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Neighborhood Disparities in Incident Hospitalized Myocardial Infarction in Four US Communities: The ARIC Surveillance Study

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Abstract

Objectives—Hospital-based surveillance of myocardial infarction (MI) in the United States (US) typically includes age, gender, and race, but not socioeconomic status (SES). We examined the association between neighborhood median household income (nINC) and incident hospitalized MI in four US communities (1993–2002).

Methods—Average annual indirect age-standardized MI rates were calculated using community-specific and community-wide nINC tertiles. Poisson generalized linear mixed models were used to calculate MI incidence rate ratios by tertile of census tract nINC (high nINC group referent).

Results—Within community, and among all race-gender groups, those living in low nINC neighborhoods had an increased risk of MI compared to those living in high nINC neighborhoods. This association was present when both community-specific and community-wide nINC cutpoints were used. Blacks, and to a lesser extent women, were disproportionately represented in low nINC neighborhoods, resulting in a higher absolute burden of MI in blacks and women living in low compared to high nINC neighborhoods.

Conclusions—These findings suggest a need for the joint consideration of racial, gender and social disparities in interventions aimed at preventing coronary heart disease.

Keywords

Neighborhood income; socioeconomic status; myocardial infarction; community surveillance; gender; race

Introduction

Epidemiologic studies document socioeconomic disparities in coronary heart disease (CHD) morbidity and mortality in the United States (US) (1–4) and other western countries. (5–11) Because lower socioeconomic position individuals (12–15) and racial/ethnic minorities (12)

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are typically under-represented in epidemiologic cohorts due to recruitment strategies and lower participation and retention rates, documented disparities may not accurately represent patterns in the underlying populations. In contrast, US and international community-based surveillance systems are designed to accurately estimate the rates of myocardial infarction (MI), CHD mortality and associated temporal trends within communities. Such information is an important complimentary tool for monitoring disparities in the burden of CHD.

European surveillance studies report inverse associations between education (8), income (8) and occupation (7) with incident fatal and nonfatal MI events as well as higher MI rates among middle-aged persons living in socially deprived neighborhoods (16,17). Neighborhood socioeconomic factors are associated, albeit moderately, with individual socioeconomic circumstances.(18,19) Moreover, there is evidence that the neighborhood socioeconomic context contributes to many health outcomes (1,20–27) and precedence for its inclusion in health surveillance systems. (19,24,28,29) Socioeconomic disparities in the burden of MI have not been systematically addressed in US surveillance efforts, largely due to the lack of socioeconomic data in medical records. However, patient addresses are universally collected for follow-up and billing, allowing linkage to census-based socioeconomic data. The Atherosclerosis Risk in Communities (ARIC) study's surveillance has documented rates and trends in CHD in four US communities by age, race, and gender for 21 years. (30,31) We extend this work to examine rates and trends in the incidence of hospitalized MI by neighborhood socioeconomic conditions and to determine if these differences vary by study community, race, gender, or year of MI event.

Methods

Overview

The ARIC study's community-based surveillance of CHD began in 1987 with methods previously described. (32) Potential acute hospitalized MI cases were identified via retrospective review of sampled hospital discharges among white and black residents aged 35–74 years from Forsyth County, North Carolina (NC); Jackson (city) Mississippi (MS); suburbs of Minneapolis, Minneapolis (MN); and Washington County, Maryland (MD). The NC and MS communities included both black and white residents, while the MD and MN communities were predominantly white.

Identification of MI Events

Annually, hospital discharge codes meeting age and residential inclusion criteria are obtained from participating hospitals. Sampling criteria (32) are applied to select cases for evaluation. Target ICD-9 primary or secondary discharge codes include: 402, 410–414, 427, 428, and 518.4. Centrally-trained staff review eligible records for presenting symptoms, medical history, and laboratory values. MIs are identified based on cardiac chest pain, cardiac biomarkers and standard twelve-lead electrocardiograms (33). Up to three electrocardiograms are recorded and classified using a standardized algorithm. Events are classified as definite, probable, suspect, or no MI by a computer-based algorithm. Hospitalizations occurring within 28 days are linked as one event. We included incident hospitalized definite or probable MI. An MI was defined as incident if there were no indications of prior MI in the medical history.

Defining Neighborhood SES

Addresses associated with MIs were geocoded by a vendor previously identified as assigning accurate geocodes. (34) We obtained exact address matches for 93% of addresses and matched an additional 2% to the census tract (CT). Assigned CT identifiers were used to link each event with 2000 US Bureau of the Census socioeconomic data. We used CT median household income (nINC) to represent neighborhood socioeconomic conditions. It is correlated with

measures of poverty and has gradients with health outcomes comparable to those seen with a more complex index measure in this (35) and other studies. (28) nINC was classified into tertiles (low, medium, high) using both community-wide (overall) and community-specific cutpoints. Community-wide nINC cutpoints were based on the tertiles of median household incomes of the CTs across *all* study communities (high: >\$50,032; medium: \$33,533–50,032; low: <\$33,533). Community-specific tertiles, based on the distribution of CT median household incomes *within* each study community, are presented in Table 1.

Population Denominators

Using 1990 and 2000 CT population counts normalized to conform to 2000 CT boundaries, we calculated age-, gender-, and race-specific population estimates for each CT for inter-censal and post-censal periods. We compared two approaches: a simple linear interpolation-extrapolation method and regression models that included nonlinear trends. The estimates from the two approaches were similar; thus, we present results for estimates from the simple linear interpolation-extrapolation method.

Exclusions

MI events occurring before 1993 were not included, as addresses were not abstracted before this time. Between 1993 and 2002, 10,500 (unweighted) definite or probable MIs were identified. We excluded patients with missing race or gender (n=136), age < 35 or > 74 years (n=52), a missing sampling weight (n=20), non-white race in Minneapolis or Washington County [because of insufficient numbers for analysis (N=145)], and missing/inadequate address information precluding assignment of a CT (n=533). Of 9,614 remaining events, we excluded 2,885 patients with a medical history of a prior MI, 547 patients with missing data on prior MI status, and 212 patients residing outside of the study area. Our final unweighted sample size was 5,970, with a weighted sample size of 8,239 patients.

Analyses

We generated a standard population by summing the age distribution represented by the total population combining both sexes and races and all ARIC study sites for the year 2000. A three year average weighted MI count for the years 1999–2001 in eight age strata (35–39, 40–44, 45–49, 50–54, 55–59, 60–64, 65–69, 70–74) was used to calculate age-specific event rates for the standard population. The indirect standardized rates for each CT were calculated by applying standard population rates to the age-, sex-, and race-specific population of each CT. This technique provided the expected number of events for each CT (gender- and race-specific) had the tract experienced the rate of the standard.

Using the expected and observed events (weighted for sampling) for each CT for specific race-gender groups, standardized incidence rate ratios (IRR) were calculated. Note that the age-adjusted (indirect) MI rate for a CT is calculated as the product of the IRR for the tract with the crude MI event rate of the standard population.

Poisson generalized linear mixed models were used to calculate IRRs for MI by tertile of nINC with the high nINC group as the referent. This technique calculates standard errors that account for clustering of MI cases within CTs. We examined effect modification by study community and year of MI, i.e. nINC*community and nINC*year interactions (p value < 0.05) in race-gender specific models. A second set of models assessed the association of nINC with incident MI within study communities, with race and gender included as covariates.

We estimated the proportionate burden of incident MI by nINC within race-gender groups. We used race-gender specific 2000 census population counts and the proportion of persons living in each nINC area (based on overall cutpoints) to derive expected race-gender-nINC population

counts, then applied age-adjusted nINC-stratum specific MI rates to estimate the expected number of MI cases in each nINC stratum. The race-gender-nINC stratum-specific MI counts were divided by the total number of events within these groups to estimate the proportion of total MI cases within each nINC stratum.

Analyses were performed using SAS Version 9.1 (SAS Institute, Inc., Cary, NC).

Results

Table 1 presents information on the eligible study populations by race and gender as well as selected year 2000 census information. Blacks comprised 80% of the residents of Jackson, MS and 25% of the residents of Forsyth, NC. The Minneapolis suburbs and Washington County populations are predominantly white. The number of CTs within communities ranged from 31 in Washington County, MD to 75 in Forsyth, NC. Jackson, MS had the smallest average number of persons in the age range of 35–74 years, while the Minneapolis suburbs had the largest average number. The median household income varied from \$25,480 in Jackson, MS to \$54,508 in the Minneapolis suburbs.

nINC was markedly lower for blacks than whites, and within race groups, modestly lower for women than men (\$27,898 for black women; \$29,547 for black men; \$45,572 for white women; and \$45,871 for white men).

Comparison of nINC – Incident MI Across Study Communities

Figure 1 presents estimated age-adjusted, community-specific and race-gender-specific hospitalized incidence rates of MI per 100,000 persons (averaged across 10 years) by tertile of nINC.

Regardless of whether community-wide or community-specific cutpoints defined the nINC strata, the Minneapolis community had lower MI rates in each nINC strata than did other communities (Figure 1a and 1b). In the other communities, MI rates tended to be similar. An exception was a comparatively higher rate of incident MI among low nINC in Forsyth County, NC.

Inverse associations were seen between nINC and the incidence of hospitalized MI when community-specific cutpoints were used to define nINC tertiles (Figure 1a and 1b). When tertiles of nINC were established using community-wide cutpoints, stepwise, inverse gradients were generally seen between nINC and incident MI. An exception occurred in Minneapolis, MN, where those in the lowest nINC group had MI rates that were similar to those in the high nINC group. However, only two CTs and a small portion of the overall population resided in low nINC areas.

Association of nINC with Incident MI by Race and Gender

Figures 1c and 1d present the estimated average annual incident rate of hospitalized MI per 100,000 persons across the study communities by race and gender. When community-specific nINC tertiles were used (Figure 1c), there were inverse associations between nINC and the incidence of hospitalized MI in all race-gender groups except for white men, where rates were similar for those in high and medium nINC areas. When community-wide nINC cutpoints were used, inverse associations were seen in all race-gender groups (Figure 1d).

Estimation of Incidence Rate Ratio of MI by nINC

Models were fit using both community-wide and community-specific cutpoints. There was no significant effect modification of the nINC-incident MI association by year or study

community; thus, in subsequent models these variables were included as covariates. When both overall and community-specific cutpoints were used, among all race-gender groups, those living in the low nINC neighborhoods had a significantly increased risk of MI than did those in the high nINC neighborhoods. The magnitude of this association ranged from a 1.2 fold increase in risk among white men to an approximately a two-fold increase in risk among black women. IRR were suggestive of a modest increase in risk among those living in medium nINC compared to high nINC neighborhoods, however, the confidence intervals sometimes included the null value. Specifically, when overall cutpoints were used, associations were not significant for black men and black women and when community-specific cutpoints were used associations were not significant for white men.

Burden of MI within nINC, by Race and Gender

Figure 2 shows the breakdown of MI cases within nINC tertiles for each race-gender group. Among blacks, most MI cases occurred among those living in low nINC areas (approximately 90% of men and 80% of women), while among whites, the MIs were more evenly distributed across nINC groups, with the middle nINC group being the modal category. The distribution of MI cases also varied by gender. Among both blacks and whites, the proportion of MI cases in low nINC groups was higher among women than men and the proportion of MI cases in high nINC groups was higher among men than women.

Discussion

We observed monotonic, inverse associations between nINC and the incidence of hospitalized MI in the four study communities regardless of whether community-wide or community-specific cutpoints defined tertiles of nINC. Similarly, across communities, in all race-gender groups, individuals residing in low nINC neighborhoods had a significantly increased risk of MI compared to those living in high nINC neighborhoods. Our findings are consistent with population-based European surveillance reports of inverse associations of MI with individual (7,8) and neighborhood (7,8,16,17) socioeconomic measures. Also, our findings are generally consistent with an earlier report based on the ARIC *cohort* study which investigated the association between neighborhood social factors and the incidence of CHD.(1)

The association between nINC and hospitalized MI did not vary across the 10 years of surveillance. This is not consistent with reports of increasing socioeconomic disparities in CHD mortality. (5,6,36–40) However, increasing socioeconomic disparities in CHD mortality are ostensibly driven by smaller or later declines in CHD mortality among those from lower compared to more affluent socioeconomic groups, (37–40) whereas studies of change in the incidence of MI across time are less common and patterns have not been as consistently demonstrated.(31,41,42)

Within nINC- and gender-specific groups, MI rates did not vary markedly by race, and when differences did occur, higher rates were seen more often among whites. Most of the burden of MI in blacks was concentrated among residents of low nINC neighborhoods as a result of the stronger nINC-MI association among blacks and their over-representation in the lowest nINC neighborhoods (in contrast to a more even distribution of MI cases across nINC groups among whites). Beyond informing targeted community-based primary prevention efforts, this has implications for secondary prevention and care, since a substantial burden of CHD in society manifests in MI survivors, among whom those with socioeconomic disadvantage are less likely to undergo coronary revascularization (43–45) and are more likely to experience higher case fatality. (17,46,47) Moreover, it illustrates the difficulty of disentangling the effects of racial and socioeconomic disparities in the occurrence of disease in our society.

CTs were the smallest unit of analysis available. While the CT is often considered a crude approximation of neighborhood characteristics, we are reassured that CTs are constructed to be socioeconomically similar and that studies that use block groups, the smallest geographical unit at which census data are generally available, produce similar results. (48) As our work uses surveillance data, we are limited to measures available in census data. There is a lack of consensus in the literature about which census measure best approximates the neighborhood socioeconomic context. In our developmental work, we found that nINC- MI associations were similar to those found when a composite neighborhood SES index was used as well as when other individual census measures were used (percentage of persons living below poverty, percentage of households headed by females).(49) The lack of individual-level data on risk factors, co-morbidities, medical history and insurance status of all persons in the communities make it difficult to explore factors that potentially mediate neighborhood SES disparities.

The two ARIC surveillance communities with substantial black populations are in the southern US, and may not be representative of populations in other regions of the country. However, the magnitude of variation in median household income by race seen in these communities was similar to those recently reported for national figures. (50) As there were relatively few blacks living in higher income neighborhoods, our estimates for high nINC blacks were less precise. This was also an issue for blacks in medium nINC neighborhoods when overall cutpoints were used. It is reassuring that when analyses were repeated using race-specific nINC cutpoints, the lower MI rates among those in the most affluent neighborhoods persisted in both black men and women (data not shown).

Our study used standardized criteria to validate hospitalized nonfatal MI cases. These cases represent a substantial portion of the burden of all CHD in these communities, and their accurate identification is crucial to optimally document and track disparities in hospital care and subsequent survival. However, the patterns of socioeconomic and racial disparities seen in hospitalized MI events may differ from other CHD events, including silent MIs and fatal CHD. Previous reports suggested that blacks are proportionately more likely have an out-of-hospital fatal CHD event than are whites (51), and that inverse socioeconomic gradients are stronger for out-of-hospital CHD events than for all incident MI events (8). We are currently linking neighborhood socioeconomic data to fatal CHD events in ARIC surveillance communities, which will allow us to examine this issue in a subsequent report.

ARIC is the only ongoing US population-based surveillance study of CHD that includes a wide age range, diverse communities, and biracial populations. Moreover, given that MIs occurred over ten years, we could estimate community-, race-, and gender-specific effects within nINC strata. Unlike cohort studies, the potential for selection bias is minimal, given the community-based surveillance approach that includes comprehensive case ascertainment. While the sequential cross-sectional “snapshot” surveillance approach is not optimal for assessing long-term risk of groups within a defined population, when assessing the burden of disease within communities across time, it may be preferable, as it more accurately reflects the dynamic nature of populations within geographic areas.

The deficit of socioeconomic information in US vital records used in disease surveillance systems has been previously discussed (52), and can be overcome by including neighborhood socioeconomic data. (19,28). Our work demonstrates its successful implementation in a community-based surveillance system relying on hospital records. The mechanisms whereby neighborhood socioeconomic conditions influence cardiovascular health are debated. Some consider neighborhood socioeconomic characteristics to be proxies for individual-level socioeconomic characteristics. However, when both are considered in analyses, independent neighborhood effects tend to persist. (1, 53–55) There is growing evidence of the impact of socioeconomic characteristics of place of residence on factors that influence cardiovascular

health. These include access to healthy food, (56) structural features of the built environment, (57–59) psychological stress (60–62) and a higher prevalence of behaviors such as smoking (63–65) and physical inactivity. (65,66)

In summary, residents of socioeconomically disadvantaged neighborhoods were at greater risk of suffering an incident MI in the ARIC surveillance communities, with stronger inverse associations seen among women and blacks. We also note the higher burden of MI among blacks and women, as they are more likely to reside in socioeconomically deprived neighborhoods. These patterns and the association of race, gender, and socioeconomic conditions with post-MI health-related trajectories, point to the importance of their joint consideration in public health interventions aimed at CHD prevention.

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List of Abbreviations and Acronyms

ARIC	Atherosclerosis Risk in Communities Study
CT	Census tract
nINC	Census tract median household income
CHD	Coronary heart disease
IRR	Incidence rate ratio
MD	Maryland
MN	Minnesota
MS	Mississippi
MI	Myocardial infarction
NC	North Carolina
US	United States

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Within Study Community

(a) Overall nINC Cutpoints

(b) Community-Specific nINC Cutpoints

Within Race-Gender Groups

(c) Overall nINC Cutpoints

(d) Community-Specific nINC Cutpoints

Figure 1.

Figure 1(a–d). Age-adjusted Incidence of Myocardial Infarction by Tertile of Median Household Income, by Study Community and Race-Gender Groups: ARIC Surveillance Communities (1993–2002)

Figure 2.
Distribution of Incident MI Cases by Tertile of Median Household Income, ARIC Surveillance Communities (1993 – 2002)

Table 1

Characteristics of Eligible Population by ARIC Study Community, 2000 Census

	Washington Co. Maryland	Minneapolis Minnesota	Jackson (city) Mississippi	Forsyth Co. North Carolina
Race-gender composition	N	N	N	N
Black Women	1,330	4,694	26,976	18,181
Black Men	1,220	4,380	21,545	15,175
White Women	29,048	48,329	8,491	53,272
White Men	27,033	45,168	7,137	47,887
Total population ¹	58,631	102,571	64,149	134,515
Number of census tracts	31	55	43	75
Average persons per census tract ¹	1,891	1,865	1,492	1,794
Median Household Income ²	\$44,307	\$54,508	\$25,480	\$41,579
Community-specific tertiles				
High nINC	>\$46,761	>\$60,383	>\$30,727	>\$48,560
Medium nINC	\$34,018–46,761	\$50,032–60,383	\$20,521–30,727	\$33,750–48,560
Low nInc	<\$34,018	<\$50,032	<\$20,521	<\$33,750

¹ Limited to White and Black persons ages 35 to 74 years.² Calculated by averaging median household incomes for each census tract in the area.

Table 2

Myocardial Infarction Incident Rate Ratios (IRR) and 95% Confidence Intervals (95% CI) for Race-Gender Groups by Census Tract Median Household Income (nINC), ARIC Community Surveillance, 1993–2002

	Overall Cutpoints		Community-Specific Cutpoints	
	N of MI Events ¹	IRR (95% CI)	N of MI Events ¹	IRR (95% CI)
Black Women				
Low nINC	645	2.14 (1.69, 2.58)	454	2.05 (1.69, 2.42)
Medium nINC	135	1.31 (0.81, 1.81)	278	1.40 (1.01, 1.79)
High nINC ²	37	-	85	-
Black Men				
Low nINC	756	1.63 (1.20, 2.06)	490	1.41 (1.05, 1.76)
Medium nINC	211	1.42 (0.95, 1.88)	413	1.43 (1.04, 1.82)
High nINC ²	65	-	129	-
White Women				
Low nINC	412	1.79 (1.58, 2.00)	523	1.74 (1.57, 1.91)
Medium nINC	988	1.37 (1.21, 1.53)	837	1.23 (1.07, 1.39)
High nINC ²	752	-	792	-
White Men				
Low nINC	595	1.24 (1.07, 1.41)	759	1.22 (1.09, 1.35)
Medium nINC	1833	1.20 (1.07, 1.33)	1569	1.11 (0.98, 1.24)
High nINC ²	1706	-	1806	-

¹ Weighted to reflect sampling fractions used in ARIC Surveillance study.

² Referent.