

Outcomes of hospitalizations for heart failure with reduced ejection fraction complicated by cardiac arrest, stratified by pre-existing implantable cardioverter-defibrillator status

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ABSTRACT

Background: Hospitalizations for heart failure with reduced ejection fraction complicated by cardiac arrest represent a high-risk population, and the role of a pre-existing implantable cardioverter-defibrillator in these patients remains unclear.

Methods: We conducted a retrospective observational study using the National Inpatient Sample from 2016 through 2022. Adult hospitalizations (age 18 years or older) with a diagnosis of heart failure with reduced ejection fraction and cardiac arrest were identified using diagnosis codes. Pre-existing defibrillator status was defined by a code indicating a device present before admission. Outcomes were compared by device status using survey-weighted methods, and a multivariable logistic regression model evaluated the independent association between device status and in-hospital mortality, adjusting for demographics, comorbidities, and clinical severity.

Results: Among 11,945 weighted hospitalizations, 545 (4.6%) had a documented pre-existing defibrillator. Crude in-hospital mortality was higher among hospitalizations with a device than those without (21.1% vs 9.7%, $P < 0.01$). After adjustment, device status was not independently associated with in-hospital mortality (adjusted odds ratio 1.34, 95% confidence interval 0.63 to 2.84). Do-not-resuscitate status (adjusted odds ratio 15.56) and cardiogenic shock (adjusted odds ratio 1.47) were strongly associated with higher mortality.

Conclusions: In this national sample, pre-existing defibrillators were uncommon. Although crude mortality was higher among patients with a device, device status was not independently associated with in-hospital mortality after adjustment, suggesting outcomes were primarily driven by baseline risk and clinical severity. Studies incorporating arrest rhythm, timing, and device interrogation are needed to clarify mechanisms and optimize post-arrest management.

Keywords: Heart failure, systolic, cardiac arrest, defibrillators, implantable, hospital mortality, National Inpatient Sample, healthcare disparities

INTRODUCTION

Heart failure with reduced ejection fraction (HFrEF) is a major public health problem and a leading contributor to cardiovascular hospitalization and death

in the United States.¹ Mortality in HFrEF reflects two dominant pathways: progressive pump failure and sudden cardiac death (SCD) from malignant ventricular arrhythmias.² Current American College of Cardiology guidance supports implantable cardioverter-defibrillator (ICD) therapy for primary prevention in patients with chronic HFrEF and a left ventricular ejection fraction of 35% or less despite guideline-directed medical therapy and an anticipated meaningful survival of more than 1 year, as well as for secondary prevention in patients who survive sustained

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ventricular tachycardia (VT), ventricular fibrillation (VF), or resuscitated SCD attributed to VT/VF after reversible causes are excluded.³ In contrast, ICDs do not prevent mortality from non-arrhythmic mechanisms such as refractory shock, multi-organ failure, or non-shockable cardiac arrest, and outcomes after cardiac arrest remain poor despite improving survival in contemporary cohorts.^{4,5}

Hospitalizations for HFrEF complicated by cardiac arrest represent a uniquely high-risk subgroup in which pre-existing ICD status may reflect underlying disease phenotype, comorbidity burden, and prior access to advanced heart failure and electrophysiology care. Real-world ICD use is also influenced by persistent sex- and race/ethnicity-associated disparities in counseling and implantation, despite groups at higher SCD risk potentially benefiting when guideline criteria are met.^{6,7} Although national data describe trends in cardiac arrest outcomes, fewer analyses have focused specifically on HFrEF hospitalizations complicated by cardiac arrest and how outcomes differ by pre-existing ICD status.

To address this gap, we used the National Inpatient Sample (NIS) to quantify the prevalence of pre-existing ICDs among adult HFrEF hospitalizations presenting with cardiac arrest, compare baseline characteristics, in-hospital severity and support, and outcomes by ICD status, and identify factors associated with in-hospital mortality.

METHODS

We conducted a retrospective observational study using the NIS from 2016 through 2022. The NIS is part of the Healthcare Cost and Utilization Project (HCUP) sponsored by the Agency for Healthcare Research and Quality and represents an approximately 20% stratified sample of U.S. community hospital discharges. National estimates were generated using HCUP-provided discharge weights and survey design variables.

STUDY POPULATION

We included adult (age 18 years or older) hospitalizations of patients with HFrEF who presented

with cardiac arrest. Cardiac arrest was identified when coded as a primary or secondary diagnosis using International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) codes I46.2 “cardiac arrest due to underlying cardiac condition,” I46.8 “other cardiac arrest,” I46.9 “cardiac arrest, cause unspecified,” I49.01 “ventricular fibrillation,” and I49.02 “ventricular flutter.” HFrEF was identified using ICD-10-CM codes in any diagnosis position, including I50.20 “unspecified systolic (congestive) heart failure,” I50.21 “acute systolic (congestive) heart failure,” I50.22 “chronic systolic (congestive) heart failure,” and I50.23 “acute on chronic systolic (congestive) heart failure.” Pre-existing ICD status was defined by ICD-10-CM code Z95.810 “presence of automatic implantable cardiac defibrillator,” indicating a device present prior to the index hospitalization.

COVARIATES

Baseline characteristics included age, sex, and race/ethnicity as provided by the NIS. Comorbidity burden was assessed using the Elixhauser comorbidity index. Markers of in-hospital clinical severity included the presence of VT/VF during the admission, cardiogenic shock, acute respiratory failure, and anoxic brain injury/hypoxic-ischemic brain injury. We also identified do-not-resuscitate (DNR) status using the NIS DNR variable when available. Use of in-hospital mechanical circulatory support was ascertained using International Classification of Diseases, Tenth Revision, Procedure Coding System procedure codes for intra-aortic balloon pump (IABP), Impella, and extracorporeal membrane oxygenation (ECMO).

OUTCOMES

The primary outcome was in-hospital mortality. Secondary outcomes included acute kidney injury, major bleeding, hospital length of stay (LOS), and total hospital charges. Total hospital charges were inflation-adjusted to a common-year U.S. dollar value using the Bureau of Labor Statistics Consumer Price Index to apply a consistent adjustment across all study years.

STATISTICAL ANALYSIS

All analyses were performed using Stata/MP version 18.0 (StataCorp, College Station, TX, USA). NIS survey design elements were incorporated using HCUP-provided discharge weights, hospital-level clustering, and stratification to generate nationally representative estimates. Baseline characteristics, clinical severity variables, and outcomes were compared between groups (pre-existing ICD vs no ICD) using survey-weighted methods. Categorical variables are reported as weighted percentages and compared using design-based tests. Continuous variables are reported as mean $\pm$ standard deviation (SD) when approximately normally distributed and as median (interquartile range [IQR]) for skewed distributions; LOS and inflation-adjusted charges were summarized as median (IQR).

To evaluate the independent association between pre-existing ICD status and in-hospital mortality, we fit a multivariable survey-weighted logistic regression model with in-hospital mortality as the dependent variable. The model included demographics, race/ethnicity, comorbidities, and clinical severity variables to adjust for potential confounding. Adjusted odds ratios (aORs) with 95% confidence intervals (CIs) are reported. A two-sided *P* value less than 0.05 was considered statistically significant.

ETHICS

The NIS contains de-identified, publicly available discharge-level data. This study did not involve direct patient contact and was considered exempt from institutional review board oversight under institutional policy for analyses of de-identified datasets. The study was performed in compliance with the human-studies guidelines of the authors' institutions.

RESULTS

BASELINE CHARACTERISTICS

Among 11,945 weighted hospitalizations of adults with HFrEF complicated by cardiac arrest, 545 (4.6%)

had a documented pre-existing ICD. Baseline characteristics are shown in Table 1. Compared with hospitalizations without an ICD, those with a pre-existing ICD were older (66.3 ± 12.9 vs 64.0 ± 13.5 years, $P < 0.01$) and had a similar sex distribution (female: 24.8% vs 29.8%, $P = 0.26$). Race/ethnicity differed by ICD status ($P = 0.01$); hospitalizations with an ICD included a lower proportion of White patients (59.6% vs 71.8%) and a higher proportion of Black patients (26.9% vs 14.6%).

Patients with pre-existing ICDs had a higher prevalence of several comorbidities, including hypertension (86.2% vs 77.4%, $P = 0.03$), diabetes mellitus (47.7% vs 36.3%, $P = 0.01$), anemia (12.8% vs 5.8%, $P < 0.01$), pulmonary circulation disorders (17.4% vs 11.2%, $P = 0.04$), peripheral vascular disorders (100.0% vs 9.2%, $P < 0.01$), chronic pulmonary disease (35.8% vs 20.6%, $P < 0.01$), hypothyroidism (19.3% vs 10.0%, $P < 0.01$), and renal failure (46.9% vs 27.7%, $P < 0.01$). Cancer was less frequently coded among ICD hospitalizations (0.0% vs 3.6%, $P = 0.04$). Other comorbidities did not differ significantly between groups.

CLINICAL SEVERITY AND IN-HOSPITAL SUPPORT

Clinical severity and in-hospital support measures are shown in Table 2. VT/VF during admission was common in both groups and did not differ by ICD status (73.4% vs 71.1%, $P = 0.60$). Cardiogenic shock (14.7% vs 24.7%, $P = 0.02$) and acute respiratory failure (50.5% vs 63.7%, $P < 0.01$) were less frequently coded among ICD hospitalizations. Rates of anoxic brain injury were similar (19.3% vs 19.7%, $P = 0.92$). DNR status was slightly higher in the ICD group (17.4% vs 13.6%, $P = 0.25$). Use of mechanical circulatory support was numerically lower among ICD hospitalizations, including IABP (4.6% vs 9.9%, $P = 0.07$), Impella (3.7% vs 5.3%, $P = 0.45$), and ECMO (0.9% vs 1.2%, $P = 0.77$), though these differences did not reach statistical significance.

IN-HOSPITAL OUTCOMES

In-hospital outcomes are presented in Table 3. Crude in-hospital mortality was higher among

Table 1. Baseline Characteristics by Pre-Existing ICD Status

Characteristic	With ICD (N = 545)	Without ICD (N = 11,400)	P Value
Age, years (mean $\pm$ SD)	66.3 $\pm$ 12.9	64.0 $\pm$ 13.5	<0.01
Female, %	24.8	29.8	0.26
Race, %			0.01
White	59.6	71.8	
Black	26.9	14.6	
Hispanic	4.8	7.2	
Asian/Pacific Islander	3.9	2.5	
Native American	0.0	0.8	
Other	4.8	3.1	
Comorbidities, %			
Hypertension	86.2	77.4	0.03
Diabetes mellitus	47.7	36.3	0.01
Cancer	0.0	3.6	0.04
Anemia	12.8	5.8	<0.01
Cardiac arrhythmias	87.2	89.8	0.38
Valvular disease	23.9	18.8	0.19
Pulmonary circulation disorders	17.4	11.2	0.04
Peripheral vascular disorders	100.0	9.2	<0.01
Chronic pulmonary disease	35.8	20.6	<0.01
Hypothyroidism	19.3	10.0	<0.01
Renal failure	46.9	27.7	<0.01
Liver disease	11.9	17.9	0.11
Coagulopathy	19.3	16.0	0.36
Obesity	17.4	19.9	0.53
Weight loss	7.3	8.1	0.78
Fluid & electrolyte disorders	55.1	61.0	0.21
Alcohol abuse	4.6	7.9	0.21
Drug abuse	5.5	6.4	0.71

Note: Values are survey-weighted unless otherwise specified. Continuous variables are presented as mean $\pm$ standard deviation (SD) and categorical variables as weighted column percentages. P values compare groups by pre-existing ICD status using survey-weighted methods.

Abbreviations: ICD, implantable cardioverter-defibrillator; SD, standard deviation.

hospitalizations with a pre-existing ICD compared with those without an ICD (21.1% vs 9.7%, $P < 0.01$). Rates of acute kidney injury were similar between groups (51.4% vs 48.0%, $P = 0.49$). Major bleeding was numerically lower in the ICD group (8.7% vs 14.8%, $P = 0.06$). Median LOS was shorter among ICD hospitalizations (6 [IQR 3 to 12] vs 8 [IQR 4 to 13] days, $P < 0.01$). Median inflation-adjusted hospital

charges were also lower in the ICD group (\$106,004 [IQR 58,446 to 209,043] vs \$184,033 [IQR 104,919 to 317,828], $P < 0.01$).

In-hospital mortality among hospitalizations without a pre-existing ICD remained relatively stable overall, ranging from 5.3% to 15.6% (15.6% in 2016 and 12.4% in 2022). In contrast, mortality among those

Table 2. Clinical Severity and In-Hospital Support by Pre-Existing ICD Status

Clinical Severity and Support	With ICD (N = 545)	Without ICD (N = 11,400)	P Value
VT/VF during admission, %	73.4	71.1	0.60
Clinical Severity/Status, %			
Cardiogenic shock	14.7	24.7	0.02
Acute respiratory failure	50.5	63.7	<0.01
Anoxic brain injury	19.3	19.7	0.92
DNR status	17.4	13.6	0.25
Mechanical Support, %			
IABP use	4.6	9.9	0.07
Impella use	3.7	5.3	0.45
ECMO use	0.9	1.2	0.77

Note: Values are survey-weighted. VT/VF indicates ventricular tachycardia or ventricular fibrillation coded during the hospitalization; anoxic brain injury was identified using diagnosis codes for anoxic brain damage.

Abbreviations: ICD, implantable cardioverter-defibrillator; VT, ventricular tachycardia; VF, ventricular fibrillation; IABP, intra-aortic balloon pump; ECMO, extracorporeal membrane oxygenation; DNR, do-not-resuscitate.

with a pre-existing ICD improved over time, falling from 46.2% in 2016 to 4.5% in 2021 before rising to 13.6% in 2022, as illustrated in Figure 2.

FACTORS ASSOCIATED WITH IN-HOSPITAL MORTALITY

After adjustment, pre-existing ICD status was not independently associated with in-hospital mortality (aOR 1.34, 95% CI 0.63 to 2.84), as summarized in Table 4 and Figure 1. VT/VF during admission was associated with lower odds of in-hospital mortality (aOR 0.67, 95% CI 0.48 to 0.94). Cardiogenic shock remained associated with higher mortality (aOR 1.47, 95% CI 1.03 to 2.09), while acute respiratory failure

showed a nonsignificant trend toward higher mortality (aOR 1.41, 95% CI 0.96 to 2.06). DNR status was strongly associated with in-hospital mortality (aOR 15.56, 95% CI 11.00 to 22.01). Compared with White patients, Black race (aOR 1.62, 95% CI 1.05 to 2.48) and other race categories (aOR 2.83, 95% CI 1.40 to 5.74) were associated with higher mortality. Other covariates were not significantly associated with mortality in the adjusted model in Table 4.

DISCUSSION

ICDs are effective at preventing SCD in appropriately selected HFrEF populations, as demonstrated

Table 3. In-Hospital Outcomes by Pre-Existing ICD Status

Outcome	With ICD (N = 545)	Without ICD (N = 11,400)	P Value
In-hospital mortality, %	21.1	9.7	<0.01
Acute kidney injury, %	51.4	48.0	0.49
Major bleeding, %	8.7	14.8	0.06
LOS, days (median [IQR])	6 (3–12)	8 (4–13)	<0.01
Inflation-adjusted charges, \$ (median [IQR])	106,004 (58,446–209,043)	184,033 (104,919–317,828)	<0.01

Note: Values are survey-weighted percentages unless otherwise specified. Length of stay and inflation-adjusted hospital charges are presented as median [interquartile range].

Abbreviations: ICD, implantable cardioverter-defibrillator; IQR, interquartile range; LOS, length of stay.

Table 4. Factors Associated with In-Hospital Mortality

Predictor	aOR	95% CI	P Value
Presence of ICD	1.34	0.63–2.84	0.45
Age, years	0.99	0.98–1.00	0.09
VT/VF during admission	0.67	0.48–0.94	0.02
Female	0.89	0.62–1.27	0.52
Race (vs White)			
Black	1.62	1.05–2.48	0.03
Hispanic	1.35	0.74–2.45	0.33
Asian/Pacific Islander	1.30	0.44–3.83	0.64
Native American	1.22	0.16–9.44	0.85
Other races	2.83	1.40–5.74	<0.01
Comorbidities			
Hypertension	1.00	0.65–1.54	0.99
Diabetes mellitus	1.35	0.98–1.87	0.07
Pulmonary circulation disorder	1.33	0.87–2.04	0.19
Peripheral vascular disorder	1.75	1.06–2.90	0.03
Chronic pulmonary disease	1.25	0.87–1.79	0.23
Hypothyroidism	1.33	0.82–2.14	0.25
Renal failure	1.30	0.91–1.85	0.15
Cancer	0.55	0.23–1.31	0.18
Anemia	0.80	0.40–1.61	0.53
Clinical Severity/Status			
Cardiogenic shock	1.47	1.03–2.09	0.03
Acute respiratory failure	1.41	0.96–2.06	0.08
DNR status	15.56	11.00–22.01	<0.01

Note: Results are from a multivariable survey-weighted logistic regression. Estimates are reported as adjusted odds ratios (aORs) with 95% confidence intervals (CIs).

Abbreviations: aOR, adjusted odds ratio; CI, confidence interval; DNR, do-not-resuscitate; ICD, implantable cardioverter-defibrillator; VT, ventricular tachycardia; VF, ventricular fibrillation.

in pivotal trials and reflected in contemporary guidelines.^{8–12} However, they do not prevent progressive pump failure, systemic illness, or cardiac arrest due to non-shockable mechanisms, which remain major drivers of mortality in advanced heart failure.^{4,13}

To our knowledge, this is among the first national analyses focused specifically on patients with HFrEF who presented with cardiac arrest. We found that pre-existing ICDs were uncommon, present in only 4.6% of these hospitalizations. Although this estimate does not represent ICD utilization among guideline-eligible candidates, the low prevalence is consistent

with real-world evidence of ICD underuse even among patients who meet established indications, with reported uptake as low as 14.2% for primary prevention and 30.2% for secondary prevention.¹⁴

Sex and race patterns in our cohort were consistent with previously reported disparities. Only one-quarter of the population was female in both groups, mirroring prior ICD trial cohorts in which women comprised approximately 16% to 29% of enrolled participants.¹⁵ Black patients have been reported to have a higher risk of sudden cardiac death and would be expected to benefit from

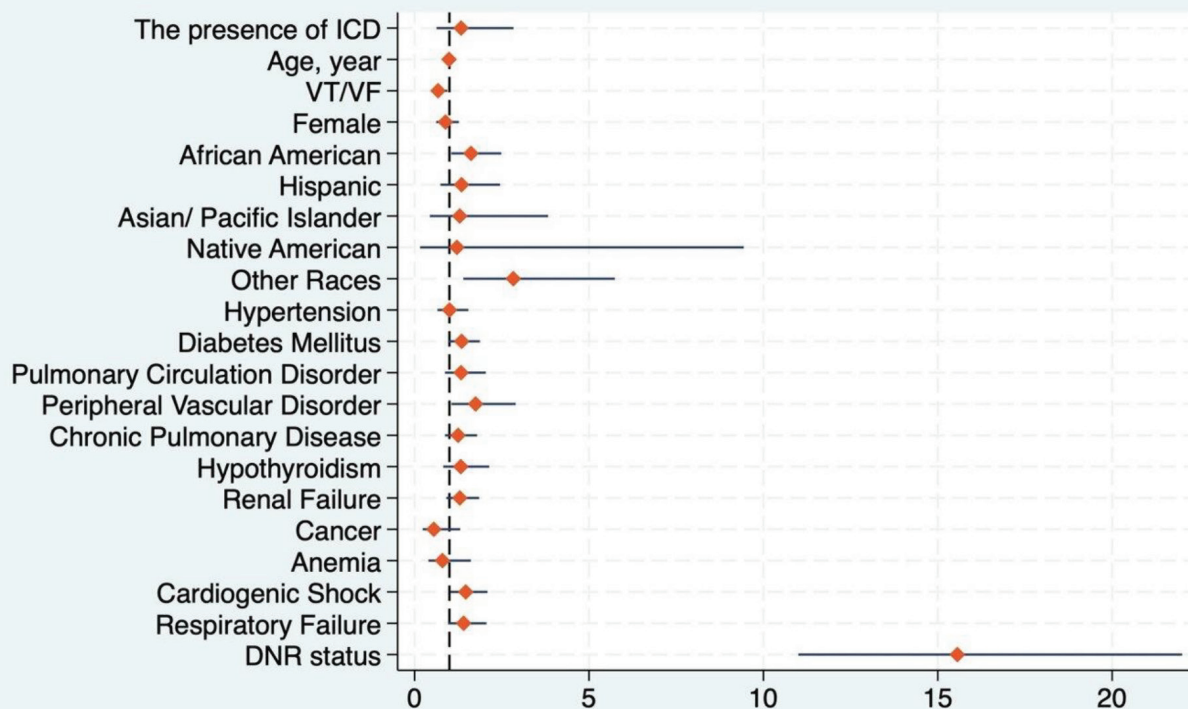


Figure 1. Independent predictors of in-hospital mortality in patients with heart failure with reduced ejection fraction presenting with cardiac arrest. Forest plot from a multivariable survey-weighted logistic regression model showing adjusted odds ratios with 95% confidence intervals for in-hospital mortality. The vertical dashed line indicates no association (adjusted odds ratio = 1.0). The model included pre-existing implantable cardioverter-defibrillator status, age, sex, race/ethnicity, ventricular tachycardia/ventricular fibrillation during admission, comorbidities, cardiogenic shock, acute respiratory failure, and do-not-resuscitate status. Abbreviations: ICD, implantable cardioverter-defibrillator; VT, ventricular tachycardia; VF, ventricular fibrillation; DNR, do-not-resuscitate.

prevention strategies, including ICD therapy when indicated.⁷ In our data, Black ICD utilization was lower than that reported by Hernandez, Hess, and co-authors among heart failure hospitalizations (15.0% vs 22.6% to 23.0%, respectively), suggesting persistent inequities in device placement.^{6,16}

Comorbidity burden was higher in the ICD group, including hypertension, diabetes, peripheral vascular disorders, chronic pulmonary disease, and renal failure. This pattern highlights systemic comorbidity clustering linked to both ischemic and nonischemic cardiomyopathy phenotypes.^{4,17} The higher prevalence of peripheral vascular disorders in the ICD group

is consistent with prior work by Inglis and co-authors describing a strong association between vascular disease and heart failure.¹⁸

Several in-hospital features should be interpreted in the context of limitations of NIS. Although we could not determine the initial arrest rhythm (e.g., pulseless electrical activity/asystole versus VT/VF), VT/VF coded during hospitalization was similar between groups. The observed VT/VF coding prevalence was high (approximately 71% to 73%) but does not confirm VT/VF as the arrest rhythm and may capture arrhythmias occurring before or after the arrest event. This rate exceeds the proportion of shockable

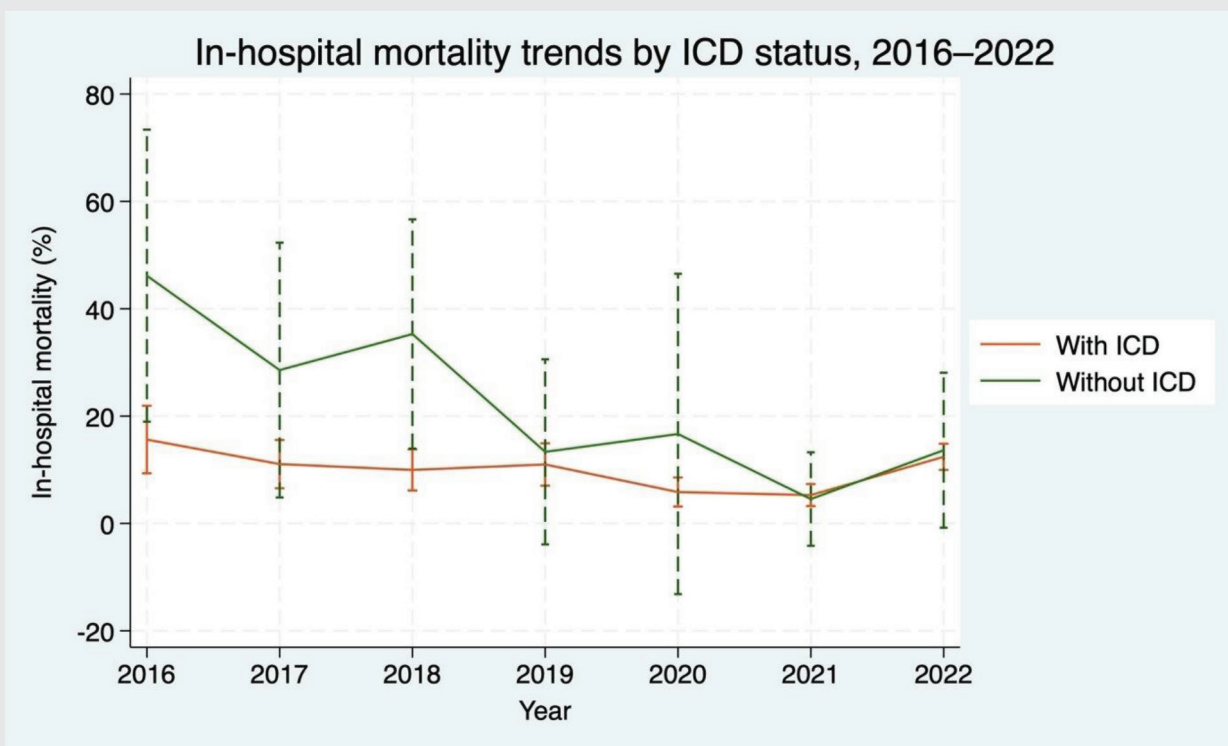


Figure 2. In-hospital mortality by year, stratified by pre-existing implantable cardioverter-defibrillator status from 2016 to 2022. Survey-weighted in-hospital mortality among adult hospitalizations with heart failure with reduced ejection fraction presenting with cardiac arrest, shown separately for those with and without a documented pre-existing device. Point labels indicate the annual mortality percentage for each group. Abbreviations: ICD, implantable cardioverter-defibrillator.

rhythms reported in prior studies (15.3% to 38% across in-hospital and out-of-hospital cardiac arrest populations), underscoring the need for rhythm-adjudicated data.^{19–21}

Markers of clinical severity, including cardiogenic shock and respiratory failure, differed between groups, whereas anoxic brain injury was similar at approximately 19%. This estimate is directionally consistent with prior reports using clinical outcomes (13%) and imaging-based post-resuscitation assessments (29%).^{22,23} DNR status was higher in patients with ICDs than those without (17.4% vs 13.6%, respectively), and mechanical circulatory support use was lower in the ICD group. These findings may reflect differences in underlying disease phenotype and goals-of-care decisions.²⁴

Over the study period, in-hospital mortality among hospitalizations without a pre-existing ICD ranged from 5.3% to 15.6% (15.6% in 2016 and 12.4% in 2022). In contrast, mortality among those with a pre-existing ICD showed greater year-to-year variability but an overall improvement, decreasing from 46.2% in 2016 to 13.6% in 2022 (nadir 4.5% in 2021), as shown in Figure 2.²⁵

After multivariable adjustment, ICD presence was not independently associated with in-hospital mortality, suggesting the crude mortality difference may be driven by baseline risk and unmeasured severity rather than a direct device effect. In the adjusted model, Black race remained associated with 1.62 times higher in-hospital mortality compared with White patients, and cardiogenic shock was associated with

1.47 times higher in-hospital mortality. This remains clinically important given ongoing excess cardiovascular mortality among Black patients, with Kyalwazi and co-authors reporting an adjusted hazard ratio of 1.30; similarly, in our analysis, Black race was associated with higher in-hospital mortality in this subgroup (aOR 1.62).²⁶

In contrast, VT/VF during hospitalization was associated with 33% lower in-hospital mortality, consistent with long-standing evidence that shockable rhythms have more favorable outcomes than non-shockable rhythms.^{19–21}

Overall, our study emphasizes that HFrEF hospitalizations complicated by cardiac arrest represent a high-risk population in which pre-existing ICD status identifies a subgroup with substantial crude mortality and distinct patterns of resource utilization. These findings support future work integrating the first documented rhythm, device interrogation, treatment, post-cardiac arrest care measures, and DNR timing to clarify mechanisms and determine whether differences in post-arrest care intensity contribute to outcome disparities.

LIMITATIONS

This study has limitations inherent to retrospective analyses of administrative claims data. First, diagnoses and procedures in the NIS are subject to coding misclassification, and we could not verify HFrEF severity, left ventricular ejection fraction values, device programming, shocks delivered, or device malfunction. Second, the NIS captures hospitalizations rather than unique individuals, so repeat admissions cannot be linked, and patient-level longitudinal outcomes are unavailable. Third, key cardiac arrest variables were not available, including arrest location, timing, witnessed status, quality and duration of compression, time-to-defibrillation, neurologic examination, and the initial arrest rhythm; VT/VF codes may reflect arrhythmias occurring before or after the arrest rather than the arrest rhythm itself. Fourth, important clinical confounders such as medications, laboratory values, hemodynamics, imaging findings, and granular measures of illness severity were unavailable, leaving

potential residual confounding despite multivariable adjustment. Fifth, DNR status in the NIS does not capture timing or post-arrest decisions, withdrawal of life-sustaining therapy, or the limitations imposed on the interpretation of observed relationships between mortality and resource utilization. Finally, outcomes were limited to the index hospitalization; longer-term survival and neurologic recovery after discharge could not be assessed.

CONCLUSION

Among hospitalizations for HFrEF complicated by cardiac arrest, pre-existing ICDs were documented in approximately 4.6% of cases. Patients with ICDs had higher crude in-hospital mortality; however, after adjustment, ICD status was not independently associated with in-hospital mortality, suggesting outcomes were driven more by baseline risk profile and clinical severity. Cardiogenic shock and Black race were associated with higher in-hospital mortality. Future studies incorporating arrest rhythm, timing, and device interrogation data are needed to clarify mechanisms and guide targeted post-arrest management in this high-risk population.

DATA AVAILABILITY

The data used in this study are available from the Healthcare Cost and Utilization Project (HCUP) National Inpatient Sample (NIS) and are subject to the HCUP Data Use Agreement. The analytic code is available from the corresponding author upon reasonable request.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE MANUSCRIPT PREPARATION PROCESS

During the preparation of this work the authors used Claude AI in order to improve language clarity and manuscript organization. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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