GEOGRAPHIC ACCESS TO INTERVENTIONAL CARDIOLOGY SERVICES IN MAINE

by

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ABSTRACT

Objectives**:** Explore (1) the characteristics of the population of Maine who have delayed geographic access to interventional cardiology (IC) services and (2) the effect of delayed geographic access on mortality due to acute coronary syndrome (ACS), non-ST segment elevated myocardial infarction (NSTEMI), and ST-segment elevated myocardial infarction (STEMI).

Background: ACS, NSTEMI, and STEMI are highly prevalent and the most common cause of death in the U.S. and the world. Patients with STEMI or unstable NSTEMI should undergo prompt reperfusion at an interventional cardiology (IC) center. It is not known whether delayed geographic access to IC services is associated with mortality.

Methods: The study was conducted in two-parts: (1) an exploration of census data to investigate disparities associated with delayed geographic IC access and (2) a secondary analysis of administrative claims data to investigate coronary mortality relative to delayed geographic IC access. Data were preprocessed in Excel 2013 and geocoded, mapped, and grouped in ArcMap 10.3. Analyses were conducted for census data in R 3.1.2 and for claims data in SPSS version 22. Delayed geographic access was defined as residence beyond a 60-minute drive time from any IC center.

Results: Delayed geographic IC access was associated with rural residence, advanced age, high school or higher level of education, and lack of health insurance. Delayed versus timely geographic IC access was associated with older age in a sample with ACS (n=3126, 78.6 vs. 64.6) and in the subgroups with NSTEMI (n=2247, 79.1 vs. 65.9) and STEMI (n=879, 76.9 vs. 61.7). Delayed versus timely geographic IC access was associated with increased unadjusted mortality due to ACS (n=3126, 6.2% vs. 3.7%) NSTEMI (n=2247, 5.1% vs. 3.0%), and STEMI (n=879, 10.2% vs. 5.3%). In a logistic regression model including delayed geographic access as the candidate predictor, controlling for age, delayed geographic access was not a significant predictor of mortality; however, each additional year of age was associated with an increase in odds of in-hospital mortality of 8% for ACS and NSTEMI and 9% for STEMI. All findings were significant at $p<.05$.

Conclusion: Delayed geographic access to IC services in Maine was associated with disparity in access to care but not with increased age-adjusted coronary mortality.

Keywords: access to health care, acute coronary syndrome, health outcome, geographic information system, mortality, ST-segment elevated myocardial infarction

Abbreviations: ACS = acute coronary syndrome; GIS = geographic information system; IC = interventional cardiology; NSTEMI = non-ST segment elevated myocardial infarction; PPCI = primary percutaneous coronary intervention; STEMI = ST-segment elevated myocardial infarction

INTRODUCTION

Coronary heart disease causes one of every seven deaths in the U.S. Acute coronary syndrome (ACS) is diagnosed when symptoms are present; the most acute type of ACS is ST-segment elevated myocardial infarction (STEMI). This year Americans will have about 1,090,000 incident ACS events; between 25% and 40% of these are STEMI.[1] In a nation of 317,292,000,[2] the expected incidence is about 3.4 ACS events and 0.9-1.4 STEMI events per thousand persons per year. Reperfusion therapy in the form of immediate primary percutaneous coronary intervention (PPCI), available only at interventional cardiology (IC) centers, is the treatment of choice.[3] Unstable patients with non-ST segment elevated myocardial infarction (NSTEMI) should undergo prompt angiography at an IC center with intent to revascularize the myocardium.[4]

STEMI and Access to Care

Complications of STEMI include cardiogenic shock, symptomatic dysrhythmias, and bleeding complications of therapy. In-hospital mortality is generally between 5% and 6%. Rates of STEMI complication and ACS mortality, as well as the proportion of ACS which are STEMI, are decreasing due to implementation of guideline-adherent pharmacological and interventional therapies. Racial and ethnic disparities in access to PPCI are decreasing; although disparities associated with female gender and age over 75 years persist.[3] Rural residence is associated with non-receipt of PPCI and greater risk-adjusted in-hospital mortality.[5]

Reperfusion with PPCI should occur within 3 hours of symptom onset and within 90 minutes of first medical contact. If timely PPCI is not available, fibrinolysis should be attempted unless contraindicated within 30 minutes of first medical contact.[3] The difference between the 90 minutes allotted for PPCI and the 30 minutes allotted for fibrinolysis leaves a 60 minute window for inter-hospital transfer unless there is a clinically important reason for delay, such as resuscitation from cardiac arrest or clarification of the diagnosis with imaging. In a review of evidence for a sequenced pharmaco-invasive strategy combining fibrinolysis and PPCI, a 60-minute cutpoint was specified to define an expected time to PPCI within which transfer should prioritized and beyond which fibrinolysis should be attempted.[6] Among U.S. adults, 79% reside within a 60-minute drive time of an IC center; thus 21% have delayed geographic IC access.[7]

Fibrinolysis is effective as an alternative to PPCI when IC access is delayed but it is limited by an increased risk of bleeding complications. The Strategic Reperfusion Early After Myocardial Infarction (STREAM) investigators reported that although fibrinolysis and PPCI transfer were equally effective, fibrinolysis was associated with more intracranial hemorrhages; this difference became non-significant when the protocol was amended to provide for half-dose fibrinolysis in those aged over 75 years.[8]

Helicopter transport is an alternative to ground transport under circumstances of delayed geographic access but it is limited by lack of continuous availability. Phillips and colleagues[9] reported that whereas only 24.2% of a series of STEMI had guideline-adherent door to balloon times for PPCI when transported by helicopter compared to 35.5% transported by ground, the median distance of helicopter transports was 51 miles compared to 37 miles for ground transport. The authors asserted that helicopter transport expanded geographic access and saved 1.2 lives per 100 flights.

NSTEMI and Access to Care

Stable patients with NSTEMI should undergo early (within 24 hours) or delayed (up to 72 hours) angiography at an IC center with intent to revascularize the myocardium. Unstable patients should receive this care immediately. The rationale for the various timings as a function of stability is to properly match the treatment with the clinical situation and avoid natural harm due to complications of the disease and iatrogenic harm due to complications of the treatment.[(4)] Timely geographic access to IC services for stable NSTEMI is defined as within 24-72 hours of first medical contact. Anyone living within a day's drive of IC capability does not have delayed access to care for a stable NSTEMI event.

Geographic Information Systems and Access to Care

Graves[(10)] employed geographic information systems (GIS) to explore access to IC services in Alabama within 30, 60, and 90 minutes. The author asserted that although 85.9% of the population had access within 60 minutes, rural residence was associated with delayed access, and a large poorly-resourced geographic region was identified with no access even within 90 minutes. Using GIS and multiple regression modeling, Graves[(11)] studied geographic distance and associated disparity as predictors of age-adjusted mortality in Alabama and Mississippi. The final model explained 31.9% of the variability in mortality; whereas rural residence was not a significant predictor, complex interactions among the factors rural residence, poverty, education, and race were identified as significant predictors.

Harris and colleagues[12] employed GIS methodology, census data, publicly available map layers, and data regarding hospitalization rates from the Maine Health Data Organization to study the effect of variability along the urban-rural continuum on rates of hospitalization for myocardial infarction and heart failure. The authors found that proximity to a hospital, poverty, and unemployment were significant predictors of increased rates of hospitalization.

Taken as a group, these findings indicate that outcomes are optimized when PPCI is offered within the guideline-specified time parameter of 90 minutes from first medical contact. It is intuitive, but not known, whether delay in geographic access to care is associated with increased mortality. Two alternatives when geographic access is delayed are fibrinolysis and helicopter transport. Fibrinolysis is limited by the incremental risk of intracerebral hemorrhage. Helicopter transport is limited by lack of continuous availability due to flying conditions.

Setting

Maine is the most rural U.S. state, with 61.3% of the population residing in rural areas.[13] National incidence rates, extrapolated to the Maine population of approximately 1,329,000,[2] predict about 4,000 incident ACS events and about 1200-1800 incident STEMI events per year. Maine has earned high ratings from the Agency for Healthcare Research and Quality[14] and the Commonwealth Fund[15] for health care quality and access. The Leapfrog Group named 13 rural hospitals as the best in the U.S.; of these 13, five are in Maine, the only state with more than one hospital on the list.[16] Maine faces several geographic challenges in access to health care, with multiple populated islands, a long rocky coast, and a mountain range northwest of the urban areas. The national Center for Heart Disease and Stroke Prevention[17] and the Maine Centers for Disease Control and Prevention[18] report that mortality is highest in the northern Maine counties toward the Canadian border and the so-called “downeast” counties toward the Atlantic coast.

Purpose

The purpose of this paper is to describe disparity and mortality associated with delayed geographic access to IC services in Maine. The specific research questions were: (1) What proportion of Maine residents have delayed geographic access to IC services? (2) Is delayed geographic access associated with disparity due to race, gender, age, rural residence, education, poverty, or lack of health insurance? (3) Is delayed geographic access associated with ACS, NSTEMI, or STEMI mortality?

METHODS

The study design was a secondary analysis of census data to investigate disparity and insurance claims data to investigate mortality. Institutional review board approval was obtained from the Maine Medical Center Office of Research Compliance (#4382) and the University of Alabama at Birmingham (X140425005).

Data Sources

Hospitals providing IC services (n=3) were defined as those in Maine reporting at least one case to Medicare of the PPCI within 90 minutes performance measure during the one-year reporting cycle[19]. The Maine Next Generation 911 road network[20] was used to define the 60-minute drive time service area polygon. Questions 1 and 2 were answered with data from the U.S. Census Bureau 2013 American Community Survey.[21] Question 3 was answered with claims data from the Maine Health Data Organization (data request number 511135, https://mhdo.maine.gov) for all ACS hospitalizations during calendar 2010. The location of all hospitals contributing data was obtained from the Maine Hospital Association.[22]

Definition of Variables

The proportion of Maine residents with delayed access (question 1) was determined by grouping the zip code centroids by location within and beyond the 60-minute service area, summing the population of zip codes beyond the service area, and dividing this numerator by the total population of Maine. Next, to determine disparities (question 2), proportions were defined with a numerator for the phenomenon of interest and a denominator for the relevant segment of the Maine population. Proportions representing zip code level data aggregated to the “within” and “beyond” groups were compared. Table 1 reports the definitions for the disparity variables.

Table 1

Definitions of disparities investigated with American Community Survey 2013 data

Variable	Numerator	Denominator
Gender	Female population	Total population
Age	Individuals aged 75 or greater	Total population
Rural residence	Rural residents	Total reporting urban/rural status
High school education	High school graduates	Total population aged 25 or greater
Poverty	Individuals living below fifty percent of federal poverty level	Total population reporting poverty status
Insurance	Individuals lacking health insurance	Total civilian non-institutionalized population

Mortality (question 3) was investigated using the 2010 Maine Health Data Organization data. Inclusion criteria for the overall ACS sample were age 20 or greater and any ICD-9 diagnosis 410.xx. Exclusion criteria were residence anywhere outside Maine or a zip code that could not be geocoded. A composite identification number was concatenated from Health Insurance Portability and Accountability Act identifiers, after which the identifiers were deleted. For individuals with more than one entry, those separated by an out-of-hospital interval less than 24 hours were considered to be related to the same ACS episode and the earlier entry was discarded to avoid counting the same ACS event twice. Entries for which this interval was greater than 24 hours were considered to be related to distinct ACS episodes and both were retained. The sample of interest for mapping and descriptive statistics was defined as all unique ACS events after the deduplication step was completed. The sample of interest for comparison of means and proportions and for fitting a logistic regression model was defined as all those independent observations remaining after a further step involving removal of all cases affecting the same individual more than once. All variables corresponding to diagnosis, outcome, and location were retained; all others were discarded. A binary grouping variable was defined by location beyond or within the service area polygon. A binary outcome variable was defined as vital status at discharge (alive or deceased). Mortality for the overall ACS sample (all 410.xx), the NSTEMI subgroup (all 410.7x), and the STEMI subgroup (all 410.xx except 410.7x) were compared between groups. The ICD-9 coding definition has demonstrated sensitivity of 94% and specificity of 99% for identification of myocardial infarction.[23]

Geographic Information Systems

A GIS approach was used to define delayed geographic access as residence in a zip code with a centroid beyond a 60-minute drive from any IC center. The IC service area polygon was determined using ArcMap 10.3 (Esri, Redlands, California). Spreadsheet data were preprocessed in Excel 2013 (Microsoft Corporation, Redmond, Washington) and geocoded, mapped, and grouped by location beyond or within the service area in ArcMap. All research questions were answered by overlay analysis with procedures and map layers described by Kurland and Gorr.[24]

Analysis

All analyses of census data were conducted in R 3.1.2 (www.r-project,org). Analyses of descriptive statistics and mortality due to ACS, NSTEMI, and STEMI were conducted in SPSS version 22 (IBM Corporation, Armonk, New York). Proportions were compared using chi-square test. Mean age was compared using t-test for independent samples. Age-adjusted mortality was investigated by status within versus beyond the IC service area by binary logistic regression.

RESULTS

What proportion of Maine residents has delayed geographic access to IC services?

Figure 1 depicts the timely geographic access service area in a shaded polygon. There are three IC centers within the timely access service area. The proportion of Maine residents residing beyond the service area is 22.2%.

Figure 1: Maine Interventional Cardiology Service Area

Is delayed geographic access associated with any disparity in race, gender, age, rural residence, education, poverty, or lack of health insurance?

Table 2 reports the differences between the population groups residing beyond and within the service area. Delayed geographic access was associated with rural residence, a higher proportion of those aged 75 years or more, a high school education or greater, living below 50% of the federal poverty level, and lacking health insurance. There was no difference in the proportion of female gender between groups. Since the highest proportion of any single non-White race was 1%, this disparity was not investigated further.

Table 2

Population findings from American Community Survey 2013 data

Variable definition	Within service area n(%)	Beyond service area n(%)	p value
Age: percent of respondents aged >75	73,492 (7.1)	26,318 (8.9)	<.001
Rurality*: percent living in a rural area	260,098 (55)	153,152 (84)	<.001
Education: percent aged >25 with high school diploma	237,676 (33)	82,176 (38)	<.001
Poverty: percent below 50% of federal poverty level	48,149 (4.8)	16,357 (5.7)	<.001
Insurance: percent without health insurance	100,181 (9.8)	36,001 (12.3)	<.001

*Respondents to this question totaled 651,911 (about half the total Maine population)

Is delayed geographic access associated with excess mortality due to ACS, NSTEMI, or STEMI?

The claims data provided for this study included admitting diagnosis, primary diagnosis, and ten additional diagnosis fields. During data cleaning, preprocessing, and inspection, several cases were noted to have more than one 410.xx ICD-9 code in the additional diagnosis fields, introducing the possibility of ambiguous subgroup assignment. Values in the admitting diagnosis field were often not 410.xx and the proportion of all cases coded as STEMI in this field was lower than the expected value of about 1/3 based on national incidence rates.[(1)] For these reasons, the ICD-9 inclusion criterion was applied only to the primary diagnosis column.

A total of 3961 cases from the 5617 successfully geocoded Maine residents met study criteria by presence of a 410.xx code in the primary diagnosis field. In order to support the use of statistical procedures, all cases representing repeat hospitalizations for the same individual were excluded; the final yield was 3126 independent observations of one incident ACS hospitalization per individual. Table 3 reports descriptive statistics for the overall ACS sample and for the NSTEMI and STEMI subgroups.

Table 3

Descriptive statistics for analysis sample from Maine Health Data Organization

Group/size	All ACS (n=3126)	NSTEMI (n=2247)	STEMI (n=879)
Age (mean/SD)	68.3/13.7	69.4/13.4	64.9/13.8
Gender (percent male): n(%)	1767 (56.5)	1267 (56.4)	500 (56.9)
Race (percent White): n(%)	3072 (98.3)	2214 (98.5)	858 (97.6)
Mortality: n(%)	137 (4.4)	81 (3.6)	56 (6.4)
Length of stay: (median/IQR)	3/(2-5)	3/(2-5)	3/(2-5)
Delayed geographic access: n(%)	817 (26.1)	630 (28.0)	187 (21.3)

Abbreviations: ACS=acute coronary syndrome; IQR=interquartile range; NSTEMI=non-ST segment elevated myocardial infarction; STEMI=ST-segment elevated myocardial infarction; SD=standard deviation

Figure 2 depicts the resident location of all 5617 Maine residents in the sample. The shaded areas depict zip code boundaries with the count of ACS cases normalized to population in three quantiles; the light, medium, and dark shading depicts the least, intermediate, and most dense concentration of ACS cases, respectively. The distribution of all Maine hospitals regardless of IC capability is also shown, demonstrating that general hospital care is distributed throughout the state compared to specialty hospital care, which is concentrated in the more densely population southern area.

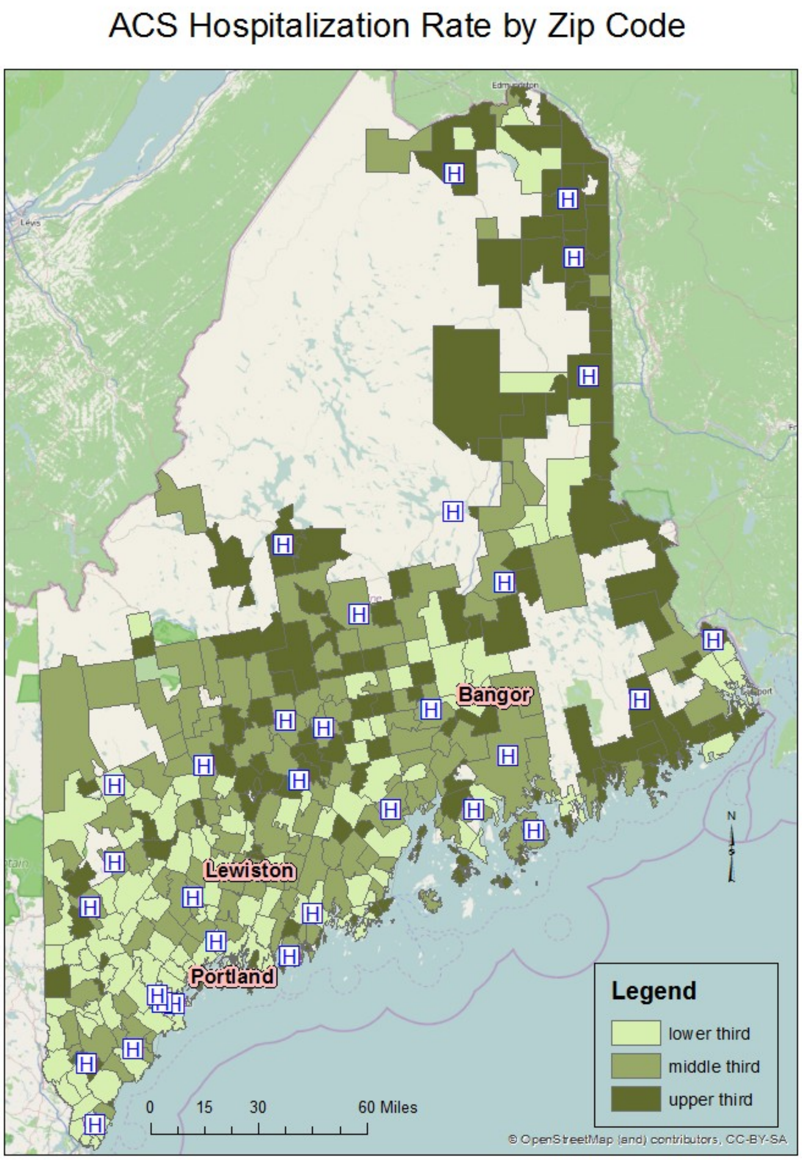

Figure 2: ACS Hospitalization Rate by Zip Code

Table 4 reports the comparison of demographic characteristics within and beyond the service area for the ACS analysis sample and for the NSTEMI and STEMI subgroups. The proportion of male and White individuals did not differ by location. The mean age of individuals residing beyond the service area was greater than those within for the overall sample and both subgroups. The comparison of means was conducted on the 3126 independent ACS event observations.

Table 4

Demographic statistics by location for analysis sample of Maine residents with ACS

Group / Characteristic	ACS		
	Within service area	Beyond service area	p value
Mean age/SD	64.6/13.0	78.6/9.7	.000
Male gender n(%)	1310 (56.7)	457 (55.9)	.692
White race n(%)	2268 (98.2)	1591 (98.4)	.727
	NSTEMI		
	Within service area	Beyond service area	p value
Mean age/SD	65.9/12.9	79.1/9.3	.000
Male gender n(%)	922 (57.0)	345 (54.8)	.332
White race n(%)	1591 (98.4)	623 (98.9)	.545
	STEMI		
	Within service area	Beyond service area	p value
Mean age/SD	61.7/12.7	76.9/10.9	.000
Male gender: n(%)	388 (56.1)	112 (59.9)	.349
White race n(%)	677 (97.8)	181 (96.8)	.671

Table 5 reports the comparison of mortality within and beyond the service area for the overall ACS sample and both subgroups. Delayed geographic access to IC services was associated with increased mortality due to ACS, NSTEMI, and STEMI.

Table 5

Mortality rate by location for analysis sample from Maine Health Data Organization

Group	Mortality		
	Within service area n (%)	Beyond service area n (%)	p-value
ACS	86 (3.7)	51 (6.2)	.003
NSTEMI	49 (3.0)	32 (5.1)	.019
STEMI	37 (5.3)	19 (10.2)	.017

Because delayed geographic access to IC services was associated with older age and increased mortality, a binary logistic regression analysis was conducted to investigate the effect of delayed geographic IC access on age-adjusted mortality. Findings of this analysis are reported in Table 6. The model including the candidate predictors delayed geographic access and age was significant for the ACS group and the NSTEMI and STEMI subgroups. All three overall models were significant ($p < .001$). Based on the Hosmer-Lemeshow Goodness-of-Fit tests, the model fit the data in the STEMI case, but not in the ACS case or in the NSTEMI case. Predictive capability of the model was medium for STEMI mortality and low for ACS and NSTEMI mortality. Delayed geographic access was not a significant predictor in any model. In all models, age was a significant predictor, with each additional year of age holding geographic access constant resulting in a 8% increase in the odds of in-hospital ACS and NSTEMI mortality and an 9% increase in the odds of STEMI mortality.

Table 6

Logistic regression findings for analysis sample from Maine Health Data Organization

Group/ (n)	Hosmer and Lemeshow test p-value	Nagelkerke Pseudo R square	Variable	p-value	Odds Ratio (95% CI)
ACS (n=3126)	.004	.109	Delayed geographic access	.190	1.287 (.882-1.877)
			Age	<.001	1.079 (1.062-1.096)
NSTEMI (n=2247)	.022	.100	Delayed geographic access	.415	1.220 (.757-1.966)
			Age	<.001	1.08 (1.057-1.104)
STEMI (n=879)	.208	.168	Delayed geographic access	.286	1.412 (.749-2.659)
			Age	<.001	1.09 (1.063-1.118)

Abbreviations: ACS=acute coronary syndrome; CI=confidence interval; NSTEMI=non-ST segment elevated myocardial infarction; STEMI=ST-segment elevated myocardial infarction

DISCUSSION

Delayed geographic access to IC services is associated in the population of Maine with a greater proportion of those with rural residence, living below fifty percent of federal poverty level, without any health insurance, and educated at the high school level or greater. Delayed geographic IC access is associated in a sample of those hospitalized with ACS and in the subgroups with NSTEMI and STEMI with older age and increased unadjusted mortality but not with increased age-adjusted mortality.

The largest difference in proportions from census variables beyond versus within the IC service area was that between the 84% of residents beyond and the 55% of residents within the service area with rural residence. The definition of "rural" used for the present study was residence not within an urbanized area (population at least 50,000) or an urban cluster (population at least 2,500 but less than 50,000) as reported in the 2013 American Community Survey.[21] The association of delayed geographic access, rural residence, and increased unadjusted mortality is congruent with findings reported by other researchers. Ambardekar and colleagues[5] showed that rural compared to urban residence is associated with increased unadjusted in-hospital mortality (5.7% vs. 4.4%, p <.0001). In a model adjusting for patient and hospital characteristics, rural residence was associated with higher compliance with most adjunctive core performance measures. On the contrary, Baldwin and colleagues[25] compared quality of care at three categories of rural hospitals by Rural-Urban Commuting Area classification to that provided by urban hospitals. The authors asserted that whereas quality of care at large rural hospitals was similar to that provided by urban hospitals, patients admitted to small and isolated small rural hospitals were least likely to receive guideline-recommended care. The present study was not designed to investigate adherence with core performance measures or to associate outcomes with care at a particular hospital regardless of urban/rural status.

Graves[10] showed that rural residence was the greatest disparity affecting those with delayed geographic access to IC services in Alabama; 94.4% of urban residents but only 75.4% of rural residents had timely access. Findings of the present study in Maine are congruent with this finding in Alabama. Graves[11] showed that, in a regression model explaining 31.9% of the variability in age-adjusted mortality, rural residence was not a significant predictor but interactions between rurality and social factors poverty, education, and race were significant predictors. Rural residence and delayed geographic access to IC services found in urban areas may be two conceptually different ways of describing the same phenomenon (i.e., distance from resources).

Delayed geographic access to IC services was associated with disparity due to poverty and lack of health insurance in the current study. Again, this finding is congruent with the research literature. Record and colleagues[26] reported on the current status of a community-wide program in a low-income county of Maine. The program, which has been sustained for forty years, has been associated with improvements in the modifiable risk factors hypertension, cholesterol, and smoking as well as decreased rates of cardiovascular hospitalization and lower cardiovascular mortality adjusted for income. These improvements are significant compared to the baseline state in the decade preceding the program's beginning in 1970 and have outpaced improvement seen throughout Maine. These authors asserted that these improvements occurred while Franklin County residents became older and poorer.

Yamashita and Kunkel[27] showed that social characteristics including poverty, lack of health insurance, and unemployment as well as geographic distance from hospital care are all associated with age-adjusted cardiac mortality. When geographic distance was adjusted for the social factors in their model, only poverty, unemployment, and rural residence were associated with mortality. Smolderen and colleagues[28] studied the effect of status on health insurance (uninsured, insured with financial concerns, and insured without financial concerns) on time elapsed during pre-hospital delay in a sample of patients treated for acute myocardial infarction. The authors asserted that the uninsured and concerned groups had longer delays. These patients were more likely to be young, non-White, single, current smokers, and high school dropouts and had higher levels of severe depressive symptoms and more frequent angina.

In the current study, delayed geographic access to IC services was not associated with disparity regarding education; in fact, those residing beyond the IC service area were more likely to be high school graduates. The overwhelming White majority and the preponderance of older age, high school education, and poverty are typical of rural northern communities.[29]

The present study has demonstrated association of delayed geographic IC access with socioeconomic disparity and with increased unadjusted coronary mortality. The review of literature has demonstrated the association of socioeconomic disparity with increased unadjusted mortality. Taken as a group, these findings indicate that disadvantageous social factors associated with delayed geographic access to IC services can contribute to coronary mortality. Even when poverty and advanced age are increasing in prevalence, community-based interventions targeting modifiable risk factors for coronary mortality can be effective. The preponderance of high school education associated with delayed geographic access to IC services should be an asset in the implementation of such programs.

In the present study, delayed geographic access to IC services was associated with increased unadjusted coronary mortality. The observed in-hospital STEMI mortality rate of 5.3% among those with timely access was congruent with the benchmark mortality rate of 5% to 6% due to STEMI in the U.S.[30] The observed in-hospital STEMI mortality rate of 10.2% affecting those with delayed geographic access is congruent with the 9.66% STEMI mortality reported by Okuyan and colleagues[31] in rural Turkey when transport was complicated by rugged geography over long distances. Transfer to IC service in Maine must be accomplished over distances which can exceed 200 miles.

In the present study, delayed geographic access was not a significant predictor in a model adjusted for age, whereas each additional year of age is associated with an 8% increase in the odds of in-hospital ACS mortality. Age-related factors which can complicate care include increased risk of bleeding complications of anticoagulant and antiplatelet therapy, increased likelihood of therapy despite relative contraindications, and appropriate non-receipt of care due to advanced directives or absolute contraindications.[(30)]

The present study is limited by survival bias, the use of a binary grouping variable, specification of a setting which may be an outlier in terms of quality of rural hospital care, and the use of an ICD-9 coding definition to define the overall sample and subgroup assignment. These limitations, along with a suggested remedy for each, are outlined below. Expansion of the study is justified to overcome these limitations.

Survival bias applies to research in clinical conditions when death has occurred before individuals are counted.[(32)] Death due to ACS occurs out of hospital in 74% of cases.[(1)] Since this analysis has counted only those who survived to reach hospital care, it is likely that mortality, especially among those with delayed geographic access, has been underestimated. Data from death certificates regarding out-of-hospital coronary mortality should be mapped and quantified for a better understanding of how many fatalities have been missed because of survival bias.

The design of the present study specified a binary grouping variable based on definition of delayed geographic IC access as a drive time greater than 60 minutes.

Although this cutpoint was justified in the literature reviewed, it may be that a different cutpoint will more clearly distinguish those for whom delayed access confers incremental mortality risk. The setting of this study was characterized by recognition of exceptional quality of rural hospital care. These findings may not be generalizable to settings with different quality of care characteristics.

The coding definition used in this study has demonstrated high sensitivity and specificity for identification of myocardial infarction previously, but it is not clear whether the definition distinguishes adequately between STEMI and NSTEMI.[(23)] The National Registry of Myocardial Infarction investigators[(33)] published a study of 100,000 cases of ACS in 2008, with data collection beginning one year after the coding definition was revised in 2005 to accurately make this distinction (NSTEMI=410.7x; STEMI=all other 410.xx except 410.7x). Those authors concluded that at the time of their writing, actual coding practice did not yet reflect use of this definition and that the rationale for the recommended change in coding practice had not been realized.

Kottke and Baechler[(34)] asserted in 2013 that four-digit ICD-9 codes are not detailed enough to reliably distinguish between types of myocardial infarction. The authors attributed most of the ambiguity to the code 410.9x, indicating infarction of an unspecified myocardial wall site. In order to accurately make this distinction, the authors developed computer algorithms that combined ICD-9 codes with troponin levels and with electrocardiogram and echocardiograph data. Seghieri and colleagues[(35)] compared 30-day mortality among 37 hospitals with varying characteristics in Italy. The authors excluded from their analysis cases coded as 410.9x and asserted that prior use of this definition in Italy had demonstrated sensitivity of 90.4%-98%, specificity of 71.9%-

90.4%, and positive predictive value of 69.5%-96%. Findings were that hospital characteristics were a stronger predictor of STEMI mortality than of NSTEMI mortality and that their definition distinguished reliably between STEMI and NSTEMI. In the present study, 130 (4.2%) of the 3126 cases in the sample were coded 410.9x in the primary diagnosis field. Inclusion criteria were applied by primary diagnosis only because of the presence of more than one ICD-9 code in the eleven other diagnosis fields. This indicates that subgroup assignment based on primary diagnosis may not be accurate. Linkage of inpatient claims data with additional data sources such as out-of-hospital claims data, emergency department medical records, and emergency medical services run sheets may provide enough clinical data to validate accuracy of coding practices.

The study was not designed to investigate the effect on coronary mortality of geographic access by helicopter. Maine is served by an active helicopter transport service with two aircraft based at two of the IC centers.[36] The analysis would require adjustment for lack of continuous availability due to flying conditions.

CONCLUSION

Delayed geographic access to IC services in Maine is associated in the population with advanced age, high school education, poverty, and lack of health insurance. Delayed geographic access is not associated with increased age-adjusted mortality in ACS, NSTEMI, or STEMI. Expansion of the study is warranted to overcome limitations. Data from other rural states and areas with greater variability in quality of rural hospital care should be analyzed to enhance generalizability of findings.

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