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National Trends in Admission and In-Hospital Mortality of Patients With Heart Failure in the United States (2001–2014)

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ORIGINAL RESEARCH

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Background—To investigate heart failure (HF) hospitalization trends in the United States and change in trends after publication of management guidelines.

Methods and Results—Using data from the National Inpatient Sample and the US Census Bureau, annual national estimates in HF admissions and in-hospital mortality were estimated for years 2001 to 2014, during which an estimated 57.4 million HF-associated admissions occurred. Rates (95% confidence intervals) of admissions and in-hospital mortality among primary HF hospitalizations declined by an average annual rate of 3% (2.5%–3.5%) and 3.5% (2.9%–4.0%), respectively. Compared with 2001 to 2005, the average annual rate of decline in primary HF admissions was more in 2006 to 2009 (ie, 3.4% versus 1.1%; P=0.02). In 2010 to 2014, primary HF admission continued to decline by an average annual rate of 4.3% (95% confidence interval, 3.9%–5.1%), but this was not significantly different from 2006 to 2009 (P=0.14). In contrast, there was no further decline in in-hospital mortality trend after the guideline-release years. For hospitalizations with HF as the secondary diagnosis, there was an upward trend in admissions in 2001 to 2005. However, the trend began to decline in 2006 to 2009, with an average annual rate of 2.4% (95% confidence interval, 0.8%–4%). Meanwhile, there was a consistent decline in in-hospital mortality by an average annual rate of 3.7% (95% confidence interval, 3.3%–4.2%) during the study period, but the decline was more in 2006 to 2009 compared with 2001 to 2005 (ie, 5.4% versus 3.4%; P<0.001). Beyond 2009, admission and in-hospital mortality rates continued to decline, although this was not significantly better than the preceding interval.

Conclusions—From 2001 to 2014, HF admission and in-hospital mortality rates declined significantly in the United States; the greatest improvements coincided with the publication of the 2005 American College of Cardiology/American Heart Association HF guidelines. **(*J Am Heart Assoc*. 2017;6:e006955. DOI: 10.1161/JAHA.117.006955.)**

Key Words: heart failure • hospitalization • mortality • outcome • quality of care

Heart failure (HF) constitutes a major public health burden with an estimated prevalence of >5.7 million in the United States and >23 million worldwide.[1,2] There was a striking increase in its prevalence from the 1970s through the 1990s, during which time it reached an epidemic level.[3,4] Although recent reports suggest that the incidence of HF has plateaued in the general population and is decreasing in some groups,[1,5,6] an estimated 915 000 individuals are still diagnosed as having HF in the United States each year. Furthermore, because of the aging of the population and improved survival after diagnosis, the prevalence of HF is still increasing and is estimated to increase by 46% from 2012 to 2030, which will result in >8 million adults with a diagnosis of HF.[2,7]

To further understand the epidemiological characteristics and burden of HF, an assessment of the trends in its admission and mortality rates is imperative. More so, an insight into these trends serves as a quality metric for evaluating the advances made in healthcare delivery and national guidelines aimed at improving patient outcomes. Prior studies on trends in HF hospitalization and in-hospital mortality in the United States demonstrated a decline between 1998 and 2009.[8–10] However, there is a lack of

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Accompanying Tables S1 through S3 are available at http://jaha.ahajournals.org/content/6/12/e006955/DC1/embed/inline-supplementary-material-1.pdf

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Clinical Perspective

What Is New?

- From 2001 to 2014, there has been a significant decline in heart failure–related admissions and in-hospital mortality in the United States.
- During the study period, we found that the greatest decline in these hospitalization outcomes coincided with the publication of the 2005 American College of Cardiology/American Heart Association heart failure management guidelines.

What Are the Clinical Implications?

- These findings highlight the importance of concerted efforts (including guideline-directed care) aimed at improving outcomes in patients with heart failure.

evidence on recent trends in HF hospitalization outcomes after 2009 and detailed assessment of progress made after publication of national guidelines.

To address these gaps in knowledge, we therefore performed an in-depth analysis of the national trends in admission and in-hospital mortality in patients with HF with the goal of providing an assessment of the progress made during the past decade through concerted efforts, such as the periodic publication of national HF management guidelines by the American College of Cardiology (ACC)/American Heart Association (AHA) joint task force.

Methods

Data Source

This study was conducted using the National Inpatient Sample (NIS) of the Health Care Utilization Project sponsored by the Agency for Healthcare Research and Quality. Details of the design and description of the NIS are available online.[11] Briefly, this nationally representative database, which represents the largest all-payer inpatient care database in the United States, contains yearly encounter-level information of hospital stays compiled in a uniform format, with privacy protection of individual patients. NIS approximates a 20% stratified sample of discharges from nonfederal, short-term, general, and other specialty hospitals in the United States. To derive national estimates from the sample, the Agency for Healthcare Research and Quality provides a trend/discharge weight that accounted for the sampling design.

The study was considered exempt from formal review by the Wayne State University (Detroit, MI) institutional review board because it involves a deidentified public database and the involved individuals did not receive a test material (ie, drug or device) as participants in the study.

Patient Population

We included all adult patients (aged ≥18 years) with a primary or secondary diagnosis of HF in the NIS database between 2001 and 2014. A primary HF diagnosis refers to hospitalizations mainly attributable to HF, whereas a secondary diagnosis refers to hospitalizations in patients with chronic HF who were admitted for reasons other than HF. These were identified via the following *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) diagnosis codes, as recommended by the ACC/AHA task force on performance measures: 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, and 428.[12] HF was classified as a primary diagnosis if any of the codes appear as the first diagnosis in the NIS database. Otherwise, it was classified as secondary if it occurs at any other level of diagnoses.

Covariates

Data on patient- and hospital-level characteristics were provided for each hospitalization in the NIS database. However, identifiable variables were not included to preserve both patient and hospital privacies. Patient-level factors, including demographics, diagnoses, comorbidities, in-hospital procedures, and disposition, as well as hospital-level factors, including bed size, location, and total number of hospitalizations, are available via the NIS database.

End Points

The main end points in this study were trends in admission and in-hospital mortality in patients admitted with a primary diagnosis of HF. In addition, we evaluated similar trends in patients admitted with a secondary diagnosis of HF. In-hospital mortality was available in the NIS data as a categorical variable (yes/no).

Statistical Analysis

National estimates, including measure of central tendencies, rates, and proportions, were calculated using the hospital-level trend weights provided for the NIS by the Agency for Healthcare Research and Quality. To quantify comorbidities per hospitalization, we used the Deyo modification of the Charlson comorbidity index (ie, Charlson/Deyo score) to identify and classify coexisting conditions (Table S1).[13] Baseline characteristics were compared using the χ^2 test for categorical variables and the ANOVA or Kruskal-Wallis

Table 1. Characteristics of Hospital Admissions With Primary or Secondary Diagnosis of HF, According to Survival Status at Discharge*

Characteristics	Total	Survived Until Hospital Discharge	In-Hospital Mortality	*P* Value
Unweighted no. (%)	12 007 813 (100)	11 305 810 (94.2)	702 003 (5.8)	
Weighted no. (%)	57 350 384 (100)	54 030 898 (94.2)	3319 485 (5.8)	
Age, mean (SD), y	73.3 (13.7)	73.0 (13.8)	77.6 (12.2)	<0.001
<65 y, %	24.7	25.3	14.4	<0.001
≥65 y, %	75.3	74.7	85.6	
Female sex, %	53.5	53.5	52.0	<0.001
Race, %				
White	72.9	72.7	77.3	
Black	15.7	16.0	11.3	
Hispanic	7.0	7.0	6.5	<0.001
Asian	1.7	1.7	2.2	
Others	2.7	2.7	2.7	
Charlson/Deyo score, median (IQR)†	2.0 (3.0)	2.0 (3.0)	3.0 (2.0)	<0.001
Charlson/Deyo score, %				
0	8.2	8.5	4.4	
1	23.1	23.4	19.2	<0.001
≥2	68.6	68.2	76.4	
Median household income by zip code, %				
First quartile	32.0	32.1	29.7	
Second quartile	26.8	26.8	26.4	<0.001
Third quartile	22.8	22.8	23.2	
Fourth quartile	18.4	18.3	20.7	
Expected primary payer, %‡				
Medicare	77.6	77.4	81.7	
Medicaid	6.7	6.9	4.4	
Private	11.8	11.9	10.4	<0.001
Self-pay	2.1	2.1	1.5	
Hospital bed size, %				
Small	14.4	14.4	14.0	
Medium	25.3	25.3	25.2	<0.001
Large	60.3	60.3	60.8	
Hospital region, %				
Northeast	19.3	19.1	21.8	
Midwest	24.6	24.8	21.5	<0.001
South	40.2	40.2	39.3	
West	15.9	15.8	17.4	
Hospital location/teaching status, %				
Rural	15.4	15.5	14.7	
Urban nonteaching	42.4	42.3	44.0	<0.001
Urban teaching	42.2	42.2	41.3	

Continued

Table 1. Continued

Characteristics	Total	Survived Until Hospital Discharge	In-Hospital Mortality	*P* Value
Length of stay, median (IQR), d	5.0 (5.0)	5.0 (5.0)	6.0 (10)	<0.001
0–2 d, %	22.4	22.1	27.8	
3–4 d, %	26.8	27.5	15.9	<0.001
≥5 d, %	50.8	50.5	56.3	

HF indicates heart failure; and IQR, interquartile range.
*Secondary diagnosis of HF refers to patients with chronic HF who were admitted for reasons other than HF.
†Refers to the Deyo modification of the Charlson comorbidity score/index.
‡Medicare and Medicaid beneficiaries include both fee-for-service and managed care, whereas private insurance includes Blue Cross, commercial carriers, and private health maintenance organizations and preferred provider organizations.

test (as appropriate) for continuous variables. Standardized national rates of hospital admission were calculated for each year (per 100 000 people) by dividing the estimated number of admissions by the US population of adults ≥18 years of age for that year. National population estimates were obtained for each year from the US census bureau,[14] and annual rates were age and sex standardized to the 2014 population using the direct standardization method to enhance unbiased comparison across the years. Yearly in-hospital mortality was calculated as percentage of HF admissions for that year. Thereafter, the average annual percentage change in admission and mortality was calculated using Poisson regression modeling with robust variance, in which calendar year was modeled as a continuous independent variable.

To evaluate trends after the 2005 and 2009 ACC/AHA guideline updates for the management of HF in adults,[15,16] we additionally evaluated trends in 3 intervals demarcated by the guideline-release years (ie, 2001–2005, 2006–2009, and 2010–2014). Change in trend from one interval to the next (ie, between 2 adjoining intervals) was evaluated via piecewise regression modeling with robust variance.

Last, stratified analysis by categories of age (<65 and ≥65 years), sex, and race was conducted for in-hospital mortality among patients with HF as a primary diagnosis.

Analyses were performed using STATA 14 (StataCorp, College Station, TX) and SPSS version 20.0 (IBM Corp, Armonk, NY), with a 2-tailed level of significance set at 0.05.

Results

The estimated number of hospital admissions in the United States with HF as the primary or secondary diagnosis was >57 million between 2001 and 2014. In total, 75.3% of these admissions occurred in patients ≥65 years and 53.5% were women (Table 1). Racial distribution was 72.9% white, 15.7% black, 7% Hispanic, 1.7% Asian, and 2.7% others. Approximately on third of the admissions occurred among patients within the first quartile of household income, and most (77.6%) were enrolled in the Medicare insurance program. Geographically, there were more admissions in the south (40.2%) compared with other regions of the country.

Trends in HF as a Primary Diagnosis

Hospitalizations

An estimated 14.6 million hospitalizations with HF as the primary diagnosis (ie, 25.5% of total HF-associated admissions) occurred in the United States between 2001 and 2014. Most of the hospitalizations occurred between the ages of 75 and <85 years (29.5%), among women (51.5%), and in whites (68.3%; Table S2). The rates of these primary HF admissions declined from 563 per 100 000 people in 2001 to 398 per 100 000 people in 2014 (Figure 1A), with an average annual decline of 3% (95% confidence interval [CI], 2.5%–3.5%; *P*<0.001; Table 2).

When we evaluated rates of decline within the 3 intervals of the ACC/AHA HF guidelines, there was a decreasing trend within each interval, but the magnitude of the decline was higher in the later intervals (ie, average annual rate of decline was 1.1% [95% CI, 0.18%–1.9%; *P*=0.02] for the first interval, 3.4% [95% CI, 2.4%–4.4%; *P*<0.001] for the second interval, and 4.3% [95% CI, 3.9%–5.9%; *P*<0.001] for the third interval) (Figure 1A). We found a significant change in trend after the 2005 guidelines compared with before the guidelines. Specifically, we found that the magnitude of the average annual rate of decline in primary HF admission was 2.4% (95% CI, 0.39%–4.4%; *P*=0.02) more in the 2006 to 2009 interval compared with the preceding 2001 to 2005 interval. However, compared with the 2006 to 2009 interval, the change in trend in 2010 to 2014 did not reach statistical significance. The decline (first versus third interval) was more pronounced in ages between 75 and <85 years (31.9% versus 27%), as well as among women (53.6% versus 49.6%), whites (70.3% versus

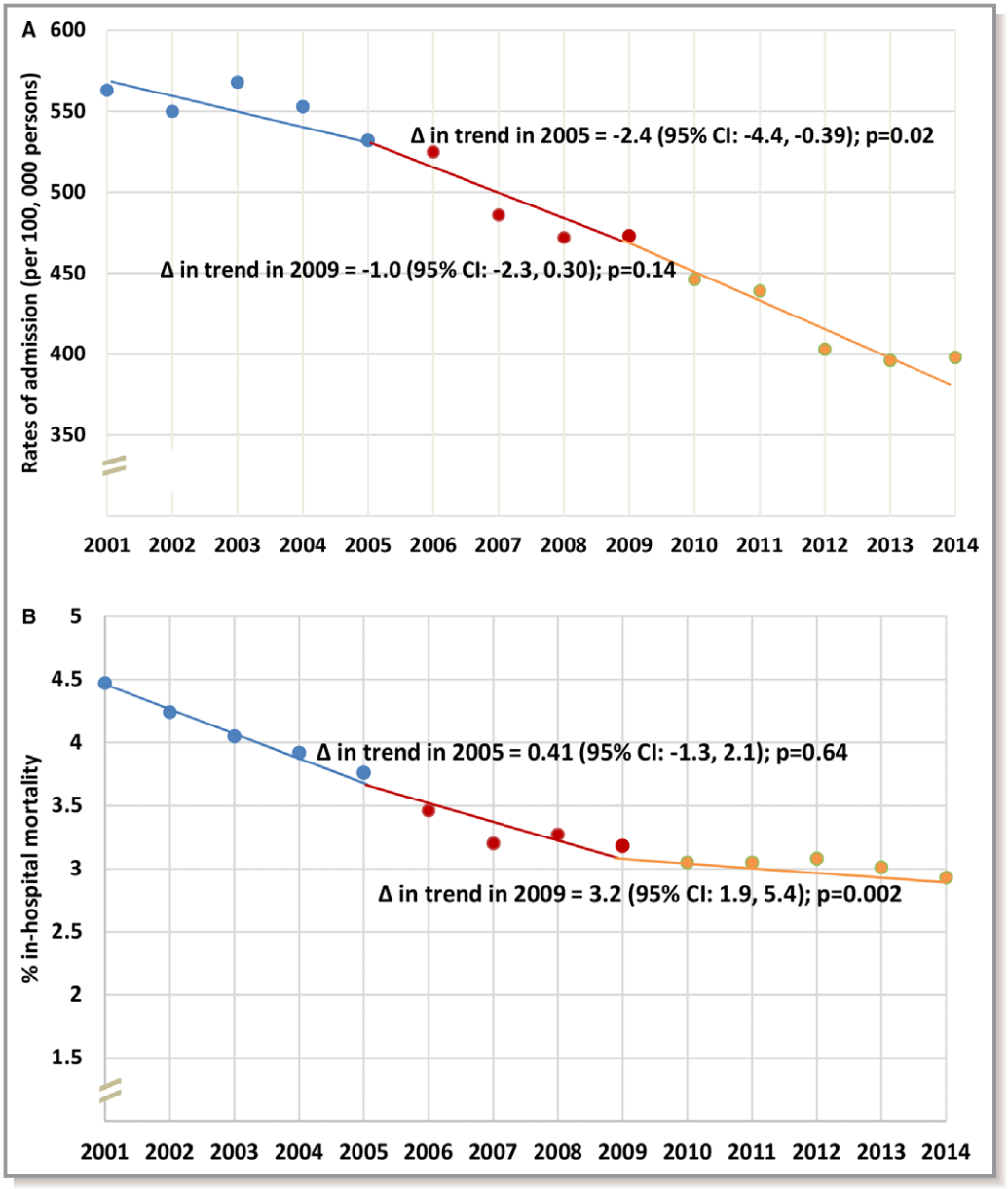

Figure 1. A, Trends in primary heart failure admission rates within intervals demarcated by the 2005 and 2009 American College of Cardiology (ACC)/American Heart Association (AHA) guidelines. There was a significant change in trend in the 2005 to 2009 interval (red) compared with before 2005 (blue). There was a nonsignificant change in trend after 2009 (orange) compared with the prior interval. B, Trends in in-hospital mortality in patients with a primary diagnosis of heart failure within intervals demarcated by the 2005 and 2009 ACC/AHA guidelines. There was no significant change in trend in the 2005 to 2009 interval (red) compared with before 2005 (blue). However, the trend appeared to have plateaued after the 2009 guidelines (orange). CI indicates confidence interval.

67%), Hispanics (8.2% versus 7.6%), Medicare beneficiaries (76.1% versus 74.9%), and privately insured patients (12.6 versus 11.6; Table 3). However, the degree of comorbid conditions per HF hospitalization, as measured by the Charlson/Deyo comorbidity score, increased over the years (eg, hospitalizations with a score ≥2 increased from 43.5% in the first interval to 63.6% in the third interval). In addition, there was an increase in hospitalization in urban teaching hospitals (35.1% versus 46.7%) with an associated decrease in rural (17.9% versus 14.2%) and urban (47% versus 39.1%) nonteaching hospitals. Last, there was a decrease in the median (interquartile range) length of stay over the 3 intervals from 5.0 (4.0) days in the first interval to 4.0 (4.0) days in the third interval.

Table 2. Average Annual Percentage Change in Rates (With 95% CIs) of HF Admissions and In-Hospital Mortality*

Variable	2001–2005	*P* Value for Trend	2006–2009	*P* Value for Trend	2010–2014	*P* Value for Trend	2001–2014	*P* Value for Trend
Primary HF admission	−1.1 (−1.9 to −0.18)	0.02	−3.4 (−4.4 to −2.4)	<0.001	−4.3 (−5.1 to −3.9)	<0.001	−3.0 (−3.5 to −2.5)	<0.001
Primary HF mortality	−4.2 (−4.5 to −3.9)	<0.001	−3.9 (−5.6 to −2.3)	<0.001	−1.0 (−1.8 to −0.23)	0.01	−3.5 (−4.0 to −2.9)	<0.001
Secondary HF admission	2.6 (2.4 to 2.8)	<0.001	−2.4 (−4.0 to −0.80)	0.004	−1.2 (−1.6 to 0.19)	0.09	−0.22 (−0.72 to 0.29)	0.40†
Secondary HF mortality	−3.4 (−4.0 to −2.7)	<0.001	−5.4 (−6.2 to −4.7)	<0.001	−1.3 (−2.4 to −0.27)	0.02	−3.7 (−4.2 to −3.3)	<0.001

CI indicates confidence interval; and HF, heart failure.
*To assess average annual percentage change within each interval, the guideline-release years were considered as the last year of the preceding interval and the first year of the following interval. Negative estimates indicate declining trends, whereas positive estimates indicate increasing trends.
†Although there was no overall linear trend from 2001 through 2014, there was a linear trend in piecewise analysis within the 2001 to 2005 and 2005 to 2009 intervals.

Mortality

In-hospital mortality among patients hospitalized with a primary diagnosis of HF declined from 4.5% in 2001 to 2.9% in 2014, although the rate of decline gradually diminished in the past few years of the study period (Figure 1B). Overall, the average annual rate of decline in mortality in patients with a primary diagnosis of HF was 3.5% (95% CI, 2.9%–4.0%; $P<0.001$; Table 2). Compared with those who survived to hospital discharge, those who died were older (70.4% versus 51.2% were aged ≥75 years), were more likely to be white (78.4% versus 67.9%), had a higher Charlson/Deyo comorbidity score (59.4% versus 53.8% had a score of ≥2), were enrolled in the Medicare insurance program (81.5% versus 75%), and were in rural (17.5% versus 16.1%) and urban (44.3% versus 43.5%) nonteaching hospitals (Table S2). In addition, mortality was highest within the first 2 days of admission, decreased to a nadir on days 3 and 4, and trended up afterwards (Figure 2).

When we evaluated changes in the in-hospital mortality rate in the 3 time intervals of the ACC/AHA HF guidelines, the observed in-hospital mortality rate decreased in each interval, but the magnitude of the decline diminished in the later intervals: the average annual rate of decline was 4.2% (95% CI,3.9%–4.5%; $P<0.001$) in the 2001 to 2005 interval, 3.9% (95% CI, 2.3%–5.6%; $P<0.001$) in the 2006 to 2009 interval, and 1.0% (95% CI, 0.23%–1.8%; $P=0.01$) in the 2010 to 2014 interval (Table 2). There was no statistically significant difference in the rate of decline in the 2006 to 2009 interval (ie, after publication of the 2005 guidelines) compared with the 2001 to 2005 interval, whereas the trend approached a plateau after the 2009 guidelines (Figure 1B).

In stratified analysis (Table 4), in-hospital mortality was higher among patients aged ≥65 years compared with <65 years, although there was a slight closing of the gap in the later years compared with the earlier part of the study period (Figure 3A). Closing of the gap was mainly attributable to a faster rate of decline in in-hospital mortality among patients aged ≥65 years, with an average annual decline of 3.2% (95% CI, 2.8%–3.7%; $P<0.001$) compared with 2.3% (95% CI, 1.4%–4.2%; $P<0.001$) among patients aged <65 years. In addition, the decline in in-hospital mortality plateaued among patients aged <65 years, whereas it was still decreasing among patients aged ≥65 years in the last interval of the study period (ie, 2010–2014). When we stratified analysis by sex, we found that in-hospital mortality was higher in men at the beginning of the study (ie, year 2001) (Figure 3B). However, the rate of decline was faster in men (5.5% [95% CI, 5.0%–6.3%]; $P<0.001$) than in women (3.2% [95% CI, 2.5%–3.9%]; $P<0.001$) during the first interval, and the apparent sex gap seems to have closed by the third interval. Last, stratified analysis by race showed that in-hospital mortality was highest

Table 3. Trends in Patient- and Hospital-Level Characteristics Among Hospitalizations With a Primary Diagnosis of HF

Characteristics	2001–2005	2006–2009	2010–2014	*P* Value
Hospitalization (per 100 000 people)	553	489	416	
Age, mean (SD), y	72.7 (13.9)	72.5 (14.5)	72.5 (14.4)	0.002
18–<45 y, %	4.0	4.3	4.2	
45–<55 y, %	7.8	8.8	8.5	
55–<65 y, %	13.7	14.4	15.2	<0.001
65–<75 y, %	22.1	20.6	20.9	
75–<85 y, %	31.9	29.3	27.0	
≥85 y, %	20.5	22.6	24.2	
Female sex, %	53.6	50.8	49.6	<0.001
Race, %				
White	70.3	67.6	67.0	
Black	17.8	19.6	20.8	
Hispanic	8.2	8.1	7.6	<0.001
Asian	1.6	1.8	1.9	
Others	2.0	3.0	2.8	
Charlson/Deyo score, median (IQR)	1.0 (1.0)	2.0 (2.0)	2.0 (2.0)	<0.001
Charlson/Deyo score, %				
0	24.1	18.9	15.8	
1	32.4	24.9	20.7	<0.001
≥2	43.5	56.2	63.6	
Median household income by zip code, %				
First quartile	33.3	33.5	33.4	
Second quartile	26.9	26.9	26.3	<0.001
Third quartile	22.3	21.8	22.7	
Fourth quartile	17.5	17.8	17.6	
Expected primary payer[†], %				
Medicare	76.1	74.3	74.9	
Medicaid	7.0	7.5	8.3	<0.001
Private	12.6	12.8	11.6	
Self-pay	2.6	3.3	3.2	
Hospital bed size, %				
Small	13.5	15.2	16.1	
Medium	26.1	24.9	26.0	0.02
Large	60.4	59.9	57.9	
Hospital region, %				
Northeast	20.1	19.1	20.4	
Midwest	23.0	23.3	23.2	<0.001
South	42.4	42.0	40.7	
West	14.5	15.6	15.7	

Continued

Table 3. Continued

Characteristics	2001–2005	2006–2009	2010–2014	*P* Value
Hospital location/teaching status, %				
Rural	17.9	16.1	14.2	
Urban nonteaching	47	44.1	39.1	<0.001
Urban teaching	35.1	39.8	46.7	
Length of stay, median (IQR), d	5.0 (4.0)	4.0 (4.0)	4.0 (4.0)	<0.001
0–2 d, %	24.8	26.5	26.2	
3–4 d, %	30.9	31.4	32.3	<0.001
≥5 d, %	44.3	42.2	41.5	

HF indicates heart failure; and IQR, interquartile range.
*Refers to the Deyo modification of the Charlson comorbidity score/index. see reference 13 (under reference section):
†Medicare and Medicaid beneficiaries include both fee-for-service and managed care, whereas private insurance includes Blue Cross, commercial carriers, and private health maintenance organizations and preferred provider organizations.

among whites compared with other races (Figure 3C). There was a declining trend across all 4 races, but the average annual rate of decline was highest among blacks (4.4% [95% CI, 3.7%–5.1%]; *P*<0.001) and lowest among whites (3.4% [95% CI, 3.0–3.7%).

Trends in HF as a Secondary Diagnosis

Hospitalizations

An estimated 42.7 million hospital admissions occurred with HF as a secondary diagnosis between 2001 and 2014. Similar to primary HF admissions, most of the secondary HF admissions occurred between the ages of 75 and <85 years (30.8%), among women (54.1%), and among whites (74.5%; Table S3). However, unlike primary HF admissions, the annual rate of secondary HF admissions initially increased from 1366 per 100 000 people in 2001 to a peak of 1502 per 100 000 people in 2006 and thereafter declined for the next 3 years to a somewhat plateau afterwards (although there was a temporary spike in 2011; Figure 4A).

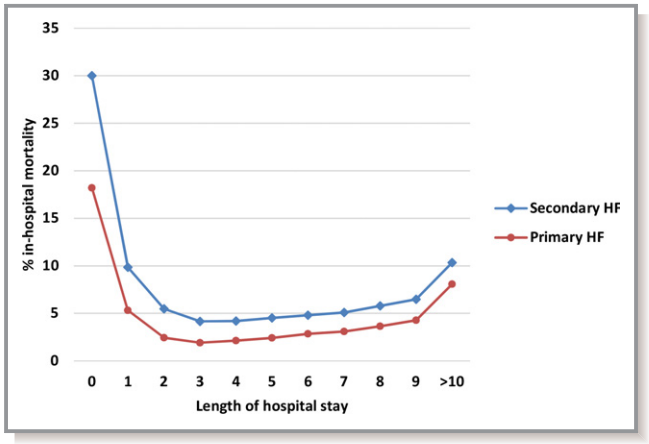

Figure 2. Percentage in-hospital mortality by total length of hospital stay among heart failure (HF)–related admissions in the United States. Primary HF indicates HF as a primary diagnosis; and secondary HF, HF as a secondary diagnosis.

When we evaluated the secondary HF admission rates in the 3 time intervals of the ACC/AHA guidelines, there was a significant change in trend after the publication of the guidelines in 2005 but no significant change after 2009 (Figure 4A, Table 2). Specifically, secondary HF hospitalization rates increased in the first interval (ie, 2001–2005), and then decreased in the second interval (ie, 2006–2009; magnitude of change, 4.8% [95% CI, 3.1%–6.4%; *P*<0.001]); the admission rates plateaued after the 2009 guidelines (ie, third interval). Across the 3 intervals (from first to third), the age at admission decreased (eg, percentage of admissions with age ≥65 years decreased from 78.7% to 73.8%; Table 5). Also, there was a decreasing percentage of women (55.9% to 52.4%), whites (77% to 72.7%), Medicare beneficiaries (79.7% to 77.8%), and rural (17.2% to 13.2%) and urban (45.5% to 37.7%) nonteaching hospital admissions. However, the degree of comorbid conditions per hospitalization, as measured by the Charlson/Deyo comorbidity score, increased over the years (eg, hospitalizations with a score of ≥2 increased from 68.1% in the first interval to 78.3% in the third interval). Last, there was a decrease in the median (interquartile range) length of stay over the 3 intervals from 6.0 (6.0) days in the first interval to 5.0 (5.0) days in the third interval.

Mortality

In-hospital mortality in patients with a secondary diagnosis of HF declined from 8.3% in 2001 to 5.6% in 2014 (Figure 4B). The average annual rate of decline was 3.7% (95% CI, 3.3%–4.2%; *P*<0.001; Table 2). Compared with those who survived to hospital discharge, those who died were older (66.4% versus 53% were aged ≥75 years) and were less likely to be

Table 4. Age-, Sex-, and Race-Specific Average Annual Percentage Change in Mortality in Patients Admitted for HF*

Variable	2001–2005	*P* Value for Trend	2006–2009	*P* Value for Trend	2010–2014	*P* Value for Trend	2001–2014	*P* Value for Trend
Age categories, y								
<65	−2.9 (−4.5 to −1.2)	0.001	−2.3 (−4.6 to 0.11)	0.06	0.01 (−2.2 to 2.3)	0.99	−2.3 (−4.2 to −1.4)	<0.001
≥65	−3.8 (−3.9 to −3.7)	<0.001	−3.9 (−5.2 to −2.7)	<0.001	−0.63 (−1.0 to −0.22)	0.003	−3.2 (−3.7 to −2.8)	<0.001
Sex								
Male	−5.5 (−6.3 to −5.0)	<0.001	−3.6 (−6.0 to −1.1)	0.004	0.75 (−0.10 to 1.6)	0.09	−3.7 (−4.6 to −2.8)	<0.001
Female	−3.2 (−3.9 to −2.5)	<0.001	−4.2 (−4.9 to −3.4)	<0.001	−1.4 (−2.0 to −0.84)	<0.001	−3.3 (−3.6 to −2.9)	<0.001
Race								
White	−4.2 (−4.3 to −4.0)	<0.001	−4.0 (−5.6 to −2.3)	<0.001	−1.7 (−2.3 to −1.1)	<0.001	−3.4 (−3.7 to −3.0)	<0.001
Black	−4.3 (−5.3 to −3.3)	<0.001	−5.0 (−6.2 to −3.8)	<0.001	−1.1 (−2.0 to −0.26)	0.01	−4.4 (−5.1 to −3.7)	<0.001
Hispanic	−2.9 (−5.3 to −0.37)	0.03	−4.6 (−7.4 to −1.7)	0.002	2.2 (−0.78 to 5.2)	0.15	−3.8 (−5.1 to −2.6)	<0.001
Asian	−9.2 (−15 to −2.9)	0.004	−4.5 (−8.7 to −0.15)	0.04	0.51 (−6.7 to 8.2)	0.89	−3.7 (−5.4 to −2.0)	<0.001

HF indicates heart failure.
*Negative estimates indicate declining trends, whereas positive estimates indicate increasing trends.

women (52.1% versus 54.3%) but were more likely to be white (77.1% versus 74.3%), to be a Medicare beneficiary (81.8% versus 78.2%), to have a higher Charlson/Deyo comorbidity score (79.5% versus 73.2% had a score ≥2), and to be in an urban nonteaching hospital (44% versus 41.9%).

In addition, similar to HF as a primary diagnosis, mortality was highest within the first 2 days of admission, decreased to a nadir on days 3 and 4, and trended up afterwards (Figure 2). Overall, patients with HF were more likely to die while hospitalized for another reason (ie, HF as a secondary diagnosis) than while hospitalized for HF.

When we evaluated the change in the in-hospital mortality in each of the 3 time intervals of the ACC/AHA HF guidelines, the rate decreased in each interval, but the magnitude of the decline was greatest in the second interval. The average annual rate of decline was 3.4% (95% CI, 2.7%–4.0%; $P<0.001$) for the first interval, 5.4% (95% CI, 4.7%–6.2%; $P<0.001$) for the second interval, and 1.3% (95% CI, 0.27%–2.4%; $P=0.02$) for the third interval (Table 2). There was a significant change in trends after both guidelines were published, but only after 2005 was the trend a decline (Figure 4B).

Discussion

In this nationally representative sample of hospital admissions in the United States, we found that, despite an increase in comorbidity burden, the rate of hospital admission primarily for HF declined from 2001 through 2014 while the trend in HF as a secondary diagnosis initially increased to a peak in 2006 but decreased afterwards to a somewhat plateau. In addition, the rate of in-hospital mortality among patients admitted with either a primary or a secondary diagnosis of HF declined from 2001 through 2014. Last, we found that, after publication of the 2005 guidelines, there was a further decrease in the trend of HF admissions as a primary or a secondary diagnosis as well as in-hospital mortality when HF was a secondary diagnosis.

At the beginning of the study period, the observed rate of in-hospital mortality among hospitalizations with a primary diagnosis of HF was more in patients aged ≥65 years, males, and whites. However, towards the end of the study period, there was slight closing of the gap between patients ≥65 years and those <65 years, whereas the sex gap was no longer apparent. In contrast, the racial gap seemed to persist, although the trends in Hispanic and Asian populations had plateaued, whereas there was still some decreasing trend among white and black race towards the end of the study period. Similar to prior studies,[17–19] we found that the observed rate of in-hospital mortality for primary HF admissions was higher among whites compared with other races. A possible explanation for this may include a higher rate of readmission among other races (thereby increasing their number of hospitalizations) compared with whites or a higher mean age at hospitalization for whites (76 years versus 63 years [for blacks], 69 years [for Hispanics], and 72 years [for Asians] in our analysis of NIS data). However, this higher risk of in-hospital mortality persisted in whites after adjusting for age, repeated hospitalization, and other possible confounding factors in prior studies.[17,18] Hence, further studies are needed to clearly identify the determinants of this racial disparity.

Our findings build on and considerably expand on results of prior studies on the trends in HF admissions from 1998 through 2009.[8–10] Notably, we showed that the rate of

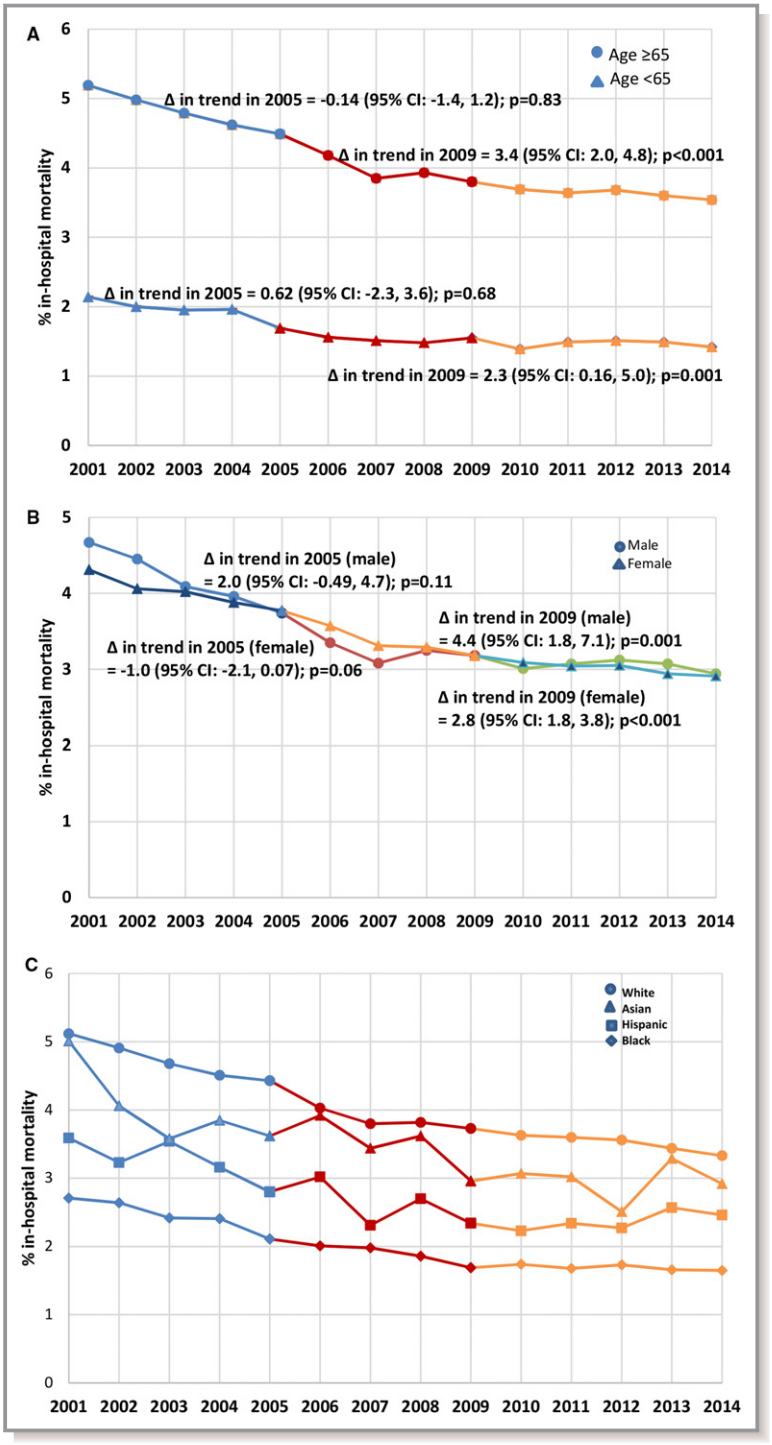

Figure 3. A, Trends in in-hospital mortality in patients with a primary diagnosis of heart failure, stratified by age. There was no significant change in trend in the 2005 to 2009 interval (red) compared with before 2005 (blue). However, the trend became less negative after the 2009 guidelines. B, Trends in in-hospital mortality in patients with a primary diagnosis of heart failure, stratified by sex. There was no significant change in trend in the 2005 to 2009 interval compared with before 2005. However, the trend became less negative after the 2009 guidelines. C, Trends in in-hospital mortality in patients with a primary diagnosis of heart failure, stratified by race. There was no significant change in trend in the 2005 to 2009 interval compared with before 2005, and the trend appeared to have plateaued after the 2009 guidelines. CI indicates confidence interval.

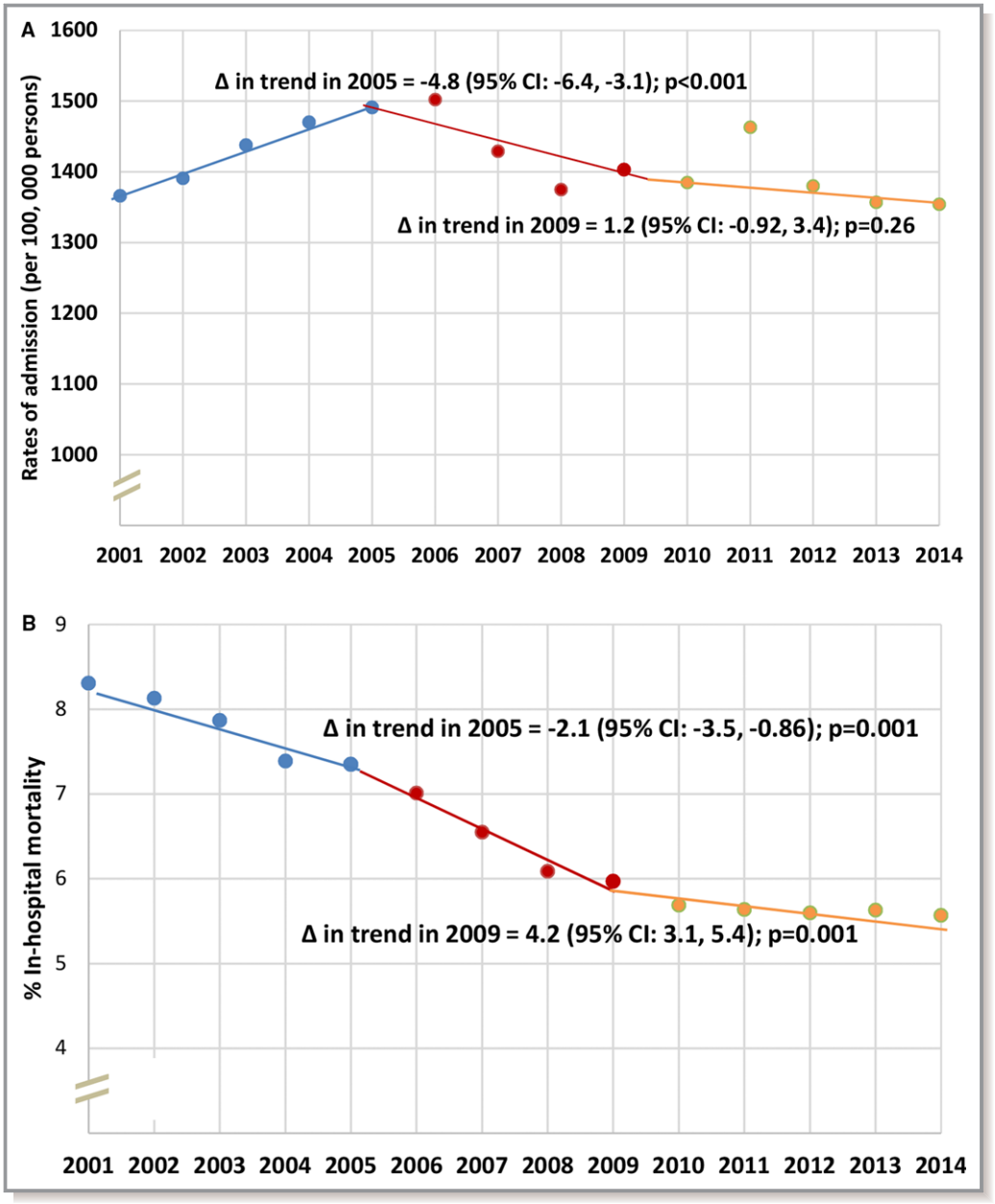

Figure 4. A, Trends in admissions with heart failure (HF) as a secondary diagnosis (ie, patients with a prior diagnosis of HF who were admitted for non-HF reasons) within intervals demarcated by the 2005 and 2009 American College of Cardiology (ACC)/American Heart Association (AHA) guidelines. There was a significant change in trend in the 2005 to 2009 interval (red) compared with before 2005 (blue); and after 2009 (orange) compared with the prior interval. B, Trends in in-hospital mortality in patients with HF as a secondary diagnosis (ie, patients with a prior diagnosis of HF who were admitted for non-HF reasons), stratified within intervals demarcated by the 2005 and 2009 ACC/AHA guidelines. There was a significant change in trend in the 2005 to 2009 interval (red) compared with before 2005 (blue). However, the trend appeared to have plateaued after the 2009 guideline (orange). CI indicates confidence interval.

primary HF admission continued to decline beyond the last year (ie, 2009) in these prior studies, whereas admissions with HF as a secondary diagnosis seem to have plateaued. Previously, Win et al showed a declining trend in in-hospital HF mortality from 2001 through 2010.[19] However, the study was done only among patients with diabetes mellitus. Hence, our study is the first to evaluate trends in HF admission beyond 2009 in addition to providing assessment of in-hospital mortality in all patients with HF from 2001 through 2014. In addition, we evaluated for the potential association of national guidelines with rates of admission and in-hospital mortality among patients with HF. Our analysis showed that

Table 5. Trends in Patient- and Hospital-Level Characteristics Among Hospitalizations With HF as a Secondary Admission Diagnosis*

Characteristics	2001–2005	2006–2009	2010–2014	*P* Value
Hospitalization (per 100 000 people)	1431	1427	1388	
Age, mean (SD), y	74.3 (13.2)	73.6 (13.7)	72.8 (13.7)	<0.001
18–<45 y, %	2.8	3.2	3.3	
45–<55 y, %	6.2	7.1	7.6	
55–<65 y, %	12.3	13.8	15.4	<0.001
65–<75 y, %	22.0	21.7	22.7	
75–<85 y, %	33.7	31.1	28.1	
≥85 y, %	23.0	23.2	23.0	
Female sex, %	55.9	54.3	52.4	<0.001
Race, %				
White	77.0	74.6	72.7	
Black	12.7	14	16.1	
Hispanic	6.6	6.7	6.7	<0.001
Asian	1.6	1.7	1.7	
Others	2.1	3.0	2.9	
Charlson/Deyo score, median (IQR)†	2.0 (2.0)	2.0 (3.0)	3.0 (2.0)	<0.001
Charlson/Deyo score, %				
0	5.0	4.4	3.6	
1	26.9	21.7	18.0	<0.001
≥2	68.1	73.9	78.3	
Median household income by zip code, %				
First quartile	30.9	31.4	32.2	
Second quartile	26.8	27.2	26.5	<0.001
Third quartile	23.2	22.6	23.1	
Fourth quartile	19.1	18.9	18.2	
Expected primary payer, %‡				
Medicare	79.7	77.9	77.8	
Medicaid	5.6	6.3	7.3	<0.001
Private	11.8	12.2	11.1	
Self-pay	1.5	1.9	2.0	
Hospital bed size, %				
Small	13.1	14.7	15.1	
Medium	25.4	24.4	25.5	<0.001
Large	61.6	60.9	59.4	
Hospital region, %				
Northeast	19.8	18.2	19.1	
Midwest	24.7	25.2	25.4	<0.001
South	39.9	40.1	39.1	
West	15.6	16.6	16.3	

Continued

Table 5. Continued

Characteristics	2001–2005	2006–2009	2010–2014	*P* Value
Hospital location/teaching status, %				
Rural	17.2	15.3	13.2	
Urban nonteaching	45.5	43.7	37.7	<0.001
Urban teaching	37.3	41.1	49.1	
Length of stay, median (IQR), d	6.0 (6.0)	5.0 (5.0)	5.0 (5.0)	<0.001
0–2 d, %	19.7	21.6	22.3	
3–4 d, %	23.7	25.1	26.6	<0.001
≥5 d, %	56.6	53.3	51.1	

HF indicates heart failure; and IQR, interquartile range.
*Secondary diagnosis of HF refers to patients with chronic HF who were admitted for reasons other than HF.
†Refers to the Deyo modification of the Charlson comorbidity score/index.
‡Medicare and Medicaid beneficiaries include both fee-for-service and managed care, whereas private insurance includes Blue Cross, commercial carriers, and private health maintenance organizations and preferred provider organizations.

the greatest improvement in HF admission and in-hospital mortality rates occurred after 2005, which coincides with the publication of the 2005 ACC/AHA HF guidelines, but little improvement was observed after release of the 2009 guidelines. A possible explanation for the improvement after 2005 includes availability of more robust evidence from clinical trials that were incorporated into the 2005 guidelines (eg, the recommendation for use of an implantable cardioverter defibrillator for the primary prevention of sudden cardiac death and cardiac resynchronization therapy for patients with ventricular dyssynchrony were first incorporated into the 2005 update of the 2001 guidelines). In addition, compared with the 2001 guidelines, the 2005 update provided a more specific and evidence-based indication for use of available HF therapies (eg, the use of hydralazine and isosorbide dinitrate in blacks with HF with a reduced ejection fraction). On the other hand, there was no major change in therapy in the 2009 guidelines.

Potential limitations of this study should also be considered. First, because of the observational nature of the study, it is impossible to claim that the change in trends after publication of the guidelines was as a result of the guideline-directed care. In other words, our findings represent an association, but not causation, because other variables not evaluated in this study could have also contributed to this change in trend. Second, HF hospitalizations were identified via *ICD-9-CM* codes for which it is possible that the coding preference has changed during the study period. We, however, mitigate against this by identifying our patient population using an extensive number of *ICD-9-CM* codes that were recommended by the ACC/AHA task force on performance measure. Third, the NIS is a sampling of hospitalizations rather than unique patients, which may contribute >1 hospitalization from readmissions. This is a general limitation of most hospital discharge databases, such as NIS, which, unfortunately, could not be adjusted for because patients are deidentified in the database. Our analysis, therefore, represents a composite of both first admission (during the study period) and readmissions, which is of great value in contemporary analysis of HF data. Hence, our admission rates should be interpreted as number of total hospitalizations per US population, whereas mortality rates represent mortality-associated hospitalizations per total hospitalizations in that year.

In summary, despite an increase in comorbidity burden, primary HF hospitalization and HF-associated (ie, HF as the primary or the secondary diagnosis) in-hospital mortality declined in the United States between 2001 and 2014. There seems to be a further decline in HF-associated admissions and in-hospital mortality among patients with a secondary diagnosis of HF after the publication of the 2005 ACC/AHA HF management guidelines compared with the preceding trend. However, little further improvement was observed beyond 2009 during the study period.

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Disclosures

None.

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SUPPLEMENTAL MATERIAL

Table S1. Deyo's modification of Charlson comorbidity index

Comorbidities	ICD-9-CM codes	score
Myocardial infarction	410.x, 412.x	1
Congestive heart failure	428.x	1
Peripheral vascular disease	443.9, 441.x, 785.4, V43.4, procedure 38.48	1
Cerebrovascular disease	430.x-438.x	1
Dementia	290.x	1
Chronic pulmonary disease	490.x-505.x, 506.4	1
Rheumatic disease	710.0, 710.1, 710.4, 714.0-714.2, 714.81. 725.x	1
Peptic ulcer disease	531.x-534.x	1
Mild liver disease	571.2, 571.4-571.6	1
Diabetes without chronic complication	250.0-250.3, 250.7	1
Diabetes with chronic complication	250.4-250.6	2
Hemiplegia or paraplegia	344.1, 342.x	2
Renal disease	582.x, 583-583.7, 585.x, 586.x, 588.x	2
Any malignancy, including lymphoma and leukemia	140.x-172.x, 174.x-195.8, 200.x-208.x	2
Moderate or severe liver disease	456.0-456.21, 572.2-572.8	3
Metastatic solid tumor	196.x-199.1	6
AIDS/HIV	042.x-044.x	6

Abbreviations: ICD-9-CM, International Classification of Diseases-Ninth Revision, Clinical Modification

Table S2. Primary heart failure admission by survival status

	Total	Survived till hospital discharge	In-hospital mortality	P value
Unweighted No. (%)	3,058,789 (100)	2,951,127 (96.5)	107,662 (3.5)	
Weighted No. (%)	14,616,729 (100)	14,105,104 (96.5)	511,626 (3.5)	
Age [years], mean (SD)	72.6 (14.2)	72.4 (14.3)	78.6 (12.2)	<0.001
18 to <45 years, %	4.2	4.2	1.6	
45 to <55 years, %	8.3	8.5	3.3	
55 to <65 years, %	14.4	14.6	7.8	<0.001
65 to <75 years, %	21.3	21.5	16.9	
75 to <85 years, %	29.5	29.4	33.9	
≥85 years, %	22.3	21.8	36.5	
Female, %	51.5	51.5	51.4	0.61
Race, %				
White	68.3	67.9	78.4	
Black	19.4	19.7	11.0	
Hispanic	7.9	8.0	6.3	<0.001
Asian	1.7	1.8	1.7	
Others	2.6	2.6	2.5	
Charlson/Deyo score‡, median (IQR)	2.0 (2.0)	2.0 (2.0)	2.0 (2.0)	
Charlson/Deyo score, %				
0	19.8	19.8	18.9	
1	26.2	26.4	21.7	<0.001
≥2	54.0	53.8	59.4	
Median household income by Zip code, %				
1st quartile	33.4	33.5	30.5	
2nd quartile	26.7	26.7	26.6	<0.001

3rd quartile	22.3	22.3	23.0	
4th quartile	17.6	17.6	20.0	
Expected primary payer, %				
Medicare	75.2	75.0	81.5	
Medicaid	7.6	7.7	4.0	
Private	12.3	12.4	10.5	<0.001
Self-pay	3.0	3.0	1.5	
Hospital bed size, %				
Small	14.8	14.8	14.8	
Medium	25.7	25.7	25.3	<0.001
Large	59.5	59.5	59.9	
Hospital region, %				
Northeast	19.9	19.8	22.4	
Midwest	23.1	23.2	21.7	<0.001
South	41.8	41.8	40.6	
West	15.2	15.2	15.3	
Hospital location/teaching status, %				
Rural	16.2	16.1	17.5	
Urban non-teaching	43.5	43.5	44.3	<0.001
Urban teaching	40.3	40.4	38.2	
Length of stay [days], median (IQR)	4.0 (4.0)	4.0 (4.0)	5.0 (8.0)	<0.001
0-2 days, %	25.8	25.6	29.7	
3-4 days, %	31.5	32.0	17.7	<0.001
≥5 days, %	42.8	42.4	52.6	

Abbreviations: SD, standard deviation; IQR, interquartile range

‡Refers to Deyo's modification of Charlson Comorbidity score/index

¶Medicare and Medicaid beneficiaries include both fee-for-service and managed care while private insurance includes Blue Cross, commercial carriers, and private HMOs and PPOs

Table S3. Secondary† heart failure admission by survival status

	Total	Survived till hospital discharge	In-hospital mortality	P value
Unweighted No. (%)	8,949,037 (100)	8,354,695 (93.4)	594,342 (6.6)	
Weighted No. (%)	42,733,720 (100)	39,925,855 (93.4)	2,807,864 (6.6)	
Age [years], mean (SD)	73.5 (13.6)	73.2 (13.6)	77.4 (12.2)	<0.001
18 to <45 years, %	3.1	3.2	1.6	
45 to <55 years, %	7.0	7.2	3.8	
55 to <65 years, %	13.9	14.2	9.3	<0.001
65 to <75 years, %	22.2	22.4	19.0	
75 to <85 years, %	30.8	30.6	34.1	
≥85 years, %	23.0	22.4	32.3	
Female, %	54.1	54.3	52.1	<0.001
Race, %				
White	74.5	74.3	77.1	
Black	14.5	14.7	11.4	
Hispanic	6.6	6.6	6.6	<0.001
Asian	1.7	1.6	2.2	
Others	2.7	2.7	2.8	
Charlson/Deyo score‡, median (IQR)	2.0 (3.0)	2.0 (3.0)	3.0 (2.0)	
Charlson/Deyo score, %				
0	4.3	4.5	1.8	
1	22.1	22.3	18.7	<0.001
≥2	73.6	73.2	79.5	
Median household income by Zip code, %				
1st quartile	31.5	31.7	29.6	
2nd quartile	26.8	26.9	26.3	<0.001
3rd quartile	23.0	23.0	23.3	
4th quartile	18.7	18.6	20.8	

Expected primary payer¶, %				
Medicare	78.5	78.2	81.8	
Medicaid	6.4	6.6	4.4	
Private	11.7	11.8	10.3	<0.001
Self-pay	1.8	1.8	1.5	
Hospital bed size, %				
Small	14.3	14.3	13.8	
Medium	25.2	25.2	25.2	<0.001
Large	60.6	60.6	61.0	
Hospital region, %				
Northeast	19.1	18.9	21.6	
Midwest	25.1	25.4	21.5	<0.001
South	39.6	39.7	39.1	
West	16.1	16.0	17.8	
Hospital location/teaching status, %				
Rural	15.1	15.2	14.2	
Urban non-teaching	42.0	41.9	44.0	<0.001
Urban teaching	42.8	42.9	41.8	
Length of stay [days], median (IQR)	5.0 (5.0)	5.0 (5.0)	6.0 (10)	<0.001
0-2 days, %	21.3	20.8	27.5	
3-4 days, %	25.2	25.9	15.6	<0.001
≥5 days, %	53.6	53.3	57.0	

Abbreviations: SD, standard deviation; IQR, interquartile range

†Secondary diagnosis of heart failure refers to patients with chronic heart failure who were admitted for reasons other than heart failure

‡Refers to Deyo's modification of Charlson Comorbidity score/index

¶Medicare and Medicaid beneficiaries include both fee-for-service and managed care while private insurance includes Blue Cross, commercial carriers, and private HMOs and PPOs

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