidities at the time of their index TTE were used to calculate the Combined Comorbidity Index score.[15] We matched patient zip codes contained in their electronic health records to urban cluster area files from the US Census Bureau to determine whether each patient was living in a primarily urban or nonurban setting. We identified urban clusters linked to each zip code and used the total zip code population percentage column in the US Census Bureau area files to classify each patient as primarily urban (>50% of the total population in the patient's zip code lived within urban limits) or rural (<50% of the total population in the patient's zip code lived within urban limits). We obtained the name of primary and secondary insurers from each patient's electronic

health record and generated relevant categories using an iterative process that included Medicare, Medicaid/MassHealth (State Health Insurance Exchange), and Other Insurance (eg, private/employer-based). For ordering providers associated with Mass General Brigham institutions, medical specialty was obtained from provider registration information provided by the Research Patient Data Registry. For external providers, specialty was obtained through an electronic query of the Centers for Medicare and Medicaid Services National Provider Identification registry. The setting where the TTE was performed (ie, inpatient versus outpatient) was determined using the census of medical encounters for each patient.

Statistical Analysis

Baseline characteristics and TTE data were summarized using scale-appropriate measures for categorical variables (eg, count, percentage) and interval variables (eg, mean±standard deviation). Differences in categorical variables were ascertained using the Fisher exact test. Cox proportional hazard models were used to assess the 1-year cumulative rate of AS diagnosis stratified by race and ethnicity. Multivariate Cox proportional hazards models were adjusted for age, sex, primary language, residential setting, type of insurance carrier, AS severity, Combined Comorbidity Index score, ordering provider specialty, and TTE setting. A Fine-Gray competing event regression model was used to determine multivariable associations between race and ethnicity and cumulative probability of 1-year AS diagnosis, accounting for death as a competing event. Stratified rate ratios were calculated using the Mantel-Haenszel method to control for unequal group sizes in each severity strata and potential trend differences associated with increased AS severity. Cumulative incidence function curves, subdistribution hazard ratios (sHRs), and relative risks [RRs] are reported with corresponding 95% CIs. Median and restricted mean event times were not defined in this group of patients given that <50% of patients experienced the primary or competing event. Probability thresholds for statistical significance were set at 0.05 using 2-sided tests; all analyses were conducted using Stata (version 16.0; StataCorp, College Station, TX) and R (version 4.0.1; R Foundation for Statistical Computing, Vienna Austria) statistical programming software.

RESULTS

Patient Characteristics

Among 14 800 included patients, 91.8% were non-Hispanic White, 4.0% were non-Hispanic Black, 2.1% were Hispanic, and 2.1% were non-Hispanic Asian. There were 12 099 (81.8%) patients who had mild AS, 2048 (13.6%) patients who had moderate AS, and 653 (4.7%) patients who had severe AS. The proportion of patients within each AS severity category was similar across all racial and ethnic groups. Among the study population, the median age was 69.8 (±15.3) years, and 46.6.% were women. Women made up a greater proportion of the racial and ethnic minority groups. As compared with non-Hispanic White individuals, non-Hispanic Black, Hispanic, and non-Hispanic Asian individuals were younger at the time of index TTE. All racial and ethnic minority groups more commonly resided in an urban setting and had Medicaid/MassHealth insurance. As compared with non-Hispanic White individuals, non-Hispanic Black and Hispanic individuals more commonly underwent TTE in the inpatient setting (19.7% and 15.2%, respectively, versus 12.7%; $P<0.0001$) and less often had a cardiologist as the TTE ordering provider (18.4% and 15.8%, respectively, versus 25.8%; $P<0.0001$). Differences in the prevalence of demographic characteristics and clinical risk factors among the racial and ethnic groups are shown in Table 1. The distribution of patient race and ethnicity did not differ over the study period (Table S1).

Cumulative 1-Year Rates of AS Diagnosis and Mortality

Among patients with any severity of AS on TTE, 37.4% (5533/14 800) received an *ICD* diagnosis of AS within 1 year of index TTE. There were significant racial and ethnic differences in the 1-year rates of AS diagnosis following index TTE (Figure 1, $P<0.0001$). Non-Hispanic White individuals had the highest cumulative rates of diagnosis (38.3%), with a similar rate noted in Hispanic individuals (37.1%). Non-Hispanic Black and non-Hispanic Asian individuals both had significantly lower rates of AS diagnosis (22.3% and 24.7%, respectively). Less than 5% of the cohort died within 1-year without receiving an AS diagnosis. Non-Hispanic Black individuals had the highest 1-year mortality (6.1%), whereas Hispanic ethnicity was associated with the lowest 1-year mortality rate (2.9%), although differences in mortality rates were not statistically significant across racial and ethnic groups ($P=0.19$; Figure 1).

In multivariable analyses, race and ethnicity were significant predictors of receiving an *ICD* diagnosis of AS. Compared with non-Hispanic White individuals, non-Hispanic Black (hazard ratio [HR], 0.65 [95% CI, 0.54–0.77]; $P<0.0001$) and non-Hispanic Asian individuals (hazard ratio [HR], 0.72 [95% CI, 0.57–0.90]; $P=0.004$) were less likely to receive a diagnosis of AS. There was no significant difference in 1-year rates of AS diagnosis between Hispanic and non-Hispanic White individuals (HR, 1.11 [95% CI, 0.91–1.3]; $P=0.29$; Figure 2). In a subgroup analysis including only patients

Table 1. Baseline Characteristics and Clinical Factors at the Time of Index TTE

	All, n=14 800	Non-Hispanic White, n=13 590	Non-Hispanic Black, n=588	Hispanic, n=310	Non-Hispanic Asian, n=312
Age, y, median	69.8 (±15.3)	70.3 (±15.3)	63.4 (±16.7)	64.4 (±15.8)	65.4 (±17.8)
Female sex, n (%)	6904 (46.6%)	6247 (45.9%)	326 (55.4%)	165 (53.2%)	166 (53.2%)
Non-English language, n (%)	947 (6.4%)	681 (5%)	76 (12.9%)	94 (62.6%)	96 (30.8%)
Urban residence, n (%)	13 981 (94.5%)	12 797 (94.2%)	577 (98.1%)	303 (97.7%)	304 (97.4%)
Insurance, n (%)					
Medicaid/ MassHealth	523 (3.6%)	343 (2.6%)	92 (15.6%)	49 (15.8%)	39 (12.6%)
Medicare	8202 (55.4%)	7731 (56.9%)	259 (44.0%)	112 (36.1%)	100 (32.1%)
Other	6075 (41%)	5516 (40.6%)	237 (40.3%)	149 (48.1%)	173 (55.5%)
Comorbidities, n (%)					
Hypertension	8216 (55.5%)	7508 (55.2%)	363 (61.7%)	220 (71%)	125 (40.1%)
Diabetes	2365 (16%)	2025 (14.9%)	181 (30.8%)	108 (34.8%)	51 (16.3%)
CHF	6099 (41.2%)	5589 (41.1%)	284 (48.3%)	133 (43%)	93 (29.8%)
CKD	3331 (22.5%)	2983 (30%)	205 (34.9%)	92 (29.7%)	51 (16.3%)
CCI score	4.0 (±4.4)	4.0 (±4.3)	6.0 (±5.8)	6.0 (±5.2)	4.0 (±4.3)
AS severity, n (%)					
Mild	12 100 (81.8%)	11 043 (81.3%)	519 (88.3%)	258 (83.2%)	280 (89.7%)
Moderate	2010 (13.6%)	1898 (14.0%)	50 (8.5%)	40 (12.9%)	22 (7.1%)
Severe	690 (4.7%)	649 (4.8%)	19 (3.2%)	12 (3.9%)	10 (3.2%)
TTE setting, n (%)					
Inpatient	1934 (13.1%)	1729 (12.7%)	116 (19.7%)	47 (15.2%)	42 (13.5%)
Ordering provider, n (%)					
Cardiologist	3745 (25.3%)	3506 (25.8%)	108 (18.4%)	49 (15.8%)	82 (26.3%)

AS indicates aortic stenosis; CCI, Combined Comorbidity Index; CHF, congestive heart failure; CKD, chronic kidney disease; and TTE, transthoracic echocardiography.

with moderate or greater AS, similar trends between race and ethnicity and cumulative diagnosis rates persisted, most significant among non-Hispanic Black individuals (HR, 0.72 [95% CI, 0.53–0.98]; P<0.04; Figure S1). Positive predictors of receiving an AS diagnosis included AS severity (moderate: HR, 3.05 [95% CI, 2.86–3.25]; P<0.0001; severe: HR, 4.21 [95% CI, 4.41–5.26]; P<0.0001; reference: mild AS), increasing age (HR, 1.07 [95% CI, 1.00–1.01]; P<0.0001 for every 10-year increase in age), and Medicare insurance as compared with commercial insurance (HR, 1.43 [95% CI, 1.34–1.53]; P<0.001). Female sex (HR, 0.81 [95% CI, 0.77–0.86]; P<0.0001), higher comorbidity score (HR, 0.97 [95% CI, 0.96–0.97]; P<0.0001), a noncardiology TTE ordering provider (HR, 0.92 [95% CI, 0.86–0.97]; P=0.005), and TTE performed in the inpatient setting (HR, 0.72 [95% CI, 0.66–0.78]; P<0.0001) were each independently associated with a decreased likelihood of receiving a diagnosis of AS (Figure 3). Among patients with at least moderate AS, predictors of receiving a diagnosis remained similar except for the clinical setting in which the TTE was performed (Figure S2).

When accounting for competing risk of death, non-Hispanic Black and non-Hispanic Asian individuals had a persistently lower probability of receiving a diagnosis of AS at 1 year following index TTE (sHR, 0.68 [95% CI, 0.59–0.80]; P<0.0001 for non-Hispanic Black individuals; sHR, 0.74 [95% CI, 0.61–0.91]; P<0.004 for non-Hispanic Asian individuals) compared with non-Hispanic White individuals (Figure S3).

Cumulative Rates of AS Diagnosis by Disease Severity

Stratified by disease severity, 1-year unadjusted rates of AS diagnosis increased for the entire cohort with increasing AS severity (Figure S4). Compared with non-Hispanic White individuals, non-Hispanic Black individuals had a significantly decreased relative rate of diagnosis across every severity, and the greatest degree of underdiagnosis occurred for severe AS (RR, 026 [95% CI, 0.14–0.47]; Table 2). Hispanic ethnicity as compared with non-Hispanic White race was associated with comparable cumulative rates of AS diagnosis for any severity; however, the likelihood of acquiring a diagnosis among Hispanic individuals decreased with increasing AS severity (mild: RR, 1.1 [95% CI, 0.89–1.38]; moderate: RR, 0.73 [95% CI, 0.49–1.08]; severe: RR, 0.40 [95% CI, 0.20–0.80]).

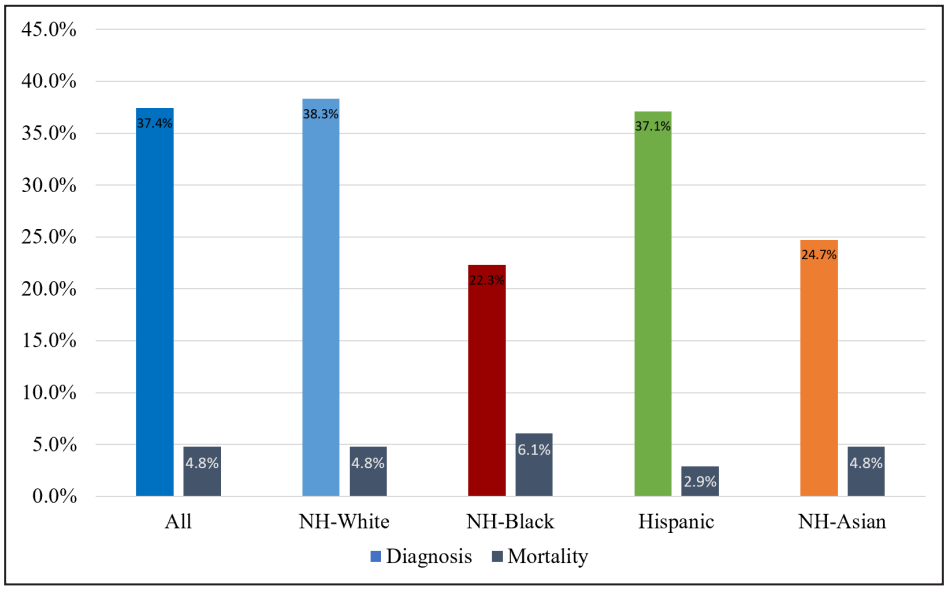

Figure 1. One-year unadjusted rates of AS *ICD* diagnosis and mortality, stratified by race and ethnicity.
Cumulative 1-year rate (percent) of AS *ICD* diagnosis and 1-year mortality rate (percent) for all severities of AS by race and ethnicity. AS indicates aortic stenosis; *ICD*, *International Classification of Diseases*; and NH, non-Hispanic.

Non-Hispanic Asian individuals had lower overall rates of receiving an AS diagnosis, and relative rates were lower for mild (RR, 0.59 [95% CI, 0.45–0.77]) and severe AS (RR, 0.63 [95% CI, 0.32–1.27]; Table 2). The associations between race and diagnosis of AS by disease severity are shown in Figure S5A through S5C.

DISCUSSION

Using an electronic data repository spanning 2 large academic medical centers and including echocardiographic and administrative data, we present several novel and impactful observations. Among patients with

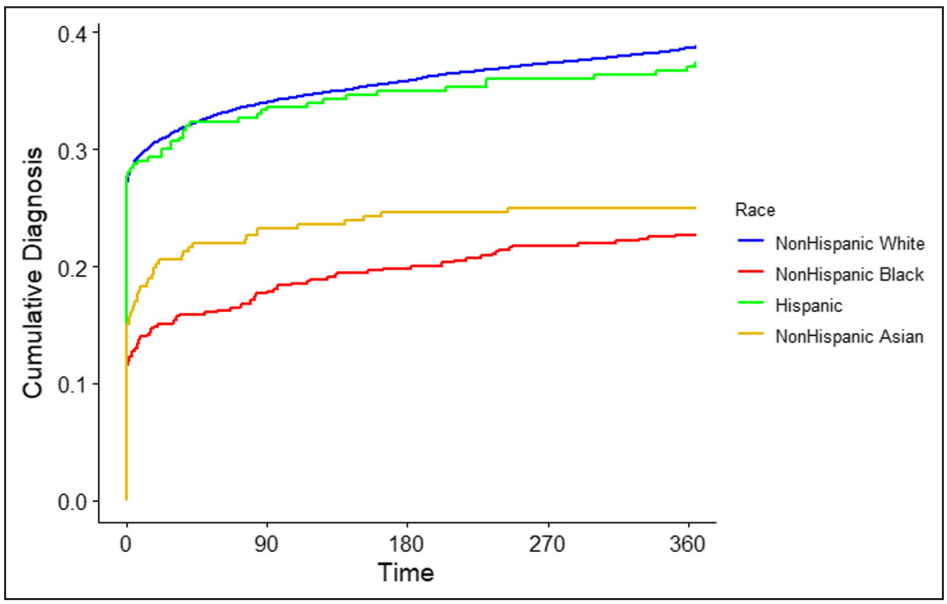

Figure 2. Adjusted 1-year rates of AS *ICD* diagnosis, stratified by race and ethnicity.
Adjustment variables included age, sex, race and ethnicity, AS severity, Combined Comorbidity Index score, primary language, primary residence, insurance payer, specialty ordering provider, and TTE setting. AS indicates aortic stenosis; *ICD*, *International Classification of Diseases*; and TTE, transthoracic echocardiography.

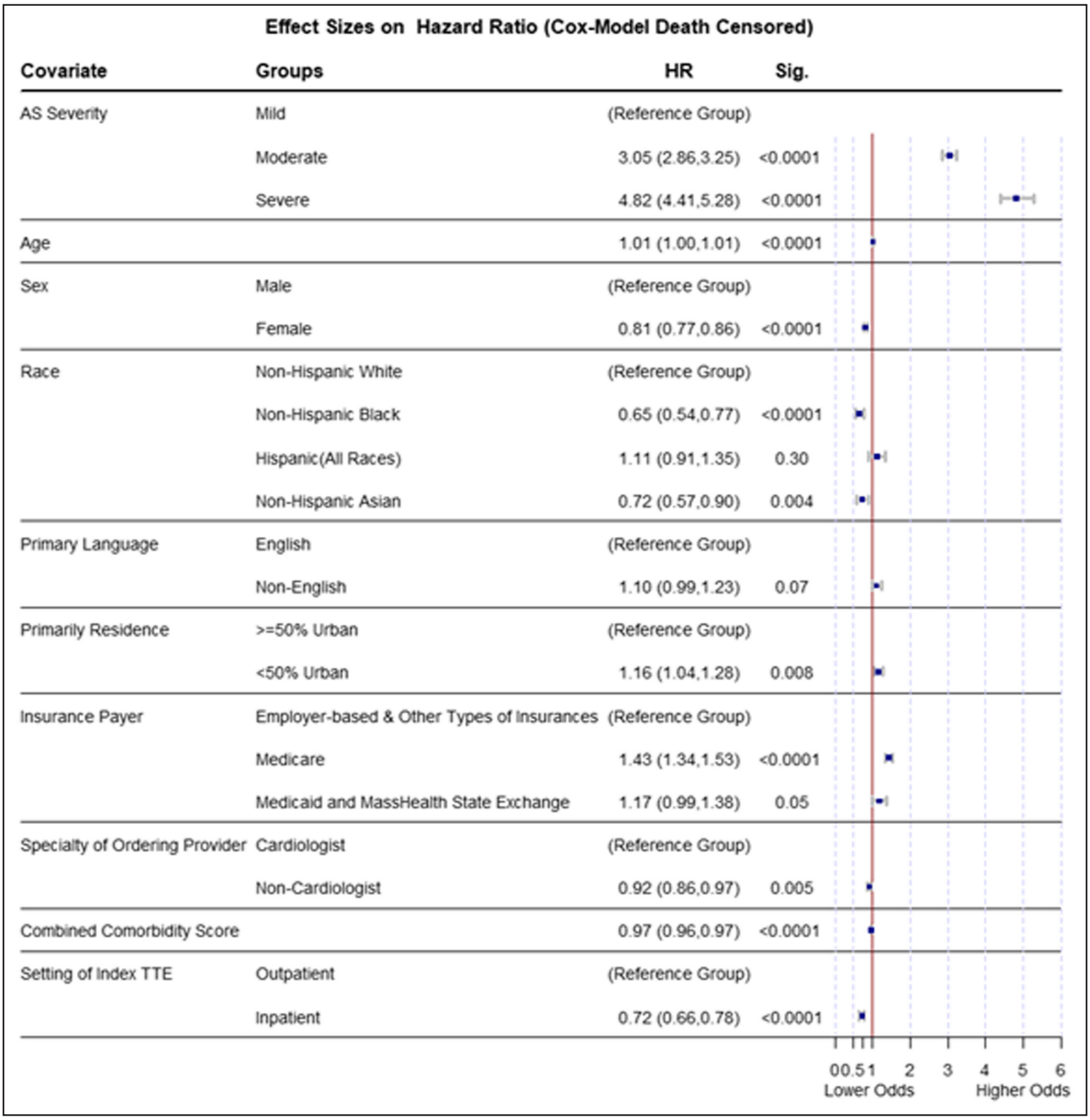

Figure 3. Predictors of receiving an AS *ICD* diagnosis.
Forest plot showing multiple adjusted hazard ratios with 95% CI. HR below 1.0 indicates lower odds of receiving an *ICD* diagnosis of AS. AS indicates aortic stenosis; HR, hazard ratio; *ICD*, *International Classification of Diseases*; Sig., significance; and TTE, transthoracic echocardiogram.

AS detected by TTE, we demonstrated (1) low rates of assignment of an *ICD* code for AS within 1 year of diagnostic TTE; (2) rates of AS diagnosis differed by disease severity; (3) differences in the rate of AS diagnosis across racial and ethnic groups, with non-Hispanic Black and non-Hispanic Asian being the least likely to receive a diagnosis; and (4) reduced likelihood of receiving an AS diagnosis for those in whom the TTE was ordered by a noncardiologist or performed in the inpatient setting. Our study demonstrates that substantial ethnic and racial disparities in the care of patients with AS occur within the earliest stages of its health care trajectory.

Approximately two-thirds of patients with a TTE diagnostic for AS did not receive a clinical *ICD* diagnostic code for AS within 12 months. The absence of a diagnostic code suggests the lack of clinical recognition

Table 2. Stratified Rate Ratios for 1-Year AS *ICD* Diagnosis by Disease Severity, Stratified by Race and Ethnicity

Race and Ethnicity*	Severity	RR	95% CI	*P* value
Non-Hispanic Black	Mild AS	0.50	0.40–0.62	
	Moderate AS	0.58	0.40–0.82	
	Severe AS	0.26	0.14–0.47	
	Non-Hispanic Black	0.47	0.40–0.57	<0.0001
Hispanic	Mild AS	1.11	0.89–1.38	
	Moderate AS	0.73	0.49–1.08	
	Severe AS	0.40	0.20–0.80	
	Hispanic (all races)	0.89	0.75–1.08	0.25
Non-Hispanic Asian	Mild AS	0.59	0.45–0.77	
	Moderate AS	1.01	0.61–1.68	
	Severe AS	0.63	0.32–1.27	
	Non-Hispanic Asian	0.65	0.52–0.81	<0.0001

AS indicates aortic stenosis; *ICD*, *International Classification of Diseases*; and RR, relative risk.
*Reference group is non-Hispanic White.

or acknowledgement of AS, a necessary step for the initiation of appropriate surveillance and treatment of a progressive and lethal disease. Low rates of AS diagnosis highlight the underrecognition of TTE-confirmed AS and underscore the presence of a large population at risk of poor outcomes. Although the importance of a timely diagnosis of mild AS carries lower clinical urgency as compared with more severe stages of AS, the diagnosis of mild AS remains important for the initiation of disease surveillance and guideline-directed TTE screening.[14] Nevertheless, moderate and severe AS were also underdiagnosed, with 1 in 3 patients with moderate AS and 1 in 7 patients with severe AS lacking a clinical diagnosis of AS. These observations highlight an alarming trend in the clinical recognition of AS that spans all disease severities. Severe, symptomatic AS has been associated with a mortality rate of nearly 50% at 2 years when left untreated.[11] Despite this, in the United States, rates of aortic valve replacement for symptomatic, severe AS remain low. Nearly two-thirds of patients remain untreated at 1 year, with greater undertreatment among Black individuals as compared with White individuals.[10] We found that AS detected on TTE often does not translate into receipt of an *ICD* diagnostic code for AS, and it is therefore unclear whether AS in these situations is recognized by providers and subsequently acted upon. Low rates of clinical diagnosis of TTE-confirmed AS may therefore contribute to decreased rates of referral for treatment.

The diagnosis of moderate and severe AS was lower among racial and ethnic minority groups despite adjustment for clinical and demographic factors, and severe AS specifically was underdiagnosed among all racial and ethnic minority groups. These findings are significant in the context of observed racial disparities in the underuse and undertreatment of severe AS. Racial and ethnic minority groups account for <10% of patients undergoing surgical aortic valve replacement in the United States,[4] a significant underrepresentation compared with their proportions in the general population. Multiple cohort studies have also demonstrated similarly low rates of TAVI use among Black[3,6,8,10] and Hispanic[5] individuals as compared with White individuals following the introduction and widespread availability of TAVI.[3,4,7] Racial disparities in the diagnosis and clinical recognition of AS may be associated with differences in health care access and quality of care. TTE performed during inpatient encounters was associated with a lower likelihood of receiving an AS diagnosis, potentially reflecting the prioritization of acute medical problems within the inpatient setting and poor transitions of care after hospitalization. Non-Hispanic Black and Hispanic individuals were both more likely to undergo TTE in the inpatient setting, a finding that may represent the greater burden of chronic comorbid conditions among racial and ethnic minority groups, greater fragmentation of care, and lower rates of preventive care.[16,17] Non-Hispanic Black and Hispanic individuals less frequently had a cardiologist as the TTE ordering provider, which was associated with a reduced likelihood of receiving a diagnosis of AS and may reflect reduced access to specialty care and/or the underrecognition of AS and its clinical relevance by noncardiologists who may be less attuned to cardiac diagnoses. Prior studies have demonstrated reduced access to cardiology specialty care among racial and ethnic minority groups,[18] and specific to AS, reduced and less timely TTE surveillance[19] and greater loss to follow-up after undergoing a diagnostic TTE.[8] Although further investigations are needed to specifically assess the impact of social determinants of health on access to AS care,[20] these findings highlight the need for the development and implementation of quality

improvement initiatives to improve the equitable recognition, surveillance, and management of AS.

In addition to the clinical implications of underdiagnosing AS, our findings bring into context the accuracy of administrative claims data in defining the incidence and prevalence of AS, particularly among racial and ethnic minority groups. Several studies have evaluated the epidemiology and prevalence of AS using *ICD* billing codes.[4,5] Although underrepresented racial and ethnic minority groups have a higher burden of cardiovascular comorbidities that associate with calcific AS,[1] Black, Hispanic, and Asian individuals have been found to have a lower prevalence of AS based on the administrative claims-based Healthcare Cost and Utilization Project Nationwide Inpatient Sample.[5] Based on these findings, a lower prevalence of AS has been regarded as a potential contributor to the underrepresentation of minority groups undergoing aortic valve interventions.[2] However, a large, diverse community-based echocardiographic study of older individuals residing in long-term care found no differences in the prevalence of AS among White, Black, or Hispanic groups.[21] Our results help to resolve these discordant findings by establishing low concordance between the echocardiographic diagnosis of AS and its clinical billing code diagnosis. Our observations reveal that *ICD* billing codes underestimate the true prevalence of AS by over 60% in all patients and by up to 80% among selected minority groups.

Our study results should be interpreted in the context of several limitations. *ICD* diagnostic codes were used as a surrogate marker for the clinical diagnosis of AS following TTE. This framework assumes that a diagnosis of AS was not acknowledged before or in the absence of an *ICD* code, and that the *ICD* code was not issued at a different institution. Yet physicians may recognize AS without the appropriate billing code, and low rates of AS diagnosis may reflect inherent variability and limitations in the accuracy and consistency of *ICD* coding by some providers. Potential solutions to mitigate these challenges include leveraging the electronic medical health record or artificial intelligence-based tools to automatically assign *ICD* codes for significant findings (ie, moderate or greater AS on TTE) and to auto-trigger referrals to a cardiology specialist based on prespecified TTE findings and/or *ICD* billing codes to maximize equality in the recognition and subsequent referral to appropriate care. Mild degrees of AS may also have been interpreted as an incidental finding on TTEs and not acted upon; however, we found similar trends in differential rates of diagnoses among racial and ethnic groups among patients with at least moderate AS. We used a single parameter, MG, to define AS severity on TTE reports. We acknowledge that transaortic gradient may be elevated in the absence of valvular AS (ie, significant aortic regurgitation, high output states, outflow obstruction) or disproportionately low gradients in the presence of low-gradient severe AS phenotypes in a minority of patients. Regardless, differential coding for AS across racial and ethnic groups is a novel observation that furthers our understanding of racial and ethnic disparities in cardiovascular care. We excluded patients with a diagnosis of AS preceding their first index TTE in our health care system, limiting our ability to make any estimations about the disease prevalence among different racial and ethnic groups. In-depth analyses by disease severity were limited by small sample sizes within the racial and ethnic AS-severity subgroups. Although our cohort was generally representative of the population receiving care at our academic medical center (77% White, 6% Black, 8% Hispanic, 5% Asian), both our cohort and institution's patient demographics are not representative of those of our diverse local and state communities, and future studies should aim for a larger representation of racial and ethnic minority groups to be appropriately powered to confirm our preliminary observations. Although stratified analyses should be considered exploratory, they suggest important differences based on AS severity that merit further evaluation. Finally, we did not evaluate differences in rates of referral for TTE for suspected AS. Nevertheless, our observations lay important groundwork for future studies to explore landmark events along the health care trajectory of AS, from diagnosis to valve replacement.

CONCLUSIONS

We identified significant racial and ethnic differences in the assignment of an *ICD* diagnostic code for AS among patients with echocardiographically confirmed AS. Decreased rates of AS diagnosis may contribute to reduced or less frequent clinical follow-up, reduced echocardiographic surveillance, and ultimately referral to aortic valve replacement. Increasing the clinical recognition and diagnosis of TTE-detected AS represents one of the earliest intervenable points in the health care trajectory of patients with AS. Future efforts are needed to dismantle barriers to care and to maximize the equitable screening, referral, and treatment of AS for all racial and ethnic groups.

ARTICLE INFORMATION

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Disclosures

None.

Supplemental Material

Table S1
Figures S1–S5

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SUPPLEMENTAL MATERIAL

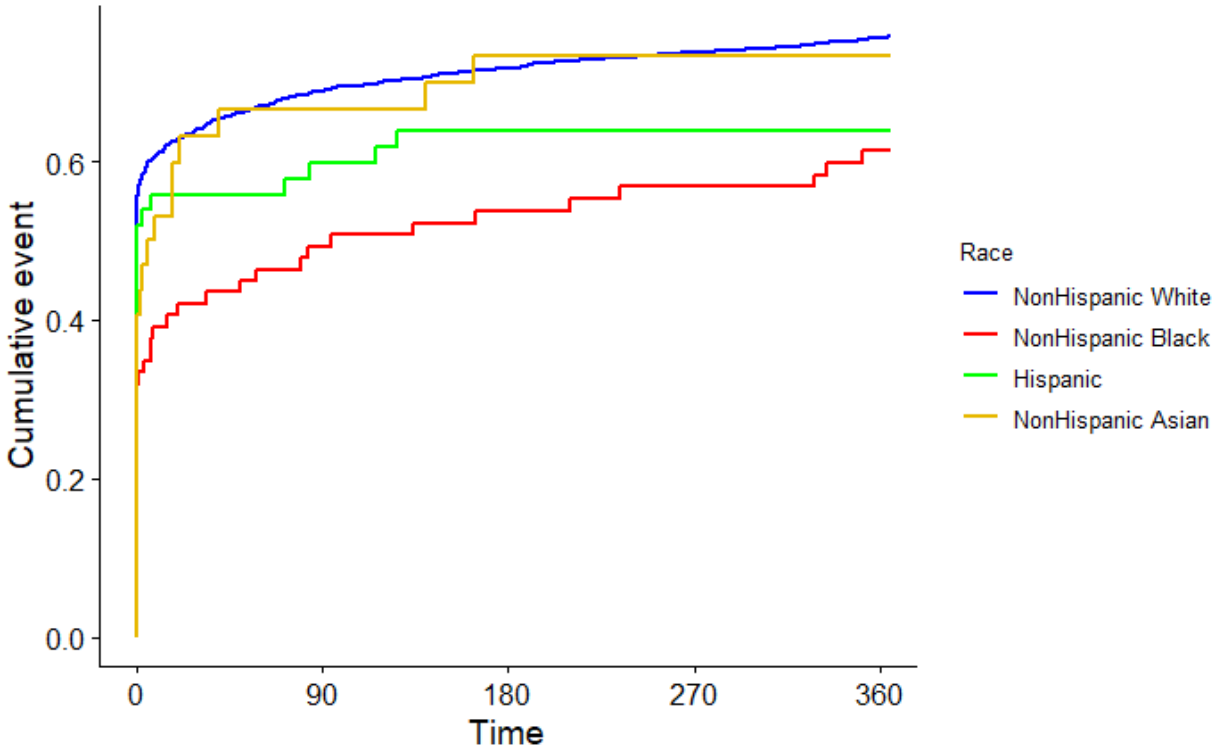
Table S1. Racial and Ethnic Distribution of Entire Cohort by Specified Time Period

Year	NH-White	NH-Black	Hispanic	NH-Asian	**Total**
1990-2012	2957 (93.9%)	63 (2.0%)	86 (2.7%)	40 (1.3%)	**3146**
2013-2020	10633 (91.2%)	525 (4.5%)	224 (1.9%)	272 (2.3%)	**11654**

$x^2 < .0001$

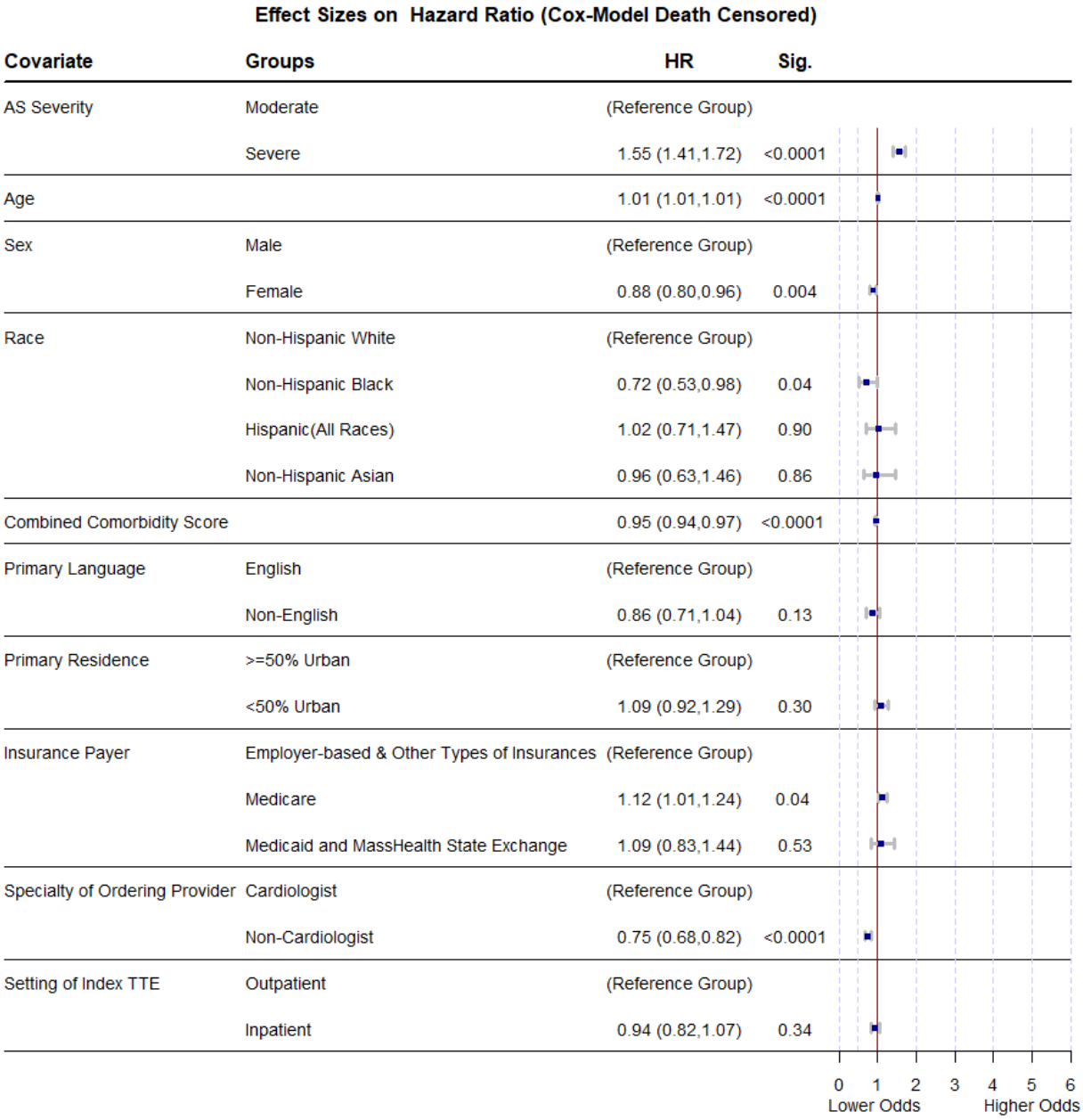
NH= non-Hispanic

Figure S1. Adjusted Cox proportional hazard subgroup analysis of association between race and cumulative AS diagnosis for moderate or greater AS.



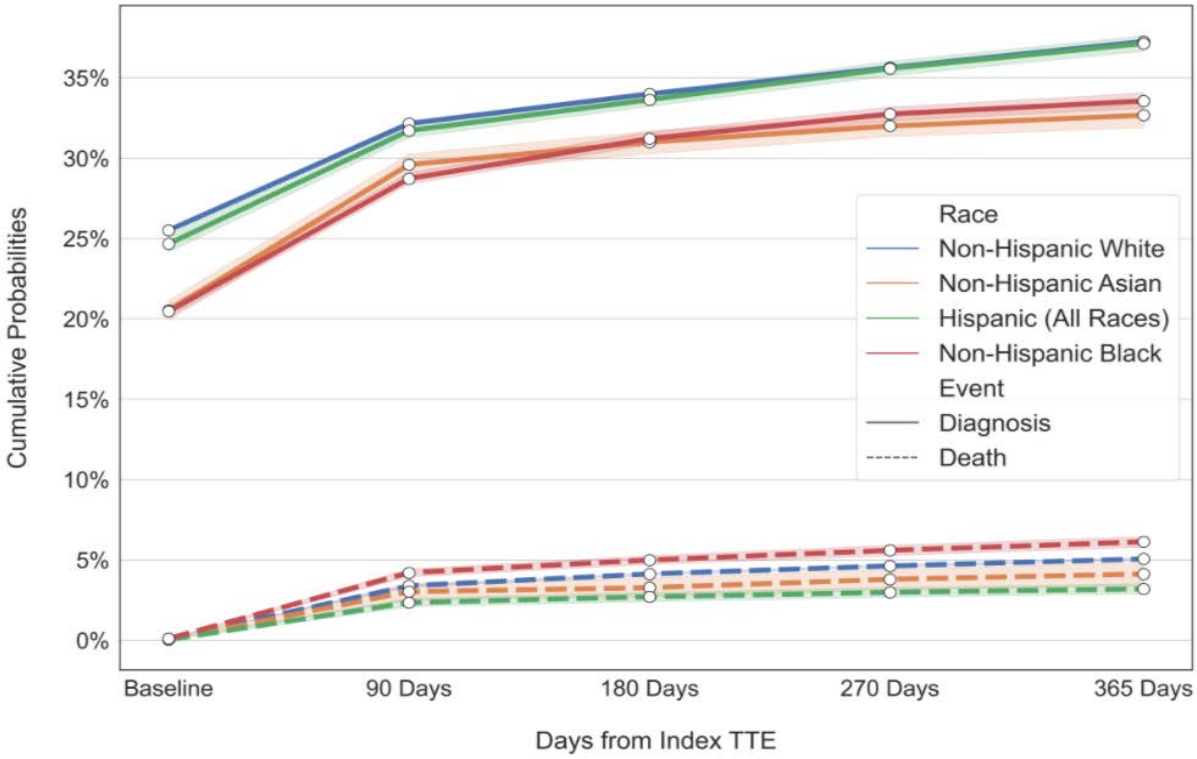
AS= aortic stenosis

Figure S2. Predictors of Receiving an AS ICD Diagnosis for Patients with at least Moderate AS. Forest plot showing multiple adjusted hazard ratios (HRs) with 95% confidence interval. HR below 1.0 indicates lower odds of receiving an ICD diagnosis of AS.



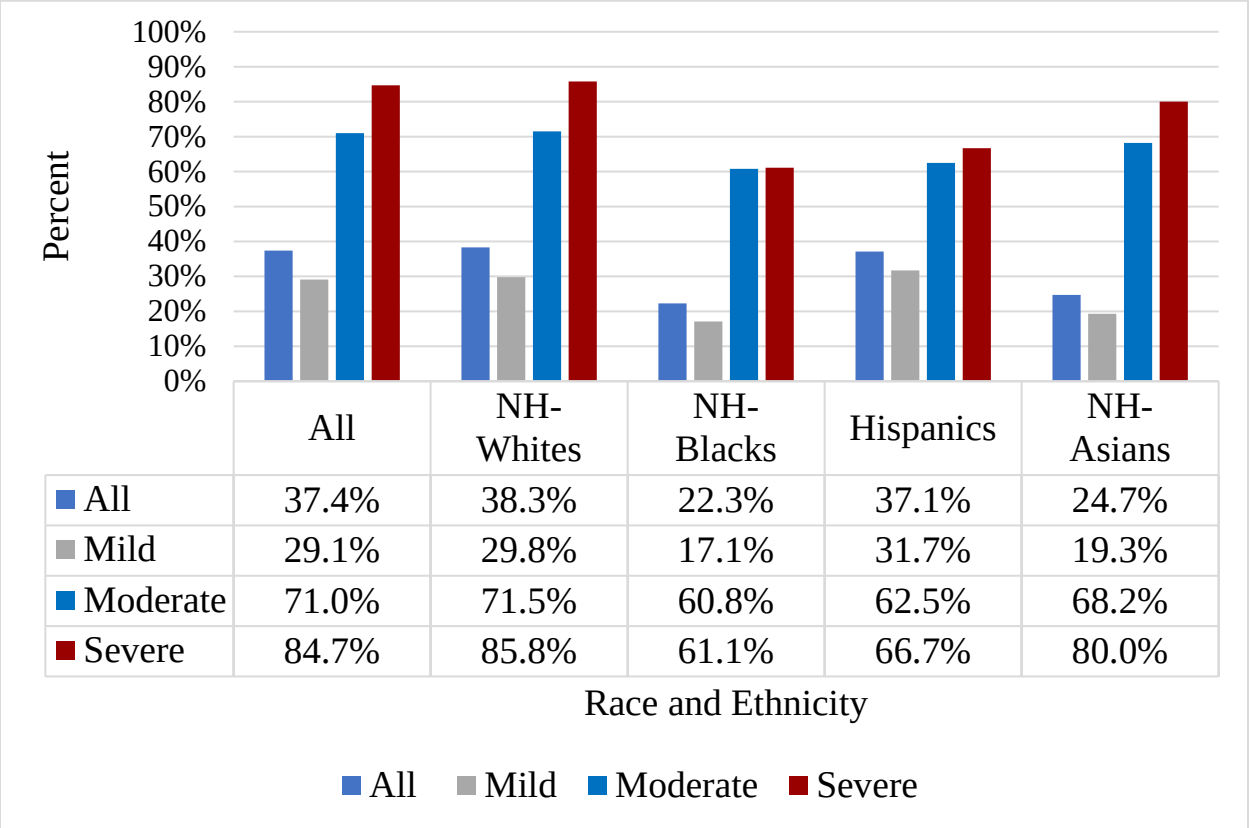
AS= aortic stenosis, HR= hazard ratio, ICD= International Classification of Diseases, TTE= transthoracic echocardiogram

Figure S3. Cumulative Incidence Function of Adjusted 1-Year Rates of AS ICD Diagnosis and Mortality, Stratified by Race and Ethnicity.



AS= aortic stenosis, ICD= International Classification of Diseases

Figure S4. 1-Year Unadjusted Rates of AS ICD Diagnosis by Disease Severity, Stratified by Race and Ethnicity. Cumulative crude rates of AS diagnosis by AS severity and race and ethnicity.

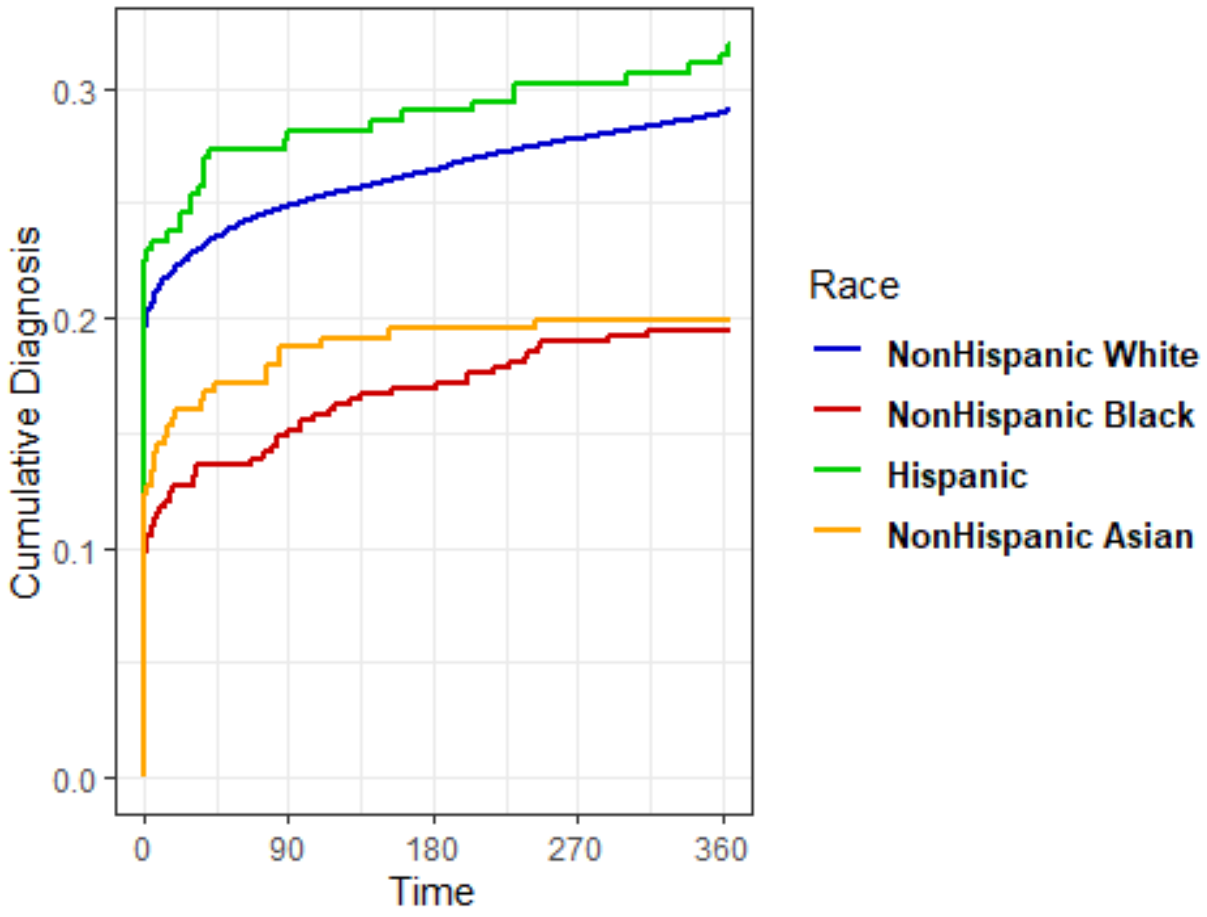


	All	NH-Whites	NH-Blacks	Hispanics	NH-Asians
All	37.4%	38.3%	22.3%	37.1%	24.7%
Mild	29.1%	29.8%	17.1%	31.7%	19.3%
Moderate	71.0%	71.5%	60.8%	62.5%	68.2%
Severe	84.7%	85.8%	61.1%	66.7%	80.0%

AS= aortic stenosis, ICD= International Classification of Diseases, NH= non-Hispanic

Figure S5A-C. Adjusted Cox proportional hazard exploratory analysis of association between race and cumulative AS diagnosis by disease severity (5A: mild AS, 5B: moderate AS, 5C: severe AS).

Figure S5A



AS= aortic stenosis

Figure S5B

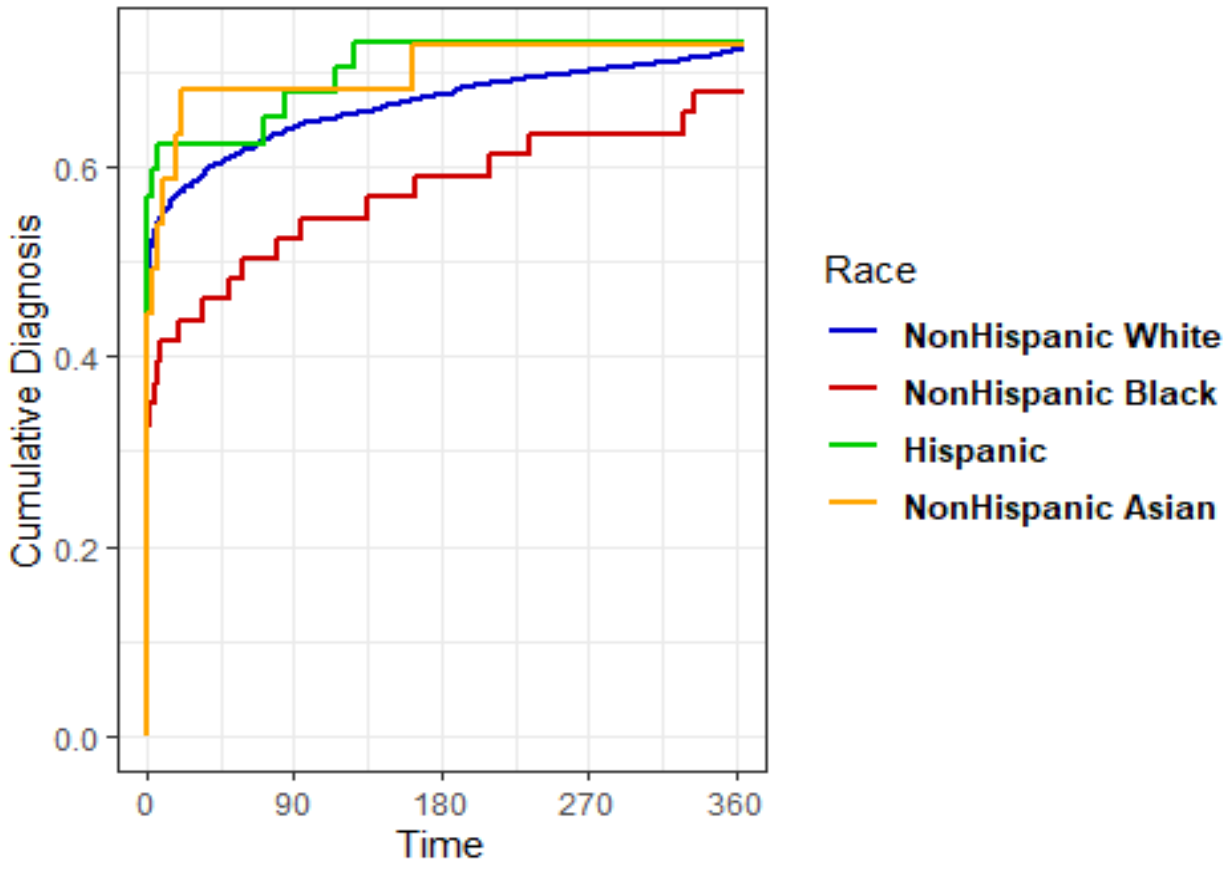
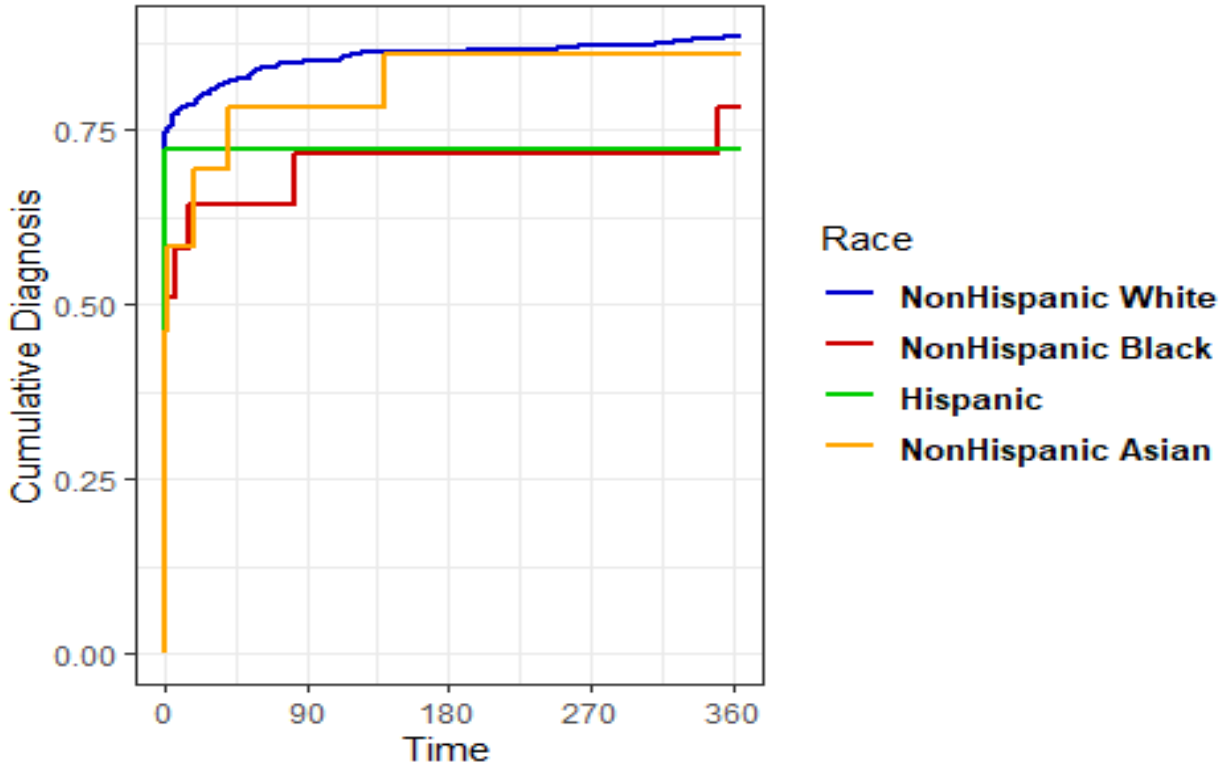

Cumulative Diagnosis
0.0
0.2
0.4
0.6
0
90
180
270
360
Time
Race
NonHispanic White
NonHispanic Black
Hispanic
NonHispanic Asian

Figure S5C


Cumulative Diagnosis
0.75
0.50
0.25
0.00
0
90
180
270
360
Time
Race
NonHispanic White
NonHispanic Black
Hispanic
NonHispanic Asian