

Geographic Disparities in the Incidence and Outcomes of Hospitalized Myocardial Infarction

Does a Rising Tide Lift All Boats?

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Background—Improvements in prevention have led to declines in incidence and mortality of myocardial infarction (MI) in selected populations. However, no studies have examined regional differences in recent trends in MI incidence, and few have examined whether known regional disparities in MI care have narrowed over time.

Methods and Results—We compared trends in incidence rates of MI, associated procedures and mortality for all US Census Divisions (regions) in Medicare fee-for-service patients between 2000–2008 (292 773 151 patient-years). Two-stage hierarchical models were used to account for patient characteristics and state-level random effects. To assess trends in geographic disparities, we calculated changes in between-state variance for outcomes over time. Although the incidence of MI declined in all regions ($P < 0.001$ for trend for each) between 2000–2008, adjusted rates of decline varied by region (annual declines ranging from 2.9–6.1%). Widening geographic disparities, as measured by percent change of between-state variance from 2000–2008, were observed for MI incidence (37.6% increase, $P = 0.03$) and percutaneous coronary intervention rates (31.4% increase, $P = 0.06$). Significant declines in risk-adjusted 30-day mortality were observed in all regions, with the fastest declines observed in states with higher baseline mortality rates.

Conclusions—In a large contemporary analysis of geographic trends in MI epidemiology, the incidence of MI and associated mortality declined significantly in all US Census Divisions between 2000–2008. Although geographic disparities in MI incidence may have increased, regional differences in MI-associated mortality have narrowed. (*Circ Cardiovasc Qual Outcomes*. 2012;5:197-204.)

Key Words: myocardial infarction ■ Medicare ■ trends ■ disparities

Acute myocardial infarction (MI) remains one of the leading causes of morbidity and mortality in the United States.¹ However, over the previous decade, a number of primary and secondary prevention strategies for MI have been adopted, resulting in better control of cardiovascular risk factors.^{2–4} Several studies suggest that these improvements are coincident with, and perhaps responsible for, recent declines in the incidence of MI in several populations.^{5–7}

However, geographic variation in the prevalence of coronary risk factors, health care utilization, and coronary disease-related mortality are well known.^{8–11} As strategies to prevent MIs have become more widely adopted, understanding whether declines in the incidence of MI have occurred similarly across populations and whether geographic disparities in cardiovascular care have narrowed serves as an

important measure of equity in our health care system. To date, no studies have examined regional differences in recent trends in MI incidence.

As a large national dynamic cohort of patients for whom demographic and clinical information is collected, Medicare beneficiaries make up one of the few populations that permits an accurate comparison of trends in cardiovascular disease burden across geographic regions.^{12,13} We estimated and compared temporal trends in the incidence of MI, rates of revascularization, and short-term mortality in the Medicare fee-for-service population across geographic regions during the last decade. We sought to examine (1) whether there have been significant regional disparities in MI incidence, treatment, and outcomes during this time period and (2) whether these regional disparities have changed over time.

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WHAT IS KNOWN

- Geographic disparities in cardiovascular disease burden and outcomes in the United States are well described historically.
- Several studies have shown recent substantial declines in myocardial infarction incidence and mortality in selected populations.
- Whether these trends have occurred similarly across geographic regions or whether disproportionate improvements have led to increasing disparities is unknown.

WHAT THE STUDY ADDS

- We demonstrate that significant declines in incidence of myocardial infarction and 30-day mortality have occurred across all US Census Divisions.
- Despite these declines, wide geographic disparities in myocardial infarction incidence and associated rates of percutaneous coronary intervention have persisted and perhaps widened.
- On the other hand, geographic disparities in 30-day mortality rates after myocardial infarction have declined.
- Efforts to reduce cardiovascular disparities may be best served at disseminating best practices at the primary prevention rather than hospital level.

Methods

Study Sample

We examined data on individuals enrolled in Medicare fee-for-service (FFS) from the Medicare beneficiary denominator file between January 1, 2000, and December 31, 2008. We identified 394 194 478 beneficiaries totaled over all years of the study. Of these, only beneficiaries older than 65 years at the beginning of each year residing within the 50 states and the District of Columbia were included in the analysis (n=292 825 626). We calculated person-years of follow-up for each beneficiary to account for new enrollment, disenrollment, or death during an index year. We linked these data with the Medicare Provider Analysis and Review (MEDPAR) files to obtain information on patient demographics, coexisting illnesses, and hospitalization for MI. The MEDPAR files contain information on all hospitalizations for FFS Medicare beneficiaries, including demographic information, zip codes of beneficiaries' primary residence, discharge diagnoses, and procedure codes. We excluded patients who could not be merged with the Medicare denominator file (n=52 475). Reasons for inability to merge included incorrect MEDPAR beneficiary identification code or sex code. The remaining 292 773 151 beneficiaries were included in the analysis.

Our interest was in measuring the incidence rates of the first hospitalized MI each year. We therefore included the first hospitalization for each patient each year with a primary discharge diagnosis of MI based on *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) codes 410.xx, except 410.x2, similar to previous approaches.⁶ Hospitalizations for MI in which patients were discharged alive within 1 day of admission not against medical advice and not transferred to a different facility were excluded because these are unlikely to have represented true MIs.¹⁴ Hospital transfers occurring within 1 calendar day were linked to form a single episode of care. We excluded patients who were not continuously enrolled in the 12-month period before the index MI hospitalization.

Patient Characteristics

We used the Hierarchical Condition Categories (HCC) to assemble variables reflecting patient coexisting conditions.¹⁵ These HCC variables were generated using secondary diagnosis and procedure codes from the index hospitalization, and primary and secondary diagnosis codes from hospitalizations in the 12 months before the index MI, including hospitalizations in 1999 for patients hospitalized for MI in the year 2000.

Cardiac Catheterization, Revascularization, and Short-Term Mortality

To compare trends in the utilization of diagnostic and therapeutic procedures across geographic regions, we identified all cases of in-hospital cardiac catheterization, percutaneous coronary intervention (PCI), and coronary artery bypass graft surgery (CABG) up to 30 days after MI using relevant ICD-9-CM and procedure codes (online-only Data Supplement Table 1). Similar to previous studies, we selected 30 days after the index event, based on the assumption that this would be a sufficient time period to capture the vast majority of associated procedures.^{5,16} We also examined all-cause mortality occurring during the hospitalization and at 30 days after admission, obtained from MEDPAR data and the Medicare denominator file, respectively.

Statistical Analyses

The principal geographic units of interest were US Census Bureau divisions, due to observed differences in the prevalence of cardiovascular risk factors observed between divisions, and states, due to differences in policies influencing cardiovascular public health occurring at the state level.^{11,17} The US Census Bureau has designated grouping of states into the 9 census divisions since 1910 for the presentation of data.¹⁸ We assigned all patients to states, based on the zip code of their primary residence. We then assigned states to US Census Bureau divisions, denoted in the present report as regions (online-only Data Supplement Table 2). For each year of the study, we calculated crude incidence rates of the first hospitalized MI per 100 000 person-years for each state and region. In addition, we calculated crude rates of cardiac catheterization, PCI, and CABG within 30 days after admission (online-only Data Supplement Figure 1).

Assessing Trends

To estimate and compare rates of change in the incidence of MI across regions, we developed 2-stage hierarchical Poisson regression models. In the first stage, we estimated a model with state-specific random intercepts and state-specific random year effects adjusted for age, sex, and race. Year was modeled as a continuous variable after visual inspection of crude incidence rates revealed linear trends. In the second stage, we permitted the state-specific baseline incidences (random intercepts) and state-specific annual rates of change (random slopes) to vary by US Census Division through the inclusion of dummy variables (indicators) for each division.

We used similar methods to compare trends in rates of 30-day cardiac catheterization, PCI, and CABG across regions, adjusted for age, sex, and race, and 30-day all cause mortality across regions, adjusted for age, sex, race, and comorbidities as ascertained by HCCs. Detailed descriptions of all hierarchical models can be found in the online-only Data Supplement Materials.

Testing for Geographic Disparities

To assess whether geographic differences in incidence, treatment, and outcomes of MI widened or narrowed over the study period, we first fitted 2 separate hierarchical models to obtain between-state variances in the years 2000 and 2008, separately. Specifically, for the year 2000 and then again for the year 2008, we fitted hierarchical models with state-specific random intercepts, adjusted similarly as above but without the variable "year." We then estimated the percentage change in the between-state variance, comparing years 2000 versus 2008. This was performed for adjusted incidence rates of MI, adjusted rates of cardiac catheterization, PCI, CABG, and adjusted 30-day mortality risk over the study period. These values

Table 1. Clinical Characteristics of Medicare Fee-for-Service Patients Hospitalized for Myocardial Infarction by US Census Division, 2000–2008

Characteristics	EN Central	ES Central	Mid Atlantic	Mountain	New England	Pacific	South Atlantic	WN Central	WS Central	Overall
Total	429 994	169 298	347 923	96 596	131 576	195 586	474 129	179 723	238 789	2 263 614
Age, y, mean (SD)	79.5 (7.6)	78.6 (7.6)	80.5 (7.7)	78.7 (7.5)	80.4 (7.6)	79.8 (7.8)	79.2 (7.6)	79.5 (7.7)	78.8 (7.6)	79.5 (7.7)
Female, %	51.8	51.5	53.4	45.0	52.5	48.8	50.7	49.2	50.3	50.9
White, %	91.3	88.8	90.5	92.4	95.7	82.6	86.1	95.7	84.8	89.1
Black, %	6.9	10.2	6.0	1.4	2.0	3.8	10.8	2.5	8.8	6.9
Other, %	1.8	1.0	3.6	6.2	2.3	13.6	3.1	1.8	6.4	4.0
Anterior MI, %	11.8	12.3	11.5	15.9	11.8	13.9	11.8	13.2	12.9	12.4
Inferolateral MI, %	16.0	16.5	14.1	21.6	14.7	17.8	15.3	17.8	16.4	16.1
History of CHF, %	16.5	17.1	17.6	10.6	15.8	13.9	15.9	13.6	16.2	15.8
History of MI, %	4.8	4.5	5.4	3.2	5.5	4.2	4.7	4.2	4.5	4.7
Unstable angina, %	4.4	4.7	4.8	3.4	4.6	3.9	4.9	3.9	4.6	4.5
Chronic atherosclerosis, %	69.2	69.3	65.5	70.1	65.4	65.5	67.0	70.3	69.1	67.8
Hypertension, %	59.8	60.5	60.3	56.5	59.6	56.8	59.4	58.9	60.4	59.4
Stroke, %	2.0	2.3	2.0	1.4	1.7	1.9	2.1	1.7	2.1	2.0
Cerebrovascular disease, %	5.2	5.9	5.1	3.7	4.5	4.5	5.3	4.7	5.7	5.1
Renal failure, %	7.1	6.5	7.0	4.4	7.1	6.0	7.0	5.1	5.8	6.5
COPD, %	24.3	26.6	23.1	21.3	22.6	21.9	25.6	21.3	23.8	23.8
Pneumonia, %	14.6	15.0	14.8	11.6	15.0	13.9	14.0	13.2	14.7	14.3
Protein calorie malnutrition, %	3.1	3.3	2.5	2.3	1.9	2.8	3.0	2.3	3.4	2.9
Dementia, %	10.3	11.7	11.8	7.7	10.3	10.7	10.9	8.5	10.6	10.6
Functional disability, %	2.8	2.6	2.9	1.8	2.3	2.8	2.6	2.2	2.9	2.6
Peripheral vascular disease, %	7.1	7.2	7.0	4.7	6.6	5.5	7.2	5.8	6.9	6.7
Metastatic cancer, %	6.7	6.0	7.4	5.6	7.2	6.3	6.5	6.2	5.9	6.5
Trauma in past year, %	5.9	5.5	6.1	6.2	6.5	6.8	5.9	5.8	5.8	6.0
Major psychiatric disorder, %	2.1	2.3	2.1	1.4	2.2	1.9	2.1	2.0	2.2	2.1
Chronic liver disease, %	0.5	0.5	0.6	0.6	0.6	0.8	0.6	0.4	0.7	0.6
Depression, %	5.4	5.3	5.9	4.7	6.2	4.4	5.3	5.7	4.9	5.3
Diabetes, %	31.1	31.5	32.3	25.5	30.7	29.1	31.2	28.4	31.4	30.7

EN indicates East North; ES, East South; WN, West North; WS, West South; MI, myocardial infarction; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease.

were calculated by subtracting the residual between-state variance estimated in 2000 from that estimated in 2008 and dividing this difference by the residual variance in 2000; for example, Relative Percent Change = $100 \times (\tau^2_{2008} - \tau^2_{2000}) / \tau^2_{2000}$. We tested whether this percentage change was significant by using the *F* test.

In addition to comparing changes in between-state variation in 2000 and 2008, we also estimated the correlation between state-specific intercepts and slopes as an assessment of whether disparities had increased or decreased over time. For all the end points, the state-specific intercepts and slopes were obtained from fitting the hierarchical models. The estimated correlations would serve as an assessment of whether those states with the highest rates of MI incidence or mortality in the year 2000 were also the states that experienced the most rapid subsequent decline. The contribution of data points to the correlation was weighted according to the statistical precision of the state-specific estimated slopes.

Analyses were conducted using SAS version 9.2, 64-bit (SAS Institute Inc, Cary, NC), and HLM Version 6 (Scientific Software International, Lincolnwood, IL). All reported probability values are 2-sided, at $\alpha=0.05$. The institutional review board of the investigators' institution reviewed the study, and the requirement for informed consent was waived, based on the nature of the study.

Results

From 292 773 151 annual unique beneficiaries, we identified 2 263 614 patients hospitalized with MI between 2000–2008. Patient characteristics differed substantially across geographic regions, particularly with regard to race and prior cardiovascular history (Table 1): for example, nonwhite patients accounted for only 4.3% of patients in the New England and West North Central regions compared with 17.4% of patients in the Pacific region. Patients in the Mountain Division had the lowest rates of congestive heart failure, prior MI, stroke, cerebrovascular disease, and peripheral vascular disease among regions.

Trends in Incidence of Hospitalized MI and Impact on Geographic Disparities

In 2000, there was wide geographic variation in the age-sex-race-adjusted incidence of MI, with the lowest rates occurring in the Mountain and Pacific regions (Figure 1). There-

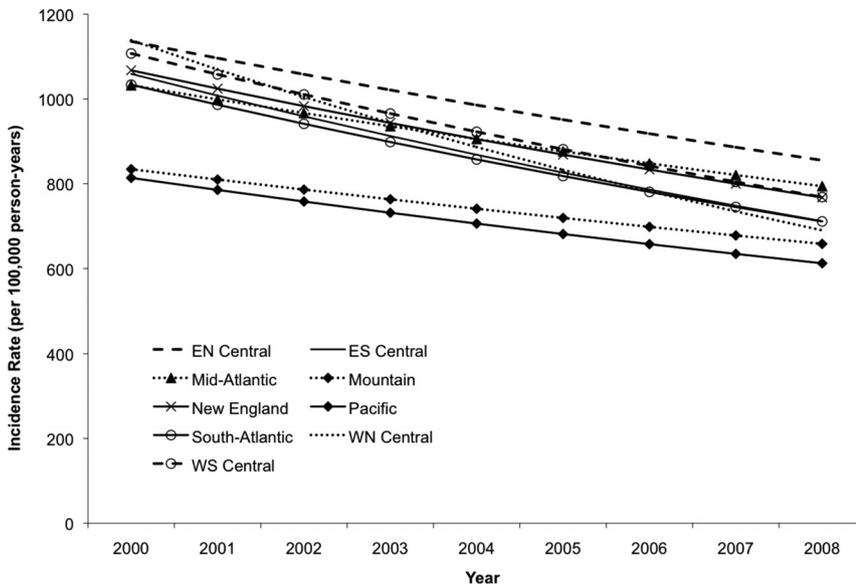


Figure 1. Temporal trends in age-sex-race adjusted incidence of hospitalized myocardial infarction by US Census Division within the Medicare fee-for-service population, 2000–2008. EN indicates East North; ES, East South; WN, West North; and WS, West South.

after, the adjusted incidence of MI declined in each of the 9 regions each year. Rates of decline in MI incidence varied across regions, ranging from 2.9–6.1% (national average relative decline of 4.3% per year) (Table 2). As a result of these trends, geographic disparities in MI incidence, as assessed by the between-state variance in incidence rates, increased by a relative 37.6% between 2000–2008 ($P=0.03$). There was no significant correlation found between age-sex-race-adjusted incidence of MI at baseline and subsequent rate of decline ($r=0.046$, $P=0.75$).

Trends in Rates of Cardiac Catheterization, PCI, and CABG and Impact on Geographic Disparities

There was wide variation in the age-sex-race-adjusted rates of cardiac catheterization and PCI within 30 days of admis-

sion for MI between regions during the entire study period (Figure 2). Across regions, rates of cardiac catheterization ranged from 43.5–60.7%; rates of PCI ranged from 25.3–40.3%; and rates of CABG ranged from 9.8–12.9%. Rates of procedures were consistently highest in the Mountain division and lowest in New England and the Mid Atlantic divisions.

In each region, rates of cardiac catheterization and PCI increased during the initial years of the study, whereas rates of CABG decreased throughout the time period. These trends persisted after adjustment for age, sex, and race (Table 2).

Geographic variation in rates of PCI after MI tended to increase over the study period (relative increase in between-state variance 31.4% between 2000–2008, $P=0.06$), whereas

Table 2. Temporal Trends in Adjusted Myocardial Infarction Incidence and Rates of Cardiac Catheterization, PCI, CABG, and Mortality at 30 Days, 2000–2008

Region	Odds Ratio for Outcome Within 30 Days of Admission Each Year Compared With Prior Year*									
	MI Incidence†		Cardiac Catheterization‡		PCI‡		CABG‡		Mortality§	
	Annual Reduction	95% CI	Odds Ratio	95% CI	Odds Ratio	95% CI	Odds Ratio	95% CI	Odds Ratio	95% CI
Nation	4.3	3.6, 4.9	1.04	1.04, 1.05	1.08	1.08, 1.09	0.96	0.96, 0.97	0.97	0.96, 0.97
EN Central	3.5	2.7, 4.3	1.05	1.04, 1.06	1.08	1.07, 1.09	0.97	0.96, 0.98	0.96	0.95, 0.96
ES Central	4.9	3.9, 5.8	1.05	1.03, 1.06	1.08	1.07, 1.09	0.96	0.95, 0.97	0.96	0.95, 0.96
Mid Atlantic	3.2	1.8, 4.6	1.04	1.03, 1.06	1.09	1.08, 1.10	0.96	0.96, 0.97	0.97	0.96, 0.97
Mountain	2.9	0.4, 5.3	1.05	1.03, 1.06	1.08	1.07, 1.10	0.97	0.96, 0.98	0.98	0.97, 0.99
New England	4.0	2.2, 5.9	1.05	1.03, 1.07	1.10	1.07, 1.12	0.95	0.94, 0.97	0.97	0.96, 0.98
Pacific	3.5	1.0, 5.9	1.04	1.03, 1.05	1.08	1.06, 1.11	0.97	0.95, 0.98	0.96	0.96, 0.97
South Atlantic	4.6	3.8, 5.3	1.05	1.03, 1.07	1.08	1.06, 1.10	0.96	0.96, 0.97	0.96	0.96, 0.97
WN Central	6.1	3.3, 8.8	1.03	1.02, 1.05	1.09	1.07, 1.10	0.97	0.96, 0.98	0.97	0.96, 0.97
WS Central	4.5	3.6, 5.3	1.05	1.03, 1.07	1.08	1.07, 1.09	0.97	0.97, 0.98	0.97	0.96, 0.98

MI indicates myocardial infarction; PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft surgery; CI, confidence interval; EN, East North; ES, East South; WN, West North; WS, West South.

*Results are from 2-stage hierarchical models, as follows: †annual reduction in age-sex-race-adjusted acute MI incidence; ‡age-sex-race-adjusted odds ratio of cardiac catheterization, PCI, and CABG surgery compared with prior year; and §comorbidity-adjusted odds ratio of 30-day mortality compared with prior year. Results are reported nationally and separately by the US Census Division.

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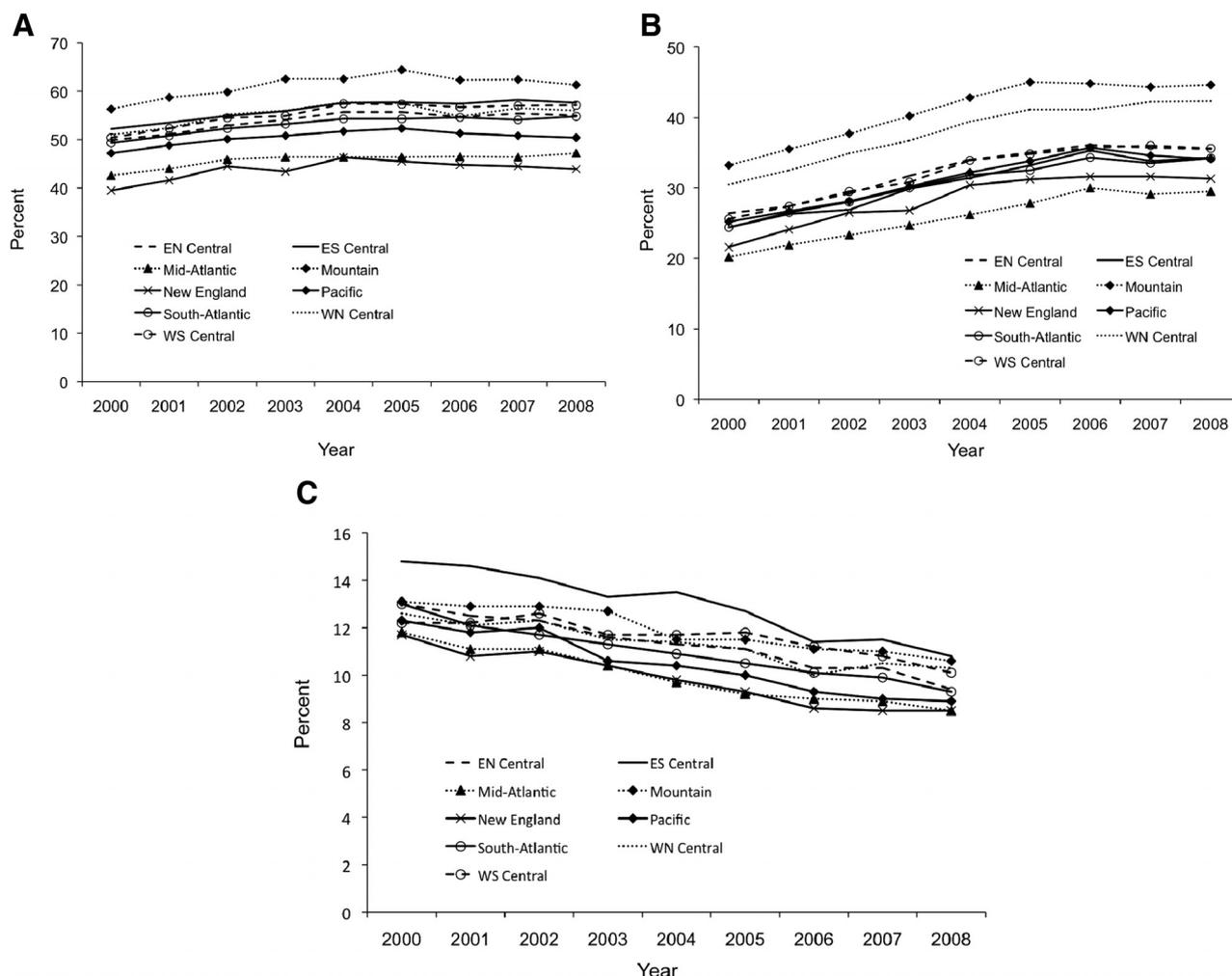


Figure 2. Temporal trends in observed rates of cardiac catheterization (A), percutaneous coronary intervention (B), and coronary artery bypass graft surgery (C) within 30 days after hospitalized myocardial infarction by the US Census Division, within the Medicare fee-for-service population, 2000–2008. EN indicates East North; ES, East South; WN, West North; and WS, West South.

geographic variation in adjusted rates of cardiac catheterization and coronary artery bypass surgery remained stable (relative increase in between-state variance between 2000–2008: -1.0% for cardiac catheterization, $P=0.95$; -5.1% for coronary artery bypass graft surgery, $P=0.71$). Baseline rates of catheterization, PCI, and CABG were not correlated with subsequent rates of increase or decrease in procedure rates among states ($r=-0.12$, $P=0.42$ for catheterization; $r=-0.17$, $P=0.23$ for PCI; $r=0.12$, $P=0.41$ for CABG).

Trends in Mortality and Impact on Geographic Disparities

Declines in risk-adjusted 30-day all-cause mortality were seen in each of the 9 regions over time (risk-adjusted odds ratio for death with each subsequent year ranged from 0.96–0.98 across regions) (Figure 3). As a result of these trends, percentage change in the between-state variance comparing years 2000 versus 2008 was -31.8% , although the result did not meet statistical significance ($P=0.08$). In addition, there was a strong negative correlation between adjusted 30-day mortality at baseline and subsequent rate of decline ($r=-0.54$, $P<0.001$), implying that states with the

highest mortality rates in 2000 had the most rapid declines in mortality in the subsequent years.

Discussion

In a study including nearly 300 million Medicare FFS beneficiary-years, we found significant declines in the incidence of MI and associated 30-day mortality in all US Census Divisions. However, there were significant differences in the incidence of MI between geographic regions throughout the study period. In addition, we found strong evidence of a wide and persistent variation in rates of cardiac catheterization and revascularization after MI across regions. Despite these trends, geographic disparities in 30-day mortality after MI have narrowed. To our knowledge, this is the largest study to date that examines geographic differences of trends in acute MI in the US elderly and the first that examines geographic differences in MI incidence, procedures, and 30-day mortality.

Widespread improvements in the treatment of cardiovascular risk factors have occurred in the United States over the previous decade.^{2–4,19,20} Several recent studies have suggested that these improvements may have coincided with

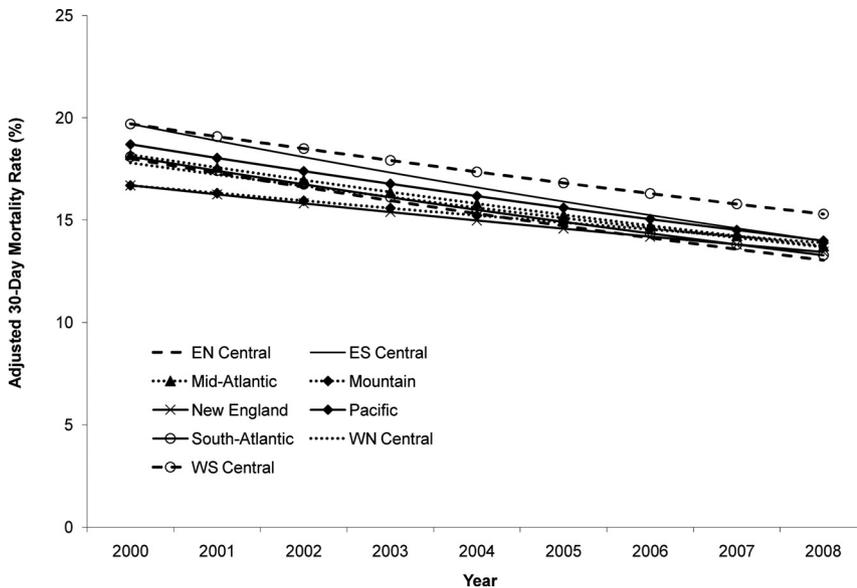


Figure 3. Temporal trends in adjusted 30-day all-cause mortality after hospitalized myocardial infarction by US Census Division, within the Medicare fee-for-service population, 2000–2008. EN indicates East North; ES, East South; WN, West North; and WS, West South.

declines in the incidence of MI.^{5–7} In a study of Medicare beneficiaries between 2002–2007, MI incidence fell by 23.4% overall, with black men and women having slower rates of decline compared with their white counterparts.⁶ The incidence of MI fell by 24% within the Kaiser Permanente Northern California population between 1999–2008, with particularly steep declines in ST-elevation MI.⁵ Similar findings have been observed within Olmsted County, Minnesota, where the incidence rate of MI declined by 20% between 1987–2006.⁷ However, whether these declines have occurred similarly across different US geographic regions had not previously been assessed.

Geographic differences in cardiovascular disease burden in the United States are well recognized. In a report among Medicare beneficiaries between 2000–2006, the Centers for Disease Control and Prevention found significant geographic disparities in hospitalizations for heart disease, including MI, with the highest rates occurring in Louisiana, Kentucky, Pennsylvania, and West Virginia.¹¹ In addition, the growth of certain cardiovascular risk factors, including obesity and diabetes, has disproportionately afflicted certain geographic regions, particularly Southern and Southeastern US states.^{21,22} Public smoking bans have been implemented at various times over the previous decade in some but not all cities and states, and the prevalence of smoking continues to vary widely between regions, with Western states showing the lowest rates.^{17,23,24} In light of these significant and potentially widening geographic differences in the prevalence of cardiovascular risk factors, the possibility existed that MI incidence had not declined similarly across regions. Our findings reassuringly indicate that improvements in the prevention and treatment of MI have indeed occurred across all US Census Divisions despite differences in risk factor burden.

Although widespread declines in MI incidence and mortality are encouraging, our data also indicate that regional disparities in cardiovascular disease and treatment continue. For example, the Pacific and Mountain divisions had incidence rates of MI that were 20–30% lower than other regions throughout the study period, and regional disparities in MI

incidence, as assessed by between-state variation in rates, actually increased by 37% over the study period. Variation in the rates of coronary procedures was substantial at the start of the study period and did not change for cardiac catheterization or CABG, while increasing by one-third for PCI between 2000–2008. Although procedure appropriateness or feasibility could not be assessed in this study, prior studies have suggested that regional variation in invasive cardiac procedures is more likely attributable to differences in physician practice patterns and systems of reimbursement rather than differences in disease severity or clinical indication.^{25–29}

Between-state differences in adjusted mortality declined during the study period despite the persistent differences in procedure rates. In addition, states starting with the highest adjusted mortality rates in 2000 also had the steepest decline. Both of these findings support the notion that geographic disparities in short-term mortality after MI have improved. These consistent reductions in MI-related mortality between regions, contrasted with the heterogeneity in MI incidence, may be reflective of the more pervasive and equitable dissemination of best practices for the management of acute coronary syndromes across US hospitals that has not been matched by equal dissemination of public health and primary prevention efforts. These observations imply that future efforts to reduce disparities in cardiovascular disease burden may have the most impact if they focus on preventing cardiovascular disease occurrence in the outpatient setting as opposed to those aimed at improving hospital care.

This study has a number of limitations. First, the use of more sensitive cardiac biomarkers may have influenced the observed incidence rates of MI. However, although the increased use of these biomarkers in later years would be expected to artificially increase the incidence of MI, in this study, we found that MI incidence has declined in all regions. Therefore, it is unlikely that our results are attributable to changes in biomarker sensitivity.

Although the vast majority of Medicare beneficiaries are enrolled in the FFS plan, since 2005, a growing percentage

has participated in Medicare Advantage managed-care plans.³⁰ It is difficult to determine whether differential enrollment across regions over time in Medicare managed-care plans may have contributed to the observed trends. We were only able to capture hospitalized events, including MIs and subsequent procedures. Out-of-hospital MIs not surviving to admission and outpatient catheterization and PCI procedures were not included, and differential trends by region could confound our analysis.

In the present study, we relied on administrative claims data for the identification of MI and coexisting illnesses. We were not able to include outpatient information, such as medication use, smoking status, and lipid levels, which might help explain the observed differences in absolute incidence rates of MI at any point in time between regions as well as the observed declines in incidence of MI in all regions. However, at present, the Medicare database is one of the only populations in which population denominators are adequately characterized across all geographic regions in the United States to allow a comprehensive regional comparison of MI incidence, treatment, and outcomes.

Changes in coding practices for coexisting conditions over time could affect the calculated risk-adjusted mortality rates. However, it has been shown that the association of these comorbid conditions and short-term mortality has not changed over time, arguing against the influence of “drift” in diagnostic coding practices.¹⁵ In addition, as the primary intent of this study was to compare trends across geographic regions, only those temporal changes in coding practices that occurred differentially between geographic regions would be expected to influence the findings.

In summary, the incidence of hospitalized MI and associated 30-day mortality decreased significantly in all US Census Divisions between 2000–2008. Although wide regional differences in both the incidence of MI and in the use of PCI have continued, disparities in short-term mortality have improved.

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Disclosures

None.

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Geographic Disparities in the Incidence and Outcomes of Hospitalized Myocardial Infarction: Does a Rising Tide Lift All Boats?

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Supplemental Material

Supplemental Methods

Detailed Description of Hierarchical Models

Assessing trends. To estimate and compare rates of change in the incidence of MI across regions we developed two-stage hierarchical Poisson regression models. In the first stage, we estimated a model with state-specific random intercepts and state-specific random year effects adjusted for age, sex and race. Year was modeled as a continuous variable after visual inspection of crude incidence rates revealed linear trends. Within each state “i” and for each year “k”, we first determined the number of annually indexed MI hospitalizations in each of 18 demographic groups, denoted by “j”. The 18 demographic groups were determined by the cross-classification of 3 age groups (65-74, 75-84, and 85 or older; with 65-74 as the reference), 2 sex groups (male and female; with female as the reference), and 3 racial groups (white, black, other; with white as the reference)). We also determined the number of Medicare beneficiaries falling into each of these groups (n_{ijk}), regardless of occurrence of MI. We fitted the following model:

Stage 1:

$$\log(E(r_{ijk})) = \log(n_{ijk}) + \beta_{0i} + \beta_{1i} \cdot year_k + \gamma_1 ageGroup_{ij} + \gamma_2 sexGroup_{ij} + \gamma_3 raceGroup_{ij}$$

where r_{ijk} is the number of AMI admissions in the j^{th} demographic category in the i^{th} state in year k ; r_{ijk} / n_{ijk} is the crude incidence of AMI; Year assumes values 0 (for 2000) to 9 (for 2008).

In the second stage, we permitted the state-specific baseline incidences (random intercepts) and state-specific annual rates of change (random slopes) to vary by U.S. Census Division through the inclusion of dummy variables (indicators) for each division:

Stage 2:

$$\begin{aligned} \beta_{0i} = & \alpha_{01}NewEngland_i + \alpha_{02}SouthAtlantic_i + \alpha_{03}MiddleAtlantic_i + \alpha_{04}EastNorthCentral_i \\ & + \alpha_{05}EastSouthCentral_i + \alpha_{06}WestNorthCentral_i + \alpha_{07}WestSouthCentral_i \\ & + \alpha_{08}Mountain_i + \alpha_{09}Pacific_i + \omega_{0i} \end{aligned}$$

$$\begin{aligned} \beta_{1i} = & \alpha_{11}NewEngland_i + \alpha_{12}SouthAtlantic_i + \alpha_{13}MiddleAtlantic_i + \alpha_{14}EastNorthCentral_i \\ & + \alpha_{15}EastSouthCentral_i + \alpha_{16}WestNorthCentral_i + \alpha_{17}WestSouthCentral_i \\ & + \alpha_{18}Mountain_i + \alpha_{19}Pacific_i + \omega_{1i} \end{aligned}$$

where $\omega_{0i} \sim N(0, \tau_0^2)$ and $\omega_{1i} \sim N(0, \tau_1^2)$

Thus, allowing “p” to index individuals and letting $Y_{ipk} = 1$ if the patient “p” with place of residence in the state “i” had the event and 0 otherwise in year “k”, our Stage 1 became:

Stage 1:

$$Logit(P(Y_{ipk} = 1)) = \beta_{0i} + \beta_{1i}year_k + \gamma_1age_{ipk} + \gamma_2sex_{ip} + \gamma_3black_{ip} + \gamma_4other_{ip}$$

where *sex* is male (coded 1) or female (coded 0), *black* is black (coded 1) or not black (coded 0) and *other* is coded 1 when the patient is neither black nor white. Additionally, *age* is continuous.

The Stage 2 model remained as above

$$\begin{aligned} \beta_{0i} = & \alpha_{01}NewEngland_i + \alpha_{02}SouthAtlantic_i + \alpha_{03}MiddleAtlantic_i + \alpha_{04}EastNorthCentral_i \\ & + \alpha_{05}EastSouthCentral_i + \alpha_{06}WestNorthCentral_i + \alpha_{07}WestSouthCentral_i \\ & + \alpha_{08}Mountain_i + \alpha_{09}Pacific_i + \omega_{0i} \end{aligned}$$

$$\begin{aligned} \beta_{1i} = & \alpha_{11}NewEngland_i + \alpha_{12}SouthAtlantic_i + \alpha_{13}MiddleAtlantic_i + \alpha_{14}EastNorthCentral_i \\ & + \alpha_{15}EastSouthCentral_i + \alpha_{16}WestNorthCentral_i + \alpha_{17}WestSouthCentral_i \\ & + \alpha_{18}Mountain_i + \alpha_{19}Pacific_i + \omega_{1i} \end{aligned}$$

, with α_{01} representing the baseline log odds of receiving the procedure in the New England region, and α_{11} representing corresponding annual change in log odds in the New England region.

Trends in 30-day all-cause mortality after MI among regions were also assessed via hierarchical logistic regression. In this model, we denote by $Y_{ipk} = 1$ if the patient “p” with place of residence in the state “i” died within 30 days from MI in year “k”:

Stage 1:

$$\text{Logit}(P(Y_{ipk} = 1)) = \beta_{0i} + \beta_{1i} \text{year}_k + \gamma_1 \text{age}_{ipk} + \gamma_2 \text{sex}_{ip} + \gamma_3 \text{black}_{ip} + \gamma_4 \text{other}_{ip} + \sum_{\ell=5} \gamma_{\ell} x_{p\ell}$$

where *sex* is male (coded 1) or female (coded 0), *black* is black (coded 1) or not black (coded 0) and *other* is coded 1 when the patient is neither black nor white. Additionally, *age* is continuous. We also include the term $\sum_{\ell=5} \gamma_{\ell} x_{p\ell}$ to adjust for patient level coexisting disease conditions based on HCCs (a complete list of covariates “x” is included in Table 1).

The Stage 2 model remained as above

$$\begin{aligned} \beta_{0i} = & \alpha_{01} \text{NewEngland}_i + \alpha_{02} \text{SouthAtlantic}_i + \alpha_{03} \text{MiddleAtlantic}_i + \alpha_{04} \text{EastNorthCentral}_i \\ & + \alpha_{05} \text{EastSouthCentral}_i + \alpha_{06} \text{WestNorthCentral}_i + \alpha_{07} \text{WestSouthCentral}_i \\ & + \alpha_{08} \text{Mountain}_i + \alpha_{09} \text{Pacific}_i + \omega_{0i} \end{aligned}$$

$$\begin{aligned} \beta_{1i} = & \alpha_{11} \text{NewEngland}_i + \alpha_{12} \text{SouthAtlantic}_i + \alpha_{13} \text{MiddleAtlantic}_i + \alpha_{14} \text{EastNorthCentral}_i \\ & + \alpha_{15} \text{EastSouthCentral}_i + \alpha_{16} \text{WestNorthCentral}_i + \alpha_{17} \text{WestSouthCentral}_i \\ & + \alpha_{18} \text{Mountain}_i + \alpha_{19} \text{Pacific}_i + \omega_{1i} \end{aligned}$$

, with α_{01} representing the baseline log odds of 30-day mortality in the New England region, and α_{11} representing the corresponding annual change in log odds in the New England region.

Supplemental Tables

Table 1. U.S. Census Divisions

New England

Connecticut
Maine
Massachusetts
New Hampshire
Rhode Island
Vermont

East North Central

Indiana
Illinois
Michigan
Ohio
Wisconsin

South Atlantic

Delaware
District of Columbia
Florida
Georgia
Maryland
North Carolina
South Carolina
Virginia
West Virginia

Mountain

Arizona
Colorado
Idaho
New Mexico
Montana
Utah
Nevada
Wyoming

Middle Atlantic

New Jersey
New York
Pennsylvania

West North Central

Iowa
Kansas
Minnesota
Missouri
Nebraska
North Dakota
South Dakota

East South Central

Alabama
Kentucky
Mississippi
Tennessee

Pacific

Alaska
California
Hawaii
Oregon
Washington

West South Central

Arkansas
Louisiana
Oklahoma
Texas

Table 2. ICD-9-CM Procedural Codes Used to Identify Revascularization Procedures

Procedure	Code
Cardiac Catheterization	88.50, 88.53, 88.58, 37.22, 37.23
Percutaneous Coronary Intervention	Before Oct 2005: 36.01, 36.02, 36.05 After Oct 2005: 36.01, 36.02, 36.05, 00.66, 36.06, 36.07
Coronary Artery Bypass Graft Surgery	36.10, 36.11, 36.12, 36.13, 36.14, 36.15, 36.16

Figure 1. Temporal Trends in Crude Incidence of Myocardial Infarction by U.S. Census Division, 2000-2008

