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

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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. 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). Baseline characteristics were compared using the \( \chi^2 \) 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                  | <0.001  |
| 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                 | <0.001  |
| Urban nonteaching                       | 42.4        | 42.3                | 44.0                 |         |
| Urban teaching                          | 42.2        | 42.2                | 41.3                 |         |

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Approximately one 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

| 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.
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.

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.
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) | <0.001 | −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 |

**Cl 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.
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      |         |

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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).

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

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**Table 3. Continued**

| Characteristics                        | 2001–2005 | 2006–2009 | 2010–2014 | \( P \) Value |
|----------------------------------------|-----------|-----------|-----------|---------------|
| Hospital location/teaching status, %   |           |           |           |               |
| Rural                                  | 17.9      | 16.1      | 14.2      | <0.001        |
| Urban non-teaching                     | 47        | 44.1      | 39.1      |               |
| 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.
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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, 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. 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. Notably, we showed that the rate of

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.
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.
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. 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

**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.
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      | <0.001  |
| 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      | <0.001  |
| 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      | <0.001  |
| 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
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
| 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
|                                | 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 | 4th quartile | 23.0 |
|------------------------|--------------|--------------|------|
| 3rd quartile           | 22.3         | 22.3         | 23.0 |
| 4th quartile           | 17.6         | 17.6         | 20.0 |

Expected primary payer, %

|       | Medicare | Medicaid | Private | Self-pay |
|-------|----------|----------|---------|----------|
|       | 75.2     | 7.6      | 12.3    | 3.0      |
|       | 75.0     | 7.7      | 12.4    | 3.0      |
|       | 81.5     | 4.0      | 10.5    | 1.5      |
|       |          |          | <0.001  |          |

Hospital bed size, %

|       | Small     | Medium    | Large    |
|-------|-----------|-----------|----------|
|       | 14.8      | 25.7      | 59.5     |
|       | 14.8      | 25.7      | 59.5     |
|       | 14.8      | 25.3      | 59.9     |
|       |           | <0.001    |          |

Hospital region, %

|       | Northeast | Midwest  | South   | West    |
|-------|-----------|----------|---------|---------|
|       | 19.9      | 23.1     | 41.8    | 15.2    |
|       | 19.8      | 23.2     | 41.8    | 15.2    |
|       | 22.4      | 21.7     | 40.6    | 15.3    |
|       |           | <0.001   |          |         |

Hospital location/teaching status, %

|       | Rural     | Urban non-teaching | Urban teaching |
|-------|-----------|--------------------|---------------|
|       | 16.2      | 43.5               | 40.3          |
|       | 16.1      | 43.5               | 40.4          |
|       | 17.5      | 44.3               | 38.2          |
|       |           | <0.001             |               |

Length of stay [days], median (IQR)

|       | 0-2 days, % | 3-4 days, % | ≥5 days, % |
|-------|-------------|-------------|-----------|
|       | 25.8        | 31.5        | 42.8      |
|       | 25.6        | 32.0        | 42.4      |
|       | 29.7        | 17.7        | 52.6      |
|       |             | <0.001      |           |
|       |             | <0.001      |           |

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
| Age [years], mean (SD) | Total       | Survived till hospital discharge | In-hospital mortality | P value |
|------------------------|-------------|----------------------------------|-----------------------|---------|
| 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, %

| 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) |
|-------------------------------------|
| 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