HEART FAILURE (HF) IMPOSES one of the highest disease burdens of any medical condition in the United States, with an estimated 5.8 million patients experiencing HF in 2006.¹ The risk of developing HF increases with advancing age,² and as a result, HF ranks as the most frequent cause of hospitalization and rehospitalization among older Americans.³,⁴ Heart failure is also one of the most resource-intensive conditions with direct and indirect costs in the United States estimated at $39.2 billion in 2010.¹

As the US population grows older, the HF hospitalization rate would be expected to increase. But several other factors may counterbalance this demographic trend. Recent declines in the incidence of ischemic heart disease,⁵,⁶ a common precursor for HF, may have led to declines in HF hospitalizations. Hypertension is an important cause of HF⁷; rates of blood pressure control have also improved over time.⁸,⁹ Higher use of secondary prevention therapies¹⁰⁻¹² may have led to fewer recurrent HF hospitalizations. Secular trends in thresholds for hospital admission may also have a role, as clinicians substitute outpatient instead of inpatient care when feasible.¹³

How HF hospitalization rates have changed in recent times is unknown, particularly on a national scale. Surveillance studies have produced clinically validated information on trends in HF incidence. The Framingham Heart Study¹⁴ found no change in HF incidence over the past 50 years for men and women of all ages categorized by systolic blood pressure quintiles.¹⁴

Context It is not known whether recent declines in ischemic heart disease and its risk factors have been accompanied by declines in heart failure (HF) hospitalization and mortality.

Objective To examine changes in HF hospitalization rate and 1-year mortality rate in the United States, nationally and by state or territory.

Design, Setting, and Participants From acute care hospitals in the United States and Puerto Rico, 55,097,390 fee-for-service Medicare beneficiaries hospitalized between 1998 and 2008 with a principal discharge diagnosis code for HF.

Main Outcome Measures Changes in patient demographics and comorbidities, HF hospitalization rates, and 1-year mortality rates.

Results The HF hospitalization rate adjusted for age, sex, and race declined from 2845 per 100,000 person-years in 1998 to 2007 per 100,000 person-years in 2008 (P < .001), a relative decline of 29.5%. Age-adjusted HF hospitalization rates declined over the study period for all race-sex categories. Black men had the lowest rate of decline (4142 to 3201 per 100,000 person-years) among all race-sex categories, which persisted after adjusting for age (incidence rate ratio, 0.81; 95% CI, 0.79-0.84). Heart failure hospitalization rates declined significantly faster than the national mean in 16 states and significantly slower in 3 states. Risk-adjusted 1-year mortality decreased from 31.7% in 1999 to 29.6% in 2008 (P < .001), a relative decline of 6.6%. One-year mortality rates declined significantly in 4 states but increased in 5 states.

Conclusions The overall HF hospitalization rate declined substantially from 1998 to 2008 but at a lower rate for black men. The overall 1-year mortality rate declined slightly over the past decade but remains high. Changes in HF hospitalization and 1-year mortality rates were uneven across states.
and a decline of about one-third for women. Heart failure incidence in Olmsted County, Minnesota, was stable from 1979 to 2000.13 Administrative data provide an alternative for assessing HF hospitalization trends on a national scale, given that surveillance studies may have limited generalizability to national trends. The availability of a complete sample of Medicare fee-for-service claims provides sufficient numbers to precisely estimate changes in HF hospitalization rates across demographic subgroups. A complete national sample can also accurately estimate trends across geographic regions to identify specific locations for targeted interventions.

Accordingly, we analyzed a 100% sample of Medicare beneficiaries to identify trends in HF hospitalization rate from 1998 to 2008, nationally and by state or territory. Because changes in survival after HF hospitalization may have changed the denominator of HF patients at risk for recurrent hospitalization, we also examine trends in 1-year mortality after HF hospitalization, nationally and by state or territory.

METHODS

We used inpatient National Claims History files from the Centers for Medicare & Medicaid Services (CMS) to identify all fee-for-service Medicare beneficiaries who were hospitalized for HF from 1998 to 2008. These administrative claims included information on patient demographics (age, sex, race), admission and discharge dates, and principal and secondary diagnosis codes (as coded by the International Classification of Diseases, Ninth Revision, Clinical Modification [ICD-9-CM]). Heart failure hospitalizations were defined as admission to an acute care hospital for a principal discharge diagnosis of HF according to the following ICD-9-CM codes: 402.01, 402.11, 402.91, 404.01, 404.11, 404.91, 428, 404.03, 404.13, and 404.93 and 428.xx.

Corresponding Medicare denominator files from 1998 to 2008 were obtained that contained information on a patient’s eligibility and enrollment in Medicare. Dates of death were ascertained through the corresponding vital status file from CMS, which includes both in-hospital and out-of-hospital deaths. Beneficiaries were excluded from the analysis if they were younger than 65 years or were hospitalized or resided outside of the 50 US states, the District of Columbia, and Puerto Rico.

Institutional review board review and approval was obtained through the Yale University Human Investigation Committee. Medicare data were protected through a data use agreement with CMS.

The unit of observation was a single beneficiary in a single year. The initial sample consisted of 479,198,670 observations in the denominator file (ie, >40 million Medicare beneficiaries each year over 11 years). We then excluded observations for patients younger than 65 years (n=93,403,663); patients enrolled in managed care programs over an entire calendar year (n=69,398,888); and patients with home residence outside of the 50 US states, the District of Columbia, and Puerto Rico (n=1,482,403). The final sample included 320,618,412 observations over the study period for patients who were 65 years or older, who had at least 1 month in Medicare fee-for-service, who were living in the targeted 52 states/territory/district. This represented 55,097,390 unique individual beneficiaries who contributed a total of 312,636,599 person-years of observation from 1998 to 2008.

Primary Outcomes

We calculated the HF hospitalization rate separately for each year by dividing the number of HF hospitalizations by the corresponding person-years of Medicare fee-for-service beneficiaries for that year. Because Medicare fee-for-service beneficiaries were enrolled throughout the year, some beneficiaries were in fee-for-service for the entire year while others were in for a few months. We tabulated the total beneficiary months at risk (subsequently converted to beneficiary years) for a given year to use as the denominator, with the total number of HF hospitalizations for a given year as the numerator. Because beneficiaries can be hospitalized multiple times for HF in a given year, we also calculated the number of unique beneficiaries who were hospitalized with HF in a given year per 100,000 denominator population.

To calculate 1-year mortality, we identified all HF hospitalizations that occurred in a given year of interest; if a patient had more than 1 HF hospitalization in a given year, 1 HF hospitalization was selected at random. The admission date of the HF hospitalization represented the “time zero” for the mortality analysis; that is, we examined the proportion of patients who died within 1 year of the HF admission. As a result, the 1-year mortality rate represented the likelihood of death within 1 year among HF patients hospitalized in a given calendar year. We assessed trends in 1-year mortality starting from 1999 rather than 1998 in or-
enter to have a full year of comorbidity data available for all beneficiaries. We conducted sensitivity analyses comparing age-sex-race mortality models with age-sex-race-comorbidity models to assess the potential influence of changing comorbidity coding patterns on trends in risk-adjusted mortality.

Statistical Analysis
To evaluate the statistical significance of changes across years in patient characteristics, HF hospitalization rate, and mortality rate, we used the Mantel-Haenszel χ² test of linear association for categorical variables and the Cuzick nonparametric test for continuous variables. The Cuzick test is an extension of the nonparametric Wilcoxon rank sum test to evaluate trends in a measured variable across more than 2 ordered groups. For assessing trends in the overall age-sex-race–adjusted HF hospitalization rate, we calculated the number of HF hospitalizations and total person-years in each state for 18 demographic combinations representing 3 age categories (65-74 years, 75-84 years, and 85 years or older), 2 sex categories, and 3 race categories (white, black, other).

Because of the natural clustering of observations within states, we used a 2-stage (patient-level and state-level) hierarchical generalized linear modeling (HGLM) approach for evaluating HF hospitalization rate and 1-year mortality rate as a function of patient characteristics and a random state-specific effect. This strategy accounts for within-state correlation of the observed outcomes. Details of the derivation, validation, and performance of an HGLM approach compared with a medical record model of HF have been published, and such an approach is used by CMS for public reporting of hospital-specific HF mortality. Hierarchical Poisson regression models with the 50 states, Puerto Rico, and Washington, DC, as random intercepts were used to estimate annual changes in the age-sex-race–adjusted HF hospitalization rate, and hierarchical logistic regression models were used to estimate annual changes in the age-sex-race-comorbidity–adjusted 1-year mortality rate. Analysis of trends for the incidence and mortality models incorporated dummy variables representing each year in order to evaluate yearly changes in hospitalization or mortality rates. The baseline year served as the reference for each subsequent year; we report the point estimate and 95% confidence intervals for each year representing the change from the baseline year’s HF hospitalization (change in incident rate ratio [IRR]) or mortality rate (change in odds ratio [OR] of 1-year mortality). Heart failure hospitalization rates and 1-year mortality rates were examined separately for each race-sex category (eg, white male, black female, etc) using age-adjusted models adjusted for HF hospitalization rate and age-comorbidity–adjusted models for mortality rates.

Risk-adjusted HF hospitalization and mortality rates were calculated for each year that represented what the rate would have been if the mix of patients were identical to the initial year (ie, 1998 for HF hospitalization, 1999 for 1-year mortality) using dummy indicator variables for each year from the regression models. The coefficients of these dummy indicator variables in the Poisson regression model for HF hospitalization represented changes in IRR for a given year compared with 1998. Similarly, the coefficient of these indicator variables in the logistic regression model for 1-year mortality represents changes in the relative OR compared with 1999; these ORs were converted into relative risk ratios using the method of Zhang and Yu before calculating risk-adjusted 1-year mortality rates.

State Analyses
We calculated risk-standardized HF hospitalization and 1-year mortality rates separately for each of the 50 states, the District of Columbia, and Puerto Rico using an approach analogous to prior work estimating risk-standardized HF mortality rates across hospitals. All Medicare fee-for-service beneficiaries were sampled if they met the study inclusion criteria. To categorize hospitals, we produced hospital-specific probabilities of particular events. This was accomplished using a bootstrapping procedure that sampled states with replacement. For example, to determine whether the change in HF hospitalization rate for a specific state/district/territory was significantly different (P < .05) from the mean change for the nation, we sampled the 52 state/district/territories with replacements for the baseline (1998) and final years (2008) and fit an HGLM using all patients within each sampled state.

This process was repeated 2000 times with replacements to estimate state-specific point estimates and 95% confidence intervals of the change in state-specific HF hospitalization rate from 1998 and 2008; states were then classified as significantly higher or lower than the national mean change in HF hospitalization rate. We estimated the probability that a particular state had an HF hospitalization rate higher than the mean national rate based on the proportion of bootstrapped estimates exceeding the national mean. We used the same approach for the 1-year mortality rate, except that the baseline year was 1999 and the final year was 2008, and we reported the number of states that were higher, no different, or lower than zero change over the study period because 1-year mortality changed only slightly over the study period.

Analyses were conducted using SAS version 9.2 (SAS Institute, Cary, North Carolina) and HLM version 6 (Scientific Software International, Lincolnwood, Illinois). Significance level was P < .05 using 2-sided tests. Maps of HF hospitalization and 1-year mortality rates were created using ArcView 10 (Esri, Redlands, California).

RESULTS
Patient characteristics of the HF cohort are reported in Table 1. The mean age increased from 79.0 years to 79.9 years (P < .001 for trend) over the study period. There was a decrease in the proportion of female patients (58.9% to 55.7%, P < .001) and increase in the
proportion of black patients (11.3% to 11.7%, \( P < .001 \)). Several comorbidities were more commonly coded over time, including hypertension (47.9% to 60.9%, \( P < .001 \)), history of pneumonia (14.5% to 22.6%, \( P < .001 \)), and renal failure (8.0% to 20.0%, \( P < .001 \)). Mean length of stay decreased from 6.8 days in 1999-2000 to 6.4 days in 2007-2008 (\( P < .001 \)).

### Hospitalization

The number of Medicare fee-for-service beneficiary years decreased from 35,981,165 in 1998 to 27,297,535 in 2008 (Table 2). From 1998 to 2008, the overall unadjusted HF hospitalization rate decreased from 2845 to 1957 per 100,000 person-years, a relative decline of 31.2%. The number of unique Medicare beneficiaries hospitalized at least once for HF in a given year decreased from 2014 per 100,000 person-years to 1462 per 100,000 over the study period. Decreases in the unadjusted HF hospitalization rates were observed across all age, sex, and race categories (Table 2). Black men had the lowest decline in unadjusted HF hospitalization rate (4142 to 3201 per 100,000 person-years, −22.7%) among all race-sex categories.

The overall risk-adjusted HF hospitalization rate decreased from 2845 per 100,000 person-years to 2007 (95% CI, 1974-2041) per 100,000, a relative decline of 29.5% (\( P < .001 \) for trend). In age-adjusted analyses stratified by race-sex categories, the HF hospitalization rate declined in 2008 compared with 1998 for white men (IRR, 0.73; 95% CI, 0.71-0.74), white women (IRR, 0.72; 95% CI, 0.70-0.74), black men (IRR, 0.81; 95% CI, 0.79-0.84), black women (IRR, 0.76; 95% CI, 0.74-0.78), other-race men (IRR, 0.64; 95% CI, 0.61-0.67), and other-race women (IRR, 0.67; 95% CI, 0.63-0.70) (eFigure, available at http://www.jama.com). Black men had the lowest rate of decline in age-adjusted HF hospitalization from 1998 to 2008 among all race-sex groups.

Risk-standardized HF hospitalization rates in 1998 and 2008 varied significantly by state (Figure 1). In 2008, the risk-standardized HF

### Table 1. Characteristics of Patients Hospitalized With Heart Failure, 1999-2008a

<table>
<thead>
<tr>
<th>Year</th>
<th>HF hospitalizations, No.</th>
<th>Age, mean (SD), y</th>
<th>Female</th>
<th>Black</th>
<th>White</th>
<th>Other raceb</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999-2000</td>
<td>1,017,410</td>
<td>79.0 (7.7)</td>
<td>598,993 (58.9)</td>
<td>114,804 (11.3)</td>
<td>860,860 (84.6)</td>
<td>41,746 (4.1)</td>
</tr>
<tr>
<td>2001-2002</td>
<td>1,026,363</td>
<td>79.1 (7.8)</td>
<td>599,416 (58.4)</td>
<td>119,665 (11.7)</td>
<td>864,831 (84.3)</td>
<td>41,867 (4.1)</td>
</tr>
<tr>
<td>2003-2004</td>
<td>1,048,103</td>
<td>79.3 (7.8)</td>
<td>601,251 (57.4)</td>
<td>123,185 (11.8)</td>
<td>880,764 (84.0)</td>
<td>44,154 (4.2)</td>
</tr>
<tr>
<td>2005-2006</td>
<td>953,706</td>
<td>79.6 (7.9)</td>
<td>536,431 (62.2)</td>
<td>113,358 (11.9)</td>
<td>798,764 (83.7)</td>
<td>41,576 (4.4)</td>
</tr>
<tr>
<td>2007-2008</td>
<td>820,727</td>
<td>79.9 (8.0)</td>
<td>457,174 (55.7)</td>
<td>95,707 (11.7)</td>
<td>688,680 (83.9)</td>
<td>36,340 (4.4)</td>
</tr>
</tbody>
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<tbody>
<tr>
<td>Hypertension</td>
<td>487,460 (47.9)</td>
<td>532,256 (51.4)</td>
<td>564,108 (53.8)</td>
<td>502,223 (52.7)</td>
<td>499,978 (60.9)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>373,151 (36.7)</td>
<td>397,640 (38.7)</td>
<td>408,184 (38.9)</td>
<td>366,621 (38.4)</td>
<td>307,059 (37.4)</td>
</tr>
<tr>
<td>Geriatric conditions</td>
<td>94,031 (9.2)</td>
<td>102,191 (10.0)</td>
<td>109,615 (10.5)</td>
<td>102,154 (10.7)</td>
<td>91,619 (11.2)</td>
</tr>
<tr>
<td>Functional disability</td>
<td>24,392 (2.4)</td>
<td>24,045 (2.3)</td>
<td>22,636 (2.2)</td>
<td>18,106 (1.9)</td>
<td>17,666 (2.1)</td>
</tr>
<tr>
<td>Malnutrition</td>
<td>31,327 (3.1)</td>
<td>31,241 (3.0)</td>
<td>35,052 (3.3)</td>
<td>36,011 (3.8)</td>
<td>40,134 (4.9)</td>
</tr>
</tbody>
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<tbody>
<tr>
<td>COPD</td>
<td>331,241 (32.6)</td>
<td>353,538 (34.4)</td>
<td>376,219 (35.9)</td>
<td>352,487 (37.0)</td>
<td>286,107 (34.9)</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>147,932 (14.5)</td>
<td>158,486 (15.4)</td>
<td>168,679 (16.1)</td>
<td>180,319 (18.9)</td>
<td>185,769 (22.6)</td>
</tr>
<tr>
<td>Respiratory failure</td>
<td>46,759 (4.6)</td>
<td>49,056 (4.8)</td>
<td>52,755 (5.0)</td>
<td>56,460 (5.9)</td>
<td>66,692 (8.1)</td>
</tr>
<tr>
<td>Liver disease</td>
<td>10,806 (1.1)</td>
<td>11,397 (1.1)</td>
<td>12,622 (1.2)</td>
<td>11,772 (1.2)</td>
<td>10,246 (1.2)</td>
</tr>
<tr>
<td>Renal failure</td>
<td>80,998 (8.0)</td>
<td>96,269 (8.4)</td>
<td>116,566 (11.1)</td>
<td>146,920 (15.4)</td>
<td>164,497 (20.0)</td>
</tr>
<tr>
<td>Major psychiatric disorder</td>
<td>21,094 (2.1)</td>
<td>21,732 (2.1)</td>
<td>21,237 (2.0)</td>
<td>17,252 (1.8)</td>
<td>16,861 (2.1)</td>
</tr>
<tr>
<td>Depression</td>
<td>59,387 (5.8)</td>
<td>68,443 (6.7)</td>
<td>74,062 (7.1)</td>
<td>62,283 (6.5)</td>
<td>51,582 (6.3)</td>
</tr>
<tr>
<td>Trauma in past year</td>
<td>47,445 (4.7)</td>
<td>52,321 (5.1)</td>
<td>58,493 (5.6)</td>
<td>54,851 (5.8)</td>
<td>49,036 (6.0)</td>
</tr>
</tbody>
</table>

| Length of stay, mean (SD), d                            | 6.8 (5.8)  | 6.8 (5.6)  | 6.6 (5.4)  | 6.5 (5.2)  | 6.4 (5.2)  |

Abbreviations: COPD, chronic obstructive pulmonary disease; HF, heart failure; MI, myocardial infarction.

aData are number (percentage) unless otherwise indicated. Comparison across years of patient characteristics using Mantel-Haenszel \( \chi^2 \) test for linear association for categorical variables and Cuzick test for continuous variables using 2-sided test. All \( P \) values < .001.

bOther race includes Asian, Hispanic, North American Native, or other not specified.

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Table 2. Heart Failure Hospitalization Rates, 1998-2008

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</thead>
<tbody>
<tr>
<td>HF hospitalization rate per 100,000 person-years</td>
<td>2845</td>
<td>2656</td>
<td>2612</td>
<td>2542</td>
<td>2468</td>
<td>2496</td>
<td>2459</td>
<td>2333</td>
<td>2223</td>
<td>2116</td>
<td>1957</td>
</tr>
<tr>
<td>No. unique HF patients per 100,000 person-years</td>
<td>2014</td>
<td>1935</td>
<td>1933</td>
<td>1886</td>
<td>1833</td>
<td>1851</td>
<td>1815</td>
<td>1724</td>
<td>1631</td>
<td>1533</td>
<td>1462</td>
</tr>
</tbody>
</table>

Observed HF hospitalization rate per 100,000 person-years

<table>
<thead>
<tr>
<th>Age, y</th>
<th>65-74</th>
<th>75-84</th>
<th>≥85</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>1783</td>
<td>1614</td>
<td>1514</td>
</tr>
<tr>
<td>Female</td>
<td>2778</td>
<td>2613</td>
<td>2556</td>
</tr>
<tr>
<td>White male</td>
<td>2749</td>
<td>2555</td>
<td>2506</td>
</tr>
<tr>
<td>White female</td>
<td>2688</td>
<td>2490</td>
<td>2474</td>
</tr>
<tr>
<td>Black male</td>
<td>4311</td>
<td>4124</td>
<td>4005</td>
</tr>
<tr>
<td>Black female</td>
<td>4410</td>
<td>4235</td>
<td>4172</td>
</tr>
<tr>
<td>Other race</td>
<td>2187</td>
<td>2177</td>
<td>2215</td>
</tr>
<tr>
<td>Other-race male</td>
<td>2157</td>
<td>2177</td>
<td>2215</td>
</tr>
<tr>
<td>Other-race female</td>
<td>2238</td>
<td>2154</td>
<td>2154</td>
</tr>
<tr>
<td>Risk-adjusted HF hospitalization rate per 100,000 person-years</td>
<td>2845</td>
<td>2752</td>
<td>2697</td>
</tr>
</tbody>
</table>

Abbreviation: HF, heart failure.

P<.001 across years for all subgroups using a continuous time variable from a Poisson regression model.

Other race includes Asian, Hispanic, North American Native, or other not specified.

Risk-adjusted rates relative to 1998.

Figure 1. Risk-Standardized Heart Failure Hospitalization Rate by State in 1998 and 2008

1998 (Mean hospitalization rate, 2845 per 100,000 person-years)

2008 (Mean hospitalization rate, 1957 per 100,000 person-years)

Risk-standardized rate = observed rate/expected rate × unadjusted mean rate calculated independently for each year.

Significantly lower than national mean (2-sided P<.05) based on bootstrapped 95% CIs.

Significantly higher than national mean (2-sided P<.05) based on bootstrapped 95% CIs.

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hospitalization rate was lowest in Vermont (1149 per 100,000 person-years) and highest in Wyoming (2931 per 100,000 person-years). Oregon had the largest relative decline in risk-standardized HF hospitalization rate between 1998 and 2008, while Wyoming did not have a significantly different change (FIGURE 2). The decline in risk-standardized HF hospitalization rate was significantly higher than the change in the national rate in 16 states and significantly lower in 3 states (Wyoming, Rhode Island, and Connecticut). The change in a state's risk-standardized HF hospitalization rates was not associated with whether it started with a low or high baseline rate; in linear regression models, the 1998 rate was not significantly associated with the subsequent change in HF hospitalization rate between 1998 and 2008 (P = .06) and explained little of the variance (r² = 0.05).

Figure 2. Change in Risk-Standardized Heart Failure Hospitalization Rate and 1-Year Mortality Rate by State

For heart failure (HF) hospitalization rate, the dotted line indicates the overall national decline. The probability represents the point estimate of the likelihood that the change in a state's HF hospitalization rate exceeds that of the overall national rate (−838 per 100,000). For 1-year mortality, the solid line represents no change. The probability represents the point estimate of the likelihood that the change in a state's mortality rate exceeded zero. All probability was based on bootstrap analysis.

One-Year Mortality
The unadjusted 1-year mortality rate for HF hospitalization was 31.7% in 1999 and 32.0% in 2008. During this time period, enrollees aged 65 to 74 years and 75 to 84 years had decreases in unadjusted 1-year mortality (23.8% to 22.0% and 31.1% to 30.3%, respectively; P < .001 for both trends), while enrollees 85 years and older had a slight increase in 1-year mortality (42.3% to 42.7%, P < .001). Unadjusted 1-year mortality increased
slightly for women (30.4% to 31.1%, \(P<.001\)) but declined for men (33.6% to 33.1%, \(P<.001\)). White beneficiaries had slightly higher unadjusted mortality rates (32.6% to 33.0%, \(P<.001\)) while black beneficiaries had slightly lower mortality rates (26.6% to 26.2%, \(P<.001\)); beneficiaries of other races had a higher unadjusted 1-year mortality rate (27.9% to 28.7, \(P<.001\)) (Table 3).

Risk-adjusted 1-year mortality (age-sex-race-comorbidity adjusted) decreased from 31.7% to 29.6% between 1999 and 2008 (\(P<.001\) for trend), a relative decline of 6.6%. Age-sex-race-adjusted models estimated a decline in 1-year mortality from 31.7% in 1999 to 30.6% in 2008. In age- and comorbidity-adjusted analyses stratified by race-sex categories, 1-year mortality in 2008 was lower compared with 1999 for white men (OR, 0.90; 95% CI, 0.89-0.92), white women (OR, 0.91; 95% CI, 0.90-0.92), black men (OR, 0.91; 95% CI, 0.87-0.95), black women (OR, 0.89; 95% CI, 0.85-0.92), and other-race men (OR, 0.89, 95% CI, 0.83-0.95) with a nonsignificant trend for other-race women (OR, 0.96; 95% CI, 0.90-1.02) (efigure). The mortality model \(C\) statistic was 0.67 with an adjusted \(r^2\) of 0.11.

The risk-standardized 1-year mortality rates in 1998 and 2008 varied substantially by state (Figure 3). In 2008, the 1-year risk-standardized mortality rate ranged from a low of 29.1% in Maine to a high of 35.2% in Arizona. Washington, DC, had the largest relative decline (from 32.0% to 30.3%) while South Dakota had the largest relative increase (from 30.2% to 33.0%) (Figure 2). There were 4 states with a statistically significant decline in 1-year risk-standardized mortality between 1998 and 2008 and 5 states with a statistically significant increase. The change in a state’s risk-standardized 1-year mortality rate was not associated with whether it started with a low or high baseline rate; the 1999 rate was not significantly associated with subsequent change in mortality rate from 1999 to 2008 (\(P>.99\)) and explained little of the variance (\(r^2=0.01\)).

**COMMENT**

To our knowledge, this is the largest study to date examining trends in HF hospitalization rates across the United States. We found a relative 29.5% decline in the risk-adjusted HF hospitalization rate from 1998 to 2008 that was primarily the result of fewer unique individuals hospitalized for HF. The decline in HF hospitalizations is even more remarkable given that a small trend toward improved survival after HF hospitalization would allow for potentially more repeat hospitalizations for HF in a given year. In absolute terms, this implies that if the 2008 Medicare fee-for-service population of 27.3 million had an HF hospitalization rate similar to that of 1998, an additional 229 000 HF hospitalizations (95% CI, 219 000-238 000) would have been expected that did not occur. With a mean HF hospitalization cost of $18 000 in 2008, this decline represents a savings of $4.1 billion in fee-for-service Medicare.

Throughout this time, there were changes in risk factors and clinical practice patterns that may explain the decline in HF hospitalizations. First, the HF hospitalization rate may have decreased because of fewer incident HF cases. Risk factors for developing HF have decreased in recent years. For example, rates of coronary artery disease, accounting for more than 60% of...
HF cases, have decreased as demonstrated by studies reporting a decrease in acute myocardial infarction rates over the past decade. In addition, the risk of developing HF after myocardial infarction has declined over time, which may reflect improvements in myocardial salvage. Hypertension is another important cause of HF, and blood pressure control has improved modestly over time, which may have contributed to a decline in incident HF. Second, changes in secondary prevention may reduce HF exacerbations leading to hospitalization: HF treatments such as β-blockers, angiotensin-converting enzyme inhibitors, and angiotensin receptor blockers are known to reduce recurrent HF episodes, and use of many of these medications has increased over time. Device therapy has also become more common for HF patients, which may have led to fewer repeat HF episodes. Third, our findings may reflect changing clinical practice patterns favoring outpatient rather than inpatient management of HF. A study by Ezekowitz et al observed that hospitalizations represented a smaller proportion of HF cases (39% to 30%) from 2000-2006 in Alberta, Canada, with a corresponding increase toward outpatient and emergency department care. However, shifts away from inpatient to outpatient care of HF would be expected to affect HF hospitalization rates to a limited extent, as clinical discretion to avoid hospitalization would presumably exist only for HF cases of milder severity. While many of these factors may have contributed toward a decline in HF hospitalizations, our study is unable to determine causality.

Our finding of a substantial decline in HF hospitalizations is in contrast with studies from earlier time periods. In the Framingham Heart Study, the incidence of HF was generally stable between 1970 and 1999. A study of subjects living in Olmsted County, Minnesota, also suggested that HF incidence was unchanged from 1979 to 2000. In the National Hospital Discharge Survey, Fang et al found an increase in HF hospitalizations between 1979 and 2004 for patients aged 65 years and older. Our results may differ from these earlier studies because HF hospitalizations may have started to decline only recently. A study by Curtis et al used a 5% sample of Medicare inpatient and outpatient claims and reported a decline in HF incidence from 32.3 to 29.1 per 1000 person-years between 1994 and 2003; this data set selected 5 out of 100 Medicare fee-for-service beneficiaries based on the last 2 digits of a unique patient identifier. Studies from Sweden, Scotland, Australia, and New Zealand have also reported that HF hospitalization rates started to decline in the 1990s.

Differences in HF case ascertainment may also explain contrasts in HF trends across prior studies. For example, a study from southeast London reported that HF incidence (identified from both hospital and clinic visits) was unchanged between 1995-1997 and 2004-2005; data on HF hospitalization were not reported separately. The study by Ezekowitz et al reported that the HF incidence rate would have decreased more slowly if outpatient and emergency department visits were included in addition to hospitalizations. While our study only examined hospitalized HF cases, documenting a decline in HF hospitalizations over time is an important finding in its own right because it suggests that overall HF incidence or its sever-

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Figure 3. Risk-Standardized 1-Year Mortality Rate by State in 1999 and 2008

<table>
<thead>
<tr>
<th>1-Year mortality rate Distribution 1999</th>
<th>1999 (Mean 1-year mortality rate, 31.7%)</th>
<th>2008 (Mean 1-year mortality rate, 32.0%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>29.0-29.9%</td>
<td>30.0-30.9%</td>
<td>31.0-31.9%</td>
</tr>
<tr>
<td>32.0-32.9%</td>
<td>33.0-33.9%</td>
<td>34.0-34.9%</td>
</tr>
<tr>
<td>35.0-35.9%</td>
<td>36.0-36.9%</td>
<td>37.0-37.9%</td>
</tr>
</tbody>
</table>

Risk-standardized rate = observed rate/expected rate × unadjusted mean rate calculated independently for each year.

Significantly lower than national mean (2-sided P < .05) based on bootstrapped 95% CIs.

Significantly higher than national mean (2-sided P < .05) based on bootstrapped 95% CIs.

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ity has decreased or that the medical system is more effectively triaging a number of HF patients for outpatient or emergency department care.

Our study reveals a decline in the denominator of fee-for-service Medicare patients over 11 years, consistent with rising enrollment for Medicare managed care programs. However, Medicare managed care patients are likely healthier than their fee-for-service counterparts, a phenomenon that makes the observed decline in HF hospitalization rates in the fee-for-service population even more dramatic, considering the latter group would be expected to be composed of sicker patients. Although the decline in risk-adjusted 1-year mortality rate of an absolute 2.1 percentage points between 1999 and 2008 was statistically significant, we must be cautious in its interpretation. First, risk-adjusted 1-year mortality appeared to have a nadir in 2006, and thus more recent mortality trends may not be as favorable. In addition, we note that the absolute number of lives saved over time was modest. If the 2008 Medicare fee-for-service HF population had the 1-year mortality rate of 1998, this represents only an additional 8378 HF patients alive at 1 year. Although any improvements in HF survival are to be welcomed, reductions in 1-year mortality over the past decade were modest on an absolute scale. Lastly, not all states had equal decreases in 1-year mortality; in fact, 5 states had significant increases in 1-year mortality over the study period, indicating a need for better treatment strategies in these areas.

Our study found that some comorbidities appeared to have increased over time in patients hospitalized for HF. Although some of this increase may have represented changes in coding patterns by hospitals, clinical data from the National Health and Nutrition Examination Survey suggest that the prevalence of comorbidities has increased over time in HF patients, including hypertension and renal dysfunction. We conducted sensitivity analyses examining how adding comorbidities would affect the mortality models. Age-sex-race–adjusted models estimated a decline in 1-year mortality from 31.7% in 1999 to 30.6% in 2008, whereas additional adjustment for comorbidities resulted in a decline to 29.6% in 2008. This suggests that secular changes in comorbidity coding would be expected to have limited influence on the change in mortality rates.

The decline in 1-year mortality for HF hospitalizations is consistent with reports of improved survival in both Framingham and Olmsted County cohorts. In a prior study of Medicare beneficiaries, risk-adjusted 1-year mortality decreased between 1994 and 2002. These trends are also consistent with our earlier study reporting 30-day mortality from 1993 to 2006 (a decrease from 12.6% to 10.8%). A recent study from the Veterans Administration (VA) of patients 80 years and older reported that 1-year mortality decreased from 49% to 27% over 1998-2008. While our study did not find such a dramatic change, this may be due to differences in the respective patient populations: VA patients were nearly entirely male, and the risk profile of HF patients who seek care at VA vs non-VA hospitals may have changed over time. Our study was unable to identify the causes of improved survival after HF hospitalization, but we speculate that improvements in clinical care (pharmacologic, device, risk factor management) that led to decreased HF hospitalizations decreased mortality as well.

Although the HF hospitalization rate has decreased nationally, our results demonstrate this has occurred unevenly across race-sex categories, especially for black men, who had the lowest rate of decline. Similarly, 1-year mortality declined for all race-sex categories except for nonwhite nonblack women. Administrative data do not identify the reasons for these disparities but demonstrate important areas for future investigation into differences in clinical presentation and treatment patterns.

Our study was limited to the Medicare population, and trends in HF hospitalization and mortality may differ in younger patients with different types of insurance. We were unable to determine whether the observed changes were due to changes by hospitals in medical coding; however, substantial up-coding or down-coding would likely result in changes to the coefficients of the CMS HF mortality model, and these coefficients remained stable from 2005 to 2008. We were unable to determine whether certain subcategories of HF may have differed, ie, systolic vs diastolic HF, and ischemic vs nonischemic HF. Our study focused on HF hospitalizations and was not able to assess changes in HF care in outpatient clinics or emergency departments and as such may underestimate overall HF incidence rates. Heart failure diagnosis and presence of comorbidities were based on the presence of administrative codes and not clinically confirmed; however, administrative codes have been shown to be highly specific for cardiovascular diagnoses and risk factors.

CONCLUSION

From 1998 to 2008, the overall risk-adjusted HF hospitalization rate declined from 2845 to 2007 per 100 000 person-years among Medicare fee-for-service beneficiaries. This decline was principally due to fewer individual patients being hospitalized with HF rather than a reduction in the frequency of HF hospitalizations. Black men had the lowest rate of decline for HF hospitalization among race-sex groups. Risk-adjusted 1-year mortality with HF hospitalization was 31.7% in 1999 and 29.6% in 2008. Substantial geographic variation existed for both HF hospitalization and 1-year mortality rates, representing marked differences in outcomes that are not explained by insurance status.

Author Contributions: Dr Chen had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Chen, Krumholz. Acquisition of data: Krumholz. Analysis and interpretation of data: Chen, Nomand, Wang, Krumholz. Drafting of the manuscript: Chen, Krumholz. Critical revision of the manuscript for important intellectual content: Nomand, Wang.


