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ORIGINAL RESEARCH

National Trends in the Burden of Atrial Fibrillation During Hospital Admissions for Heart Failure

Samuel W. Reinhardt, MD; Fouad Chouairi, MS; P. Elliott Miller, MD; Katherine A. A. Clark, MD, MBA; Bradley Kay, MD; Michael Fuery, MD; Avirup Guha, MBBS; James V. Freeman, MD, MPH, MS; Tariq Ahmad, MD, MPH; Nihar R. Desai, MD, MPH; Daniel J. Friedman, MD

BACKGROUND: Heart failure (HF) and atrial fibrillation (AF) frequently coexist and may be associated with worse HF outcomes, but there is limited contemporary evidence describing their combined prevalence. We examined current trends in AF among hospitalizations for HF with preserved (HFpEF) ejection fraction or HF with reduced ejection fraction (HFrEF) in the United States, including outcomes and costs.

METHODS AND RESULTS: Using the National Inpatient Sample, we identified 10 392 189 hospitalizations for HF between 2008 and 2017, including 4 250 698 with comorbid AF (40.9%). HF hospitalizations with AF involved patients who were older (average age, 76.9 versus 68.8 years) and more likely White individuals (77.8% versus 59.1%; $P<0.001$ for both). HF with preserved ejection fraction hospitalizations had more comorbid AF than HF with reduced ejection fraction (44.9% versus 40.8%). Over time, the proportion of comorbid AF increased from 35.4% in 2008 to 45.4% in 2017, and patients were younger, more commonly men, and Black or Hispanic individuals. Comorbid hypertension, diabetes mellitus, and vascular disease all increased over time. HF hospitalizations with AF had higher in-hospital mortality than those without AF (3.6% versus 2.6%); mortality decreased over time for all HF (from 3.6% to 3.4%) but increased for HF with reduced ejection fraction (from 3.0% to 3.7%; $P<0.001$ for all). Median hospital charges were higher for HF admissions with AF and increased 40% over time (from $22 204 to $31 145; $P<0.001$).

CONCLUSIONS: AF is increasingly common among hospitalizations for HF and is associated with higher costs and in-hospital mortality. Over time, patients with HF and AF were younger, less likely to be White individuals, and had more comorbidities; in-hospital mortality decreased. Future research will need to address unique aspects of changing patient demographics and rising costs.

Key Words: atrial fibrillation ■ healthcare costs ■ heart failure

Atrial fibrillation (AF) is the most common arrhythmia in patients with heart failure (HF), and its prevalence and incidence increase with age and with severity of HF, reaching up to 50% in patients with New York Heart Association class IV symptoms.[1,2] Studies have shown that the presence of AF portends poorer outcomes among patients with HF,[3–6] although AF has not always been an independent risk factor for mortality when adjusting for other variables.[7–9] Prior analyses have shown an increasing prevalence of and hospitalizations for AF[10–12] and HF[13] as separate entities, but have not examined them as comorbid conditions. In addition, the relationship between HF subtype (ie, HF with preserved ejection fraction [HFpEF] versus

Correspondence to: Samuel W. Reinhardt, MD, Section of Cardiovascular Medicine, Yale School of Medicine, 789 Howard Ave, Third Floor, New Haven, CT 06510. E-mail: samuel.reinhardt@yale.edu

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CLINICAL PERSPECTIVE

What Is New?

- Atrial fibrillation (AF) is increasingly common among hospitalizations for heart failure (HF) in the United States and is associated with higher costs and in-hospital mortality.
- Over time, hospitalized patients with HF with comorbid AF are growing younger, are less often of White race, and increasingly have comorbidities, including hypertension, diabetes mellitus, and vascular disease.
- The costs of HF hospitalizations with AF increased by 40% from 2008 to 2017.

What Are the Clinical Implications?

- Comorbid AF affecting HF hospitalizations represents an independent risk factor for mortality, and its presence should alert providers to patients who are at increased risk for poor inpatient outcomes.
- Future research on prevention and treatment of comorbid AF and HF will need to address critical aspects of changing patient demographics (increasing comorbidity burden and proportion of Black and Hispanic patients) and rapidly rising costs.

Nonstandard Abbreviations and Acronyms

CHA_2DS_2-VASc	Congestive heart failure, Hypertension, Age ≥75 (2), Diabetes, Stroke/transient ischemic attack (TIA)/systemic embolism (2), Vascular Disease, Age ≥65, and Sex category
HFpEF	heart failure with preserved ejection fraction
HFrEF	heart failure with reduced ejection fraction
NIS	National (Nationwide) Inpatient Sample

HF with reduced ejection fraction [HFrEF]) and the changing demographics of comorbid AF has not been well described. As such, we sought to characterize the contemporary trends in hospitalizations for HF (overall and by HF subtype) with comorbid AF using a large, nationwide, inpatient database to provide an updated picture of the burden of these diseases and their association with mortality and costs.

METHODS

Data Source and Study Population

The National (Nationwide) Inpatient Sample (NIS) is the largest publicly available all-payer inpatient discharge database in the United States and contains weighted data for >35 million annual hospitalizations nationally.[12] All data and materials are publicly available for purchase from the Online Healthcare Cost and Utilization Project Central Distributor and can be accessed at https://www.distributor.hcup-us.ahrq.gov/. In this study, data were used from 2008 until 2017, which includes a design change in 2012. Between 2007 and 2011, the discharges in NIS represented all inpatient discharges from a random 20% sample of acute-care hospitals in the United States. Since 2012, discharges in this database represent a random sample of 20% of discharges from all nonfederal US hospitals, stratified by hospital, census division, ownership status, urban versus rural location, teaching status, bed size, patient diagnosis-related group, and admission month. We followed the recommendation from the Agency for Healthcare Research and Quality for analysis using survey data, using patient-level and hospital-level trend weights provided to obtain national estimates. From 2008 to 2011, the new trend weight ("trendwt") released by Healthcare Cost and Utilization Project was used to account for the sampling change, whereas from 2012 to 2017 discharge weight ("discwt") was used to weight cases.[14] This allowed for comparison across the period when the NIS redesign occurred. Because the NIS database includes only deidentified patient data, this study was deemed exempt by the Yale School of Medicine Institutional Review Board.

NIS was queried to identify all hospital admissions with a primary diagnosis of HF, stratified by the presence or absence of AF or atrial flutter, from 2008 to 2017. We used *International Classification of Diseases, Ninth Revision, Clinical Modification* and *International Classification of Diseases, Tenth Revision, Clinical Modification* (*ICD-9-CM* and *ICD-10-CM*, respectively) codes to identify our study population, which included hospitalizations for HF of patients aged ≥18 years, stratified by presence of AF or atrial flutter and further demarcated by type of HF (HFpEF and HFrEF; Table S1).[13] The total number of hospitalizations with HFpEF plus HFrEF was lower than the number in the overall HF cohort, as there were patients whose HF was not further delineated in billing codes. Patients in whom HF subtype could not be identified were included in the overall analysis but excluded from the subgroup analyses.

Clinical Variables and Outcomes

Demographic and clinical variables, including socioeconomic status and primary payer, were examined across the overall HF cohort and then within HFrEF

and HFpEF. Clinical comorbidities were assessed using *ICD-9-CM* and *ICD-10-CM* codes, and were used to calculate CHA_2DS_2-VASc[15] (Congestive Heart Failure, Hypertension, Age ≥75 [2], Diabetes, Stroke/transient ischemic attack [TIA]/systemic embolism [2], Vascular Disease, Age ≥65, and Sex category) scores (Table S2). Vascular disease was a composite of coronary artery disease, peripheral arterial disease (including carotid artery disease), and aortic atherosclerotic plaque. Of note, comorbidities were identified from the HF admission of interest, as NIS tracks HF admissions and not individual patients, precluding the use of preadmissions claims data to identify comorbidities. Outcomes included in-hospital mortality, discharge disposition, length of stay, and overall hospital charges (adjusted for inflation). Temporal trends were assessed among the demographic/clinical variables, as well as the outcomes for the study period from 2008 to 2017. Ablation procedures were also examined over time to account for possible changes in cost. To evaluate the degree of missingness of the race variable in NIS, we plotted the rate of missingness over time as well as the percentage of admissions that were of patients from each race to see if there was a relationship between the percentage missingness of the race variable and the proportion of patients from any race.

Statistical Analysis

Admissions for HF (with or without AF) were weighted by trend weights identified in the NIS database and were then separated into cohorts by year. Age, sex, race, comorbidities, indicators of socioeconomic status, primary payer, hospital type, and region were compared across cohorts. Outcomes, including discharge destination, in-hospital mortality, length of stay, and total hospital charges, were also compared across HF types for the entire study period and then over time within each HF subtype. For comparisons between groups, χ^2 tests were used for categorical variables and *t* tests (parametric distribution) or Mann-Whitney *U* tests were used for continuous variables. Because of the large sample size, standardized differences were also calculated for between-group comparisons of baseline characteristics. When examining trends over time, the χ^2 test was used for categorical variables, and ANOVA (parametric) or Kruskal-Wallis (nonparametric) was used for continuous variables. A logistic regression model for the association between AF and mortality was constructed, using age, diabetes mellitus, vascular disease, stroke/TIA/systemic embolism, hypertension, and congestive HF (ie, the comorbidities included in the CHA_2DS_2-VASc score), to help control for comorbidity burden as a contributor to mortality. Total hospital charges were adjusted for inflation and normalized to US dollars in 2017. Statistical analyses were performed using SPSS v25 (IBM, Armonk, NY).

RESULTS

Patient Characteristics

Between 2008 and 2017, we identified 10 392 189 hospitalizations for HF, of which 4 250 698 (40.9%) had comorbid AF. Demographics and socioeconomic data for the entire study period are summarized in Table 1. Among all HF admissions, comorbid AF was associated with older age (mean age, 76.9 years versus 68.8 years; $P<0.001$), White race (77.8% versus 59.1%; $P<0.001$), and a higher income quartile (45.3% versus 36.5% in quartiles 3 and 4; $P<0.001$) compared with those without AF. Among all HF hospitalizations, those with comorbid AF had a higher percentage of patients with vascular disease (59.5% versus 56.7%), stroke/TIA/thromboembolism (3.5% versus 3.0%), and obstructive sleep apnea (12.7% versus 11.5%) and lower percentages of hypertension (78.2% versus 79.7%), obesity (17.4% versus 20.1%), and diabetes mellitus (39.7% versus 47.6%; $P<0.001$ for all) than those without AF. HF hospitalizations with comorbid AF were associated with higher CHA_2DS_2-VASc scores (mean, 4.8 versus 4.4; $P<0.001$ for all). Comorbid AF was more common during HF admissions for Medicare beneficiaries (83.4% versus 67.8%) and less common among admissions for Medicaid or private insurance subscribers (4.6% versus 11.8%, and 9.2% versus 13.8%, respectively; $P<0.001$), compared with admissions without comorbid AF.

Comparing Admissions for HFrEF Versus HFpEF

Of the total above, we identified 3 117 059 admissions for HFpEF, 4 675 898 for HFrEF, and 2 599 232 for which the type of HF was not further classified (uncategorized HF). When examining HF hospitalizations that were classified as HFrEF or HFpEF, those with AF were associated with significantly older age than those without AF for both subtypes; patients with HFpEF were older than patients with HFrEF (HFpEF, 79.2 years [AF] versus 71.5 years [no AF]; HFrEF, 75.0 years [AF] versus 67.0 years [no AF]; $P<0.001$ for all; Table 1). HFpEF hospitalizations were more commonly for female patients (62.3% [AF] versus 63.3% [no AF]), whereas HFrEF hospitalizations were majority male patients (percentage female, 37.9% [AF] versus 41.0% [no AF]).

Both HFpEF and HFrEF admissions with AF, compared with those without AF, were more likely to be of

Table 1. Overall Demographics, Socioeconomic Status, and Payer and Hospital Information for Patients Hospitalized With HF and AF, 2008 to 2017

Variables	All HF			HFpEF			HFrEF		
	No AF (n=6 141 491)	AF (n=4 250 698)	Standardized Difference	No AF (n=1 715 638)	AF (n=1 401 421)	Standardized Difference	No AF (n=2 768 346)	AF (n=1 907 552)	Standardized Difference
Age, mean (SD), y	68.8 (15.5)	76.9 (11.7)	0.59	71.5 (14.2)	79.2 (10.3)	0.62	67.0 (15.5)	75.0 (12.2)	0.57
Women, %	49.7	48.7	−0.02	63.3	62.3	−0.02	41.0	37.9	−0.06
Race/ethnicity, %									
White	59.1	77.8	0.41	62.7	81.6	0.43	56.9	75.3	0.40
Black	26.4	12.2	−0.37	23.8	9.5	−0.39	29.1	14.9	−0.35
Hispanic	9.2	5.7	−0.88	8.7	5.0	−0.15	8.7	5.8	−0.11
Asian or Pacific Islander	2.1	1.8	−0.02	2.0	1.8	−0.015	2.0	1.6	−0.03
Native American	0.6	0.4	−0.03	0.5	0.3	−0.03	0.7	0.4	−0.04
Unknown	2.6	2.0	−0.04	2.4	1.8	−0.04	2.6	2.0	−0.04
Comorbidities									
Hypertension	79.7	78.2	−0.04	86.0	82.6	−0.09	79.2	78.3	−0.02
Diabetes mellitus	47.6	39.7	−0.16	52.2	40.3	−0.24	46.2	40.7	−0.11
Vascular disease	56.7	59.5	0.06	49.9	52.2	0.25	63.2	66.9	0.08
Stroke/TIA/ thromboembolism	3.0	3.5	0.03	3.1	3.5	0.02	3.1	3.6	0.03
OSA	11.5	12.7	0.04	16.9	15.5	−0.04	10.5	12.9	0.07
Obesity	20.1	17.4	−0.07	28.5	21.8	−0.15	18.0	16.7	−0.03
CHA_2DS_2-VASc score, mean (SD)	4.4 (1.4)	4.8 (1.3)	0.29	4.7 (1.3)	5.0 (1.2)	0.26	4.3 (1.4)	4.7 (1.3)	0.29
Ablation, %	0.1	0.6	1.23	0.0	0.3	0.93	0.1	0.8	1.98
Hospital type, %									
Rural	13.9	12.9	−0.03	11.7	10.9	−0.03	10.9	10.8	−0.003
Urban nonteaching	35.8	36.3	0.01	35.2	35.8	0.01	33.2	33.4	0.004
Urban teaching	50.2	50.8	0.01	53.1	53.4	0.006	56.0	55.8	−0.004
Hospital region, %									
Northeast	18.6	22.7	0.10	20.8	24.3	0.08	18.9	21.0	0.05
Midwest	22.2	24.4	0.05	23.2	25.3	0.05	22.6	25.0	0.06
South	43.2	37.8	−0.11	41.1	35.2	−0.12	42.4	37.9	−0.09
West	16.0	16.1	0.003	14.8	15.2	0.01	16.1	16.1	−0.001

(*Continued*)

Table 1. Continued

Variables	All HF			HFpEF			HFrEF		
	No AF (n=6 141 491)	AF (n=4 250 698)	Standardized Difference	No AF (n=1 715 638)	AF (n=1 401 421)	Standardized Difference	No AF (n=2 768 346)	AF (n=1 907 552)	Standardized Difference
Payer information, %									
Medicare	67.8	83.4	0.37	74.5	87.7	0.34	63.9	80.8	0.38
Medicaid	11.8	4.6	−0.26	9.1	3.1	−0.25	13.7	5.7	−0.27
Private insurance	13.8	9.2	−0.14	11.9	7.4	−0.15	14.7	10.1	−0.14
Median household income*									
Quartile 1	37.2	28.1	−0.19	34.2	24.9	−0.20	38.0	29.9	−0.17
Quartile 2	26.4	26.5	0.002	26.4	25.9	−0.01	26.1	26.6	0.01
Quartile 3	21.2	24.3	0.07	22.3	25.5	0.08	21.2	24.0	0.07
Quartile 4	15.3	21.0	0.15	17.1	23.7	0.16	14.6	19.5	0.13

AF indicates atrial fibrillation; CHA_2DS_2-VASc, Congestive Heart Failure, Hypertension, Age, Diabetes, Stroke, Vascular Disease, Age, and Sex category; HF, heart failure; HFpEF, HF with preserved ejection fraction; HFrEF, HF with reduced ejection fraction; OSA, obstructive sleep apnea; and TIA, transient ischemic attack.

*Determined by patient's ZIP code.

White race (HFpEF: 81.6% [AF] versus 62.7% [no AF]; HFrEF: 75.3% [AF] versus 56.9% [no AF]; $P<0.001$ for all), and less likely to involve Black patients (HFpEF: 9.5% [AF] versus 23.8% [no AF]; HFrEF: 14.9% [AF] versus 29.1% [no AF]; $P<0.001$ for all) or Hispanic (HFpEF: 5.0% [AF] versus 8.7% [no AF]; HFrEF: 5.8% [AF] versus 8.7% [no AF]; $P<0.001$ for all) than those without AF (Table 1).

Comorbidity analysis showed significant differences across hospitalizations by HF subtype. Specifically, when compared with HFrEF/AF hospitalizations, HFpEF/AF hospitalizations had higher rates of hypertension (82.6% versus 78.3%), lower rates of vascular disease (52.2% versus 66.9%) and stroke/TIA/thromboembolism (3.5% versus 3.6%), but a higher CHA_2DS_2-VASc score (mean, 5.0 versus 4.7; $P<0.001$ for all comparisons; Table 1). For both HFpEF and HFrEF hospitalizations, those with comorbid AF had lower rates of hypertension and diabetes mellitus, higher rates of vascular disease and stroke/TIA/thromboembolism, and higher CHA_2DS_2-VASc scores compared with hospitalizations without AF (Table 1).

With respect to payer, HF hospitalizations with AF were much more likely to be paid for by Medicare (HFpEF: 87.7% [AF] versus 74.5% [no AF]; HFrEF: 80.8% [AF] versus 63.9% [no AF]; $P<0.001$ for all) and less likely by Medicaid (HFpEF: 3.1% [AF] versus 9.1% [no AF]; HFrEF: 5.7% [AF] versus 13.7% [no AF]) or private insurance (HFpEF: 7.4% [AF] versus 11.9% [no AF]; HFrEF: 10.1% [AF] versus 14.7% [no AF]; $P<0.001$ for all) than non-AF admissions. HFpEF admissions with AF were more likely than HFrEF admissions to be paid for by Medicare ($P<0.001$). Median income was generally higher among HF hospitalizations with AF (HFpEF: 49.2% versus 39.4% in quartiles 3 and 4 [$P<0.001$]; HFrEF: 43.5% versus 35.8% in quartiles 3 and 4 [$P<0.001$ for all comparisons]) than in those without AF.

Trends Over Time

The percentage of HF hospitalizations with comorbid AF rose steadily over the study period from 35.4% in 2008 to 45.4% in 2017 (Figure 1). This rise was consistent across HF subtypes, with both HFpEF and HFrEF seeing increases in the proportion of AF cases over time (HFpEF: 38.0% in 2008 to 49.1% in 2017; HFrEF: 34.5% in 2008 to 44.4% in 2017; Figure 2).

Data on demographic trends over time among patients with AF in the overall HF, HFpEF, and HFrEF hospitalization populations are shown in Tables 2 through 4. From 2008 to 2017, the average age fell in all 3 groups (overall HF: 77.6 to 76.4 years; HFpEF: 79.8 to 78.9 years; HFrEF: 76.1 to 74.5 years; $P<0.001$ for all; Figure 3). Male sex was more common over time in all 3 hospitalization classes (overall

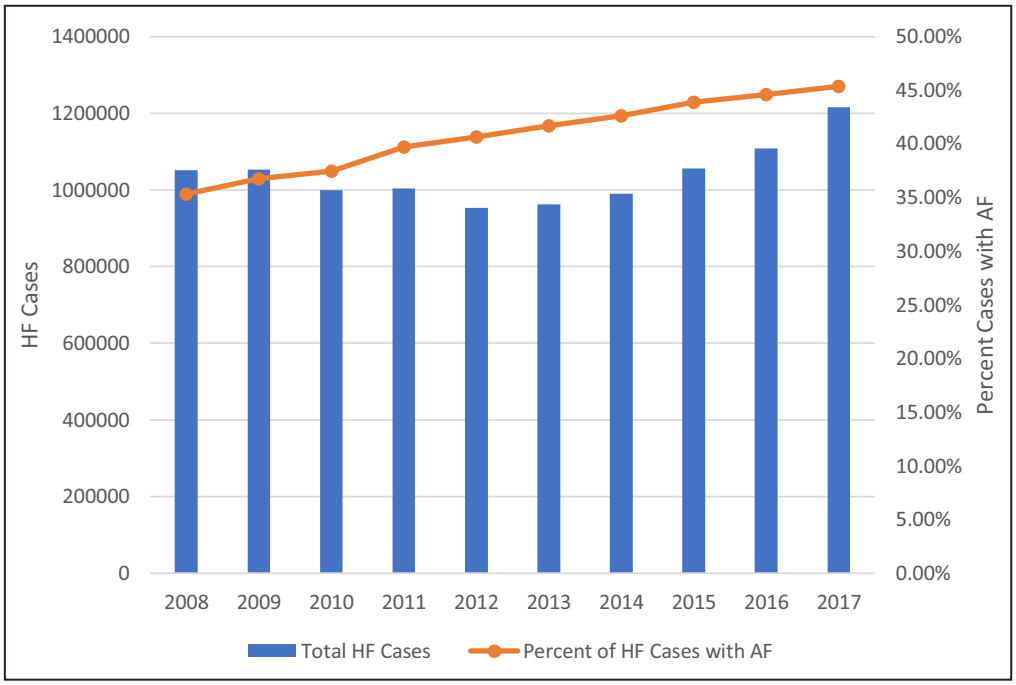

Figure 1. Heart failure (HF) hospitalizations and proportion with atrial fibrillation (AF) over time.
The histogram in blue shows the number of HF hospitalizations in the United States by year through the study period (*y* axis on the left). The orange line shows the proportion of HF hospitalizations that had comorbid AF over time (*y* axis on the right).

HF: 48.9% [2008] to 53.0% [2017]; HFpEF: 34.8% [2008] to 39.8% [2017]; HFrEF: 58.8% [2008] to 63.7% [2017]; *P*<0.001 for all; Figure 4). Among all HF admissions, the percentage of White patients with comorbid AF fell over time (from 79.9% to 76.1%) and the percentage of Black and Hispanic patients rose (Black: from 10.2% to 13.5%; Hispanic: from 5.4% to 6.2%; *P*<0.001). These trends were mirrored in the

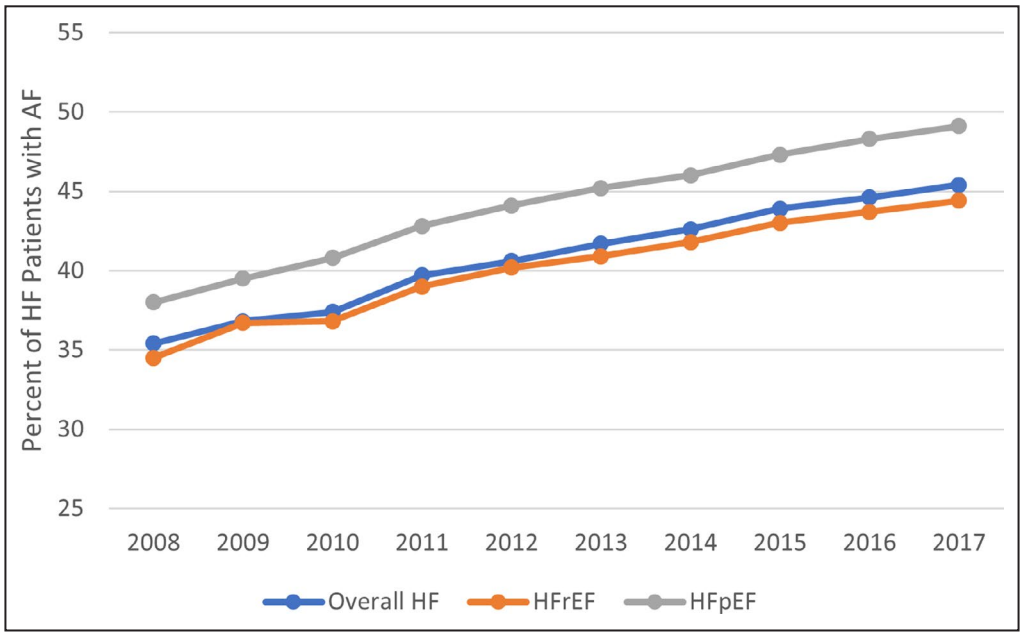

Figure 2. Atrial fibrillation (AF) as a percentage of total heart failure (HF) admissions and across HF subtypes, 2008 to 2017.
Graph showing the percentage of HF hospitalizations in which comorbid AF was present. Blue represents overall HF admissions; gray represents admissions coded as HF with preserved ejection fraction (HFpEF); orange represents admissions coded as HF with reduced ejection fraction (HFrEF).

Table 2. Patients Hospitalized With HF and AF: Trends Over Time for Demographic, Economic, and Hospital Variables, 2008 to 2017

Variables	2008 (n=371 659)	2009 (n=387 013)	2010 (n=373 950)	2011 (n=399 046)	2012 (n=387 055)	2013 (n=400 680)	2014 (n=421 995)	2015 (n=463 205)	2016 (n=494 315)	2017 (n=551 780)	*P* Value
Age, mean (SD), y	77.6 (11.7)	77.4 (11.9)	77.4 (12.0)	77.5 (12.0)	77.1 (11.6)	76.9 (11.6)	76.7 (11.7)	76.6 (11.7)	76.4 (11.7)	76.4 (11.7)	<0.001
Women, %	51.1	50.4	49.8	50.0	49.2	48.6	47.9	47.3	47.1	47.0	<0.001
Race/ethnicity, %											<0.001
White	79.9	79.4	78.2	78.3	78.4	78.2	77.9	76.9	76.8	76.1	
Black	10.2	10.5	12.4	12.2	11.8	11.9	12.3	13.1	13.1	13.5	
Hispanic	5.4	5.5	5.3	5.9	5.3	5.8	5.7	5.8	6.0	6.2	
Asian or Pacific Islander	1.7	1.8	1.8	1.5	1.8	1.8	1.7	2.1	1.9	1.9	
Native American	0.6	0.5	0.6	0.3	0.5	0.4	0.3	0.3	0.3	0.3	
Unknown	2.3	2.4	1.7	1.8	2.3	1.9	2.0	1.8	1.9	1.9	
Comorbidities											
Hypertension	63.5	67.8	70.7	74.3	77.4	78.1	80.2	82.6	86.4	91.2	<0.001
Diabetes mellitus	35.0	37.0	38.0	39.6	40.2	41.0	41.8	42.0	40.1	41.0	<0.001
Vascular disease	54.8	57.0	57.0	59.1	60.5	60.1	60.7	61.0	61.2	61.0	<0.001
Stroke/TIA/ thromboembolism	3.2	3.5	3.6	3.6	3.6	3.4	3.5	3.5	3.7	3.7	<0.001
OSA	5.6	7.7	9.1	10.9	12.1	13.2	14.7	15.9	16.7	16.8	<0.001
Obesity	8.5	11.0	12.6	15.0	16.4	17.9	19.8	20.8	22.7	23.9	<0.001
CHA_2DS_2-VASc score, mean (SD)	4.6 (1.3)	4.6 (1.3)	4.7 (1.3)	4.7 (1.3)	4.8 (1.3)	4.8 (1.3)	4.8 (1.3)	4.8 (1.3)	4.8 (1.3)	4.8 (1.3)	<0.001
Ablation, %	0.6	0.7	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	<0.001
Hospital type, %											<0.001
Rural	15.3	14.4	14.4	13.7	13.9	13.8	12.0	11.3	11.1	10.6	
Urban nonteaching	46.1	45.4	45.7	44.0	40.9	40.3	28.9	29.2	28.1	24.7	
Urban teaching	38.6	40.3	39.9	42.3	45.3	45.9	59.1	59.5	60.9	64.7	
Hospital region, %											<0.001
Northeast	22.2	22.7	21.9	22.0	22.3	22.2	21.8	21.2	20.9	20.9	
Midwest	24.1	25.1	24.7	24.2	24.4	23.9	24.6	24.4	24.4	24.4	
South	37.2	36.7	37.7	37.7	37.5	38.0	38.0	38.1	38.3	38.3	
West	16.5	15.4	15.6	16.1	15.8	15.9	15.7	16.2	16.4	16.4	
Payer information, %											<0.001
Medicare	82.8	83.1	82.8	84.2	84.6	84.0	83.5	83.4	82.9	83.2	
Medicaid	3.6	4.0	4.6	4.0	4.2	4.1	4.8	5.0	5.5	5.4	
Private insurance	10.7	10.1	9.8	9.1	8.3	8.7	9.1	9.0	8.8	8.6	

(*Continued*)

Table 2. Continued

Variables	2008 (n=371 659)	2009 (n=387 013)	2010 (n=373 950)	2011 (n=399 046)	2012 (n=387 055)	2013 (n=400 680)	2014 (n=421 995)	2015 (n=463 205)	2016 (n=494 315)	2017 (n=551 780)	*P* Value
Other	2.9	2.8	2.8	2.7	2.9	3.2	2.6	2.6	2.8	2.8	
Median household income*											<0.001
Quartile 1	26.6	26.9	26.7	27.8	29.2	27.7	28.2	29.1	29.3	28.9	
Quartile 2	27.9	26.4	26.8	24.9	25.5	26.9	28.4	25.2	26.2	27.2	
Quartile 3	23.2	24.3	24.6	26.1	24.1	24.4	23.1	24.8	24.3	24.0	
Quartile 4	22.3	22.4	21.9	21.2	21.2	21.0	20.2	20.9	20.2	19.9	

AF indicates atrial fibrillation; CHA_2DS_2-VASc, Congestive Heart Failure, Hypertension, Age, Diabetes, Stroke, Vascular Disease, Age, and Sex category; HF, heart failure; OSA, obstructive sleep apnea; and TIA, transient ischemic attack.

*Determined by patient's ZIP code.

HF subgroups: HFpEF (White race: 82.9% to 80.5%; Black race: 8.6% to 10.0%; Hispanic: 4.9% to 5.4%; *P*<0.001) and HFrEF (White race: 79.8% to 72.6%; Black race: 11.8% to 16.5%; Hispanic: 5.0% to 6.7%; *P*<0.001; Figure 5). The rate of missingness of race over time decreased substantially but did not result in a large change in the proportion of hospitalizations for any race (Figure S1).

Comorbidities changed over time among all HF admissions with comorbid AF. Hypertension was present in 63.5% of overall comorbid HF/AF admissions in 2008 and rose gradually and significantly over time to 91.2% in 2017; similar trends were observed by HF subtype (HFpEF: 68.1% to 92.7%; HFrEF: 60.3% to 90.6%; *P*<0.001 for all; Tables 2 through 4). Other comorbidities also increased over time, including diabetes mellitus (overall HF: 35.0% to 41.0%; HFpEF: 35.6% to 41.3%; HFrEF: 35.0% to 41.1%; *P*<0.001 for all; Tables 2 through 4), vascular disease (overall HF: 54.8% to 61.0%; HFpEF: 46.5% to 53.7%; HFrEF: 60.7% to 68.0%; *P*<0.001 for all; Tables 2 through 4), obesity (overall HF: 8.5% to 23.9%; HFpEF: 10.6% to 27.7%; HFrEF: 7.6% to 21.5%; *P*<0.001 for all; Tables 2 through 4), and prior stroke/TIA/thromboembolism (overall HF: 3.2% to 3.7%; HFpEF: 3.1% to 3.5%; HFrEF: 3.1% to 3.8%; *P*<0.001 for all; Tables 2 through 4). Calculated CHA_2DS_2-VASc scores also increased over time (overall HF: mean [SD] 4.6 [1.3] to 4.8 [1.3]; HFpEF: 4.8 [1.2] to 5.1 [1.1]; HFrEF: 4.4 [1.4] to 4.7 [1.3]; *P*<0.001 for all; Tables 2 through 4). Ablation procedures were relatively stable to slightly decreased over time in all HF admissions and within the 2 subgroups (overall HF: 0.6% to 0.6%; HFpEF: 0.4% to 0.3%; HFrEF: 1.0% to 0.9%; *P*<0.001 for all; Tables 2 through 4).

Medicare was the predominant payer, and this increased over time among overall HF/AF admissions (82.8% in 2008 to 83.2% in 2017; Table 2) and HFpEF/AF admissions (86.9% in 2008 to 87.6% in 2017; Table 3), with a slight decrease among HFrEF/AF admissions (80.7% in 2008 to 79.9% in 2017; Table 4; *P*<0.001 for all). All 3 groups also saw an increase in the proportion of patients on Medicaid (overall HF: 3.6% to 5.4%; HFpEF: 2.5% to 3.5%; HFrEF: 4.0% to 7.0%) and a decrease in patients with private insurance (overall HF: 10.7% to 8.6%; HFpEF: 8.5% to 7.0%; HFrEF: 11.5% to 9.8%; *P*<0.001 for all). There was also a significant trend toward lower socioeconomic status over time, as reflected by the lower percentage of patients in income quartiles 3 and 4 (overall HF: 45.5% in 2008 to 43.9% in 2017; HFpEF: 50.6% in 2008 to 47.1% in 2017; HFrEF: 43.5% in 2008 to 42.2% in 2017; *P*<0.001 for all).

Patient Outcomes and Charges

Outcomes across the entire study period are shown in Table 5. Comorbid AF was associated with increased

Table 3. Patients Hospitalized With HFpEF and AF: Trends Over Time for Demographic, Economic, and Hospital Variables, 2008 to 2017

Variables	2008 (n=72 587)	2009 (n=89 674)	2010 (n=103 472)	2011 (n=121 924)	2012 (n=126 715)	2013 (n=138 705)	2014 (n=152 610)	2015 (n=171 650)	2016 (n=195 805)	2017 (n=228 280)	*P* Value
Age, mean (SD), y	79.8 (10.3)	79.9 (10.4)	79.8 (10.7)	80.0 (10.7)	79.5 (10.1)	79.4 (10.1)	79.2 (10.2)	79.2 (10.2)	78.9 (10.3)	78.9 (10.3)	<0.001
Women, %	65.2	65.2	63.8	64.2	63.0	62.5	62.0	61.2	61.0	60.2	<0.001
Race/ethnicity, %											<0.001
White	82.9	82.8	81.4	82.6	82.1	82.6	82.3	81.3	81.0	80.5	
Black	8.6	8.5	10.2	9.8	9.3	9.1	9.1	9.7	9.7	10.0	
Hispanic	4.9	4.5	4.4	5.2	4.5	4.8	4.8	5.1	5.3	5.4	
Asian or Pacific Islander	1.8	1.7	1.9	1.5	1.6	1.8	1.6	2.1	1.9	2.0	
Native American	0.4	0.5	0.5	0.2	0.3	0.3	0.3	0.2	0.3	0.2	
Unknown	1.4	2.1	1.7	1.8	2.2	1.5	1.9	1.6	1.8	1.9	
Comorbidities											
Hypertension	68.1	71.9	74.1	77.9	81.1	81.3	82.8	84.9	88.4	92.7	<0.001
Diabetes mellitus	35.6	37.4	39.7	39.9	39.6	40.9	41.5	42.3	40.7	41.3	<0.001
Vascular disease	46.5	48.7	48.8	51.6	52.7	52.6	53.2	53.6	53.5	53.7	<0.001
Stroke/TIA/ thromboembolism	3.1	3.6	3.8	3.7	3.5	3.4	3.4	3.2	3.5	3.5	<0.001
OSA	7.9	9.8	11.3	13.2	14.1	15.2	17.1	18.1	18.9	18.5	<0.001
Obesity	10.6	13.6	15.2	18.2	19.5	21.3	23.6	24.7	26.5	27.7	<0.001
CHA_2DS_2-VASc score, mean (SD)	4.8 (1.2)	4.9 (1.2)	4.9 (1.2)	5.0 (1.2)	5.0 (1.2)	5.0 (1.2)	5.0 (1.2)	5.0 (1.2)	5.1 (1.2)	5.1 (1.1)	<0.001
Ablation, %	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.3	0.3	<0.001
Hospital type, %											<0.001
Rural	12.2	11.7	11.3	11.0	11.2	11.9	10.5	10.1	10.4	10.2	
Urban nonteaching	46.3	44.4	46.9	46.1	41.4	41.8	29.9	30.0	29.2	25.8	
Urban teaching	41.6	43.9	41.8	42.9	47.4	46.3	59.6	59.9	60.4	64.0	
Hospital region, %											<0.001
Northeast	25.8	25.4	24.4	23.3	25.5	25.1	24.7	24.3	23.5	23.5	
Midwest	25.0	26.3	25.3	25.8	25.2	24.5	25.7	25.1	25.3	25.1	
South	32.9	33.1	34.7	35.2	34.4	35.8	35.1	35.4	35.9	36.1	
West	16.3	15.4	15.6	15.6	14.9	14.6	14.5	15.1	15.4	15.6	
Payer information, %											<0.001
Medicare	86.9	87.1	86.9	88.1	88.6	88.1	87.7	87.8	87.4	87.6	
Medicaid	2.5	2.7	3.0	2.7	2.8	2.6	3.2	3.2	3.5	3.5	

(*Continued*)

Table 3. Continued

Variables	2008 (n=72 587)	2009 (n=89 674)	2010 (n=103 472)	2011 (n=121 924)	2012 (n=126 715)	2013 (n=138 705)	2014 (n=152 610)	2015 (n=171 650)	2016 (n=195 805)	2017 (n=228 280)	*P* Value
Private insurance	8.5	8.3	8.4	7.5	6.8	7.3	7.4	7.2	7.2	7.0	
Other	2.1	1.9	1.7	1.7	1.8	2	1.7	1.8	1.9	1.9	
Median household income*											<0.001
Quartile 1	22.6	23.6	23.0	24.0	25.3	24.7	25.0	25.6	26.0	25.8	
Quartile 2	26.8	24.5	26.1	24.0	24.9	26.3	27.9	24.6	25.7	27.1	
Quartile 3	24.2	25.9	25.6	27.8	25.6	25.1	24.3	26.3	25.5	24.9	
Quartile 4	26.4	26.0	25.3	24.3	24.1	23.8	22.8	23.5	22.8	22.2	

AF indicates atrial fibrillation; CHA_2DS_2-VASc, Congestive Heart Failure, Hypertension, Age, Diabetes, Stroke, Vascular Disease, Age, and Sex category; HFpEF, heart failure with preserved ejection fraction; OSA, obstructive sleep apnea; and TIA, transient ischemic attack.

*Determined by patient's ZIP code.

in-hospital mortality among all HF admissions (3.6% versus 2.6%; *P*<0.001) and within the HFpEF (3.0% versus 1.9%; *P*<0.001) and HFrEF (3.6% versus 2.4%) subsets. Over time, mortality decreased for HF/AF hospitalizations (3.6% to 3.4%) while staying relatively stable among HFpEF/AF hospitalizations (2.9% to 2.8%; *P*<0.001 for both), but increased among HFrEF/AF admissions (3.0% to 3.7%; *P*<0.001; Tables S3 through S5). In logistic regression models adjusting for patient age and comorbidities (those included in the CHA_2DS_2-VASc score), AF remained significantly associated with mortality: overall HF: odds ratio (OR), 1.12 (95% CI, 1.11–1.12); HFpEF: OR, 1.25 (95% CI, 1.23–1.27); and HFrEF: OR, 1.24 (95% CI, 1.23–1.26; *P*<0.001 for all).

HF hospitalizations with AF were more likely to result in discharge to a skilled nursing facility or to home health care, and less likely to be routine discharge home, compared with HF admissions without AF (Table 5). Over time, there was a decrease in routine discharge home and an increase in discharge to home health care among all HF/AF hospitalizations and the HFpEF/AF and HFrEF/AF subsets (Tables S3 through S5).

Among all HF admissions, those with comorbid AF demonstrated greater median hospital charges ($26 620 versus $25 267; *P*<0.001) and results were similar among HFpEF and HFrEF subsets (HFpEF: $26 754 versus $26 258; HFrEF: $28 883 versus $27 408; *P*<0.001 for both) (Table 5). When examining trends over time among AF-associated admissions, charges adjusted for inflation rose significantly in overall HF ($22 204 in 2008 to $31 156 in 2017; *P*<0.001; Table S3), HFpEF ($22 107 in 2008 to $29 928 in 2017; *P*<0.001; Table S4), and HFrEF ($23 124 in 2008 to $33 091 in 2017; *P*<0.001; Table S5).

DISCUSSION

In this nationally representative analysis of AF trends among hospital admissions for HF, we found several clinically and economically relevant findings. AF is increasingly common among HF admissions overall and within both HFpEF and HFrEF and affects more HFpEF admissions (compared with HFrEF admissions). HFpEF hospitalizations were predominantly of female patients, and HFrEF hospitalizations were mostly of male patients; both HFpEF and HFrEF saw an increase over time in the proportion of male patients with AF. HF hospitalizations with comorbid AF had a higher proportion of White patients than HF hospitalizations without AF; however, over time, the proportions of Black and Hispanic patients increased in all HF subtypes, most notably among HFrEF admissions. HF hospitalizations with AF were associated with a high burden of comorbidities (hypertension, diabetes mellitus, and vascular

Table 4. Patients Hospitalized With HFrEF and AF: Trends Over Time for Demographic, Economic, and Hospital Variables, 2008 to 2017

Variables	2008 (n=97 258)	2009 (n=136 290)	2010 (n=144 189)	2011 (n=166 385)	2012 (n=176 125)	2013 (n=190 330)	2014 (n=209 845)	2015 (n=240 410)	2016 (n=260 155)	2017 (n=286 565)	*P* Value
Age, mean (SD), y	76.1 (12.2)	75.9 (12.2)	75.8 (12.3)	75.6 (12.4)	75.3 (12.2)	75.0 (12.2)	74.9 (12.2)	74.8 (12.2)	74.5 (12.3)	74.5 (12.2)	<0.001
Women, %	41.2	40.7	40.0	39.3	38.3	37.9	37.1	36.8	36.4	36.3	<0.001
Race/ethnicity, %											<0.001
White	79.8	78.7	77.2	75.9	76.5	75.7	75.2	74.1	73.7	72.6	
Black	11.8	12.4	14.5	14.8	13.7	14.3	14.7	15.8	15.8	16.5	
Hispanic	5.0	5.1	4.7	5.9	5.2	5.9	5.9	5.9	6.3	6.7	
Asian or Pacific Islander	1.1	1.1	1.4	1.1	1.7	1.6	1.7	2.0	1.9	1.9	
Native American	0.7	0.6	0.6	0.3	0.5	0.4	0.3	0.3	0.3	0.4	
Unknown	1.5	2.1	1.6	1.9	2.4	2.1	2.0	1.9	2.0	2.0	
Comorbidities											
Hypertension	60.3	65.8	68.7	72.9	76.0	76.9	79.2	81.8	85.8	90.6	<0.001
Diabetes mellitus	35.0	37.7	38.5	40.6	41.7	41.9	42.8	42.4	40.1	41.1	<0.001
Vascular disease	60.7	63.9	64.1	66.4	68.0	67.4	68.1	68.0	68.3	68.0	<0.001
Stroke/TIA/ thromboembolism	3.1	3.4	3.4	3.5	3.7	3.5	3.7	3.7	3.9	3.8	<0.001
OSA	5.5	7.6	9.1	10.9	11.9	13.1	1.42	15.3	15.9	16.2	<0.001
Obesity	7.6	10.2	11.7	13.9	15.1	16.7	18.1	19.0	20.5	21.5	<0.001
CHA_2DS_2-VASc score, mean (SD)	4.4 (1.4)	4.5 (1.4)	4.5 (1.4)	4.5 (1.4)	4.6 (1.3)	4.6 (1.3)	4.6 (1.3)	4.6 (1.3)	4.7 (1.3)	4.7 (1.3)	<0.001
Ablation, %	1.0	1.1	0.8	0.8	0.8	0.8	0.9	0.8	0.8	0.9	<0.001
Hospital type, %											<0.001
Rural	12.1	12.1	12.6	11.0	11.8	11.6	10.2	9.9	10.0	9.3	
Urban nonteaching	45.7	41.8	42.2	42.4	39.1	38.4	27.5	28.2	26.8	23.5	
Urban teaching	42.3	26.1	45.2	46.6	49.1	50.0	62.3	61.9	63.2	66.9	
Hospital region, %											<0.001
Northeast	23.0	23.3	23.3	21.5	22.1	21.5	21.0	19.8	19.7	19.0	
Midwest	26.8	28.2	26.4	25.0	25.0	24.5	24.5	24.5	23.9	24.2	
South	35.9	34.3	35.4	37.3	37.3	38.3	38.5	39.0	39.5	39.1	
West	14.3	14.2	14.9	16.1	15.6	15.8	16.0	16.6	16.8	17.6	
Payer information, %											<0.001
Medicare	80.7	81.4	81.0	81.9	82.1	81.3	80.6	80.7	79.9	79.9	
Medicaid	4.0	4.5	5.1	4.8	5.0	5.1	5.9	6.2	7.1	7.0	
Private insurance	11.5	11.1	10.8	9.9	9.4	9.6	10.3	10.1	9.7	9.8	

(*Continued*)

Table 4. Continued

Variables	2008 (n=97 258)	2009 (n=136 290)	2010 (n=144 189)	2011 (n=166 385)	2012 (n=176 125)	2013 (n=190 330)	2014 (n=209 845)	2015 (n=240 410)	2016 (n=260 155)	2017 (n=286 565)	*P* Value
Other	3.8	3.0	3.1	3.4	3.5	4.0	3.2	3.0	3.3	3.3	
Median household income*											<0.001
Quartile 1	28.4	29.8	27.3	29.2	30.3	29.4	29.6	31.0	31.1	30.8	
Quartile 2	28.2	26.6	27.0	25.0	25.8	26.7	28.6	25.2	26.3	27.0	
Quartile 3	23.2	24.0	24.1	25.9	24.1	24.4	22.9	24.1	23.7	23.6	
Quartile 4	20.3	19.6	21.6	19.8	19.8	19.5	19.0	19.7	18.9	18.6	

AF indicates atrial fibrillation; CHA_2DS_2-VASc, Congestive Heart Failure, Hypertension, Age, Diabetes, Stroke, Vascular Disease, Age, and Sex category; HFrEF, heart failure with reduced ejection fraction; OSA, obstructive sleep apnea; and TIA, transient ischemic attack.

*Determined by patient's ZIP code.

disease), and this burden increased significantly over time in both HF subtypes. In-hospital mortality was significantly higher for patients hospitalized with HF and comorbid AF compared with those without AF, and this was true for both the HFrEF and HFpEF subsets. In-hospital mortality for HF/AF admissions decreased overall during the study period but increased for HFrEF admissions. Finally, HF hospitalizations with comorbid AF were associated with higher charges, and hospital charges increased substantially over time.

Our finding of increasing proportion of comorbid AF among HF hospitalizations is consistent with reports of increasing incidence and prevalence of AF in the United States and internationally.[10–12,16] We found that patients hospitalized with HF and AF were significantly older than patients with HF without AF, which is in line with with overall increased prevalence of AF with increasing age.[11] Interestingly, the average age in our cohort decreased over time in all 3 groups (overall HF, HFpEF, and HFrEF). This dichotomy suggests that the aging of the US population is unlikely to be a significant driver of the increase in comorbid AF in the setting of HF. However, the increasing prevalence of risk factors for AF, including hypertension, diabetes mellitus, and vascular disease, could explain much of the increase over time and is consistent with prior analyses of risk factors among patients with AF.[10] Rising obesity rates are likely also contributing, given the established association between increasing body mass index and incident AF.[17,18]

Among all HF hospitalizations, men more commonly had AF, although female patients comprised >60% of admissions for HFpEF, regardless of AF status. Over time, the proportion of female patients with AF and HF declined overall, and within both HF subtypes. This trend may be a reflection of the decreasing age of the cohort: AF prevalence is known to be higher in men than women at younger ages, with increasing balance between the sexes with increasing age.[11] Thus, as the inpatient HF population with AF shows a decrease in age over time, it would be reasonable to expect an increase in the proportion of men represented.

White race was significantly more common among HF admissions with comorbid AF overall and across both HF subtypes. This is consistent with reports from several large observational studies that have demonstrated AF prevalence is significantly greater among White individuals compared with other races (often twice that of Black individuals).[19–21] Notably, in our study, the proportion of White patients decreased over time, whereas the percentage of Black and Hispanic patients rose; this trend was most prominent among admissions for HFrEF, where White patients decreased from 79.8% in 2008 to 72.6% in 2017, and Black patients increased from

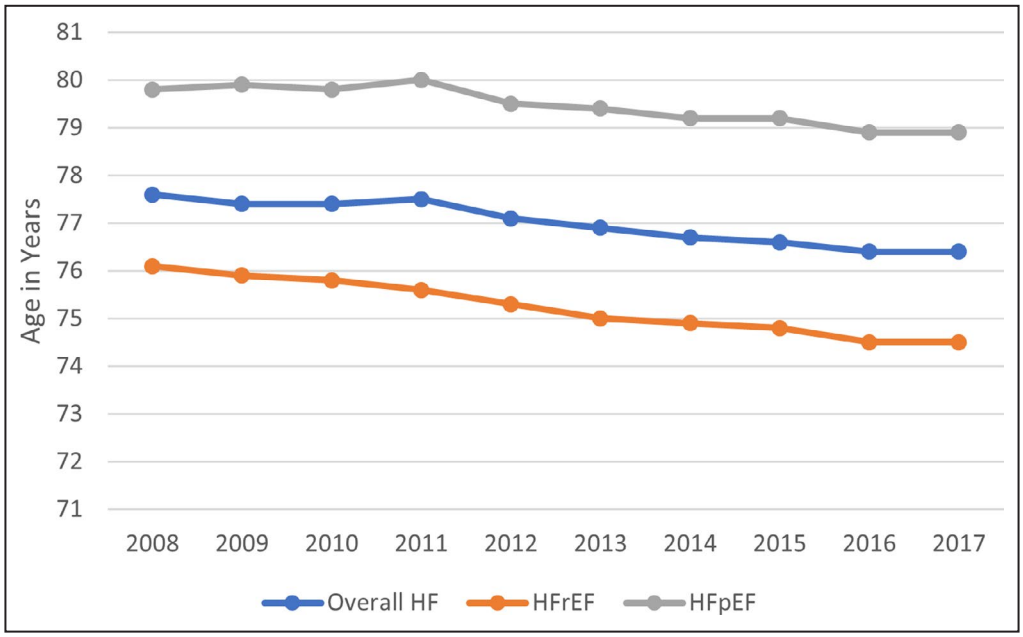

Figure 3. Average age of heart failure (HF) hospitalizations with comorbid atrial fibrillation over time, 2008 to 2017.
Linear plot showing the average age of inpatients among hospitalizations for HF with comorbid atrial fibrillation. The blue curve represents overall HF admissions; gray represents admissions coded as HF with preserved ejection fraction (HFpEF), which had the oldest patients; orange represents admissions coded as HF with reduced ejection fraction (HFrEF), which had younger patients. All 3 groups showed a decrease in average age over time.

11.8% to 16.5% over the same time period. These changes may be partially attributable to increased presence, and suboptimal treatment, of risk factors among racial and ethnic minorities, especially Black patients, including hypertension, diabetes mellitus, and obesity.[11,13]

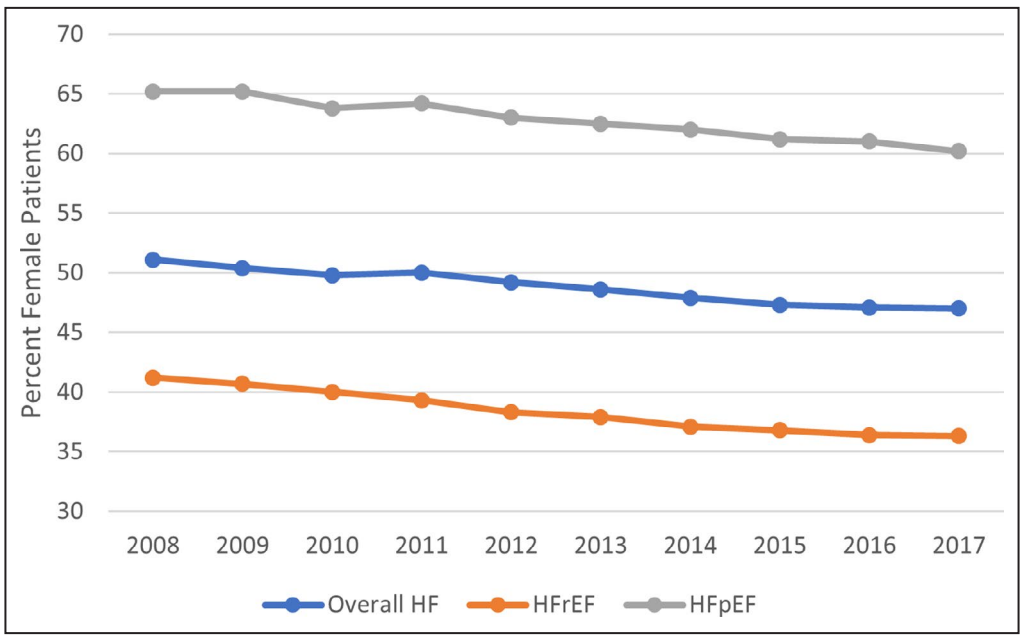

Figure 4. Temporal trends of female sex among heart failure (HF) hospitalizations with comorbid atrial fibrillation, 2008 to 2017.
Linear plot showing the percentage of female inpatients among hospitalizations for HF with comorbid atrial fibrillation. The blue curve represents overall HF admissions; gray represents admissions coded as HF with preserved ejection fraction (HFpEF), which had the highest number of female patients; orange represents admissions coded as HF with reduced ejection fraction (HFrEF), which had the lowest number of female patients. All 3 groups showed a decrease in the percentage of female patients over time.

There have previously been conflicting reports about the effect of AF on mortality among patients with HF, with some earlier studies reporting no difference[22,23] or even improvement[24,25] in survival with the presence of AF. However, many of these studies were performed before the era of current guideline-directed medical therapy for HF. More recent analyses have at times indicated an association of higher mortality with AF in HF,[3,5,6] whereas others have shown that when controlling for other risk factors, AF no longer remains an independent predictor of mortality.[7,26] In our study, AF was associated with higher in-hospital mortality among hospitalized patients with HF, both overall and by HF subtype. This remained true even after adjustment for age and comorbidities, although residual confounding remains a possibility.

Hospital charges showed a significant increase over time in the overall HF with AF category, growing by >40% from 2008 to 2017, even when adjusting for inflation. This rise in charges was also seen, and to a similar degree, among patients with HFpEF (35.4%) and HFrEF (43.1%) with AF. Patients with AF incurred higher charges in the overall HF cohort and among patients with both HFpEF and HFrEF. These findings are consistent with prior work showing increased incremental costs of AF among all patients with HF.[27] Specifically among patients with HFpEF, AF was found to be an independent risk factor for higher costs in a recent secondary analysis from the ALDO-DHF (Aldosterone Receptor Blockade in Diastolic HF) trial.[28] The exact driver of increased charges in this study is unclear, but could be related to higher burden of comorbidities (both of individual comorbidities and reflected in the higher median CHA_2DS_2-VASc score), as well as older age. Ablation procedures during HF hospitalization with AF do not appear to be significantly contributing to higher costs, as the percentage of admissions with an ablation remained low throughout the study period. Future studies should explore the relationship between AF and costs among HF hospitalizations, with the goal of identifying risk factors for higher costs and possible strategies to lower them.

The increasing burden of AF among HF admissions underscores the need to better study and

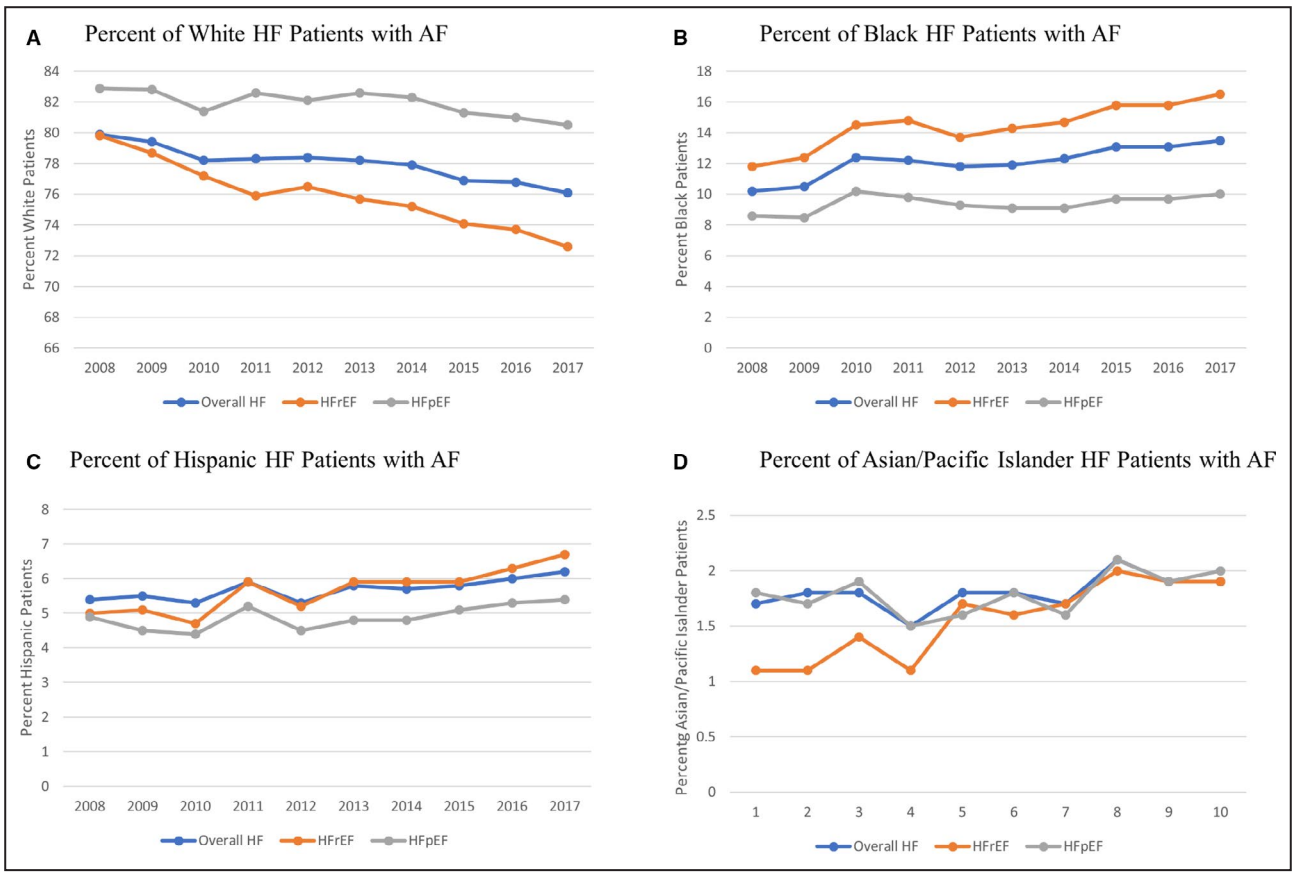

Figure 5. Changes in racial demographics over time among heart failure (HF) hospitalizations with comorbid atrial fibrillation (AF), 2008 to 2017.
In each panel, the blue curve represents overall HF admissions, gray represents admissions coded as HF with preserved ejection fraction (HFpEF), and orange represents admissions coded as HF with reduced ejection fraction (HFrEF). Each panel represents a racial/ethnic group: proportion of White patients over time (**A**), Black patients over time (**B**), Hispanic patients over time (**C**), and Asian/Pacific Islander patients over time (**D**).

Table 5. Overall Outcomes for Patients Hospitalized With HF With or Without AF, 2008 to 2017

Variables	All HF			HFpEF			HFrEF		
	No AF (n=6 141 491)	AF (n=4 250 698)	*P* Value	No AF (n=1 715 638)	AF (n=1 401 421)	*P* Value	No AF (n=2 768 346)	AF (n=1 907 552)	*P* Value
Discharge disposition, %			<0.001			<0.001			<0.001
Routine	56.3	43.7		51.4	39.0		58.3	45.2	
Transfer to short-term hospital	3.1	2.6		1.9	1.7		3.1	2.7	
Skilled nursing facility†	16.6	25.1		20.5	28.1		14.3	22.0	
Home health care	19.7	25.1		23.4	27.8		20.3	25.7	
Against medical advice	1.5	0.7		0.9	0.4		1.5	0.7	
Died in hospital	2.6	3.6		1.9	3.0		2.4	3.6	
Length of stay, median (IQR), d	4 (2–6)	4 (3–7)	<0.001	4 (3–6)	4 (3–7)	<0.001	4 (2–6)	4 (3–7)	<0.001
Total hospital charges, median (IQR), USD*	25 267 (14 514–46 361)	26 620 (15 274–49 572)	<0.001	26 258 (15 782–45 653)	26 754 (15 876–47 461)	<0.001	27 408 (15 768–50 959)	28 883 (16 498–55 141)	<0.001

AF indicates atrial fibrillation; HF, heart failure; HFpEF, HF with preserved ejection fraction; HFrEF, HF with reduced ejection fraction; IQR, interquartile range; and USD, US dollars.
*Adjusted for inflation to 2017 USD.
†Includes intermediate care or other care facilities.

implement therapies for these conditions. Two recent trials (CASTLE-HF [Catheter Ablation Versus Standard Conventional Therapy in Patients With Left Ventricular Dysfunction and Atrial Fibrillation][29] and AATAC [Ablation Versus Amiodarone for Treatment of Atrial Fibrillation With Congestive Heart Failure and an Implanted ICD/CRTD][30]) demonstrated reduced mortality in patients with HFrEF with AF ablation, but further work is needed to determine if a similar mortality benefit is present in HFpEF. A recent meta-analysis of β-blockade in comorbid HF/AF, which demonstrated no apparent benefit of β-blocker use, has underscored the potential challenges in optimal management of this complex and increasingly prevalent group of patients.[31]

Study Limitations

Our findings should be considered in light of several limitations. First, it is a retrospective observational analysis of a large inpatient sample; thus, no conclusions can be made about causality. Second, hospitalizations and comorbidities were identified through *ICD-9-CM* and *ICD-10-CM* codes, a method that allows for misclassification, although many of the trends identified in our study (increasing AF prevalence and increasing HF costs) are consistent with prior studies. This limitation also applies to the classification of HFpEF and HFrEF using *ICD-9-CM* codes for diastolic and systolic HF, respectively, which have not been independently validated for use in administrative databases and may not reflect the current definitions of HF subtypes based on ejection fraction. Third, the subgroup analysis did not include the subset of HF admissions (2 599 232) for which the type of HF was not classified into HFpEF or HFrEF; the relatively large size of this group may reduce the ability to draw strong conclusions from the subgroup analysis. Fourth, NIS provides only information about inpatient hospitalizations and not patients per se, rendering us unable to comment on long-term outcomes following an HF hospitalization with comorbid AF. Similarly, we cannot distinguish between initial HF hospitalizations and HF readmissions. Fifth, the high degree of missingness for the race/ethnicity variable at the beginning of the study period may have resulted in underestimation of admissions of racial and ethnic minorities. However, even as the degree of race/ethnicity missingness decreased substantially over the study period, the proportion of hospitalizations of Black, Hispanic, and Asian/Pacific Islander patients increased at a slow but steady pace. Thus, we expect the degree of underestimation of admissions of racial and ethnic minorities, if present, was modest and did not meaningfully impact the increasing prevalence of these patients among HF admissions over time. Last, the NIS reports hospital charges, which

are not equivalent to costs to the patient and can vary significantly across payers.

CONCLUSIONS

In this analysis of the NIS, we found that AF is an increasingly common comorbid condition among patients hospitalized with HF in the United States. AF is most common among White individuals but showed increasing prevalence among Black and Hispanic individuals from 2008 to 2017; the average age and proportion of women also both decreased over time. Higher charges were seen in all HF admissions and in both HFpEF and HFrEF admissions with AF compared with those without AF, and charges increased by >35% over time, including the overall HF cohort and both subtypes. The burden of comorbidities has increased significantly over time in comorbid HF and AF. AF is associated with higher in-hospital mortality across all HF hospitalizations and within the HFrEF and HFpEF subgroups. Future research on prevention and treatment of comorbid AF and HF will need to address critical aspects of changing patient demographics (increasing comorbidity burden and proportion of Black and Hispanic patients) and rapidly rising costs.

ARTICLE INFORMATION

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Affiliations

Section of Cardiovascular Medicine (S.W.R., P.E.M., K.A.C., B.K., J.V.F., T.A., N.R.D., D.J.F.); and Department of Internal Medicine (M.F.), Yale School of Medicine, New Haven (F.C.), CT; Harrington Heart and Vascular Institute, Case Western Reserve University, Cleveland, OH (A.G.); and Center for Outcomes Research and Evaluation, New Haven, CT (N.R.D.).

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Supplementary Material

Tables S1–S5
Figure S1

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Supplemental Material

Table S1. ICD-9-CM and ICD-10 codes for classification of heart failure, heart failure subtype, atrial fibrillation, and comorbidities.

Diagnoses	ICD-9	ICD-10
Heart Failure	398.91, 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, 425.2, 425.4-425.9, 428.x	I11.0, I13.0, I13.2, I09.81, I09.9, I25.5, I42.0, I425-I42.9, I43.x, I50.x
Heart Failure with Preserved Ejection Fraction (HFpEF)	428.3x	I50.3
Heart Failure with Reduced Ejection Fraction (HFrEF)	428.2x, 428.4x	I50.2, I50.4
Atrial fibrillation	427.3x	I48.x
Vascular Disease (peripheral vascular disease, coronary artery disease/ischemic heart disease, carotid artery disease, or atherosclerotic aortic disease)	410.x-414.x, V458.1, V458.2, 440.x-443.x	I20.x-I25.x, I70.x-I71.x, I73.1-I73.9, I77.1, I79.0, K55.1, K55.8-9, Z951, Z95.8-9
Diabetes mellitus	250.0x - 250.9x	E10.x-E13.x
Hypertension	401.x-405.x, 437.22, 642.0-642.2, 642.7-642.9	I10.x-I15.x, I67.4
Stroke, Transient Ischemic Attack (TIA) or Systemic Thromboembolism	362.30, 362.31, 433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 434.x, 436.x, 438.x, 444.x	I63.x, I69.3, I69.9, I74.x, I97.8, G45.x, H34.0-H34.2, H34.9, Z86.7
Obstructive Sleep Apnea	327.23	G47.33
Obesity	278.00, 278.01, 278.03, V85.30, V85.31, V85.32, 'V85.33, V85.34, V85.35, V85.36, V85.37, V85.38, V85.39, V85.40, V85.41, V85.42, V85.43, V85.44, V85.45	E66.1, E66.01, E66.2, E66.8, E66.9, Z68.30, Z68.31, Z68.32, Z68.33, Z68.34, Z68.35, Z68.36, Z68.37, Z68.38, Z68.39, Z68.40, Z68.41, Z68.42, Z68.43, Z68.44, Z68.45
Ablation	37.34	02583ZZ, 4A023FZ, 4A0234Z, 02K83ZZ

Calculation of CHA_2DS_2VASc Scores.
CHA_2DS_2-VASc scores were calculated based on the sum of point values for the risk factors listed in the score: Congestive Heart Failure, Hypertension, Age over 75 years [2 points], Diabetes mellitus, Stroke/transient ischemic attack(TIA)/systemic thromboembolism [2 points], Vascular Disease, Age over 65 years, and Sex category [female].[1] Of note, "vascular disease" was a composite of coronary artery disease, peripheral arterial disease (including carotid artery disease), and aortic atherosclerotic plaque. The maximum score is 9 points.

Table S2. CHA_2DS_2VASc Comorbidity Point Values.

Condition	Score
Congestive Heart Failure	1
Hypertension	1
Age ≥75 years	2
Diabetes mellitus	1
Stroke, transient ischemic attack, or systemic thromboembolism	2
Vascular disease	1
Age 65-74 years	1
Sex Category (female)	1
Maximum Score	9

Table S3. Outcomes Over Time for Hospitalizations for Heart Failure with Comorbid Atrial Fibrillation, 2008-2017.

Variables (N)	2008 (371659)	2009 (387013)	2010 (373950)	2011 (399046)	2012 (387055)	2013 (400680)	2014 (421995)	2015 (463205)	2016 (494315)	2017 (551780)
Discharge Disposition										
Routine	47.9	46.9	44.6	43.3	43.2	42.1	42.6	42.8	42.8	42.0
Transfer to Short Term Hospital	2.6	2.7	2.6	2.7	2.6	2.6	2.7	2.6	2.5	2.4
Skilled Nursing Facility*	23.4	23.6	24.8	25.3	24.7	24.8	24.7	24.3	23.9	23.8
Home Health Care	21.9	22.4	23.7	24.5	25.2	26.1	25.8	25.9	26.6	27.4
Against Medical Advice	0.6	0.6	0.6	0.6	0.5	0.6	0.6	0.8	0.8	0.8
Died in Hospital	3.6	3.8	3.6	3.7	3.7	3.6	3.6	3.5	3.5	3.4
Length of Stay, days; median [IQR]	4 [3-7]	4 [3-7]	4 [3-7]	4 [3-7]	4 [3-7]	4 [3-7]	4 [3-7]	4 [3-7]	4 [3-7]	4 [3-7]
Total Hospital Charges, USD; median [IQR]	22204 [12909-41366]	23284 [13449-44106]	24196 [13894-45277]	25324 [14540-46816]	25365 [14628-47489]	26586 [15307-49595]	27132 [15728-49956]	28583 [16540-52614]	29917 [17247-54986]	31145 [18064-56950]

IQR indicates interquartile range; USD, United States dollars

*includes intermediate care or other care facilities.

Table S4. Outcomes Over Time for Hospitalizations for HFpEF with Comorbid Atrial Fibrillation, 2008-2017.

Variables (N)	2008 (72587)	2009 (89674)	2010 (103472)	2011 (121924)	2012 (126715)	2013 (138705)	2014 (152610)	2015 (171650)	2016 (195805)	2017 (228280)	P-Value
Discharge Disposition											**<0.001**
Routine	42.7	41.1	39.4	38.9	38.6	37.5	38.0	39.1	39.0	38.4	
Transfer to Short Term Hospital	1.5	1.6	1.7	1.7	1.8	1.7	1.8	1.8	1.7	1.8	
Skilled Nursing Facility*	26.7	27.9	28.8	28.6	28.7	29.1	27.9	27.6	27.6	27.2	
Home Health Care	25.8	25.9	26.7	26.9	27.6	28.6	27.9	27.7	28.4	29.4	
Against Medical Advice	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.5	
Died in Hospital	2.9	3.2	3.1	3.0	3.1	3.2	3.0	3.0	2.9	2.8	
Length of Stay, days; median [IQR]	4 [3-7]	4 [3-7]	4 [3-7]	4 [3-7]	4 [3-7]	4[3-7]	4 [3-7]	4 [3-7]	4 [3-7]	4 [3-7]	**<0.001**
Total Hospital Charges, USD; median [IQR]	22107 [13393-39107]	23440 [14173-41881]	24450 [14660-43507]	25338 [15024-44740]	25407 [14988-45449]	26286 [15623-47052]	26802 [15989-46921]	27966 [16611-49501]	28943 [17250-51090]	29928 [17801-52556]	**<0.001**

HFpEF indicates heart failure with preserved ejection fraction; IQR, interquartile range; USD, United States dollars.
*includes intermediate care or other care facilities.

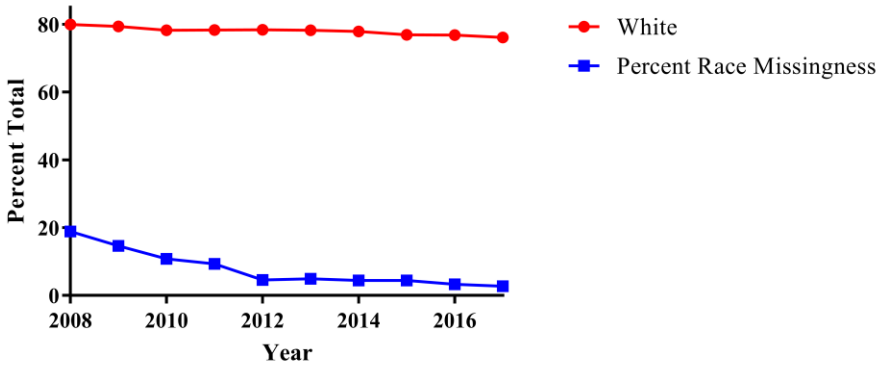
Table S5. Outcomes Over Time for Hospitalizations for HFrEF with Comorbid Atrial Fibrillation, 2008-2017.

Variables (N)	2008 (97258)	2009 (136290)	2010 (144189)	2011 (166385)	2012 (176125)	2013 (190330)	2014 (209845)	2015 (240410)	2016 (260155)	2017 (286565)	P-Value
Discharge Disposition											**<0.001**
Routine	49.0	48.1	46.0	45.0	44.6	44.0	44.7	44.6	46.9	44.3	
Transfer to Short Term Hospital	2.3	2.5	2.4	2.6	2.7	2.7	2.9	2.9	2.8	2.6	
Skilled Nursing Facility*	21.2	21.7	22.7	22.7	22.4	22.4	21.9	21.1	21.5	21.4	
Home Health Care	23.9	23.4	24.9	25.5	25.9	26.6	25.9	25.8	26.1	26.9	
Against Medical Advice	0.5	0.6	0.5	0.6	0.6	0.6	0.7	0.9	1.0	1.0	
Died in Hospital	3.0	3.6	3.4	3.7	3.7	3.5	3.8	3.7	3.7	3.7	
Length of Stay, days; median [IQR]	4 [3-7]	4 [3-7]	4 [3-7]	4 [3-7]	4 [3-7]	4 [3-7]	4 [3-7]	4 [3-7]	4 [3-7]	4 [3-7]	**<0.001**
Total Hospital Charges, USD; median [IQR]	23124 [13747-44185]	24525 [14095-47294]	26179 [14927-50390]	27318 [15640-51585]	27302 [15758-52283]	28668 [16470-54998]	28963 [16740-55006]	30486 [17586-57685]	31636 [17989-59763]	33091 [18926-62090]	**<0.001**

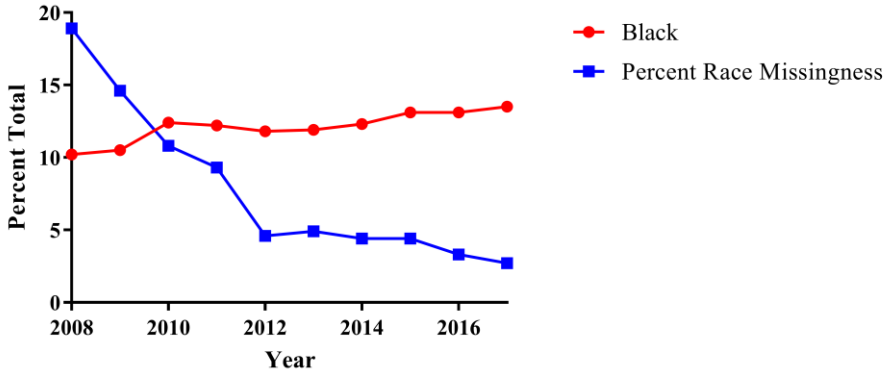
HFrEF indicates heart failure with reduced ejection fraction; IQR, interquartile range; USD, United States dollars.
*includes intermediate care or other care facilities

Figure S1. Graph showing the degree of race missingness in the National Inpatient Sample compared to the proportion of HF admissions for each race/ethnicity over time. It shows that even as the degree of missingness decreases significantly, the proportion of each race stays relatively constant, with a slight decrease in White race (**a**) and small but steady increases in the proportion of Black (**b**), Hispanic (**c**), and Asian or Pacific Islander (**d**).

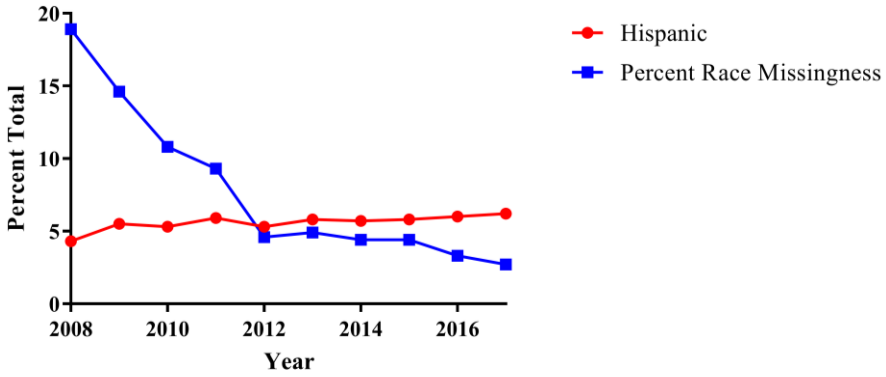
a) Percent White Race vs. Race Missingness over Time



b) Percent Black Race vs. Race Missingness over Time



c) Percent Hispanic Ethnicity vs. Race Missingness over Time



d) Percent Asian or Pacific Islander Race vs. Race Missingness over Time