

National Trends in Recurrent AMI Hospitalizations 1 Year After Acute Myocardial Infarction in Medicare Beneficiaries: 1999–2010

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Background—There are few data characterizing temporal changes in hospitalization for recurrent acute myocardial infarction (AMI) after AMI.

Methods and Results—Using a national sample of 2 305 441 Medicare beneficiaries hospitalized for AMI from 1999 to 2010, we evaluated changes in the incidence of 1-year recurrent AMI hospitalization and mortality using Cox proportional hazards models. The observed recurrent AMI hospitalization rate declined from 12.1% (95% CI 11.9 to 12.2) in 1999 to 8.9% (95% CI 8.8 to 9.1) in 2010, a relative decline of 26.4%. The observed recurrent AMI hospitalization rate declined by a relative 27.7% in whites, from 11.9% (95% CI 11.8 to 12.1) to 8.6% (95% CI 8.5 to 8.8) versus a relative decline in blacks of 13.6% from 13.2% (95% CI 12.6 to 13.8) to 11.4% (95% CI 10.9 to 12.0). The risk-adjusted rate of annual decline in recurrent AMI hospitalizations was 4.1% (HR 0.959; 95% CI 0.958 to 0.961), and whites experienced a higher rate of decline (HR 0.957, 95% CI 0.956 to 0.959) than blacks (HR 0.974, 95% CI 0.970 to 0.979). The overall, observed 1-year mortality rate after hospitalization for recurrent AMI declined from 32.4% in 1999 to 29.7% in 2010, a relative decline of 8.3% ($P < 0.05$). In adjusted analyses, 1-year mortality after recurrent AMI hospitalization declined 1.8% per year (HR, 0.982; 95% CI 0.980 to 0.985).

Conclusions—In a national sample of Medicare beneficiaries hospitalized for AMI from 1999 to 2010, hospitalization for recurrent AMI decreased, as did subsequent mortality, albeit to a lesser extent. The risk of recurrent AMI hospitalization declined less in black patients than in whites, increasing observed racial disparities by the end of the study period. (*J Am Heart Assoc.* 2014;3:e001197 doi: 10.1161/JAHA.114.001197)

Key Words: epidemiology • mortality • myocardial infarction

Improvements in primary cardiovascular prevention, including control of hypertension, hyperlipidemia, and cigarette smoking, have translated into substantial declines

in hospitalizations and deaths due to acute myocardial infarction (AMI) over the past decade.¹ In contrast, there are few data characterizing the incidence of hospitalization for recurrent AMI. Previous studies of recurrent AMI have evaluated subjects before the introduction of modern cardiovascular prevention strategies^{2,3} or have been constrained to demographically and geographically homogeneous populations.^{4–8} Increasing use of routine revascularization for AMI⁹ and secondary prevention therapies^{10–15} may have reduced rates of hospitalization for recurrent AMI over the past decade. Conversely, improved AMI survival rates may have created a population at higher risk of hospitalization for recurrent AMI.¹⁶

Accordingly, we sought to examine recent national trends in the occurrence and outcomes (ie, mortality) of recurrent AMI hospitalization using a complete sample of fee-for-service Medicare beneficiaries hospitalized for AMI from 1999 to 2010. Medicare data provide sufficient numbers to precisely estimate changes in recurrent AMI hospitalization rates, and to examine differences between relevant demographic subgroups. Comparing trends in recurrent AMI hospitalization rates between age groups merits attention because older patients are at particularly high risk for recurrent cardiovascular events.

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In addition, previous work evaluating recent temporal trends in AMI hospitalization rates has shown that black men and women experienced a lower decline in AMI hospitalization rate than their white counterparts,¹ but it is unknown whether such differences also exist in recurrent AMI hospitalization rates. These analyses can provide insight about whether contemporary management strategies for AMI have resulted in decreasing rates of recurrent AMI hospitalization, and whether these gains have been shared equally across demographic subgroups.

Methods

Data Source

We used Medicare Provider Analysis and Review inpatient data from the Centers for Medicare and Medicaid Services to identify a complete sample of fee-for-service Medicare beneficiaries who were hospitalized for AMI between January 1, 1999 and December 31, 2011. These administrative billing claims data include information on patient demographics (age, sex, and race), admission and discharge dates, and principal and secondary diagnosis codes as coded by the International Classification of Diseases, Ninth Revision, Clinical Modification. Medicare denominator files were used to ascertain beneficiary eligibility, and enrollment in fee-for-service Medicare. Institutional Review Board review and approval was obtained through the Yale University Human Investigation Committee. Medicare claims data were provided through a data use agreement with Centers for Medicare and Medicaid Services.

Study Sample

Subjects were included if they were aged 65 years or older and discharged alive from an acute care hospital with a principal discharge diagnosis of AMI (International Classification of Diseases, Ninth Revision, Clinical Modification code: 410.xx) between January 1, 1999 and December 31, 2010. We identified the first admission for AMI during the study period as the “index AMI” hospitalization and the first subsequent AMI admission as the “recurrent AMI hospitalization.” We excluded patients with principal discharge diagnosis International Classification of Diseases, Ninth Revision, Clinical Modification codes 410.x2, as these represent subsequent episodes of care related to the index AMI. Patients with a total length of stay of ≤ 1 day were excluded, as those hospitalizations are unlikely to represent true AMI. We also excluded (1) beneficiaries aged < 65 years; (2) beneficiaries without ≥ 1 year of Medicare fee-for-service enrollment before and after their index AMI hospitalization, as data would be limited to assess comorbidity (see “Patient Characteristics” section below) and outcomes; (3) beneficiaries with conflicting

dates of death and hospitalization; and (4) patients who were subsequently transferred to another acute care hospital for continuing care after an initial AMI. Patients who died during the 1-year follow up period without experiencing hospitalization for recurrent AMI were censored at the time of death; all others were censored at the end of the follow-up period.

Patient Characteristics

We used the Medicare Provider Analysis and Review data set to collect information on patient characteristics, including age, sex, race, and comorbidities. Race was determined from the Medicare denominator files, which use patient-reported data from the Social Security Administration. Coexisting illnesses were classified according to the categorization used by Centers for Medicare and Medicaid Services for the AMI 30-day mortality measure.¹⁷ We identified comorbidities from both primary and secondary diagnosis codes of all patient hospitalizations up to 1 year before the initial hospitalization for AMI. For example, the inpatient data from 1998 were used to obtain comorbidity information on patients who were hospitalized for AMI in 1999.

Outcomes

Our first study outcome was recurrent AMI within 1 year of (admission for) the index AMI. Our second outcome was 1-year all-cause mortality rates among patients who were hospitalized for recurrent AMI.

Statistical Analysis

Baseline characteristics of patients hospitalized for AMI during the study period were collapsed into 3-year intervals to simplify presentation, and we used the Cochran–Armitage trend test to examine the significance of trends. We used Cox proportional hazards regression models to assess annual trends in recurrent AMI hospitalization rates, adjusting for age, sex, race, and all comorbidities shown in Table. We fitted separate Cox models to analyze trends in recurrent AMI hospitalization rates among subgroups (ie, age, sex, and race). All Cox models included an ordinal time variable, ranging from 0 to 11, corresponding to years 1999 (time=0) through 2010 (time=11) to represent the risk-adjusted annual trend in 1-year recurrent AMI hospitalizations. Similarly, Cox proportional hazards regression models were used to analyze 1-year mortality among patients who experienced recurrent AMI hospitalization.

Y.W. conducted all analyses using SAS 9.3 64-bit version (SAS Institute Inc, Cary, NC), and takes responsibility for the accuracy of the results. Hazard ratios are reported with 95% CI. Statistical tests were 2-sided at a significance level of 0.05. The Yale University Human Investigation Committee

Table. Patient Characteristics

Characteristics	1999–2001	2002–2004	2005–2007	2008–2010	Cumulative
Total	592 255	631 114	565 082	516 990	2 305 441
Age in years, mean (SD)	78.8 (7.8)	78.8 (8.1)	78.9 (8.3)	78.9 (8.5)	78.8 (8.2)
Female, n (%)	303 715 (51.3)	321 297 (50.9)	282 310 (50.0)	254 543 (49.2)	1 161 865 (50.4)
White, n (%)	525 818 (88.8)	555 212 (88.0)	496 067 (87.8)	452 153 (87.5)	2 029 250 (88.0)
Black, n (%)	42 645 (7.2)	47 188 (7.5)	43 024 (7.6)	40 325 (7.8)	173 182 (7.5)
Other race, n (%)	23 792 (4.0)	28 714 (4.5)	25 991 (4.6)	24 512 (4.7)	103 009 (4.5)
Comorbidity, n (%)					
Coronary artery disease	413 276 (69.8)	459 239 (72.8)	415 081 (73.5)	383 472 (74.2)	1 671 068 (72.5)
Hypertension	326 468 (55.1)	373 051 (59.1)	344 592 (61.0)	343 818 (66.5)	1 387 929 (60.2)
Diabetes	182 534 (30.8)	199 071 (31.5)	177 807 (31.5)	164 339 (31.8)	723 751 (31.4)
COPD	135 963 (23.0)	152 168 (24.1)	139 223 (24.6)	106 540 (20.6)	533 894 (23.2)
Congestive heart failure	95 656 (16.1)	102 466 (16.2)	90 212 (16.0)	79 159 (15.3)	367 493 (15.9)
Pneumonia	73 783 (12.5)	87 483 (13.9)	81 442 (14.4)	79 956 (15.5)	322 664 (14.0)
Dementia	56 303 (9.5)	66 764 (10.6)	60 434 (10.7)	58 597 (11.3)	242 098 (10.5)
Renal failure	27 923 (4.7)	38 572 (6.1)	54 477 (9.6)	66 316 (12.8)	187 288 (8.1)
Peripheral vascular disease	38 715 (6.5)	44 107 (7.0)	39 733 (7.0)	35 977 (7.0)	158 532 (6.9)
Cancer	37 070 (6.3)	40 736 (6.5)	37 047 (6.6)	34 393 (6.7)	149 246 (6.5)
Trauma	31 268 (5.3)	38 071 (6.0)	36 030 (6.4)	32 167 (6.2)	137 536 (6.0)
Depression	27 372 (4.6)	34 267 (5.4)	30 676 (5.4)	28 552 (5.5)	120 867 (5.2)
History of MI	29 546 (5.0)	32 848 (5.2)	27 353 (4.8)	26 107 (5.0)	115 854 (5.0)
Cerebrovascular disease	33 581 (5.7)	32 471 (5.1)	25 257 (4.5)	22 256 (4.3)	113 565 (4.9)
Unstable angina	36 748 (6.2)	31 937 (5.1)	22 021 (3.9)	17 102 (3.3)	107 808 (4.7)
Respiratory failure	15 475 (2.6)	17 774 (2.8)	20 445 (3.6)	25 121 (4.9)	78 815 (3.4)
Malnutrition	13 212 (2.2)	16 266 (2.6)	17 528 (3.1)	23 703 (4.6)	70 709 (3.1)
Functional disability	15 897 (2.7)	16 246 (2.6)	12 807 (2.3)	13 409 (2.6)	58 359 (2.5)
Stroke	12 731 (2.1)	12 653 (2.0)	10 802 (1.9)	9649 (1.9)	45 835 (2.0)
Psychiatric disease	11 536 (1.9)	12 202 (1.9)	10 029 (1.8)	10 877 (2.1)	44 644 (1.9)
Liver disease	2980 (0.5)	3730 (0.6)	3566 (0.6)	3291 (0.6)	13 567 (0.6)
Length of stay, mean (SD)	7.1 (6.2)	6.8 (6.2)	6.4 (5.9)	5.9 (5.4)	6.5 (5.4)
Discharged to home, n (%)	367 198 (62.0)	365 415 (57.9)	314 186 (55.6)	286 929 (55.5)	1 332 545 (57.8)
Discharged to ICF/SNF, n (%)	114 897 (19.4)	126 223 (20.0)	115 842 (20.5)	102 881 (19.9)	461 088 (20.0)
Discharged to home care, n (%)	76 993 (13.0)	89 618 (14.2)	89 283 (15.8)	81 684 (15.8)	336 594 (14.6)
Discharged to hospice, n (%)	148 064 (0.25)	8836 (1.4)	14 692 (2.6)	17 061 (3.3)	41 498 (1.8)

COPD indicates chronic obstructive pulmonary disease; MI, myocardial infarction; ICF, intermediate care facility; SNF, skilled nursing facility.

approved the study and waived the requirement for participant informed consent.

Results

Patient Characteristics

During the 12-year study period, 3 067 263 patients experienced an index AMI hospitalization. The number of patients who

experienced an index AMI hospitalization decreased from 1283 (95% CI 1278 to 1287) per 100 000 person-years in 1999 to 830 (95% CI 827 to 833) per 100 000 person-years in 2010. Among patients who experienced an index AMI hospitalization, 2 305 441 were enrolled continuously in the Medicare fee-for-service program for at least 12 months before and 12 months following (in the absence of death) the index AMI hospitalization, were discharged alive after at least 1 day, and were not transferred to another short-term acute-care hospital.

The characteristics of the patients in the final study sample are presented in Table. The mean age was 78.8 years (SD 8.2 years), 50.4% were women, and 12.0% were of nonwhite race. The most common comorbidities were coronary artery disease (72.5%), hypertension (60.2%), diabetes (31.4%), chronic obstructive pulmonary disease (COPD) (23.2%), and heart failure (15.9%).

There were several notable (and statistically significant, $P < 0.05$) changes in the characteristics of patients hospitalized for AMI during the 12-year study period. The percentage of females decreased from 51.1% in 1999 to 48.8% in 2010, and the percentage of nonwhites increased from 11.0% to 12.7%. The prevalence of a diagnosis of coronary artery disease prior to the index MI and hypertension both increased over the study period, from 68.3% to 74.1% and 53.1% to 66.9%, respectively. The prevalence of renal failure also increased notably from 4.2% to 13.5%. The mean length of stay decreased from 7.2 days (SD 6.2 days) in 1999 to 5.6 days (SD 5.3 days) in 2010. The percentage of patients discharged to home decreased over the study period (62.6% to 56.0%), while the percentage of patients discharged to home care increased (13.4% to 15.9%). Among participants who did not experience a recurrent AMI hospitalization during the year following an initial AMI hospitalization, the 1-year mortality declined from 21.7% (95% CI, 21.6 to 21.9) in 1999 to 21.1% (95% CI, 20.9 to 21.3) in 2010.

One-Year Recurrent AMI Hospitalization Rate

The overall (during the entire study period) 1-year recurrent AMI hospitalization rate was 10.1% (95% CI 10.0 to 10.1). The mean number of days until readmission for recurrent AMI increased from 108 in 1999 to 117 in 2010 ($P < 0.05$).

The observed (ie, unadjusted) annual recurrent AMI hospitalization rate declined from 12.1% (95% CI 11.9 to 12.2) in 1999 to 8.9% (95% CI 8.8 to 9.1) in 2010, a relative decline of 26.4% (Figure 1). The mean, relative annual decline was 2.4%. The decline in recurrent AMI hospitalization rate was observed among all demographic subgroups (Figure 1). Throughout the study period, the lowest recurrent AMI hospitalization rate was observed in those 65 to 74 years old (9.5%, 95% CI 9.2 to 9.7). Although a decline in recurrent AMI hospitalization rate was observed in both males and females, females consistently had a higher rate of recurrent AMI hospitalization than males over the course of the study period. The recurrent AMI hospitalization rate declined by a relative 27.0% in females, from 12.6% (95% CI 12.4 to 12.9) in 1999 to 9.2% (95% CI 9.0 to 9.5) in 2010, and by 25.2% in males, from 11.5% (95% CI 11.3 to 11.7) in 1999 to 8.6% (95% CI 8.4 to 8.8) in 2010. When compared by race, the reduction in recurrent AMI hospitalization rate was larger in whites than blacks. The recurrent AMI hospitalization rate declined by a relative 27.7% in whites, from 11.9% (95% CI

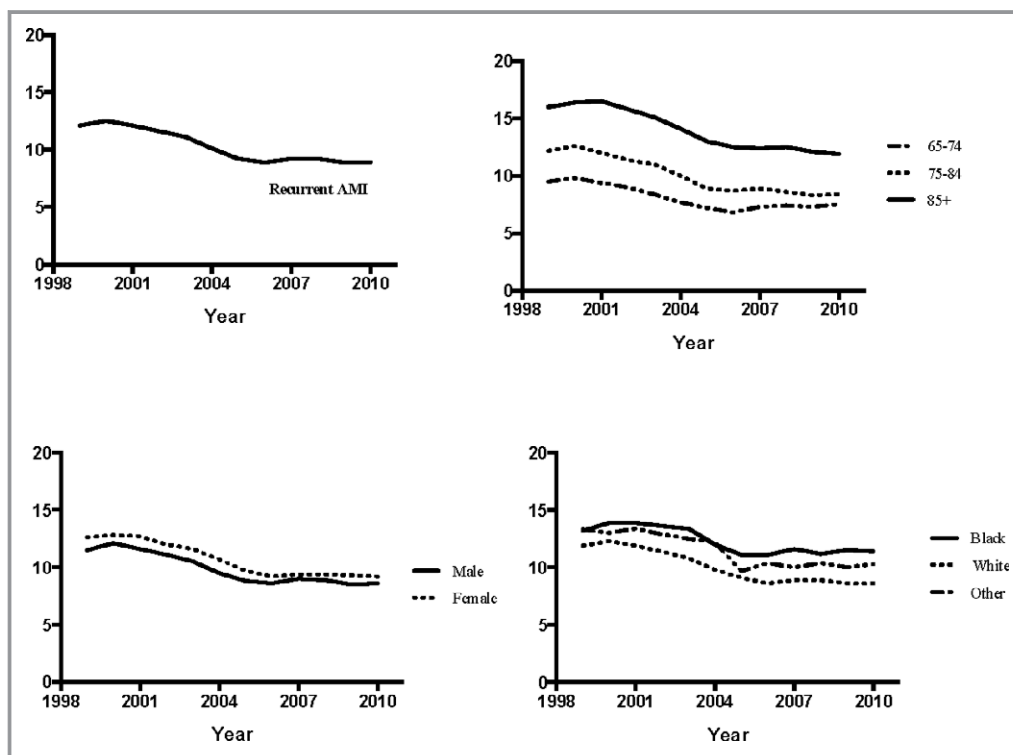


Figure 1. Observed 1-year rates of recurrent acute myocardial infarction (AMI) hospitalization.

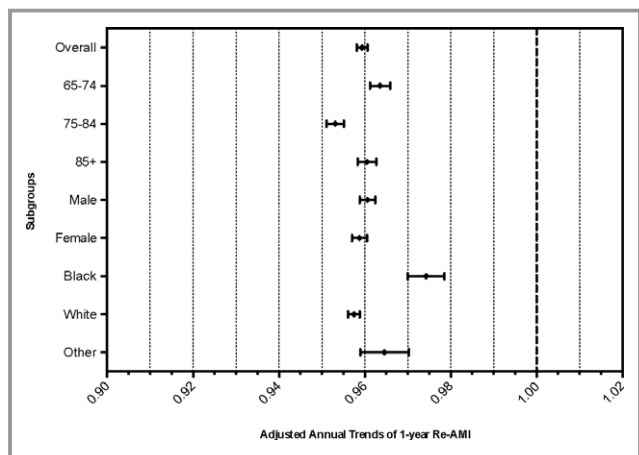


Figure 2. Risk-adjusted annual trends in reinfarction rates. Cox proportional hazards regression models were used to assess annual trends in recurrent acute myocardial infarction (AMI) hospitalization rates, adjusting for age, sex, race, and all comorbidities shown in Table.

11.8 to 12.1) to 8.6% (95% CI 8.5 to 8.8) versus a relative decline in blacks of 13.6% from 13.2% (95% CI 12.6 to 13.8) to 11.4% (95% CI 10.9 to 12.0). The discrepancy between recurrent AMI hospitalization rates in whites and blacks was therefore higher by the end of the study period (ie, 8.6% versus 11.4%) compared with the beginning (11.9% versus 13.2%).

As shown in Figure 2, after adjusting for demographic and clinical covariates, the overall risk-adjusted rate of

annual decline in recurrent AMI hospitalizations was 4.1%, corresponding to a HR of 0.959 (95% CI 0.958 to 0.961). The rate of annual decline was highest among those 75 to 84 years of age, HR 0.953 (95% CI 0.951 to 0.955). While males and females had similar adjusted rates of decline in recurrent AMI hospitalization, whites experienced a statistically significantly higher rate of decline (HR 0.957, 95% CI 0.956 to 0.959) than black patients (HR 0.974, 95% CI 0.970 to 0.979).

1-Year All-Cause Mortality After Recurrent AMI Hospitalization

The overall, observed 1-year mortality rate after hospitalization for recurrent AMI declined from 32.4% in 1999 to 29.7% in 2010, a relative decline of 8.3% ($P<0.05$) (Figure 3). Within age subgroups, the decline in 1-year mortality was greatest among those 75 to 84 years of age, declining relatively 16.4%, from 31.7% in 1999 to 26.5% in 2010 ($P<0.05$). Declines in 1-year mortality were observed across both sexes and all races. Consistently higher 1-year mortality rates were observed in females compared with males: 30.8% versus 28.5% by 2010 ($P<0.0001$).

In adjusted analyses, (Figure 4) the 1-year mortality declined 1.8% per year (HR 0.982 [95% CI 0.980 to 0.985]). Among the age subgroups, the lowest rate of decline was observed in those over 85 years of age (HR 0.988 [95% CI 0.984 to 0.993]). Adjusted rates of mortality decline were similar in both sexes and in all racial groups.

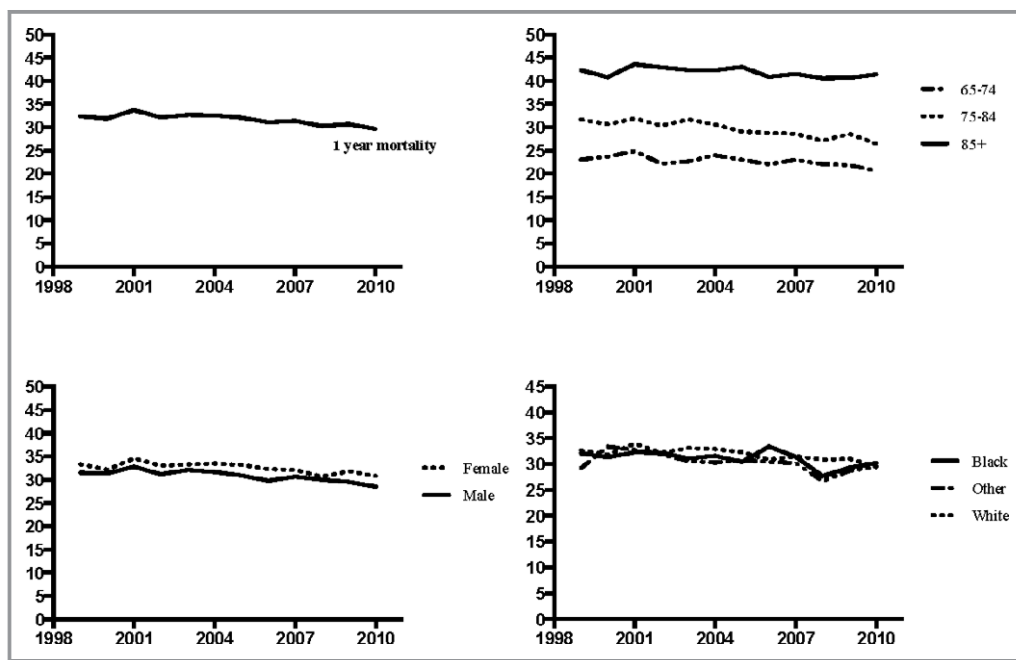


Figure 3. Observed 1-year rates of mortality.

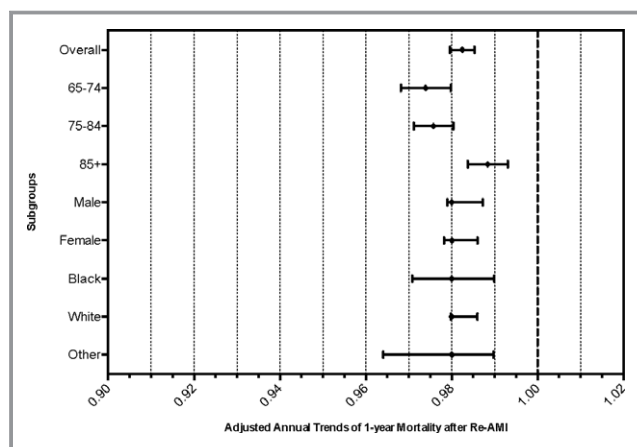


Figure 4. Risk-adjusted annual trends in 1-year mortality. Cox proportional hazards regression models were used to assess annual trends in mortality rates, adjusting for age, sex, race, and all comorbidities shown in Table. AMI indicates acute myocardial infarction.

Discussion

In a national sample of Medicare fee-for-service beneficiaries, we found that the incidence of recurrent AMI hospitalization declined substantially from 1999 to 2010. The overall risk-adjusted rate of annual decline in recurrent AMI hospitalizations was 4.1%. Declines were seen in all demographic groups, but blacks had less decline in recurrent AMI hospitalizations as compared with whites. Females and those in the oldest age group (85 years and older) remained at higher risk for recurrent AMI hospitalization throughout the study period, compared with males and younger persons, respectively. When considering risk-adjusted mortality after hospitalization for recurrent AMI, there was an annual decline of 1.8%, and females again had persistently higher mortality than males.

Our analysis extends prior work examining temporal trends in recurrent AMI hospitalization rates. A Swedish study found an adjusted decrease in average risk of 2.5% per calendar year for women and 3.1% for men for recurrent AMI from 1972 to 2001.⁴ A decline of 5.9% per year in the rate of recurrent AMI was observed in the Danish MONICA population from 1982 to 1991,⁵ and similar decreases in the rate of recurrent AMI were observed during this time period in Iceland⁶ and Finland.^{7,8} In the United States, a decline in annual rate of recurrent AMI in men (2.6% per year) and women (1.9% per year) was reported between 1987 and 1994 in 4 different United States communities in the ARIC study.^{18,19} Notably, these previous studies do not include contemporary data from a racially diverse population. To our knowledge, our study is the first to examine changes in the rate of hospitalization for recurrent AMI after AMI over the last decade using US-based national data.

Although we cannot identify the specific reasons for the decline in recurrent AMI hospitalizations and 1-year mortality rates, several theories might explain these observations. One possible explanation is that the improvements may reflect the implementation of secondary prevention as recommended by the American College of Cardiology and American Heart Association, including increasing use of aspirin, β -blockers, angiotensin converting enzyme inhibitors, thienopyridines, and statins.^{20–25} A study based on the Global Registry of Acute Coronary Events, which includes data from 113 hospitals across 14 countries, reported that use of these medications increased in AMI patients from 23% in 2000 to 58% in 2005,²⁵ findings similar to the increases reported in the Worcester, Mass study from 1995 to 2005.²³ Furthermore, the use of percutaneous coronary intervention has increased substantially over the last decade, which may also have contributed to improved outcomes. A recent study based on the United States Nationwide Inpatient Sample database, an all-payer inpatient care database from 1000 hospitals, reported that percutaneous coronary intervention for ST-segment elevation myocardial infarction increased by 33.5% among patients aged 65 to 79 and 22% in patients >80 years of age in the United States from 2001 to 2010.²⁶ Of note, the observed decrease in recurrent AMI hospitalizations occurred despite the increasing use of high-sensitivity troponin assays to diagnose AMI over the study period. It is possible that the observed decrease would have been even greater if laboratory assays for AMI diagnosis had not changed.

While the overall declines in recurrent AMI hospitalization and subsequent mortality rates over the past decade are encouraging, not all groups benefitted equally from improvements in recurrent AMI hospitalizations. When compared by race, the reduction in observed, recurrent AMI hospitalization rate in whites was double that seen in blacks, with a relative decline of 27.7% versus 13.6% from 1999 to 2010 ($P < 0.05$). Racial disparities in recurrent AMI hospitalization rates thereby actually widened over the study period. The explanation for the attenuated decline observed in black patients is likely multifactorial. A higher prevalence of cardiac risk factors (hypertension, diabetes, smoking, obesity), as well as socioeconomic factors (ie, healthcare access, insurance) leading to differences in quality of care have been linked to worse outcomes in blacks as compared to whites.^{27–30} As multivariable models were constructed separately for each demographic subgroup, it is possible that differences in cardiac risk factors contributed to the differences observed between blacks and whites in recurrent AMI hospitalization rates. Furthermore, some evidence suggests that nonwhite race is a risk factor for nonadherence to recommended American College of Cardiology/American Heart Association guidelines for treatment of AMI.^{31–34} A study of AMI patients in the 1992–2003 Medicare Current Beneficiary Survey reported

that while overall combination drug therapy increased over the study period, nonwhite race was independently associated with suboptimal treatment.³⁴ Notably, mortality rates were similar in blacks and whites, making differential censoring an unlikely explanation for the differences in recurrent AMI hospitalization.

There are several potential limitations in our study. Our data are based on the Medicare fee-for-service population, and trends in recurrent AMI hospitalizations may differ in younger patients or those with different health insurance. Because we relied on administrative data, we were also not able to obtain detailed clinical information about risk factor profiles (eg, cigarette smoking), mechanism of recurrent MI (eg, stent thrombosis), and cause of death. Comorbidities were ascertained from administrative codes and not clinically confirmed, and hospitals may have changed patterns of medical coding over time. Finally, we used a linear model to examine changes in recurrent AMI rates. The decline in recurrent AMI appears to diminish in the final years of the study period, and future studies are needed to determine whether there is continuing decline in recent years.

Conclusions

In a national cohort of Medicare patients, the risk-adjusted rate of annual decline in recurrent AMI hospitalizations was 4.1% from 1999 to 2010. The risk-adjusted rate of annual decline in mortality within 1 year after recurrent AMI hospitalization was 1.8% during this period. Improvements in recurrent AMI hospitalization rates were significantly attenuated in black patients, resulting in widened racial disparities by the end of the study period. Future work should examine strategies to ensure that gains realized in post-AMI outcomes can be shared equally among all patients, regardless of race.

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Disclosures

Dr Krumholz works under contract with the Centers for Medicare & Medicaid Services to develop and maintain performance measures; he is also a recipient of research grants from Medtronic and from Johnson & Johnson, through Yale University, to develop methods of clinical data sharing. Dr Krumholz is the chair of a cardiac scientific advisory board for UnitedHealth. Dr Masoudi has contracts with the Oklahoma Foundation for Medical Quality and the American College of Cardiology Foundation. All other authors (Chaudhry, Khan, Dharmarajan, Wang, and Dodson)—none.

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