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Sex and Race Disparities in Hypertrophic Cardiomyopathy: Unequal Implantable Cardioverter-Defibrillator Use During Hospitalization

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Abstract

Objective: To evaluate if there are sex and race disparities in use of implantable cardioverter-defibrillator (ICD) devices for prevention of sudden cardiac death in patients with hypertrophic cardiomyopathy (HCM).

Patients and Methods: Using the National Inpatient Sample from January 2003 through December 2014, we identified all adult admissions with a diagnosis of HCM and an ICD implantation. Race was classified as White versus non-White. Trends in ICD use, predictors of ICD implantation, device-related complications, hospitalization costs, and lengths of stay were evaluated.

Results: Among a total of 23,535 adult hospitalizations for HCM, ICD implantation was performed in 3954 (16.8%) admissions. Over the study period, there was an overall increasing trend in ICD use (11.6% in 2003 to 17.0% in 2014, $P<.001$). Compared with admissions not receiving an ICD, those receiving an ICD had shorter median lengths of in-hospital stay but higher hospitalization costs ($P<.001$). Compared with men and White race, female sex (odds ratio, 0.72; 95% CI, 0.66 to 0.78; $P<.001$) and non-White race (odds ratio, 0.87; 95% CI, 0.79 to 0.96; $P<.001$) were associated with lower adjusted odds of receiving an ICD. Women and non-White hospitalizations had higher rates of device related complications, longer lengths of in-hospital stay, and higher hospitalization costs compared with men and White race, respectively (all $P<.01$).

Conclusion: Among HCM hospitalizations, ICD devices are underused in women and racial minorities independent of demographics, hospital characteristics, and comorbidities. Women and racial minorities also had higher rates of complications and greater resource use compared with men and those belonging to the White race, respectively.

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The implantable cardioverter-defibrillator (ICD) is a well-established therapy for prevention of sudden cardiac death (SCD) in several subgroups of patients including those with ischemic heart disease and cardiomyopathies.[1,2] Patients with hypertrophic cardiomyopathy (HCM) may be at increased risk of SCD, and multiple studies have documented the important role of ICD in sudden death prevention.[3-5] The clear effectiveness of ICDs in terminating life-threatening ventricular arrhythmias has led to broad adoption of ICD therapy for secondary prevention of SCD.[5-7] Implantation of an ICD for primary prevention of SCD in HCM patients is based on risk stratification using various clinical parameters, and the current HCM guidelines recommend ICD implantation in individuals with recognized risk markers or modifiers for SCD.[8] Prophylactic use of ICD has dramatically improved outcomes associated with HCM[9-11]; however, little contemporary information exists on the demographic trends in use of ICD in HCM patients across the United States.

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Further, studies evaluating ICD use in heart failure patients have shown important sex and racial disparities.[12,13] Data from a hospital-based quality improvement program have documented sex differences in ICD use, but racial disparities were mitigated in the recent era.[14] In addition, analysis of a national cohort has shown an increase in sex differences in ICD implantation between 2006 and 2012 in the United States.[15] Chatterjee et al[15] suggested that these differences may have been due to the influence of comorbidities and possible sex-specific differences in patient and physician attitudes towards quality of life. However, it remains unclear if these disparities persist in the use of ICD among HCM patients. This is of particular interest in HCM given the evidence of differing presentations and severity of disease in men and women, and also among various racial/ethnic groups.[16,17] Therefore, using a large nationally representative database, we evaluated the contemporary trends in ICD use among hospitalized patients with HCM and also evaluated differences based on sex and race.

PATIENTS AND METHODS

The National (Nationwide) Inpatient Sample (NIS) is an all-payer administrative database of hospital inpatient stays and represents a 20% stratified sample of United States inpatient hospitalizations across the country. It is a part of the Healthcare Quality and Utilization Project (HCUP), sponsored by the Agency for Healthcare Research and Quality. Databases from the HCUP use International Classification of Diseases, Ninth Revision, Clinical Modification diagnosis and procedure codes with up to 30 diagnosis codes for each admission. Institutional Review Board approval was not required due to the publicly available nature of this de-identified database.

All adult admissions (18 years or older) with a primary diagnosis of HCM between January 2003 and December 2014 were identified using International Classification of Diseases, Ninth Revision, Clinical Modification codes (425.1, 425.11, 425.18) from the HCUP-NIS database. Admissions receiving an ICD device were identified using codes 00.51 and 37.94.[15,18,19] These codes identify a procedure where a total ICD system is implanted. Admissions with an existing ICD device were identified and excluded. The Deyo's modification of the Charlson comorbidity index was used to identify the burden of comorbid diseases.[20] Admissions with missing race information were excluded. Race was classified as White, and non-White (Black, Hispanic, Asian or Pacific Islander, Native American, others). Coding for race in NIS combines race and ethnicity provided by the data source into one data element ("RACE"). If both race and ethnicity were available, ethnicity was preferred over race in setting the HCUP value for "RACE."[21]

The primary aims of our study were to evaluate trends in new ICD implantation, identify predictors of ICD use in HCM hospitalizations, and examine results for possible disparities based on sex and race. We also evaluated the prevalence of ICD-associated complications, hospitalization costs, and lengths of stay. In-hospital periprocedural complications related to ICD implantation were evaluated in admissions with ICD implantation as the primary procedure and were classified into cardiac and pericardial complications (hemopericardium, cardiac tamponade, and acute pericarditis), pulmonary complications (pneumothorax and other iatrogenic complications), vascular injury, and postprocedural hemorrhage/hematoma (Supplementary Table 1, available online at http://www.mayoclinicproceedings.org).[19]

Statistical Analysis

Discharge weights provided with the HCUP-NIS database were used to generate national estimates as recommended by HCUP-NIS and trend weights were used for samples from 2000 to 2011 to adjust for the 2012 HCUP-NIS redesign.[22] The inherent restrictions of the HCUP-NIS database related to research design, data interpretation, and data analysis were reviewed and addressed.[22] Categorical variables are expressed as percentages and compared with the Pearson

χ^2 test or Fisher exact test. Continuous variables are reported as mean ± SD or median (interquartile range [IQR]) and were compared using Student *t* test or Kruskal-Wallis test as appropriate. Cochrane-Armitage test was used for trends analysis. A multivariable hierarchical logistic regression analysis incorporating demographic characteristics, primary payer status, hospital characteristics, comorbidities, and year of hospital admission was used to identify predictors of ICD implantation. The associated risk for each variable of interest was expressed as odds ratio (OR) with corresponding 95% CI. All *P* values were based on two-sided tests and were considered statistically significant at $P<.05$. Analyses were performed using SPSS v25.0 (IBM Corp, Armonk NY).

RESULTS

Between 2003 and 2014, we identified 23,535 adult hospitalizations for HCM, and ICD implantation was performed in 3,954 (16.8%) of these admissions. Over the study period, there was an overall increasing trend in ICD use. The proportion of HCM hospitalizations receiving an ICD increased from 11.6% (189 of 1632) in 2003 to 19.0% (440 of 2316) in 2011 and then declined to 17.0% (505 of 2985) in 2014 ($P<.001$ for trend) (Figure A). Differences in baseline characteristics of admissions receiving ICD and those that did not are shown in Table 1. Admissions receiving an ICD were younger (mean age 52.5±15.8 vs 61.6±16.4 years; $P<.001$), less likely to be female (45.2% vs 62.4%; $P<.001$), more often belonged to the higher income quartiles, and received care at large and teaching hospitals compared with those that did not receive an ICD. There was a lower prevalence of important comorbidities such as hypertension, coronary artery disease, peripheral vascular disease, and chronic lung disease among those who received an ICD. Greater prevalence of ventricular arrhythmias (39.5% vs 7.8%; $P<.001$), and complete heart block were observed in patients hospitalized for HCM and receiving an ICD device.

Sex and Race Differences in ICD Implantation

Overall, ICD use among those admitted with HCM was lower in women compared with men (12.8% vs 22.7%; $P<.001$). Temporal trends revealed an increasing trend in ICD use from 2003 to 2014 in women (7.7% to 12.9%; $P<.001$) and a relatively stable trend among men (20.0% to 22.5%; $P=.09$). However, women had a lower proportion of ICD use compared with men consistently across the study period (Figure B). When patients receiving an ICD were stratified by sex, significant differences in clinical characteristics were observed (Table 2). Women were older, more often belonged to the lowest income quartiles, and had higher comorbidity index scores compared with men. Women also had higher rates of ventricular arrhythmias (43.3% vs 36.3%; $P<.001$) indicating that they were more likely receiving an ICD for secondary prevention compared with men.

When patients admitted with HCM were stratified by race, the proportion of ICD use was comparable among those belonging to White and non-White races ($P=.92$). Temporal trends revealed an increase in ICD use in both groups from 2003 to 2014 (Figure C). Compared with White HCM admissions, non-White admissions were younger, more often belonged to the lowest income quartile, and less likely to receive care at large hospitals; but they more often received care at teaching hospitals (Table 2). Those belonging to non-White race also had higher prevalence of hypertension, renal disease, and atrial fibrillation. Prevalence of ventricular arrhythmias was comparable among White and non-White admissions (Table 2).

Predictors of ICD Implantation

The multivariable hierarchical logistic regression identified demographic, hospital-related, and other predictors of ICD implantation. Younger age groups, higher income quartiles, large and teaching hospitals, presence of ventricular arrhythmias, heart block, and atrial fibrillation were associated with higher odds of ICD implantation (Table 3). Importantly, women (OR, 0.72; 95% CI, 0.66 to 0.78; $P<.001$) and non-White race (OR, 0.87;

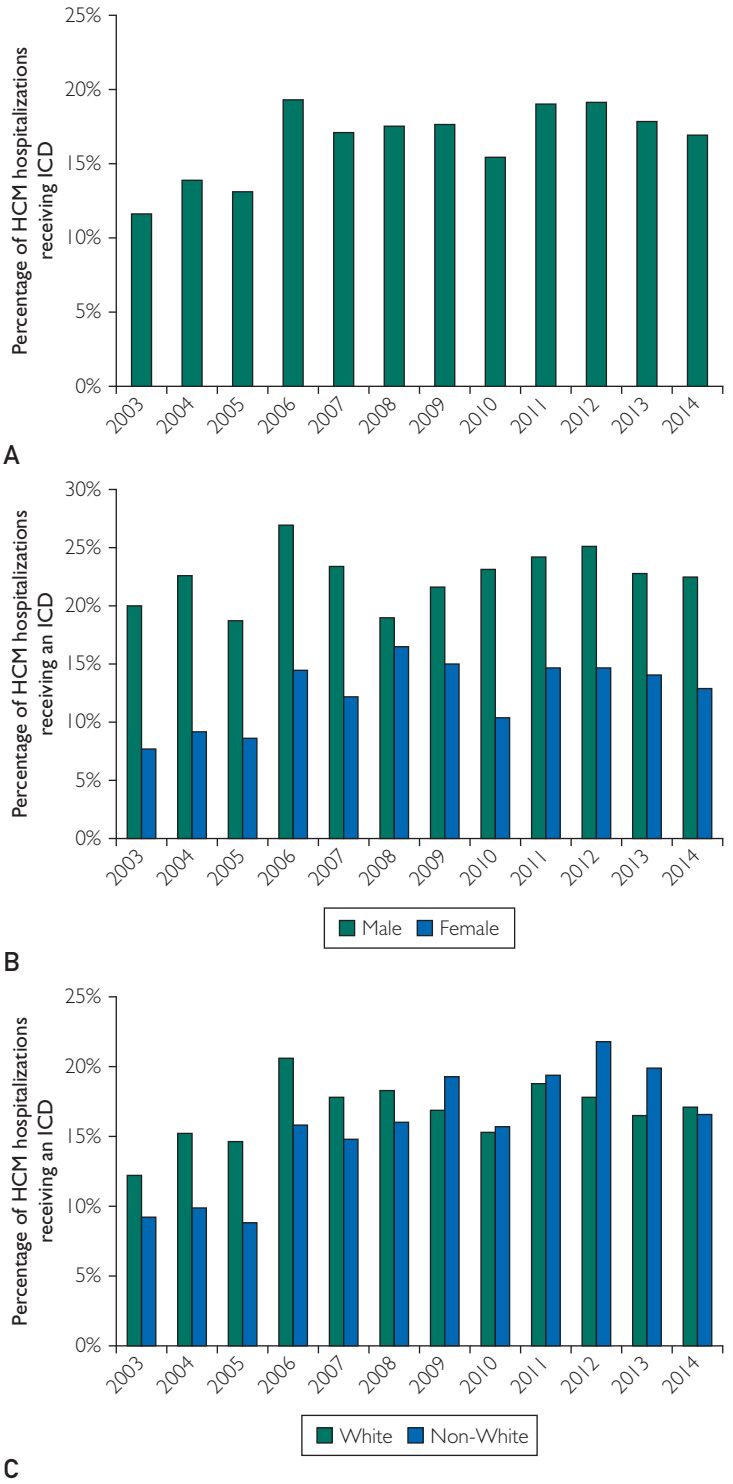

FIGURE. Trends in implantable cardioverter-defibrillator (ICD) implantation among hypertrophic cardiomyopathy (HCM) hospitalizations. A, Temporal trend of the overall proportion of HCM hospitalizations receiving an ICD. B, Temporal trends of the proportion of male and female HCM hospitalizations receiving an ICD ($P<.001$ for trend over time in females; $P=.09$ in males). C, Temporal trends of the proportion of White and non-White HCM hospitalizations receiving an ICD (both $P<.01$ for trend over time).

TABLE 1. Characteristics of HCM Hospitalizations With and Without New ICD Implantation[a,b]

Characteristic (N=23,535)	ICD (n=3955)	No ICD (n=19,580)	*P*
Age, years			<.001
≤50	1669 (42.2)	4788 (24.5)	
51-60	923 (23.3)	4223 (21.6)	
61-70	869 (22.0)	4253 (21.7)	
>70	494 (12.5)	6316 (32.3)	
Female sex	1787 (45.2)	12,220 (62.4)	<.001
Race			.04
White	2804 (70.9)	13,866 (70.8)	
Black	560 (14.2)	3020 (15.4)	
Hispanic	310 (7.8)	1488 (7.6)	
Others[c]	281 (7.1)	1207 (6.2)	
Median household income quartile			<.001
0-25th	734 (19.3)	5098 (26.9)	
26th-50th	818 (21.5)	4562 (24.1)	
51st-75th	1004 (26.4)	4731 (24.9)	
75th-100th	1247 (32.8)	4576 (24.1)	
Primary payer			<.001
Medicare	1045 (26.5)	9104 (46.6)	
Medicaid	429 (10.9)	1820 (9.3)	
Private	2119 (53.8)	6775 (34.6)	
Others[d]	346 (8.8)	1856 (9.5)	
Hospital bed size			<.001
Small	294 (7.5)	1886 (9.7)	
Medium	686 (17.4)	3905 (20.0)	
Large	2955 (75.1)	13,710 (70.3)	
Hospital teaching	3,177 (80.7%)	13,331 (68.4)	<.001
Hospital region			<.001
Northeast	1427 (36.1)	5200 (26.6)	
Midwest	492 (12.4)	3441 (17.6)	
South	1311 (33.1)	6734 (34.4)	
West	725 (18.3)	4206 (21.5)	
Charlson comorbidity index score			<.001
0-3	3377 (85.4)	12,575 (64.2)	
4-6	554 (14.0)	6207 (31.7)	
≥7	23 (0.6)	799 (4.1)	
Hypertension	1876 (47.4)	12,803 (65.4)	<.001
Coronary disease	883 (22.3)	6197 (31.6)	<.001
Diabetes, uncomplicated	25 (0.6)	325 (1.7)	<.001
Peripheral vascular disease	89 (2.3)	788 (4.0)	<.001
Chronic lung disease	687 (17.4)	5096 (26.0)	<.001
Renal disease	207 (5.2)	1569 (8.0)	<.001
Ventricular arrhythmias	1562 (39.5)	1534 (7.8)	<.001
Atrial fibrillation	834 (21.1)	4280 (21.9)	.29
Complete heart block	330 (8.3)	1036 (5.3)	<.001

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TABLE 1. Continued

Characteristic (N=23,535)	ICD (n=3955)	No ICD (n=19,580)	*P*
Left bundle branch block	272 (6.9)	1054 (5.4)	<.001
Septal myectomy	254 (6.4)	3107 (15.9)	<.001

[a]HCM, hypertrophic cardiomyopathy; ICD, implantable cardioverter-defibrillator.
[b]Values shown are n (%).
[c]Asian or Pacific Islander, Native American, and others.
[d]Self-pay, no charge, or others.

95% CI, 0.79 to 0.96; *P*<.004) were associated with lower odds of ICD implantation among HCM hospitalizations. Compared with hospitals in the Northeast, HCM admissions receiving care in Midwest, South, and West were less likely to receive an ICD during hospitalization. Presence of any comorbidity and higher comorbidity index scores were associated with lower rates of ICD use.

Differences in ICD Use for Primary and Secondary Prevention

Among HCM hospitalizations implanted with an ICD device, 2418 (61.1%) received an ICD for primary prevention whereas 1537 (38.9%) had an ICD implantation secondary to ventricular tachycardia/fibrillation (VT/VF) or cardiac arrest (CA). When HCM hospitalizations without VT/VF or CA were evaluated for sex and race differences in ICD use, similar findings to the overall analysis were observed. Female sex (OR, 0.60; 95% CI, 0.54 to 0.66; *P*<.001) and non-White race (OR, 0.83; 95% CI, 0.75 to 0.93; *P*=.001) were less likely to receive an ICD for primary prevention compared with male and White HCM hospitalizations, respectively, in adjusted analysis (Supplementary Table 2, available online at http://www.mayoclinicproceedings.org).

In HCM hospitalizations with VT/VF or CA, adjusted analysis identified that female sex was associated with higher odds of receiving an ICD device (OR, 1.20; 95% CI, 1.02 to 1.42; *P* =.03). However, there was no difference in receipt of ICD device for secondary prevention between White and non-White HCM hospitalizations (Supplementary Table 3, available online at http://www.mayoclinicproceedings.org).

In-Hospital Complications, Length of Stay, and Hospitalization Costs

In the subgroup receiving an ICD as the primary procedure (n=3627), few device-related complications (4.7%, n=170) were identified. Cardiac or pericardial complications were identified in 3.8% (n=138), pulmonary complications in 0.8% (n=28), and vascular injury or postprocedural hemorrhage was identified in 0.2% (n=8) of hospitalizations receiving an ICD device. Higher rates of device-related complications were seen in women (6.6% vs 3.1%; *P*<.001) compared with men, and in non-White hospitalizations (6.4% vs 4.0%; *P*=.003) compared with White HCM hospitalizations.

Compared with admissions not receiving an ICD, those with ICD implanted had shorter median lengths of in-hospital stay (median [IQR], 3 [1 to 6] vs 3 [2 to 6] days; *P*<.001] and higher hospitalization costs (median [IQR] in thousands of USD, 107.9 [73.0 to 156.3] vs 29.5 [15.0 to 65.5] USD; *P*<.001). When men and women receiving an ICD device were compared, women had longer lengths of in-hospital stay (median [IQR], 3 [1 to 6] vs 2 [1 to 5] days; *P*<.001) and higher hospitalization costs (median [IQR] in thousands of USD, 113.0 [74.9 to 160.9] vs 102.1 [70.8 to 151.7]; *P*=.001) compared with men. A similarly longer length of in-hospital stay (median [IQR], 3 [1 to 7] vs 2 [1 to 5] days; *P*<.001) and higher hospitalization costs (median [IQR] in thousands of USD, 117.7 [74.3 to 165.6] vs 104.1 [72.4 to 154.3] USD; *P*=.003) were seen in non-White hospitalizations compared with White HCM hospitalizations.

TABLE 2. Characteristics of HCM Hospitalizations Receiving an ICD Stratified by Sex and Race[a,b]

Characteristic (N=3955)	Male (n=2168)	Female (n=1787)	*P*	White (n=2804)	Non-White[c] (n=1151)	*P*
Age, years			<.001			<.001
≤50	1020 (47.1)	649 (36.3)		1075 (38.3)	594 (51.6)	
51-60	552 (25.5)	371 (20.8)		692 (24.7)	231 (20.1)	
61-70	454 (21.0)	414 (23.2)		683 (24.4)	186 (16.2)	
>70	353 (6.5)	141 (19.8)		354 (12.6)	140 (12.2)	
Median household income quartile			.01			<.001
0-25th	372 (17.8)	362 (21.1)		491 (18.0)	243 (22.6)	
26th-50th	435 (20.9)	383 (22.3)		525 (19.2)	293 (27.3)	
51st-75th	585 (28.1)	419 (24.4)		752 (27.6)	252 (23.4)	
75th-100th	693 (33.2)	554 (32.2)		960 (35.2)	287 (26.7)	
Primary payer			<.001			<.001
Medicare	424 (19.6)	621 (34.9)		790 (28.3)	255 (22.3)	
Medicaid	220 (10.2)	209 (11.8)		180 (6.4)	250 (21.8)	
Private	1268 (58.6)	851 (47.9)		1661 (59.4)	458 (40.0)	
Others[d]	250 (11.6)	96 (5.4)		163 (5.8)	183 (16.0)	
Hospital bed size			.01			.003
Small	184 (8.6)	110 (6.2)		222 (8.0)	71 (6.2)	
Medium	360 (16.8)	327 (18.3)		453 (16.2)	233 (20.3)	
Large	1604 (74.7)	1351 (75.6)		2113 (75.8)	841 (73.4)	
Teaching hospital	1740 (81.0)	1437 (80.4)	.65	2221 (79.6)	956 (83.5)	.005
Hospital region			.002			<.001
Northeast	832 (38.4)	595 (33.3)		994 (35.4)	433 (37.7)	
Midwest	261 (12.0)	231 (12.9)		388 (13.8)	103 (9.0)	
South	672 (31.0)	639 (35.8)		951 (33.9)	360 (31.3)	
West	403 (18.6)	322 (18.0)		471 (16.8)	254 (22.1)	
Charlson comorbidity index score			<.001			.31
0-3	1947 (89.8)	1430 (80.0)		2397 (85.5)	980 (85.1)	
4-6	211 (9.7)	343 (19.2)		394 (14.1)	161 (14.0)	
≥7	10 (0.5)	14 (0.8)		13 (0.5)	10 (0.9)	
Hypertension	996 (45.9)	880 (49.2)	.04	1272 (45.4)	604 (52.5)	<.001
Coronary disease	472 (21.8)	411 (23.0)	.36	618 (22.0)	266 (23.1)	.47
Peripheral vascular disease	43 (2.0)	46 (2.6)	.24	70 (2.5)	19 (1.7)	.12
Chronic lung disease	233 (10.7)	455 (25.5)	<.001	492 (17.5)	196 (17.0)	.71
Renal disease	128 (5.9)	78 (4.4)	.03	112 (4.0)	94 (8.2)	<.001
Ventricular arrhythmias	788 (36.3)	774 (43.3)	<.001	1,098 (39.2)	464 (40.3)	.50
Atrial fibrillation	448 (20.7)	386 (21.6)	.48	649 (23.2)	185 (16.1)	<.001
Complete heart block	146 (6.7)	184 (10.3)	<.001	255 (9.1)	75 (6.5)	.01
Left bundle branch block	145 (6.7)	127 (7.1)	.61	227 (8.1)	44 (3.8)	<.001

[a]HCM, hypertrophic cardiomyopathy; ICD, implantable cardioverter-defibrillator.
[b]Values shown are n (%).
[c]Black, Hispanic, Asian or Pacific Islander, Native American, or others.
[d]Self-pay, no charge, or others.

DISCUSSION

Implantable cardioverter-defibrillators have been a major advance in the management of HCM, and are an established therapy for prevention of SCD among at-risk patients.[7,11] Although several single- and multi-center reports have shown increased adoption of ICD therapy in patients with HCM,[23,24] it remains unclear if a similar pattern is seen across the United States. In

TABLE 3. Predictors of ICD Implantation in HCM Hospitalizations[a]

Characteristic (N=23,535)	OR	95% CI		*P*
		Lower limit	Upper limit	
Age, years				
≤50	3.21	2.73	3.78	<.001
51-60	2.29	1.95	2.69	<.001
61-70	2.24	1.95	2.58	<.001
>70		Reference category		
Female sex	0.72	0.66	0.78	<.001
Race				
White		Reference category		
Non-White[b]	0.87	0.79	0.96	.004
Median household income quartile				
0-25th		Reference category		
26th-50th	1.15	1.02	1.29	.03
51st-75th	1.27	1.13	1.43	<.001
75th-100th	1.46	1.30	1.65	<.001
Primary payer				
Medicare		Reference category		
Medicaid	1.13	0.95	1.33	.16
Private	1.33	1.18	1.51	<.001
Others[c]	0.92	0.77	1.09	.33
Hospital bed size				
Small		Reference category		
Medium	1.18	1.00	1.39	.06
Large	1.34	1.16	1.56	<.001
Teaching hospital	1.69	1.53	1.86	<.001
Hospital region				
Northeast		Reference category		
Midwest	0.59	0.52	0.68	<.001
South	0.82	0.74	0.91	<.001
West	0.67	0.60	0.76	<.001
Hypertension	0.70	0.64	0.76	<.001
Diabetes, uncomplicated	0.59	0.38	0.92	.02
Peripheral vascular disease	0.95	0.75	1.22	.70
Chronic lung disease	0.76	0.68	0.84	<.001
Renal disease	0.76	0.63	0.90	.002
Coronary artery disease	0.73	0.66	0.80	<.001
Ventricular arrhythmias	6.95	6.34	7.63	<.001
Complete heart block	1.79	1.53	2.08	<.001
Atrial fibrillation	1.15	1.04	1.28	.005
Septal myectomy	0.22	0.19	0.26	<.001
Calendar year	1.03	1.02	1.04	<.001

[a]HCM, hypertrophic cardiomyopathy; ICD, implantable cardioverter-defibrillator; OR, odds ratio.
[b]Black, Hispanic, Asian or Pacific Islander, Native American, and others.
[c]Self-Pay, no charge, and others.

this study using nationally representative data, we observed a significant increase in new ICD implantation among hospitalized patients with HCM in the United States. Further, we also identified an increase in ICD implantation across subgroups of sex and race.

In addition to multiple studies reporting the safety and efficacy of ICDs in prevention of SCD, more recent evidence has shown that ICD therapy does not impair overall well-being or quality of life in HCM patients.[11] Unlike ischemic heart disease wherein nearly 30% of patients have heart failure–related mortality or hospitalizations despite ICD therapy,[1,25] HCM patients rarely experience such deterioration.[11] These encouraging reports and improving technology may explain the overall increase in ICD use during the study period. However, ICD use appeared to decline between 2011 and 2014, possibly due to evidence-based guidelines.[8]

However, we observed that the use of ICD devices was not uniform across all demographics of the HCM population. Women were less likely to receive an ICD for primary prevention compared with men, and this trend was consistent throughout the 12-year study period. This perceived disparity could be due to a multitude of factors. Women are known to present with more advanced disease and at older ages compared with men.[16,26,27] Additionally, reports evaluating HCM patients older than 60 years have shown that these patients are at a low risk of SCD and HCM-related morbidity.[28] These findings may explain lower ICD use in women in comparison with men. However, age-stratified analysis in our study has shown a similarly lower use of ICDs in women even in younger age groups. Whether this disparity in ICD use is due to patient preference or to other socioeconomic or clinical factors remains to be addressed. Women were more likely to receive an ICD for secondary prevention. Given that women presenting with HCM are more susceptible to progression of heart failure or death,[27] a greater use of ICD therapy may be seen to avoid further burden from recurrent ventricular arrhythmias. Indeed, evidence suggests that female sex is associated with superior response to cardiac resynchronization therapy in terms of left ventricular reverse remodeling and left ventricular function, which are expected to reduce risk of subsequent ventricular arrhythmia.[29,30]

It is well known that younger African-American individuals experience increased rates of HCM-related SCD.[17,31] This is attributed to underdiagnosis of HCM and underreferral for effective therapies in this population in comparison with White HCM patients.[17] Further, evidence has shown that higher rates of hypertension along with concentric and apical hypertrophy can impact HCM identification in the Black population.[32,33] These findings suggest the need for improved recognition of HCM in minority populations to provide timely access to prophylactic ICD therapy. Our study indicates, however, that even after identifying HCM, non-White admissions were less likely to receive an ICD compared with White admissions following adjustment for all relevant confounders. This suggests that other factors may impede ICD use in minority populations, such as differential access to advanced care and possible provider bias. Our data cannot identify the disease severity and clinical variables necessary to risk stratify for ICD use in these populations. As such, variations in presence of risk factors could also partly explain the observed disparity. However, race-specific differences were not observed in ICD use for secondary prevention potentially due to adherence to guideline recommendations for managing patients with ventricular arrhythmias.

We also observed regional variation in ICD use among HCM hospitalizations for both primary and secondary prevention. Highest rates of ICD use were observed in the Northeast compared with other regions. Although differences in patient characteristics and risk factors could partly explain these variations, prior investigations have identified the presence of geographic variations beyond these factors.[18,34,35] Report from the National Cardiovascular Data Registry has identified marked regional differences in use of primary prevention ICDs across the United States.[34] Matlock et al[34] put forth underuse, poor integration of patient preference into decision-making resulting in overuse, and overuse in high-utilization regions as possible explanations for the variation. In a national survey of

physicians, Matlock et al[35] did identify that in high health care use regions, physicians were more likely to recommend an ICD even when the benefit is unclear.

The potential for device-related complications is an important consideration in HCM patients receiving an ICD.[8] Nearly 15% of patients receiving an ICD have complications, most commonly involving inappropriate discharges and lead complications.[36,37] Most studies evaluating ICD-related complications in HCM examine long-term data,[36,37] but in-hospital complications after ICD therapy in HCM patients were not evaluated. In the present study, we found an in-hospital complication rate of 4.7% in HCM admissions receiving an ICD as the primary procedure. Although we are unable to comment on long-term outcomes of devices, our results suggest that rates of in-hospital complications associated with ICD use in HCM populations appear lower than those previously reported. This may relate to a younger population with fewer comorbid conditions compared with patients with heart failure, especially those with ischemic heart disease.

Higher costs associated with ICD have long been a point of contention when evaluating associated health care resource allocation and use.[38-40] In agreement, we found that hospitalization costs of HCM admissions receiving an ICD were significantly higher than those discharged without an ICD. Several analyses of ICD use have shown that the therapy is cost-effective in non-HCM populations[39-41] with an estimated mean quality-adjusted life gain of up to 3 years in high-risk patients.[40] Data from Maron et al[11] suggest lower morbidity and better post-ICD therapy quality of life in HCM patients than in non-HCM diseases, further justifying device use in these patients.

Study Limitations

This study has the inherent limitations of administrative data. Although HCUP-NIS uses several quality measures to limit errors, there are potential issues related to coding diagnoses, comorbidities, and procedures. Race is self-reported, which may lead to ascertainment bias in certain minorities, and exclusion of hospitalizations with missing race could have influenced observed results. Important information such as echocardiographic and other imaging data, laboratory parameters, and other procedural characteristics that estimate disease severity and influence outcomes are not available in the NIS database. Further, despite extensive covariate adjustment, the observed results may be due to residual confounders. Data on clinical parameters used to risk stratify HCM patients and identify their suitability for ICD therapy are not captured in the NIS. Additionally, the NIS database does not capture outpatient stays; hence, the data might not provide a complete picture of ICD implantation in the HCM population. However we believe this study provides important insights into the nonuniform use of ICD among HCM hospitalizations and can serve as a step for further investigations using robust clinical data.

CONCLUSION

There has been a significant increase in ICD use among those admitted with HCM in the contemporary era. However, ICD devices are underused in women and racial minorities with HCM, similar to other populations at risk for SCD. Regional variations were also identified with higher rates of ICD use for HCM in the Northeast compared with other regions of the United States. In-hospital device-related complications appear to be lower than previously reported, and hospitalizations associated with ICD have significantly higher resource use.

SUPPLEMENTAL ONLINE MATERIAL

Supplemental material can be found online at http://www.mayoclinicproceedings.org. Supplemental material attached to journal articles has not been edited, and the authors take responsibility for the accuracy of all data.

Abbreviations and Acronyms: **HCM,** hypertrophic cardiomyopathy; **HCUP,** Healthcare Quality and Utilization Project; **ICD,** implantable cardioverter-defibrillator; **NIS,** National Inpatient Sample; **OR,** odds ratio

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