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Sudden Cardiac Arrest with Shockable Rhythm in Patients with Heart Failure

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Abstract

Background: Patients with shockable sudden cardiac arrest (SCA, ventricular fibrillation/tachycardia), have significantly better resuscitation outcomes than those with non-shockable rhythms (pulseless electrical activity/asystole). Heart failure (HF) increases risk of SCA, but presenting rhythms have not been previously evaluated.

Objective: We hypothesized that based on unique characteristics, HFpEF (preserved ejection fraction, LVEF ≥ 50%), bHFpEF (borderline, LVEF >40% and <50%) and HFrEF (reduced EF, LVEF < 40%), manifest significant differences in presenting rhythm during SCA.

Methods: Consecutive cases of SCA with HF (age ≥ 18 years) were ascertained in the Oregon Sudden Unexpected Death Study (2002–2019). LVEF was obtained from echocardiograms performed prior and unrelated to the SCA event. Presenting rhythms were identified from first responder reports. Logistic regression was used to evaluate the independent association of presenting rhythm with HF sub-type.

Results: Among 648 subjects with HF and SCA (median age: 72 years; interquartile range, 62–81), 274 had HFrEF (23.4% female), 92 had bHFpEF (35.9% female) and 282 had HFpEF (42.5% female). Rates of shockable rhythms were 44.5%, 48.9% and 27.0% for HFrEF, bHFpEF and HFpEF, respectively (P<0.001). Compared with HFpEF, adjusted odds ratios for shockable rhythm were 1.86 (95% confidence interval, CI, 1.27–2.74; P=0.002) in HFrEF and 2.26 (95% CI, 1.35–3.77; P=0.002) in bHFpEF. Rates of survival to hospital discharge were 10.6% in HFrEF, 22.8% in bHFpEF and 9.9% in HFpEF (P=0.003).

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Conclusion: Rates of shockable rhythm during SCA depend on the HF clinical sub-type. Patients with bHFpEF had the highest likelihood of shockable rhythm, correlating with highest rates of survival.

Graphical Abstract.

Summary of main study findings and future directions. Subjects with borderline preserved ejection fraction are more likely to suffer a shockable sudden cardiac arrest and have a higher likelihood of survival to hospital discharge. Our findings suggest the potential of patients with this heart failure sub-type to benefit from the prophylactic implantable cardioverter-defibrillator, but this would need to be evaluated in prospective randomized clinical trials. bHFpEF, heart failure with borderline preserved ejection fraction; HFpEF, heart failure with preserved ejection fraction; HFrEF, heart failure with reduced ejection fraction.

Keywords

Congestive heart failure; ventricular fibrillation; pulseless electrical activity; sudden death; survival; defibrillation

INTRODUCTION

Approximately 6.2 million adults in the United States have heart failure (HF), with an annual incidence estimated at 915,000 cases^{1, 2}, resulting in significant morbidity and mortality³. Sudden cardiac arrest (SCA) is also a major public health problem with a mortality rate >90%, resulting in >350,000 US lives lost annually due to sudden cardiac death (SCD)⁴. Since HF is a major risk factor for SCA^{5, 6}, there is a sizeable overlap between the two conditions with HF contributing significantly to SCA-associated mortality.

SCA can present with shockable rhythms [ventricular fibrillation (VF) and ventricular tachycardia (VT)] or non-shockable rhythms (asystole and pulseless electrical activity, PEA), with shockable rhythms having significantly higher likelihood of survival (25–40%) compared to non-shockable rhythms (<5%)^{7–9}. Also, for the last 4 decades, overall rates of SCA with shockable rhythms have been progressively declining compared to non-shockable rhythms^{10, 11}. Given the major contribution of HF to SCA, it is important to understand SCA presenting rhythms in HF.

However HF is recognized as a clinical spectrum with at least 2 distinct sub-types: HF with preserved ejection fraction (HFpEF, left ventricular ejection fraction (LVEF) $\geq 50\%$) and HF with reduced ejection fraction (HFrEF, LVEF $< 40\%$)^{12, 13}. More recently, patients with HF and an LVEF of $>40\%$ to $<50\%$ have been included in a third category called “borderline HFpEF” (bHFpEF)^{12–15}. An improved understanding of shockable vs. non-shockable SCA could have important implications for survival in HF patients who suffer SCA, as well as new opportunities for primary prevention with the implantable cardioverter defibrillator (ICD), that also targets shockable rhythms. We therefore hypothesized that based on distinct pathophysiology and clinical profile, there are significant differences in SCA presenting rhythms between HFpEF, bHFpEF and HFrEF.

METHODS

Study Population

Between 2002 and 2019, we prospectively enrolled cases with out-of-hospital SCA from the Oregon Sudden Unexpected Death Study (Oregon SUDS), an ongoing community-based study of out-of-hospital SCA in the Portland, OR metro area^{16, 17}. We performed a case-case analysis in the subgroup of Oregon SUDS SCA cases with diagnosis of HF in whom archived information regarding LVEF was available prior to SCA. For all analyses, the HFpEF subtype was the reference group. We included data from subjects (≥ 18 years of age) enrolled from February 1, 2002 to March 19, 2019. The study protocol was approved by the Institutional Review Boards of Cedars-Sinai Medical Center, Oregon Health and Science University, and all relevant hospitals/health systems. SCA cases were included if they had: available medical records with a clinical diagnosis of HF (documented by physician records), LVEF evaluated from archived echocardiograms performed prior and unrelated to the SCA event, and documented presenting heart rhythm at time of SCA.

Definitions and Clinical Database

SCA was defined as a sudden loss of pulse that occurred with a rapid witnessed collapse (or if unwitnessed, the subject should have been seen alive within 24 h)¹⁸, excluding those with non-cardiac origin, terminal illness, or unnatural cause of death. In-house adjudication of sudden cardiac arrest was performed by three trained physician researchers¹⁶. Patients were defined as having HF if medical records prior to arrest included a documented diagnosis of HF (including outpatient visits and hospital records).

Definition of HF clinical sub-types: HFrEF was defined as HF with an LVEF $< 40\%$ assessed by echocardiography only; bHFpEF as HF with an LVEF of $>40\%$ to $<50\%$; HFpEF as HF with an LVEF $\geq 50\%$ ¹². The presenting rhythm was defined as the first electrocardiographic rhythm recorded by the Emergency Medical Services (EMS) personnel during resuscitation of SCA. VF was defined as a pulseless condition with disorganized electrical signals. VT was defined as pulseless, regular wide complex tachycardia. PEA was defined as non-palpable pulse in the presence of an organized electrical rhythm. Asystole was defined as the absence of electrical activity¹⁹.

Information on age, sex, race/ethnicity, smoking status (active, former, nonsmoker) and clinical comorbidities was obtained from physician records. Comorbidities included coronary artery disease (CAD), hypertension, hyperlipidemia, obesity, diabetes, chronic obstructive pulmonary disease (COPD) or asthma, chronic kidney disease, atrial fibrillation/flutter and prior medications. Diagnosis of CAD was based on physician records, history of myocardial infarction, angina, or any record of positive stress test, percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG) from physician or EMS reports, and/or a $\geq 50\%$ stenosis in any coronary artery determined by angiogram or forensic pathology. Measured body weight and height were obtained from physician records, procedure reports or the forensic record. Obesity was defined as documented by physician records or a body mass index (measured body weight in kilograms divided by the square of the height in meters) equal or higher than 30 kg/m^2 ²⁰. Diabetes was defined as diagnosed diabetes documented by physician records or a glycated hemoglobin equal or higher than 6.5% ²¹.

Information on SCA circumstances and resuscitation outcomes conforming to Utstein-style for SCA was obtained from the EMS reports²². This included details of SCA location, EMS response time (defined as the time from dispatch of EMS to their arrival on the scene), whether collapse was witnessed, whether bystander cardiopulmonary resuscitation (CPR) was performed, whether resuscitation was performed by EMS, and outcomes of resuscitation, i.e. return of spontaneous circulation and survival to hospital discharge.

Statistics

Data were presented as medians and interquartile ranges, unless otherwise indicated, for continuous variables and as percentages for categorical variables. Chi-squared tests were used to compare percentages. Kruskal-Wallis tests were used to test for differences between groups for continuous variables. P values for post-hoc analyses were adjusted with Bonferroni correction for multiple (pairwise) comparisons. The main outcome was the SCA presenting heart rhythm. We performed logistic regression (univariate and multivariate) to obtain unadjusted- and adjusted-odds ratios with confidence intervals as the measure of the association between the initial rhythm and HF sub-type. Multivariate analyses included model 1 (adjusted for age, sex, and race/ethnicity) and model 2 (full model, adjusted for age, sex, race/ethnicity, obesity, diabetes, CAD, hypertension, hyperlipidemia, COPD or asthma, chronic kidney disease, and atrial fibrillation/flutter). Several sensitivity analyses were performed. All analyses were performed using Stata 15 (StataCorp LP, TX). All statistical tests were two sided and a P value less than 0.05 was considered statistically significant.

RESULTS

Characteristics of Study Subjects

From 1,314 eligible adult individuals with the diagnosis of HF and SCA, we excluded those with missing information on echocardiography (n=520), comorbidities (n=11) and initial rhythm (n=135). Final analyses included 648 subjects (66.5% males). Characteristics of the study population are shown in Table 1 and in Supplementary Table 1. The median (interquartile range) age was 72 (62–81) years, of which 274 (42.3%) had HFrEF, 92

(14.2%) had bHFpEF, and 282 (43.5%) had HFpEF. Compared with subjects with HFpEF, those with HFrEF were more likely to be male ($P<0.001$), had a lower BMI ($P=0.001$), and had a lower prevalence of hypertension ($P=0.004$) and COPD or asthma ($P=0.001$) but had a higher prevalence of CAD ($P<0.001$). Overall, bHFpEF and HFrEF had more clinical characteristics in common than bHFpEF had with HFpEF (Figure 1A and Table 1).

Overall, 7.9% of all HF patients had a primary prevention ICD, but still suffered SCA: HFrEF 14.6% ($n=40$), bHFpEF 9.8% ($n=9$) and HFpEF 0.7% ($n=2$). Among those with ICD, shockable rhythm was present in 23.5% (Supplementary Table S2).

Resuscitation findings

Among all subjects with HF, 37.5% had VF/VT (shockable rhythm) (Table 2). Shockable rhythm was more prevalent in HFrEF (44.5%) and in bHFpEF (48.9%) than in HFpEF (27.0%; $P<0.001$ vs. HFrEF or bHFpEF) (Figure 1B). Overall, shockable rhythm was more frequent among men; however, we did not detect significant sex-related differences within HF sub-types (Figure 2). PEA was less prevalent in bHFpEF than HFpEF ($P=0.03$).

Likelihood of Shockable Rhythm

Compared with HFpEF, the unadjusted odds ratios for shockable SCA in bHFpEF and HFrEF, respectively, were 2.60 (95% confidence interval, CI, 1.60–4.22; $P<0.001$) and 2.18 (95% CI, 1.53–3.10; $P<0.001$) (Table 3). This association remained significant after full adjustment for age, sex, race/ethnicity, obesity, diabetes, CAD, hypertension, hyperlipidemia, COPD or asthma, chronic kidney disease, and atrial fibrillation/flutter (Model 2). The adjusted odds ratios for shockable SCA were 2.26 (95% CI, 1.35–3.77; $P=0.002$) among subjects with bHFpEF and 1.86 (95% CI, 1.27–2.74; $P=0.002$) among those with HFrEF (Figure 1C).

Likelihood of Survival to Hospital Discharge

Overall, individuals with shockable rhythm had higher odds for surviving to hospital discharge than those with non-shockable rhythm after adjustment for age, sex, race/ethnicity, LVEF, and comorbidities (OR: 5.21, 95% CI: 2.99–9.07). Survival to hospital discharge was higher in bHFpEF compared with HFrEF ($P=0.011$) or HFpEF ($P=0.006$), with no differences in EMS response time across HF sub-types ($P=0.91$) (data not shown). Subjects with HFrEF and bHFpEF, respectively, had odds ratios of 1.07 (95% CI, 0.62–1.86; $P=0.80$) and 2.68 (95% CI, 1.44–5.01; $P=0.002$) for survival compared with those with HFpEF. The magnitude of the association between bHFpEF and survival was attenuated after adjustment for shockable rhythm but remained significant [odds ratio: 1.99 (95% CI, 1.03–3.83; $P=0.040$)]. However, this association did not hold after full adjustment for age, sex, race/ethnicity, comorbidities, and shockable rhythm [odds ratio: 1.88 (95% CI, 0.94–3.75; $P=0.073$)].

Sensitivity Analysis

The association between initial rhythm and HF sub-type remained significant after Model 2 was further adjusted for Utstein variables ($n=626$). Compared with HFpEF, the adjusted odds ratios for shockable SCA were 2.48 (95% CI, 1.43–4.31; $P=0.001$) in bHFpEF and

1.80 (95% CI, 1.19–2.73; $P=0.006$) in HFrEF. Likewise, the association also remained significant when we restricted the analysis to cases with witnessed SCA only ($n=386$).

In the 90% subset ($n=629$) of patients with complete Utstein-style guideline data, compared with subjects with HFpEF and a response time in the first tertile (0.8–5.20 min), those with bHFpEF and HFrEF had, respectively, 3.80 ($P=0.011$) and 2.20 ($P=0.040$) times higher odds of having a shockable initial rhythm, adjusting for age, sex, race/ethnicity, and comorbidities (Figure 3). Among cases with a response time in the second tertile (5.22–7.37 min), those with bHFpEF and HFrEF had, respectively, 2.6 ($P=0.039$) and 2.7 (0.007) times higher odds of having a shockable initial rhythm compared with those with HFpEF. We found no significant association between shockable rhythm and HF sub-type in the third tertile (7.38–28.45 min).

Since presenting rhythm recorded by first responders at time of SCA may not represent the first lethal rhythm in those with indwelling ICDs, we performed a sensitivity analysis excluding those patients with ICDs ($n=51$). Multivariate regression analysis ($n=597$) showed the association between HF subtype and shockable SCA remained significant in Model 2. Compared with HFpEF, the adjusted odds ratios for shockable SCA were 2.32 (95% CI, 1.35–3.99; $P=0.002$) among subjects with bHFpEF and 2.30 (95% CI, 1.53–3.46; $P<0.001$) among those with HFrEF. In this subset, the significant association between bHFpEF and survival to hospital discharge also remained after full adjustment, including adjustment for shockable rhythm [odds ratio: 2.16 (95% CI, 1.07–4.38); $P=0.032$].

DISCUSSION

In this community-based population of patients with diagnosis of HF who suffered SCA, the SCA presenting rhythm was determined by the HF clinical sub-type. Compared to subjects with HFpEF, those with bHFpEF had nearly 2.5-fold higher likelihood of presenting with shockable SCA; subjects with HFrEF had two-fold higher odds of having shockable SCA. Corresponding with higher rates of shockable rhythm, bHFpEF patients had the highest likelihood of survival to hospital discharge. To the best of our knowledge, these are novel findings.

Despite having normal LV systolic function, HFpEF patients had the lowest prevalence of shockable rhythms during SCA. We postulated that this association could potentially be explained by other characteristics of individuals with HFpEF that are associated with a lower likelihood of shockable rhythm -- female sex, higher rates of COPD or asthma, and lower rates of CAD (Figure 1A and Table 1)¹⁹. However, the association between type of HF and shockable rhythm remained significant after multivariable adjustment for these factors. We cannot rule out the possibility of undetected pulmonary embolism, a condition with an established association with PEA²³. Conversely, HFrEF SCA, with younger age and higher rates of established CAD, was more likely to manifest with VF/VT, a finding consistent with an earlier study from our group¹⁹. It is interesting that even though the clinical characteristics of bHFpEF fell largely between the other 2 groups, this group was observed to have the highest likelihood of shockable SCA. While this needs to be investigated further,

this would suggest that bHFpEF is more similar to HFrEF than to HFpEF, at least with regard to manifestation with shockable rhythms.

We also considered that variables related to resuscitation could have contributed to differences in manifestation with shockable versus non-shockable rhythm including ambulance response time, location of SCA, whether SCA was witnessed, rates of bystander CPR.²⁴ However, there were no significant differences identified for these determinants of shockable vs. non-shockable rhythms, across the 3 HF sub-types (Table 2). Therefore, resuscitation variables did not explain the observed differences in presenting rhythm across HF sub-types. Coinciding with higher rates of shockable rhythms, subjects with bHFpEF had higher rates (~23%) of survival to hospital discharge, compared with those with HFrEF or HFpEF (less than 11%). Accordingly, the magnitude of the association between survival and bHFpEF was attenuated when adjusted for shockable rhythm. No previous study has compared the rate of survival to hospital discharge across HF sub-types.

Based on multiple randomized clinical trials followed by established clinical practice over almost two decades, the prophylactic ICD has proven benefit in HFrEF^{25–27}. Our findings indicate that the highest likelihood of shockable SCA is actually among subjects with bHFpEF, suggesting that the bHFpEF group may also potentially benefit from the prophylactic ICD (Graphical Abstract). However, this important question would need to be addressed in future prospective, randomized clinical trials.

The present study has some limitations that are inherent in the design of large community-based analyses that are observational in nature. The clinical diagnosis of HF was based on physician records obtained from multiple hospitals that served the patients evaluated in this study, with potential for misclassification due to differences in clinical practice. A subgroup of HF patients had missing information on LVEF by echocardiography and were therefore excluded from analyses. This is an unavoidable limitation of community-based studies where tests may not be uniformly performed or be available for all subjects. However, because of the design we were able to ascertain and analyze a relatively large sample size of adults with HF who had out-of-hospital SCA, numbers that are not obtainable from existing cohort studies.

CONCLUSIONS

We report novel findings regarding the presenting rhythm of SCA across the three clinical sub-types of HF. Adult subjects with HFrEF and bHFpEF had higher likelihood of shockable SCA compared with HFpEF, and in the bHFpEF group this was associated with improved SCA survival. These findings were not explained by SCA circumstances and resuscitation-related factors, indicating their relationship to inherent clinical and pathophysiological differences across the HF sub-types. bHFpEF patients represent a subgroup of HFpEF patients that have the highest likelihood of shockable SCA, correlating with the highest rates of survival from SCA in patients with heart failure.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Heart failure with borderline preserved ejection fraction is most likely to be associated with shockable sudden cardiac arrest (SCA).
Analyses were performed using data from 648 subjects with diagnosis of heart failure who had SCA. A, summary of clinical characteristics, where the number of stick figures represent likelihood of a given characteristic categories of heart failure. B, proportion of subjects with heart failure and shockable rhythm. C, association between heart failure sub-types and shockable SCA. bHFpEF, heart failure with borderline preserved ejection fraction; HFpEF, heart failure with preserved ejection fraction; HFrEF, heart failure with reduced ejection fraction.

Figure 2. Frequency of shockable initial rhythm by sex in out-of-hospital sudden cardiac arrest. Bars and error bars represent mean and 95% confidence intervals, respectively. bHFpEF, heart failure with borderline preserved ejection fraction (>40% to <50%); HFpEF, heart failure with preserved ejection fraction (>50%); HFrEF, heart failure with reduced ejection fraction (<40%).

Figure 3. Association between heart failure sub-types and shockable out-of-hospital sudden cardiac arrest (SCA) by response time.

Analysis was performed using data from 629 subjects with the diagnosis of heart failure who had SCA. Ranges for tertiles of response time are as follows: lowest tertile, 0.8–5.20 min; middle tertile, 5.22–7.37 min; highest tertile, 7.38–28.45 min. bHFpEF, heart failure with borderline preserved ejection fraction (>40% to <50%); HFpEF, heart failure with preserved ejection fraction (>50%); HFrEF, heart failure with reduced ejection fraction (<40%).

Table 1.

Characteristics of the study population according to heart failure sub-types based on left ventricular ejection fraction.

Characteristic	All (n=648)	HFrEF (n=274)	bHFpEF (n=92)	HFpEF (n=282)	P value for differences between HF sub-types
Age, yr					0.11
Median	72	70	71	73	
Interquartile range	62–81	61–80	61.5–81	62–83	
Male sex, %	66.5	76.6	64.1	57.5	<0.001
Race/ethnicity, %					0.17
European-American	76.1	79.6	75.0	73.1	
African-American	10.2	9.1	14.1	9.9	
Other	13.7	11.3	10.9	17.0	
BMI, kg/m ² *					<0.001
Median (n)	28.9 (597)	27.7 (257)	28.8 (86)	30.5 (254)	
Interquartile range	24.9–35.3	24.6–33.0	25.3–36.2	25.4–37.6	
LVEF _{ECHO} , %					
Median	45.0	27.5	45.0	60.0	
Interquartile range	30–57.5	22.5–35.0	42.5–47.5	55–62.5	
Time from LVEF echo to arrest, days					0.25
Median	295	265.5	454.5	295.5	
Interquartile range	90–794	94–683	86.5–1,092	90–837.5	
Medical history					
Obesity, %	43.7	37.6	42.4	50.0	0.012
Diabetes, %	52.5	51.1	46.7	55.7	0.28
Coronary artery disease, %	77.3	83.9	79.4	70.2	0.001
Hypertension, %	84.4	78.8	87.0	89.0	0.003
Hyperlipidemia, %	62.8	60.2	66.3	64.2	0.47
COPD or asthma, %	39.4	31.8	33.7	48.6	<0.001
Chronic kidney disease, %	49.5	50.7	41.3	51.1	0.23
Atrial fibrillation/flutter, %	48.2	47.8	46.7	48.9	0.93

* Information was missing in some participants. Thus, data represent estimates from subpopulations (n), as indicated. bHFpEF, heart failure with borderline preserved ejection fraction (>40% to <50%); BMI, body mass index (body weight in kilograms divided by the square of the height in meters); COPD, chronic obstructive pulmonary disease; HFpEF, heart failure with preserved ejection fraction (> 50%); HFrEF, heart failure with reduced ejection fraction (< 40%); LVEF_{ECHO}, left ventricular ejection fraction estimated by echocardiography.

Table 2.

Sudden cardiac arrest characteristics according to Utstein-style guidelines.

Characteristic	All (n=648)	HFrEF (n=274)	bHFpEF (n=92)	HFpEF (n=282)	P value for differences between HF sub-types
Home arrest, % *					0.50
Yes	63.1	65.6	59.8	61.7	
Witnessed collapse, % *					0.56
Yes	59.9	61.8	55.4	59.6	
Bystander CPR, %					0.70
Yes	36.1	38.0	34.8	34.8	
Response time, min *					0.91
Median	6.3	6.2	6.6	6.4	
Interquartile range	5.0–8.0	4.7–8.2	5.0–8.0	5.0–8.0	
Initial heart rhythm, %					<0.001
VF or VT (shockable rhythm)	37.5	44.5	48.9	27.0	
PEA	25.9	26.6	15.2	28.7	
Asystole	35.0	27.4	32.6	43.3	
PEA or asystole	1.5	1.5	3.3	1.1	
Resuscitation attempted, %					0.11
Yes	90.9	93.4	91.3	88.3	
ROSC, %					0.11
Yes	40.4	39.1	53.3	37.6	
Unknown	0.3	0.4	0.0	0.4	
Survival to hospital discharge, %					0.003
Yes	12.0	10.6	22.8	9.9	

* Information was missing in some participants. Thus, data represent estimates from subpopulations (n): location of arrest was missing for n=1; witnessed status was missing for n=4; and response time was missing for n=19.

bHFpEF, heart failure with borderline preserved ejection fraction (>40% to <50%); CPR, cardiopulmonary resuscitation; HFpEF, heart failure with preserved ejection fraction (>50%); HFrEF, heart failure with reduced ejection fraction (<40%); PEA, pulseless electrical activity; ROSC, return of spontaneous circulation; VF, ventricular fibrillation; VT, ventricular tachycardia.

Table 3.

Association between heart failure sub-types and shockable rhythm.

	Odds ratio (95% CI) for shockable rhythm (vs. non-shockable)					
	Unadjusted	P value	Model 1 [*]	P value	Model 2 [†]	P value
Heart Failure sub-type						
HFpEF	1.00 (reference)		1.00 (reference)		1.00 (reference)	
bHFpEF	2.60 (1.60–4.22)	<0.001	2.53 (1.54–4.15)	<0.001	2.26 (1.35–3.77)	0.002
HFrEF	2.18 (1.53–3.10)	<0.001	1.95 (1.36–2.81)	<0.001	1.86 (1.27–2.74)	0.002

^{*} Adjusted for age, sex, and race/ethnicity.

[†] Adjusted for age, sex, race/ethnicity, and comorbidities (obesity, diabetes, coronary artery disease, hypertension, hyperlipidemia, chronic obstructive pulmonary disease or asthma, chronic kidney disease, atrial fibrillation/flutter).

bHFpEF, heart failure with borderline preserved ejection fraction (>40% to <50%); HFpEF, heart failure with preserved ejection fraction (≥ 50%); HFrEF, heart failure with reduced ejection fraction (< 40%).