Neighborhood socioeconomic and racial disparities in angiography and coronary revascularization: the ARIC surveillance study

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\textbf{A B S T R A C T}

\textbf{Purpose:} Disparities in the receipt of angiography and subsequent coronary revascularization have not been well-studied.

\textbf{Methods:} We estimated prevalence ratios and 95\% confidence intervals (PR, 95\% CIs) for the association between neighborhood-level income (nINC) and receipt of angiography; and among those undergoing angiography, receipt of revascularization procedures, among 9941 hospitalized myocardial infarction patients under epidemiologic surveillance by the Atherosclerosis Risk in Communities Study (1993--2002).

\textbf{Results:} In analyses by tertile of nINC controlling for age, study community, gender, and year, compared with white patients from high nINC areas, black patients from low nINC (0.60, 0.54--0.66) and medium nINC (0.70, 0.60--0.78) areas, as well as white patients from low nINC areas (0.83, 0.75--0.91) were less likely to receive angiography, whereas black patients from high nINC and white patients from medium nINC areas were not. Associations were attenuated, but persisted, after we controlled for event severity, medical history, receipt of Medicaid, and hospital type. Compared with high nINC white patients, black patients were less likely, and white patients were as likely, to undergo cardiac revascularization, given receipt of an angiogram.

\textbf{Conclusions:} Black and lower nINC patients were less likely to undergo angiography than were white patients and those from higher nINC areas. Among those receiving angiography, race, but not nINC, gradients persisted.

Introduction

Racial disparities in the receipt of diagnostic angiography\textsuperscript{1–3} and coronary revascularization\textsuperscript{3–12} among patients experiencing myocardial infarction (MI) are well-documented, with most investigators reporting that white patients are more likely to undergo these procedures than black patients. Gender differences in these procedures have been investigated, with reports of no differences\textsuperscript{13} as well as a higher use of revascularization procedures among men\textsuperscript{7,13,14}.

In contrast, the association of socioeconomic status (SES) with the receipt of diagnostic angiography and cardiac revascularization has been less well-studied among patients with MI in the United States. A U.S.-based study of Medicare beneficiaries reported that receipt of angiography and coronary revascularization procedures were less common among those residing in the lowest quintile of zip code-level SES\textsuperscript{14}, whereas a review of hospital records of Pennsylvania residents reported modestly lower rates of revascularization among those living in lower SES areas, as defined by zip codes\textsuperscript{6}. A Canadian study reported variations in rates of angiography but not coronary revascularization by census-based SES measures\textsuperscript{2}, whereas a recent Australian study of patients with acute coronary syndrome reported no differences by SES in the receipt of coronary artery bypass graft (CABG) and only modest variations in the receipt of coronary catheterization procedures, except in areas with a significant indigenous population, where socioeconomic disparities were evident\textsuperscript{15}.

We investigated the association of neighborhood SES with variations in the receipt of angiography and coronary revascularization procedures among hospitalized MI patients in four...
administratively defined regions of the United States. We further examined whether associations between neighborhood SES and receipt of coronary revascularization varied by race, gender, and year of event.

Methods

Overview

The Atherosclerosis Risk in Communities (ARIC) study's community-based surveillance of coronary heart disease began in 1987 with methods previously described [16,17]. Potential MI events were identified via a retrospective review of hospital discharges for MI among white and black residents ages 35 to 74 years from four communities: Forsyth County, North Carolina (NC); the city of Jackson, Mississippi (MS); northwest suburbs of Minneapolis, Minnesota (MN); and Washington County, Maryland (MD). The NC and MS areas included substantial numbers of both black and white participants, whereas the MD and MN communities were predominantly white.

MI case ascertainment and receipt of angiography and coronary revascularization

Hospital discharge diagnosis codes meeting age and residential inclusion criteria were obtained annually from the participating hospitals, and a stratified random sampling was applied [17] to select potential events for full record abstraction and evaluation. ARIC study personnel reviewed records for presenting symptoms, medical history, and pertinent laboratory values and electrocardiograms (ECGs). Events were classified as definite, probable, suspect, or no MI by computer algorithm, with selected cases reviewed for final classification. Only events classified as definite or probable MI were included in these analyses. We defined an MI as incident if there was no evidence of a previous MI in the medical record and classified all other MIs as repeat events.

Our primary outcome was the receipt of angiography and any revascularization procedure, as indicated in the medical record. In secondary analyses we considered each type of revascularization procedure (angioplasty, stent, and CABG) separately. We did not include thrombolytic therapy (eg, tissue plasminogen activator reperfusion, intravenous streptokinase) because its receipt is not dependent upon angiography.

Neighborhood SES

Patient addresses were abstracted from the medical record and geocoded by a commercial vendor previously chosen for coding accuracy [18]. Exact address matches were obtained for 93% of addresses and an additional 2% matched to the census tract (CT). We linked each event with 2000 U.S. Bureau of the Census data. We used CT median household income (neighborhood-level income [nINC]) to represent neighborhood socioeconomic conditions, as nINC is correlated with poverty and has gradients with health outcomes comparable to those seen with more complex index measures in this [19] and other studies [20]. nINC was further classified into tertiles across all study communities (high: $>50,032; medium: $33,533–$50,032; low: $<33,533).

Covariates and effect modifiers

We included age, race, study community, gender, year of the MI, whether the admitting hospital was classified as teaching or nonteaching (on the basis of whether the facility had an internal medicine residency program), and prehospital delay (time elapsed between symptom onset and hospital arrival) as covariates. For most analyses, we divided prehospital delay into the following categories: <2 hours, 2 to 12 hours, >12 hours to ≤3 days. We classified health insurance status into two categories: Medicaid recipient versus not. This decision was made because of the strong association of receipt of Medicaid with poverty [21,22] and because in our work to date, receipt of Medicaid has been consistently associated with cardiovascular disease (CVD) outcomes [23].

Measures of MI severity and other characteristics included the presence of cardiac pain, shock, cardiac biomarker levels, and ECG data. Cardiac pain on admission was dichotomized as presence or absence of pain occurring anywhere in the anterior chest, left arm, or jaw. Evidence of cardiogenic shock was abstracted from medical records and classified as low, medium and high. Cardiac biomarker levels were classified as "normal," "equivocal," "incomplete," or "normal." ECGs were recorded and classified as "evolving diagnostic," "diagnostic," "evolving ST-T," "equivocal" or "absent," "uncodable" or "other" via a standardized algorithm. As an alternative way of evaluating the potential contribution of event severity to the nINC-procedure associations, we conducted all analyses with and without patients with MI who died within 24 hours.

We ascertained presence of related conditions (diabetes, angina, CABG, hypertension, stroke, or heart failure, smoking, chronic obstructive pulmonary disease) as indicated in the medical record, whether history or diagnosed at the time of the MI.

Exclusion criteria

From 1987 through 2002, an estimated 11,656 definite or probable MI events occurred among persons ages 35 to 74 years in the four communities. We included MIs occurring in 1993 or after (n = 10,461) because address data were not abstracted before this time. We excluded 135 MIs among patients who were not black or white, 145 MIs among blacks living in MN or MD, and 240 missing data on receipt of cardiac procedures. After these exclusions, 9941 (14,063 weighted, according to previously described sampling criteria) MI events were available for analysis.

Analyses of receipt of cardiac revascularization was limited to 7375 (9315 weighted) patients undergoing angiography. We restricted analyses for receipt of stent to year 1998 and later, when these data became available.

Analyses

We calculated weighted, age-adjusted and race-specific (MS and NC study communities only) proportions of patients receiving angiography overall and by tertile of nINC. Among the subset of patients undergoing angiography, we also calculated proportions undergoing any revascularization procedure as well as by type of revascularization procedure (angioplasty, stent, CABG).

Because angiography is a common diagnostic procedure among patients experiencing acute MI, we implemented Poisson regression by using generalized estimation equations and a robust variance estimator to estimate prevalence ratios (PRs) and 95% confidence intervals (CIs). All analyses were weighted to account for the underlying sampling probabilities. We assessed effect modification (P < .05) by age, gender, and year of MI. In the two study communities with a substantial number of black patients (NC and MS), we created nINC race strata. Within these strata, we tested effect modification by age, study community, gender, and year of MI. In analyses of white patients from all four communities, we considered age, study community, gender, and year of MI as effect modifiers.

Initially, we stratified patients by whether they experienced an incident or a repeat MI. Although the proportion of patients...
undergoing angiography tended to be greater among incident than repeat MI cases, the associations by nINC and by race were essentially the same (data not shown), and we combined these groups. The modeling strategy accounted for the clustering of patients within CTs as well as repeat events among patients.

Results

Table 1 presents characteristics of the MI patients overall and among the subset of those receiving angiography and coronary revascularization. Patients were 61 years of age, on average. Thirty-four percent were women, and 21 percent were black. The average nINC was $42,404, and 12% were Medicaid recipients. The distribution of CT median household income varied markedly among black and white patients. Almost 80% of black patients with MI lived in low nINC areas, whereas fewer than 20% of whites lived in low nINC areas. The prevalence of current smoking among the patients with MI was high, as were comorbidities and previous CVD.

Overall, 66% of patients with MI received angiography. Of these, 73% subsequently had a coronary revascularization procedure (48% of all patients with MI). Angiography and revascularization recipients tended to live in more affluent neighborhoods and were less likely to be black, female, and recipients of Medicaid than were all patients with MI. Although those undergoing angiography and revascularization were more likely to have had an incident than a recurrent MI, they were less likely to have a history of CVD risk factors, chronic obstructive pulmonary disease, stroke, angina or coronary insufficiency, or heart failure than were all patients with MI.

Figure 1 presents the age- and gender-adjusted proportion of patients with MI undergoing angiography (shaded area), and among those undergoing angiography, the proportion receiving any and each coronary revascularization procedure by tertile of nINC. Three graphs are included: two for MS and NC (Fig. 1A [black] and B [white]) and one for MD and MN (Fig. 1C [white]). Black patients with MI in MS and NC were consistently less likely to undergo angiography than were white patients in the same and other communities, and within race groups, those in the low nINC areas were less likely to receive angiography compared with those in the medium and high nINC areas. Black patients with MI were consistently less likely to undergo any and each coronary revascularization procedure than were whites in the same and other study communities. Further, in both race groups, those in low nINC areas tended to undergo coronary revascularization less than those from more affluent areas. However, clear nINC gradients were not apparent and CIs tended to overlap.

Table 2 presents PR estimates and 95% CIs for receipt of angiography and, among those undergoing angiography, receipt of any revascularization procedure for race-nINC groups in the MS and NC communities, with high nINC whites serving as the referent. In initial analyses, there was no significant effect modification by gender or year of MI; thus, these variables were included as
covariates in subsequent models. In models adjusting for age, study community, gender, and year of MI (Model 1), compared with white patients from high nINC areas, black patients from low nINC (0.60, 0.54–0.66) and medium nINC (0.70, 0.60–0.78) areas, as well as white patients from low nINC areas (0.83, 0.75–0.91) were less likely to receive angiography, whereas black patients from high nINC (0.90, 0.73–1.09) and white patients from medium nINC (0.97–0.91–1.04) were not. Associations among low and medium nINC blacks and low nINC whites were attenuated, but persisted after controlling for other covariates, including receipt of Medicaid, comorbidities and indicators of MI severity (Model 2).

Among patients undergoing angiography, in models adjusting for age, study community, gender, and year of MI (Model 1), compared with high nINC whites, blacks at all nINC levels were less likely to undergo coronary revascularization. Differences were largest for black patients living in low nINC areas (0.69) and smallest (0.84) among those living in high nINC areas. After adjustment for additional covariates (Model 2), associations were attenuated and CIs for estimates for high nINC black patients included the null values. Further, clear nINC gradients were no longer evident. In both minimally and fully adjusted models, white patients in low and medium nINC areas were as likely to undergo...
Discussion

In the areas under epidemiologic surveillance by ARIC, MI patients from lower nINC areas were less likely to undergo angiography than were those from higher nINC neighborhoods. After controlling for MI severity and CVD risk factors, this graded association, while attenuated, persisted among blacks. In contrast, among whites, only a modest association persisted, and it was limited to the low nINC group. Among those undergoing angiography, after taking into account MI severity and CVD risk factors, there was no variation in receipt of revascularization by nINC. However, black patients with MI from all nINC strata were modestly less likely to undergo revascularization than were whites in the same study areas.

The paucity of socioeconomic information in vital records used for disease surveillance systems in the United States has been previously discussed [24], as has the potential for overcoming this deficit by including neighborhood socioeconomic data [20,25]. We demonstrate that this approach can also be successfully used with a community-based surveillance system relying on hospital records [23,26]. Studies generally report only moderate correlations between individual and contextual SES measures [25,27], and although studies that consider the joint “effects” of neighborhood and individual SES on health outcomes often report an attenuation of neighborhood effects, most report that significant neighborhood effects persist [28–31].

Given the lack of individual SES data in the hospital records used to identify our surveillance cases, it is challenging to address this issue in our work. However, we included receipt of Medicaid as an individual-level covariate since Medicaid eligibility is most often based on poverty status [21,22]. In our multivariable analyses, those receiving Medicaid were modestly less likely to undergo angiography (0.85–0.76–0.93 in models including black and white patients in MS and NC and 0.88–0.81–0.96 for white patients in all four study communities) and any revascularization (0.88–0.80–0.98 in models including black and white patients in MS and NC and 0.92–0.84–1.00 for whites in all four study communities) than were nonrecipients. Furthermore, the inclusion of Medicaid in models presented in Table 2 did not substantially impact the nINC-angiography or the nINC-revascularization associations.

Mechanisms by which place of residence influences cardiovascular health include access to healthy food [32], the built environment [33], exposure to psychological stress [34], and a greater prevalence of unhealthy behaviors, such as smoking [35] and physical inactivity [35]. Although these factors do not directly impact the type of care that one receives when hospitalized for an MI, they may indirectly impact diagnostic and treatment options during an MI hospitalization via their contribution to patients’ health status at the time of hospitalization.

We did not find support in our data for an effect of receipt of care at different types of hospitals among patients by race or nINC, because controlling for type of hospital (teaching vs. non-teaching) did not change our results. In addition we examined within-hospital variation in the receipt of angiography by race and nINC by restricting our analysis to seven hospitals in MS and NC which had more than 100 MI cases in each race stratum (only one hospital had fewer cases). White patients were 1.1 to 2.5 times as likely to undergo angiography as compared with black patients at the same facility. The number of events precluded further examination stratified by nINC within race groups. Nonetheless, black patients with MI from low nINC neighborhoods were consistently less likely to undergo coronary revascularization than were those in high nINC neighborhoods (data not shown). Similar but weaker nINC disparities were evident among whites in these hospitals.

Although the two ARIC surveillance areas with a substantial black population are in the southern United States and are thus unlikely to be representative of blacks in other regions of the country, the magnitude of variation in nINC by race seen in the ARIC surveillance communities was similar to recent nationwide figures [36]. Because there were relatively small numbers of blacks living in greater-income neighborhoods, our estimates for high nINC blacks were less precise. It is reassuring that when we repeated our analyses using race-specific nINC cut points, patterns persisted.

The lack of information on whether angiography or coronary procedures were offered or refused is a limitation of our study. Although it is commonly believed that racial disparities in the receipt of cardiac care are partly the result of greater refusal rates among black patients, empirical data assessing variations in refusal rates by race are not consistent. Although some reports suggest greater catherization refusal rates among black patients [12], other studies suggest that differential rates of refusal of

Table 3

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<th>nINC</th>
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<th>Revascularization procedure</th>
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<td>Model 1</td>
<td>Model 2</td>
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<tr>
<td>Low nINC</td>
<td>0.83 (0.77–0.89)</td>
<td>0.92 (0.87–0.98)</td>
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<tr>
<td>Medium nINC</td>
<td>0.97 (0.93–1.02)</td>
<td>1.02 (0.98–1.05)</td>
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<td>High nINC</td>
<td>1.00 (referent)</td>
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ARIC – Atherosclerosis Risk in Communities; CABG – coronary artery bypass grafting; CI – confidence interval; COPD – chronic obstructive pulmonary disease; ECG – electrocardiogram; MI – myocardial infarction; nINC – neighborhood income; PR – prevalence ratio.

* Model 1: nINC, age, gender, study community, and year of MI.

1 Model 2: Model 1 plus hospital type (teaching vs. non-teaching); prehospital delay time; presence of pain; shock, enzyme and ECG data; smoking status; co-occurring COPD; history of diabetes, angina, CABG, hypertension, stroke, and heart failure/pulmonary edema; Medicaid status.
catheterization or interventional cardiac procedures do not likely explain racial disparities [10,37–39]. Furthermore, a recent study reporting racial disparities in refusal rates found that once physician recommendations were taken into account, disparities by race were no longer evident [40]. To date, issues relating to variations in patient refusal to undergo revascularization as well as physicians’ recommendations by SES have not been addressed systematically [9].

Although some literature suggests that race/ethnicity does not independently influence care [41] and that racial disparities in health care primarily reflect socioeconomic disparities [37,42,43] or variations in the social context [1], our results do not support this view. Within each nINC strata, black MI patients were less likely to undergo angiography than were their white counterparts. Similarly, among those undergoing angiography, after we took into account comorbidities and MI characteristics, black patients in all nINC groups (with no evidence of an nINC gradient) were less likely to undergo cardiac revascularization than white patients in all nINC groups. The work reported here, as well as a larger body of work addressing racial disparities [44], indicate that disparities in cardiac care are not fully explained by factors such as health insurance or disease severity. Thus, as recently recommended [9], educational interventions aimed at increasing the awareness levels of both patients and physicians should be explored as potential strategies for addressing these persistent disparities in care.

Acknowledgments

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[14] Ng Y, Kasl SV, Kasl SV. Variations in patient refusal to undergo revascularization as well as physician recommendations by SES have not been addressed systematically [9].

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