Journal of the American Heart Association

ORIGINAL RESEARCH

Inequities in Treatments and Outcomes Among Patients Hospitalized With Hypertrophic Cardiomyopathy in the United States

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BACKGROUND: Hypertrophic cardiomyopathy (HCM) is the most common heritable cardiac disease. In small studies, sociodemographic factors have been associated with disparities in septal reduction therapy, but little is known about the association of sociodemographic factors with HCM treatments and outcomes more broadly.

METHODS AND RESULTS: Using the National Inpatient Survey from 2012 to 2018, HCM diagnoses and procedures were identified by *International Classification of Diseases, Ninth/Tenth Revision, Clinical Modification* (*ICD-9-CM* and *ICD-10-CM*) codes. Logistic regression was used to determine the association of sociodemographic risk factors with HCM procedures and in-hospital death, adjusting for clinical comorbidities and hospital characteristics. Of 53 117 patients hospitalized with HCM, 57.7% were women, 20.5% were Black individuals, 27.7% lived in the lowest zip income quartile, and 14.7% lived in rural areas. Among those with obstruction (45.2%), compared with White patients, Black patients were less likely to undergo septal myectomy (adjusted odds ratio [aOR], 0.52 [95% CI, 0.40–0.68]), or alcohol septal ablation (aOR, 0.60 [95% CI, 0.42–0.86]). Patients with Medicaid were less likely to undergo each procedure (aOR, 0.78 [95% CI, 0.61–0.99] for myectomy; aOR, 0.54 [95% CI, 0.36–0.83] for ablation). Women (aOR, 0.66 [95% CI, 0.58–0.74]), patients with Medicaid (aOR, 0.78 [95% CI, 0.65–0.93]), and patients from low-income areas (aOR, 0.77 [95% CI, 0.65–0.93]) were less likely to receive implantable cardioverter-defibrillators. Women (aOR, 1.23 [95% CI, 1.10–1.37]) and patients from towns (aOR, 1.16 [95% CI, 1.03–1.31]) or rural areas (aOR, 1.57 [95% CI, 1.30–1.89]) had higher odds of in-hospital death.

CONCLUSIONS: Among 53 117 patients hospitalized with HCM, race, sex, social, and geographic risk factors were associated with disparities in HCM outcomes and treatment. Further research is required to identify and address the sources of these inequities.

Key Words: disparities ■ ethnicity ■ hypertrophic cardiomyopathy ■ outcomes ■ race ■ sex

Hypertrophic cardiomyopathy (HCM), an autosomal dominant genetic disease characterized by disorganized architecture of the myocardium and left ventricular hypertrophy, is the most common heritable cardiac disease.[1–4] HCM often involves obstruction of left ventricular outflow and is categorized into obstructive (oHCM) and nonobstructive HCM. A wide range of symptoms and outcomes are associated with HCM, from no symptoms and normal life expectancy to heart failure and sudden cardiac death (SCD).[2] Outcomes of HCM have improved in the past 35 years because of the development of effective therapeutic strategies.[5] The

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This manuscript was sent to Sula Mazimba, MD, MPH, Associate Editor, for review by expert referees, editorial decision, and final disposition.

Supplemental Material is available at https://www.ahajournals.org/doi/suppl/10.1161/JAHA.122.029930

For Sources of Funding and Disclosures, see page 9.

JAHA is available at: www.ahajournals.org/journal/jaha

CLINICAL PERSPECTIVE

What Is New?

- Our study is the largest study assessing the association of social risk factors with hypertrophic cardiomyopathy procedures and in-hospital death to date (N=53 117 admissions for patients with hypertrophic cardiomyopathy).
- We observed that race, sex, and other social risk factors were associated with significant disparities in in-hospital death and in receiving septal reduction therapy and implantable cardioverter-defibrillator treatment among patients with hypertrophic cardiomyopathy.

What Are the Clinical Implications?

- The disparities we observed in treatment patterns may be due to modifiable factors, including structural and interpersonal racism, differences in access to specialized care, and differences in prior treatments.
- This study provides important insights for clinicians and policymakers regarding the next steps in identifying and addressing the sources of these inequities.

Nonstandard Abbreviations and Acronyms

HCM	hypertrophic cardiomyopathy
NIS	National Inpatient Sample
oHCM	obstructive hypertrophic cardiomyopathy
SCD	sudden cardiac death
SRT	septal reduction therapy

advancement of septal reduction therapies (SRTs) for oHCM, including septal myectomy and alcohol septal ablation, and the implantation of primary prevention implantable cardioverter-defibrillators in patients with HCM at risk of SCD have been important contributors to a decrease in death from this disease.[2,5]

However, these gains may not have been shared equally for a host of reasons related to unequal access to care in the United States on the basis of race, ethnicity, sex, income, and geography. Likely due to structural and individual racism, both historical and current, Black individuals are underrepresented in HCM clinical studies and registries[6–10] and have lower rates of referral to HCM Centers of Excellence, referral for genetic testing, and referral for risk stratification for SCD.[9,10] These are particularly notable given that Black patients with HCM have worse cardiovascular outcomes, including SCD and development of class III or IV heart failure, when compared with White patients with HCM.[6,9,10] Women are also underrepresented in HCM registries and, compared with men, are diagnosed at older ages and with more severe symptoms,[11] and are at a higher risk of progressing to heart failure or death.[11–13] Furthermore, patients with low income are less likely than patients with higher income to be seen in specialized HCM clinics even though they are more likely to present with a more complex disease phenotype, comorbidities, and poorer quality of life.[14] While less is known about HCM among patients in rural areas, rurality is associated with worse outcomes for many cardiovascular conditions, likely due to worse access to specialty care and a high burden of social risk factors in rural areas.[15,16]

To date, most studies on the treatment and outcomes for HCM have been limited to relatively small sample sizes from single- or multicenter studies, which limits their ability to quantify differences in treatment patterns and outcomes for key subgroups.[9,10,17] We therefore sought to assess disparities in HCM diagnosis and treatments across social risk factors using the largest publicly available all-payer inpatient care database in the United States, the National Inpatient Sample (NIS). We aimed to determine, among individuals hospitalized between 2012 and 2018 with a diagnosis of HCM, (1) clinical and demographic characteristics, (2) rates of HCM treatments and in-hospital death, and (3) the association between sociodemographic risk factors and HCM treatments and in-hospital death.

METHODS

Data

This study is a retrospective analysis of the 2012 to 2018 NIS provided by the Healthcare Cost and Utilization Project of the Agency for Healthcare Research and Quality.[18] The NIS approximates a 20% sample of all discharges from US hospitals and includes data for >7 million hospital stays yearly.[18] The NIS data were obtained under appropriate data use agreements, and the investigators are not authorized to share data independently.

We included all hospitalizations for individuals <18 years old with a diagnosis of HCM (n=53 117). Hospitalizations for HCM were identified using previously validated *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) codes for 2012 through third quarter 2015, and *Tenth Revision* (*ICD-10-CM*) codes for fourth quarter 2015 through 2018.[19,20] oHCM was identified by *ICD-9-CM* code 425.11 and *ICD-10-CM* code I42.1, and nonobstructive HCM was identified by *ICD-10-CM* code 425.18 and *ICD-10-CM* code I42.2. For the 1634 patients who were transferred to another acute-care hospital, we assigned them to the accepting hospital to avoid double-counting hospitalizations because the NIS

does not link patient records after transfers. For example, a patient from a rural area who presented to a local facility and was then transferred to a referral center for a myectomy would have their hospitalization assigned to the referral center. We also excluded 9 hospitalizations for patients <18 years old and 1461 hospitalizations missing data on key predictors (Figure S1).

Predictors

Our primary predictor was race and ethnicity. Race and ethnicity are treated as a single variable by Healthcare Cost and Utilization Project in the NIS instead of separate variables, so race/ethnicity was categorized into 3 groups: White, Black, and Hispanic. The remaining groups (Asian or Pacific Islander, Native American, and Other) were too small to analyze individually, so patients from these groups were not included in the study. Race and ethnicity data are provided to Healthcare Cost and Utilization Project by hospitals, so these designations may reflect patient self-report or administrative assignment. Secondary predictors included sex, median zip income quartile, insurance status, and rurality. Median zip income quartile was defined as the quartile of the median household income for a patient's zip code. Medical comorbidities were ascertained using the Elixhauser approach, which has been validated for use in risk adjustment in administrative data sets.

Outcomes

Our primary outcomes included HCM procedures (septal myectomy, alcohol septal ablation, and implantable cardioverter-defibrillator procedures) and death during hospitalization. HCM procedures were identified using previously validated *International Classification of Diseases, Ninth Revision, Procedure Coding System* (*ICD-9-PCS*) codes from 2012 through the third quarter of 2015 and *Tenth Revision* (*ICD-10-PCS*) codes from the fourth quarter of 2015 through 2018.[19–23] Septal myectomy was identified by *ICD-9-PCS* code 37.33 and *ICD-10-PCS* codes 02BK0ZZ, 02BK0ZX, 02BL0ZZ, 02BL0ZX, 025M0ZZ, 02BM0ZZ; septal ablation was identified by *ICD-9-PCS* code 37.34 and *ICD-10-PCS* codes 025M3ZZ, 02BK3ZX, 02BK4ZX, 02BK4ZZ, 02BK3ZZ, 02BL3ZZ, 02BL3ZX, 02BL4ZX, 02BL4ZZ, 025M4ZZ, 02BM3ZZ, 02BM4ZZ, 02BM3ZX, and 02BM4ZX; implantable cardioverter-defibrillator procedures were identified by *ICD-9-PCS* codes 00.51, 00.54, 37.94, 37.95, 37.96, 37.97, and 37.98 and *ICD-10-PCS* codes 0JH608Z, 0JH609Z, 0JH808Z, 0JH809Z, 0JH638Z, 0JH639Z, 0JH838Z, 0JH839Z, and 02HK3KZ.

Statistical Analysis

Patient demographics, sociodemographic risk factors, comorbidities, HCM procedures, and cardiovascular outcomes were calculated for the entire group of HCM hospitalizations, and for HCM hospitalizations stratified by oHCM and nonobstructive HCM, and were reported as frequencies and percentages. To determine the odds of receiving SRT and of in-hospital death, we used logistic regression fit using generalized estimating equations adjusting for age, medical comorbidities using the Elixhauser classification,[24] presence of a preexisting implantable cardioverter-defibrillator, and within hospital-year clustering. The odds ratios for receipt of a septal myectomy or alcohol septal ablation were calculated only for patients with oHCM; the odds ratios for receipt of an implantable cardioverter-defibrillator were calculated after excluding those with a preexisting implantable cardioverter-defibrillator.

All statistical analyses were conducted using R version 4.0.5 (R Foundation for Statistical Computing, Vienna, Austria). A significance level of 0.05 was used, and hypothesis tests were 2-sided. All analyses were performed in compliance with the Healthcare Cost and Utilization Project data use agreement. This study was approved by the Human Research Protection Office at Washington University in St. Louis. The requirement for informed consent was waived due to the deidentified nature of the data.

RESULTS

Our sample consisted of 53 117 HCM hospitalizations (Table 1). The patients were 57.7% women (n=30 634), 20.5% were Black individuals (n=10 869), and 6.4% were Hispanic (n=3423); 27.7% of patients lived in the lowest zip income quartile, 11.1% were insured by Medicaid, and 14.7% were from rural areas. Other than oHCM or nonobstructive HCM, the most common admission diagnoses were atrial fibrillation, acute or chronic diastolic heart failure, and subendocardial or non–ST-segment–elevation myocardial infarction.

There were differences by race and ethnicity in age (proportion >75 years of age 38.1% among White patients, 20.9% among Black patients, and 24.4% among Hispanic patients; Table 2), as well as in the presence of comorbidities. Black patients were the most likely to have a diagnosis of hypertension (30.6% among White patients, 49.0% among Black patients, 32.2% among Hispanic patients), congestive heart failure (43.5% versus 48.9% versus 41.0%), obesity (18.0% versus 23.3% versus 20.3%), and diabetes (10.0% versus 17.9% versus 14.7%; *P* for all <0.001). Black patients were less likely to have a preexisting diagnosis of cardiac arrhythmia (61.8% among White patients, 47.8% among Black patients, 52.4% among Hispanic patients), and there was no racial or ethnic difference in the likelihood of having a preexisting implantable cardioverter-defibrillator. With respect to

Table 1. Patient Characteristics

	All HCM, n (%)	Obstructive HCM, n (%)	Nonobstructive HCM, n (%)
Total (N)	53 117	24 010 (45.2)	29 107 (54.8)
Sex, female	30 634 (57.7)	14 807 (61.7)	15 827 (54.4)
Age, y			
18–34	2178 (4.1)	892 (3.7)	1286 (4.4)
35–54	10 618 (20.0)	4441 (18.5)	6177 (21.2)
55–64	10 136 (19.1)	4743 (19.8)	5395 (18.5)
65–74	12 284 (23.1)	5822 (24.2)	6462 (22.2)
75+	17 901 (33.7)	8112 (33.8)	9789 (33.6)
Race or Ethnicity			
White	38 825 (73.1)	18 494 (77.0)	20 331 (69.8)
Black	10 869 (20.5)	4106 (17.1)	6763 (23.2)
Hispanic	3423 (6.4)	1410 (5.9)	2013 (6.9)
Insurance			
Medicare	33 527 (63.1)	15 289 (63.7)	18 238 (62.7)
Medicaid	5916 (11.1)	2386 (9.9)	3530 (12.1)
Private insurance	12 274 (23.1)	5753 (24.0)	6521 (22.4)
Uninsured	1400 (2.6)	582 (2.4)	818 (2.8)
Median zip income			
Q1: $0–$47 999	14 699 (27.7)	6494 (27.0)	8205 (28.2)
Q2: $48 000–$60 999	13 097 (24.7)	5986 (24.9)	7111 (24.4)
Q3: $61 000–$81 999	12 821 (24.1)	5804 (24.2)	7017 (24.1)
Q4: $82 000+	12 500 (23.5)	5726 (23.8)	6774 (23.3)
Rurality			
Urban	29 555 (55.6)	13 408 (55.8)	16 147 (55.5)
Town	15 777 (29.7)	7003 (29.2)	8774 (30.1)
Rural	7785 (14.7)	3599 (15.0)	4186 (14.4)
Comorbidities			
Hypertension, complicated	18 319 (34.5)	7605 (31.7)	10 714 (36.8)
Cardiac arrhythmia	30 993 (58.3)	14 411 (60.0)	16 582 (57.0)
Congestive heart failure	23 627 (44.5)	10 285 (42.8)	13 342 (45.8)
Presence of implantable cardioverter-defibrillator	6774 (12.8)	3160 (13.2)	3614 (12.4)
Obesity	10 225 (19.3)	4789 (19.9)	5436 (18.7)
Diabetes, complicated	6348 (12.0)	2587 (10.8)	3761 (12.9)
Teaching status			
Urban teaching	38 135 (71.8)	17 935 (74.7)	20 200 (69.4)
Urban nonteaching	11 629 (21.9)	4739 (19.7)	6890 (23.7)
Rural	3353 (6.3)	1336 (5.6)	2017 (6.9)
Hospital region			
Northeast	12 834 (24.2)	5648 (23.5)	7186 (24.7)
Midwest	12 646 (23.8)	5963 (24.8)	6683 (23.0)
South	18 714 (35.2)	8219 (34.2)	10 495 (36.1)
West	8923 (16.8)	4180 (17.4)	4743 (16.3)
Profit status			
For-profit	3152 (10.8)	1833 (7.6)	4985 (9.4)
Not-for-profit	23 123 (79.4)	19 775 (82.4)	42 898 (80.8)
Public	2832 (9.7)	2402 (10.0)	5234 (9.9)

HCM indicates hypertrophic cardiomyopathy.

Table 2. Patient Characteristics by Race and Ethnicity

	All HCM			
	White, n (%)	Black, n (%)	Hispanic, n (%)	*P* value
Total (N)	38825 (73.0)	10869 (20.5)	3423 (6.44)	
Sex, female	22419 (57.7)	6298 (57.9)	1917 (56.0)	0.116
Age, y				<0.001
18–34	1202 (3.1)	720 (6.6)	256 (7.5)	
35–54	6406 (16.5)	3131 (28.8)	1081 (31.6)	
55–64	7001 (18.0)	2520 (23.2)	615 (18.0)	
65–74	9423 (24.3)	2226 (20.5)	635 (18.6)	
75+	14793 (38.1)	2272 (20.9)	836 (24.4)	
Comorbidities				
Hypertension, complicated	11896 (30.6)	5321 (49.0)	1102 (32.2)	<0.001
Cardiac arrhythmia	24003 (61.8)	5195 (47.8)	1795 (52.4)	<0.001
Congestive heart failure	16904 (43.5)	5319 (48.9)	1404 (41.0)	<0.001
Obesity	6993 (18.0)	2536 (23.3)	696 (20.3)	<0.001
Diabetes, complicated	3894 (10.0)	1950 (17.9)	504 (14.7)	<0.001
Presence of implantable cardioverter-defibrillator	4978 (12.8)	1385 (12.7)	411 (12.0)	0.9
Insurance				<0.001
Medicare	25953 (66.8)	5916 (54.4)	1658 (48.4)	
Medicaid	2765 (7.1)	22754 (20.9)	877 (25.6)	
Private insurance	9399 (24.2)	2161 (19.9)	714 (20.9)	
Uninsured	708 (1.8)	518 (4.8)	174 (5.1)	
Median zip income				<0.001
Q1: $0–$47999	8070 (20.8)	5423 (49.9)	1206 (35.2)	
Q2: $48000–$60999	9884 (25.5)	2363 (21.7)	850 (24.8)	
Q3: $61000–$81999	10214 (26.3)	1831 (16.8)	776 (22.7)	
Q4: $82000+	10657 (27.4)	1252 (11.5)	591 (17.3)	
Rurality				<0.001
Urban	19620 (50.5)	7506 (69.1)	2429 (71.0)	
Town	12349 (31.8)	2630 (24.2)	798 (23.3)	
Rural	6856 (17.7)	733 (6.7)	196 (5.7)	

Comparisons were conducted using chi-square tests of independence. HCM indicates hypertrophic cardiomyopathy.

socioeconomic factors, compared with White patients, Black and Hispanic patients were more likely to be on Medicaid (7.1% among White patients, 20.9% among Black patients, 25.6% among Hispanic patients) or uninsured (1.8% versus 4.8% versus 5.1%; $P<0.001$ for both). Black and Hispanic patients were more likely to live in the lowest zip income quartile and in urban areas. Patient characteristics by race, ethnicity, and obstructive versus nonobstructive phenotypes are shown in Table S1 for completeness.

Hospital Characteristics

A total of 13020 US hospital-years were included in the analysis (Table S2). There was broad representation by hospital-year with respect to hospital size (26% small versus 31% medium versus 42% large) and with respect to region of the United States (20% Northwest versus 24% Midwest versus 36% South versus 20% West). The majority (75%) of the hospitals were private, not-for-profit hospitals, and 52% were urban teaching hospitals.

Septal Reduction Procedures

Among hospitalizations for patients with HCM, 24010 (45.2%) were classified with oHCM. Of the patients with oHCM, 6.1% received septal myectomy, and 2.2% received alcohol septal ablation (Table 3). After adjustment for comorbidities and hospital characteristics, women were more likely to receive septal myectomies (adjusted odds ratio [aOR], 1.18 [95% CI, 1.01–1.38]). Black patients were less likely than White patients to receive septal myectomy (aOR, 0.52 [95% CI, 0.40–0.68]) or alcohol septal ablation (aOR, 0.60 [95% CI, 0.42–0.86]). Compared with patients with private

Table 3. Odds of SRT Procedures Among Obstructive Hypertrophic Cardiomyopathy Admissions

	Septal myectomy (n=1654), aOR (95% CI)	Alcohol septal ablation (n=772, aOR (95% CI)
Sex (ref: male)		
Female	1.18 (1.01–1.38)	1.20 (0.97–1.48)
Race or ethnicity (ref: White)		
Black	0.52 (0.40–0.68)	0.60 (0.42–0.86)
Hispanic	0.82 (0.60–1.12)	0.79 (0.49–1.26)
Insurance (ref: private)		
Medicare	0.54 (0.44–0.66)	0.79 (0.60–1.06)
Medicaid	0.78 (0.61–0.99)	0.54 (0.36–0.83)
Uninsured	0.54 (0.33–0.89)	0.73 (0.36–1.47)
Zip income (ref: top quartile)		
Q1: $0–$47 999	0.83 (0.65–1.05)	0.86 (0.60–1.23)
Q2: $48 000–$60 999	0.96 (0.77–1.20)	1.08 (0.78–1.49)
Q3: $61 000–$81 999	1.05 (0.87–1.27)	1.05 (0.78–1.41)
Rurality (ref: urban)		
Town	1.19 (0.98–1.43)	1.04 (0.81–1.34)
Rural	1.50 (1.19–1.90)	1.44 (1.03–2.01)
Hospital size (ref: large)		
Medium	0.57 (0.45–0.73)	0.40 (0.29–0.55)
Small	0.29 (0.20–0.42)	0.47 (0.32–0.69)
Teaching status (ref: urban teaching)		
Urban nonteaching	0.39 (0.31–0.50)	0.15 (0.09–0.24)
Rural	0.09 (0.04–0.21)	0.04 (0.01–0.15)
Hospital region (ref: Northeast)		
Midwest	1.38 (1.02–1.87)	0.64 (0.45–0.92)
South	1.43 (1.07–1.92)	1.00 (0.73–1.38)
West	1.36 (0.99–1.88)	1.08 (0.76–1.55)
Profit status (ref: for-profit)		
Not-for-profit	0.83 (0.60–1.16)	0.62 (0.40–0.94)
Public	0.79 (0.53–1.19)	0.93 (0.58–1.50)

Analyses are adjusted for age group, sex, race, ethnicity, insurance status, zip code median income, rurality, Elixhauser comorbidities, presence of implantable cardioverter-defibrillator, listed hospital characteristics, and clustering by hospital-year. aOR indicates adjusted odds ratio; and SRT septal reduction therapy.

Table 4. Odds of Implantable Cardioverter-Defibrillator Implantation Among Hypertrophic Cardiomyopathy Admissions

	Implantable cardioverter-defibrillator implantation (n=1598), aOR (95% CI)
Sex (ref: male)	
Female	0.66 (0.58–0.74)
Race or ethnicity (ref: White)	
Black	1.10 (0.94–1.29)
Hispanic	1.00 (0.80–1.25)
Insurance (ref: private)	
Medicare	0.72 (0.61–0.84)
Medicaid	0.78 (0.65–0.93)
Uninsured	0.84 (0.62–1.13)
Zip income (ref: top quartile)	
Q1: $0–$47 999	0.77 (0.65–0.93)
Q2: $48 000–$60 999	0.91 (0.77–1.08)
Q3: $61 000–$81 999	0.91 (0.77–1.06)
Rurality (ref: urban)	
Town	0.95 (0.84–1.09)
Rural	1.11 (0.92–1.35)
Hospital size (ref: large)	
Medium	0.62 (0.54–0.72)
Small	0.44 (0.36–0.53)
Teaching status (ref: urban teaching)	
Urban nonteaching	0.53 (0.45–0.63)
Rural	0.19 (0.12–0.32)
Hospital region (ref: Northeast)	
Midwest	0.77 (0.65–0.92)
South	1.02 (0.87–1.19)
West	0.86 (0.72–1.04)
Profit status (ref: for-profit)	
Not-for-profit	0.81 (0.65–1.00)
Public	0.82 (0.63–1.08)

Analyses are adjusted for age group, sex, race, ethnicity, insurance status, zip code median income, rurality, Elixhauser comorbidities, presence of implantable cardioverter-defibrillator, listed hospital characteristics, and clustering by hospital-year. aOR indicates adjusted odds ratio.

insurance, patients with Medicaid were less likely to receive septal myectomy (aOR, 0.78 [95% CI, 0.61–0.99]) or alcohol septal ablation (aOR, 0.54 [95% CI, 0.36–0.83]); patients without insurance were also less likely to receive septal myectomy (aOR, 0.54 [95% CI, 0.33–0.89]). Patients from rural areas were more likely than patients from urban areas to receive septal myectomy (aOR, 1.50 [95% CI, 1.19–1.90]) and ablation (aOR 1.44 [95% CI, 1.03–2.01]). Patients at small or medium hospitals, compared with large hospitals, and at rural nonteaching or urban nonteaching hospitals, compared with urban teaching hospitals, were markedly less likely to receive SRT.

Implantable Cardioverter-Defibrillator Procedures

Overall, of admitted patients with HCM who did not already have an implantable cardioverter-defibrillator, 3.0% underwent implantable cardioverter-defibrillator implantation (Table 4). There were no differences by race or ethnicity. Female patients were less likely than male patients to receive an implantable

Table 5. Odds of In-Hospital Mortality Among Hypertrophic Cardiomyopathy Admissions

	In-hospital death, aOR (95% CI)
Sex (ref: male)	
Female	1.23 (1.10–1.37)
Race or ethnicity (ref: White)	
Black	0.96 (0.83–1.11)
Hispanic	1.16 (0.94–1.44)
Insurance (ref: private)	
Medicare	0.99 (0.84–1.17)
Medicaid	1.13 (0.91–1.4)
Uninsured	0.99 (0.65–1.5)
Zip income (ref: top quartile)	
Q1: $0–$47 999	0.98 (0.83–1.15)
Q2: $48 000–$60 999	0.93 (0.80–1.09)
Q3: $61 000–$81 999	1.05 (0.91–1.21)
Rurality (ref: urban)	
Town	1.16 (1.03–1.31)
Rural	1.57 (1.30–1.89)
Hospital size (ref: large)	
Medium	1.08 (0.95–1.22)
Small	0.95 (0.81–1.10)
Teaching status (ref: urban teaching)	
Urban nonteaching	0.95 (0.84–1.08)
Rural	0.85 (0.66–1.10)
Hospital region (ref: Northeast)	
Midwest	0.78 (0.67–0.92)
South	0.85 (0.73–0.99)
West	1.04 (0.89–1.21)
Profit status (ref: for-profit)	
Not-for-profit	1.06 (0.87–1.29)
Public	1.23 (0.96–1.57)

Analyses are adjusted for age group, sex, race, ethnicity, insurance status, zip code median income, rurality, Elixhauser comorbidities, presence of implantable cardioverter-defibrillator, listed hospital characteristics, and clustering by hospital-year. aOR indicates adjusted odds ratio.

cardioverter-defibrillator (aOR, 0.66 [95% CI, 0.58–0.74]). Compared with patients in the highest income quartile, patients in the lowest income quartile were less likely to receive an implantable cardioverter-defibrillator (aOR, 0.77 [95% CI, 0.65–0.93]). There were no differences by zip income or rurality. Again, patients at small or medium hospitals, compared with large hospitals, and at rural nonteaching or urban nonteaching hospitals, compared with urban teaching hospitals, were markedly less likely to receive procedures.

In-Hospital Death

Overall, 3.2% of patients with HCM died in the hospital (Table 5). Compared with men, women were more likely to die during hospitalization (aOR, 1.23 [95% CI, 1.10–1.37]). There was no significant difference in the odds of in-hospital death by race or ethnicity (among Black patients, aOR, 0.96 [95% CI, 0.83–1.11]; among Hispanic patients, aOR, 1.16 [95% CI, 0.94–1.44]). Compared with patients from urban areas, patients from towns (aOR, 1.16 [95% CI, 1.03–1.31]) and rural areas (aOR, 1.57 [95% CI, 1.30–1.89]) were more likely to die during hospitalization. In-hospital death rates by HCM procedure are shown in Table S3.

DISCUSSION

In these data from the largest publicly available inpatient health care database in the United States—a national random sample of 53 117 admissions for patients with HCM between 2012 and 2018—we observed that race, sex, insurance status, and geography were associated with significant disparities in the receipt of SRT and implantable cardioverter-defibrillator treatment and in-hospital death among patients with HCM.

With respect to clinical and demographic characteristics, most of the patients with HCM in this sample were ≥65 years of age. A slight majority were female, similar to demographics of the entire NIS and to the US population for those >65 years of age. The percentage of Black patients was slightly higher in our sample compared with the US population (≈20% in our sample compared with ≈12% in the US population during the study period). The reasons for this are unclear but may be related to the fact that Black individuals with HCM are known to have worse cardiovascular outcomes, including SCD and development of class III or IV heart failure, which may prompt hospitalization.[6,9,10] This premise is supported by the fact that we did observe a higher incidence of congestive heart failure as a comorbidity in Black patients, compared with White patients. Conversely, Hispanic patients were significantly underrepresented in our sample compared with the US population (≈6% in our sample, ≈18% of the US population during the study period), which may relate either to underdiagnosis or to genetic differences in disease prevalence, both of which are less well understood in Hispanic/Latino US populations than White or Black populations.

This national sample also presented the opportunity to explore the treatments provided to hospitalized patients with HCM. Compared with White patients, Black patients were >40% less likely to receive SRT, but there were no differences in implantable cardioverter-defibrillator placement. Two prior studies reported that Black patients were less likely to receive SRT, though they had a combined total of 295 Black patients and were composed solely of data from HCM referral centers.[9,10] Both of these studies also assessed the association between race and implantable cardioverter-defibrillator placement, but their results

were inconsistent. Wells and colleagues reported that, compared with White patients, Black patients were less likely to receive implantable cardioverter-defibrillators despite similar rates of SCD between Black and White patients.[9] In contrast, Eberly and colleagues[10] reported no difference in implantable cardioverter-defibrillator treatment between Black and White patients. Our observations support and extend the findings observed by Eberly et al. Our sample is much larger and represents the experience of patients treated in a range of hospitals, not just specialty centers. It is interesting that we observed marked differences in SRT but not in implantable cardioverter-defibrillator treatments. Given that the absolute wall thickness indication for implantable cardioverter-defibrillators (ie, wall thickness ≥3 cm) is unequivocal, and the fact that 1 small study has shown that Black individuals with HCM are more likely than White individuals with HCM to have wall thickness ≥3 cm,[25] we hypothesize that this indication for implantable cardioverter-defibrillator implantation may supersede any bias that is present and may contribute to the rate of implantable cardioverter-defibrillator implantation we observed in Black patients with HCM. One recent study, by Patlolla and colleagues,[26] also used an inpatient sample to assess implantable cardioverter-defibrillator implantation during hospitalization for HCM and reported a lower odds of non-White patients receiving implantable cardioverter-defibrillator procedures from 2003 to 2014 compared with White patients, but these investigators grouped all non-White (Black, Hispanic, Asian or Pacific Islander, Native American, and Other) patients together, and therefore, their results cannot be directly compared with ours.

The disparities we observed in treatment patterns may be due to modifiable factors, including structural and interpersonal racism, differences in access to specialized care, and differences in prior treatments rather than biologic differences in the disease. No existing data suggest that Black individuals with oHCM are more responsive to medical therapy or have fewer symptoms when compared with White individuals with oHCM, yet we observed that Black individuals were >40% less likely to receive septal myectomy. The fact that Black individuals with HCM are more likely to have midcavitary/apical disease compared with White individuals with HCM[25] should not confound our data, as we only assessed HCM with evidence of left ventricular outflow tract obstruction in this analysis (ie, those with apical HCM or midcavitary gradients would not be included in the oHCM group). Furthermore, previous studies have observed that, compared with White individuals with HCM, Black individuals with HCM have significantly lower rates of referral to HCM centers for symptom management and SCD risk stratification despite similar (or higher) rates of adverse cardiovascular outcomes, including SCD.[6,9,10,25]

Sex was also associated with significant disparities in this cohort. Compared with men, female patients with HCM were more likely to die during hospitalization and were about 30% less likely to receive an implantable cardioverter-defibrillator. Some previous studies have reported lower long-term survival rates in women with HCM,[12,13,27] and 1 study reported similar long-term survival rates between men and women,[28] but no study, to our knowledge, has reported on in-hospital death rate according to sex in HCM. There are limited data on the rates of implantable cardioverter-defibrillator procedures in women with HCM compared with men with HCM. One study from a single HCM referral center reported no difference in rates of implantable cardioverter-defibrillator procedures[29]; however, Patlolla et al[26] reported lower rates in women compared with men. Our findings both support and extend the observations by Patlolla in that our sample is larger, more recent (2012–2018 versus 2003–2014), and more likely to reflect current practices for implantable cardioverter-defibrillator procedures for HCM.

The explanation for the observed disparities between men and women may reflect biologic differences in the disease as well as physician referral bias. It has been reported that women with HCM have more adverse hemodynamics, including higher left-sided filling pressures and higher rates of pulmonary hypertension, compared with men with HCM, and this may explain, in part, the increased in-hospital death we observed.[12] However, given that rates of SCD are reportedly similar between men and women,[11] the significantly lower rate of implantable cardioverter-defibrillator procedures we observed may be more likely to reflect physician referral bias. Physician referral bias has also been implicated to explain the observation that women are referred to HCM centers at older ages and with more advanced symptoms.[12,27] Although we adjusted for age and comorbidities in our study, we do not have information about extent of disease, and it is quite possible that physician referral bias has contributed to the increased in-hospital death we observed.

Our study found that patients in the lowest income quartile and patients with Medicaid or no insurance were generally less likely to receive SRT or implantable cardioverter-defibrillator treatment, though not all comparisons reached statistical significance. There is a paucity of data on the association of socioeconomic status and SRT and implantable cardioverter-defibrillator treatment in patients with HCM. A small study from Australia reported an underrepresentation of socioeconomically disadvantaged patients in specialized multidisciplinary clinics.[14] A study from the Yale New Haven Health System observed that, within a general cardiology care cohort, individuals with HCM and lower socioeconomic status had significantly less implantable cardioverter-defibrillator treatment and higher all-cause death compared with those of higher

socioeconomic status.[8] Our data likely reflect similar lack of access to specialty care and advanced, high-cost procedures in these groups.

Finally, we found that patients with HCM from towns and rural areas were more likely than patients from urban areas to receive SRT but also more likely than patients from urban areas to die during hospitalization. It is possible that patients from towns and rural areas have limited access to diagnostic testing and specialized HCM care, and that this may result in patients from these areas presenting later or with more severe disease. Our findings that rural hospitals had extremely low odds of procedure use support this possibility. This, in turn, could contribute to higher death rates among patients with HCM from rural areas, but this remains speculative.

Our study should be interpreted in the context of several potential limitations. The NIS is an inpatient sample, and no conclusions can be made regarding long-term treatment or outcomes. Our data depend on the accuracy of *ICD* diagnostic codes, and the accuracy of these diagnoses could not be independently confirmed. Race is fundamentally a social construct, and in this study, it is being used as an imperfect proxy for racism. Further, the race variable available in this administrative data set is not patient reported, nor does it allow for simultaneous categorization of both race and ethnicity. We do not have information on possible contraindications to procedures or on patient preference, which may influence the use of procedures or choice between different therapeutic options. Nor do we have data to allow for assessment of whether appropriate criteria were used for selection (eg, how many patients with oHCM had left ventricular outflow tract gradient >50 mm Hg and New York Heart Association class III or higher symptoms on optimal medical therapy and therefore should have been considered for SRT). Our data document the association of social determinants with the treatments provided and on patient outcomes, including death, but do not allow determination of the mechanisms of those effects. While socioeconomic status and geographic location may be obvious factors limiting access to care relevant to treatments and outcomes, the roles of differences in disease process or of clinician bias based on race, ethnicity, or sex remain unknown and important areas of focus for future study. Nevertheless, as the largest study assessing the association of social risk factors with HCM procedures and in-hospital death to date, we believe that this study of >50 000 inpatient admissions across the United States with HCM can provide important insights for clinicians and policymakers.

CONCLUSIONS

In a random sample of 53 117 patient with HCM admissions across the United States, race, sex, social risk factors, and geography were associated with significant disparities in both in-hospital death and the receipt of SRT and implantable cardioverter-defibrillator treatments. Further research is required to identify and address the sources of these inequities to provide optimal care to all patients with HCM.

ARTICLE INFORMATION

Received February 20, 2023; accepted April 18, 2023.

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Acknowledgments

The authors acknowledge Tierney Lanter for assistance with the manuscript. She was not compensated beyond her employment for her assistance.

Sources of Funding

Dr Fox was supported by NIH/NHLBI T32 HL007081. Dr Joynt Maddox was supported by NIH/NCATS 2UL1TR002345-06. Dr Cresci was supported, in part, by the National Institutes of Health (Cresci R01 NR013396) and the Barnes Jewish Hospital Foundation Cardiovascular Genetics Fund (Cresci, PI).

Disclosures

Dr Joynt Maddox receives research support from the National Heart, Lung, and Blood Institute (R01HL143421 and R01HL164561); National Institute of Nursing Research (U01NR020555); National Institute on Aging (R01AG060935, R01AG063759, and R21AG065526); and from Humana. She also serves on the Health Policy Advisory Council for the Centene Corporation (St. Louis, MO). The remaining authors have no disclosures to report.

Supplemental Material

Tables S1–S3
Figure S1

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SUPPLEMENTAL MATERIAL

Table S1. Patient Characteristics by Race and Ethnicity, and Obstructive versus Nonobstructive Phenotype

	Obstructive HCM				Nonobstructive HCM			
	White	Black	Hispanic	p	White	Black	Hispanic	p
Total (N)	18494 (77.0%)	4106 (17.1%)	1410 (5.80%)		20331 (69.8%)	6763 (23.2%)	2013 (6.90%)	
Female	11216 (60.6%)	2737 (66.7%)	854 (60.6%)	<0.001	11203 (55.1%)	3561 (52.7%)	1063 (52.8%)	<0.001
Age				<0.001				<0.001
18-34	530 (2.90%)	260 (6.30%)	102 (7.20%)		672 (3.30%)	460 (6.80%)	154 (7.70%)	
35-54	2974 (16.1%)	1073 (26.1%)	394 (27.9%)		3432 (16.9%)	2058 (30.4%)	687 (34.1%)	
55-64	3488 (18.9%)	977 (23.8%)	278 (19.7%)		3513 (17.3%)	1543 (22.8%)	337 (16.7%)	
65-74	4647 (25.1%)	896 (21.8%)	279 (19.8%)		4776 (23.5%)	1330 (19.7%)	356 (17.7%)	
75+	6855 (37.1%)	900 (21.9%)	357 (25.3%)		7938 (39.0%)	1372 (20.3%)	479 (23.8%)	
Insurance				<0.001				<0.001
Medicare	12286 (66.4%)	2290 (55.8%)	713 (50.6%)		13667 (67.2%)	3626 (53.6%)	945 (46.9%)	
Medicaid	1258 (6.8%)	820 (20.0%)	308 (21.8%)		1507 (7.40%)	1454 (21.5%)	569 (28.3%)	
Private insurance	4622 (25.0%)	813 (19.8%)	318 (22.6%)		4777 (23.5%)	1348 (19.9%)	396 (19.7%)	
Uninsured	328 (1.80%)	183 (4.50%)	71 (5.00%)		380 (1.90%)	335 (5.00%)	103 (5.10%)	
Median ZIP income				<0.001				<0.001
Q1: $0-$47,999	3927 (21.2%)	2093 (51.0%)	474 (33.6%)		5625 (27.7%)	792 (11.7%)	357 (17.7%)	
Q2: $48,000-$60,999	4744 (25.7%)	891 (21.7%)	351 (24.9%)		5423 (26.7%)	1169 (17.3%)	425 (21.1%)	
Q3: $61,000-$81,999	4791 (25.9%)	662 (16.1%)	351 (24.9%)		5140 (25.3%)	1472 (21.8%)	499 (24.8%)	
Q4: $82,000+	5032 (27.2%)	460 (11.2%)	234 (16.6%)		4143 (20.4%)	3330 (49.2%)	732 (36.4%)	
Rurality				<0.001				<0.001
Urban	9407 (50.9%)	2927 (71.3%)	1074 (76.2%)		10213 (50.2%)	4579 (67.7%)	1355 (67.3%)	
Town	5815 (31.4%)	920 (22.4%)	268 (19.0%)		6534 (32.1%)	1710 (25.3%)	530 (26.3%)	
Rural	3272 (17.7%)	259 (6.30%)	68 (4.80%)		3584 (17.6%)	474 (7.00%)	128 (6.40%)	
Comorbidities								
Hypertension, complicated	5340 (28.9%)	1832 (44.6%)	433 (30.7%)	<0.001	6556 (32.2%)	3489 (51.6%)	669 (33.2%)	<0.001
Cardiac arrhythmia	11507 (62.2%)	2097 (51.1%)	807 (57.2%)	<0.001	12496 (61.5%)	3098 (45.8%)	988 (49.1%)	<0.001
Congestive heart failure	7805 (42.2%)	1913 (46.6%)	567 (40.2%)	<0.001	9099 (44.8%)	3406 (50.4%)	837 (41.6%)	<0.001
Obesity	3479 (18.8%)	1008 (24.5%)	302 (21.4%)		3514 (17.3%)	1528 (22.6%)	394 (19.6%)	<0.001

Diabetes	1728 (9.30%)	683 (16.6%)	176 (12.5%)		2166 (10.7%)	1267 (18.7%)	328 (16.3%)	<0.001
Presence of ICD	2321 (12.6%)	630 (15.3%)	209 (14.8%)	<0.001	2657 (13.1%)	755 (11.2%)	202 (10.0%)	<0.001

HCM, hypertrophic cardiomyopathy; ICD, implantable cardioverter-defibrillator. Comparisons were conducted using chi-square tests of independence.

Table S2. Hospital-Year Characteristics

	Hospital-Years
Total (N)	13020
Size	
Small	3429 (26.3%)
Medium	4081 (31.3%)
Large	5510 (42.3%)
Ownership	
Government, nonfederal (public)	1290 (9.9%)
Private, not-for-profit (voluntary)	9726 (74.7%)
Private, investor owned (proprietary)	2004 (15.4%)
Teaching status	
Rural	1734 (13.3%)
Urban - Non-teaching hospital	4498 (34.5%)
Urban - Teaching hospital	6788 (52.1%)
Region	
Northeast	2562 (19.7%)
Midwest	3137 (24.1%)
South	4715 (36.2%)
West	2606 (20.0%)

Because hospitals cannot be tracked year to year, data are presented as hospital-years. To estimate annual n, divide by 7.

Table S3. In-hospital Mortality Rate by Hypertrophic Cardiomyopathy Procedure

	Mortality Rate
Overall (n=53117)	3.23%
Septal myectomy (n=1654)	3.33%
Alcohol septal ablation (n=772)	1.55%
ICD procedure (n=1598)	0.56%
Any HCM procedure (n=3871)	1.91%

Figure S1. Participant Flow Diagram