Access to Revascularization Among Patients with Acute Myocardial Infarction in New York City—Impact of Hospital Resources

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ABSTRACT *Timely revascularization can improve survival in patients with acute myocardial infarction. Identification of factors associated with increased use of revascularization in appropriate patients could improve outcomes. Using New York City hospital discharge records for 1988–1992 and 1998–2002, we determined revascularization rates for patients hospitalized with MI by neighborhood. Odds ratios for revascularization were estimated using a spatial model adjusting for neighborhood sociodemographic characteristics, while accounting for similarities in the rate of revascularization among geographically adjacent neighborhoods. Only 16 out of 112 New York City hospitals performed coronary revascularization. They were located in 14 of 41 neighborhoods. In general, patients living in neighborhoods with higher percentages of patients admitted to hospitals capable of revascularization service were more likely to be revascularized than those in neighborhoods with low percentages of patients admitted to hospitals with revascularization resources. This was true regardless of neighborhood availability of revascularization, after accounting for neighborhood socioeconomic characteristics and patients' clinical status. Revascularization rates in New York City increased from 1988–1992 to 1998–2002 in every neighborhood and as a whole from 103 to 326 per 1,000 hospitalized AMI patients. This increase was not explained by the addition of new revascularization services. Thus, in New York City, where only certain hospitals can perform revascularization, efficient delivery of patients to hospitals with these resources appears to increase the likelihood of revascularization performance among AMI patients without increasing the number of new hospitals capable of revascularization.*

KEYWORDS *Acute myocardial infarction, Coronary heart diseases, Neighborhoods, Revascularization, SPARCS.*

In the U.S., coronary heart disease mortality rates are higher among poor and black patients than among white patients.^{1,2} This could be due to limited access to health care resources. Invasive cardiac revascularization procedures, including percutaneous transluminal coronary angioplasty (PTCA) and coronary artery bypass graft surgery (CABG), have been shown to improve the outcome of coronary heart

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disease.^{3–6} However, numerous studies have shown that these procedures tend to be less frequently performed in blacks than whites, even after controlling for potential confounders such as disease severity, income level, health insurance status, physician recommendation, and patients' preferences.^{7,8}

We previously showed that community of residence affects use of cardiac procedures.⁹ Place of residence may help determine how, and by whom, care is provided. Unequal geographic distributions of health care professionals, hospitals, and services provided by those hospitals exist throughout the U.S.¹⁰ In New York City (NYC), for example, only selected hospitals are licensed to perform cardiac revascularization. In many city neighborhoods, especially in disadvantaged neighborhoods, residents are admitted to hospitals lacking revascularization capacity and must be transferred elsewhere for revascularization. We have reported that in certain neighborhoods in NYC, due to lack of hospitals performing revascularization in the neighborhood, patients with acute myocardial infarction (MI) were less likely to be revascularized than were similar patients living in neighborhoods with hospitals performing revascularization.⁹ Whether and how this consequence of geographic location impedes access to the needed care throughout all NYC is not known.

We now report the impact of availability (whether the neighborhood has revascularization services) and access (whether the patient was admitted to hospitals with revascularization resources) on the use of revascularization among acute MI patients in NYC.

METHODS

Data Sources

The study databases were the 1988–1992 and 1998–2002 SPARCS (Statewide Planning and Research Cooperative System) data, created by the New York State Department of Health.¹¹ SPARCS is legislatively mandated and contains discharge data abstracted for at least 95% of all New York State hospital admissions except psychiatric and federal hospitals. SPARCS includes age, sex, race, admission status, physician and hospital identifiers, principal diagnosis and up to 14 secondary diagnoses, principal procedure code and up to 14 other procedure codes, and disposition status. Diagnoses and procedures are coded by the International Classification of Disease, Ninth Revision, Clinical Modification (ICD-9-CM). Data are abstracted from medical records by trained personnel in each hospital, and the New York State Department of Health verifies the accuracy of reported information.

MI was defined by ICD-9-CM principal diagnosis codes 410.0 through 410.9. Since MI rarely occurs before age 35, this study was limited to patients ≥ 35 years. Revascularization was identified by procedure codes, including PTCA (ICD 36.01, 36.02, 36.05, 36.06) and CABG (ICD 36.10 through 36.19). Cardiovascular co-morbidity was defined by ICD-9 codes from secondary diagnoses and included diabetes (ICD 250) and hypertension (ICD 401–405). We defined complications of MI as congestive heart failure (ICD 428) and cardiogenic shock (ICD 785.51) by other diagnostic codes. Admission status was categorized as emergency, urgent, or elective.

SPARCS hospital codes provide hospital name (which was used to determine hospital location) and revascularization resources. Race was categorized as white, black, Native American, Asian or Pacific Islander, and other. Ethnicity was additionally defined by Hispanic origin. We therefore defined race/ethnicity as non-

Hispanic white, non-Hispanic black and Hispanic (including white Hispanics, black Hispanics and all other Hispanics). Other races with small percentages (<4%) were excluded from the analysis. Insurance status was based on primary and secondary coverage and was categorized as 1) private insurance (alone or with public insurance); 2) public insurance (Medicare, Medicaid and other government insurance); 3) no insurance.

All the above individual characteristics were converted to neighborhood characteristics presented as percentages to fit into the spatial models.

Neighborhoods

We adopted neighborhoods as defined by the United Hospital Fund.¹² By aggregating the adjoining zipcodes that share similar socioeconomic characteristics, as well as approximate NYC Community Planning Districts, the neighborhoods were defined. In most cases, zipcodes generally fall within the boundaries of a community-planning district. In several instances, however, individual zipcodes are bisected by community planning district boundaries. Where this has occurred, two or more districts were combined to form one neighborhood. Thus, the 59 community planning districts were reduced to 41 neighborhoods: four in Staten Island, seven in the Bronx, and ten each in Brooklyn, Manhattan, and Queens. This neighborhood category has been used widely by the NYC Department of Health for community health surveys. According to the 2000 census, the number of residents in each neighborhood ranged from 29,266 to 464,736, and the range of per capita income among the neighborhoods was \$8,732 (for Mott Haven—Hunts Point in the South Bronx, where more than 97% of the population were non-Hispanic blacks and Hispanics) to \$70,625 (for Gramercy Park—Murray Hill in Manhattan, with more than 76% non-Hispanic white population). Neighborhood income was derived from U.S. Census data (1990 and 2000) based on zipcode.

Statistical Analysis

Smoothed crude and adjusted relative odds of revascularization were estimated using a spatial model, adjusting for neighborhood-level sociodemographic characteristics (race, type of health insurance, average household income, neighborhood availability of revascularization resources) and accounting for similarities in the likelihood of revascularization among geographically adjacent neighborhoods. The specific model is presented in the [Appendix](#).

This spatial model is employed to adjust for neighborhood-level sociodemographic characteristics, such as race, type of health insurance, average household income, neighborhood availability of revascularization resources, and to explicitly account for similarities in the likelihood of revascularization among geographically adjacent neighborhoods. In order to avoid the problem of collinearity, we centered covariates by their grand mean. We ran two independent Markov chains. After an initial burn-in of 50,000 Markov Chain Monte Carlo (MCMC) iterations, convergence was checked via plotting and overlaying sample traces from the two sequences and Gelman and Rubin's statistics.¹³ A thinning interval of 50 was used, with each posterior based on 2000 MCMC samples from 50,000 iterations of two parallel chains. The model was based on data from both periods. To measure the trend, the period of 1988–1992 was considered the baseline and the change in odds of revascularization from 1988–1992 to 1998–2002 was assessed while adjusting for neighborhood-level covariates.

RESULTS

1. Revascularization resources and neighborhood characteristics.
- In 1990, there were 15 hospitals in NYC with revascularization service, and this number increased by 16 in 2000. Nine hospitals were located in Manhattan, two each in the Bronx, Queens and Brooklyn and one in Staten Island. The distributions of these hospitals in 14 NYC neighborhoods are displayed in Figures 1–3. Neighborhoods without revascularization resources, compared to those with, had a larger proportion of black and Hispanic populations, lower median household income, higher percentage of population in poverty, fewer physicians per 100,000 population, and higher total death and CVD death rates (Table 1).
2. Revascularization by neighborhood.
- During these two periods, the increase in revascularization rates for MI patients by neighborhood varied from 200 to 470 per 1,000 hospitalizations. Relative odds of revascularization for each neighborhood, using the NYC average as a reference, are displayed in Figure 1 (unadjusted) and in Figure 2, where the odds ratios were adjusted for neighborhood-level covariates. Figure 1 reveals that neighborhoods with hospitals performing revascularization—as well as neighborhoods adjacent to them—tended to have a greater rate of revascularization. There was a moderate level of local autocorrelation, i.e., 0.77 with 95% credible interval from 0.41 to 0.99. However, after adjusting for neighborhood socioeconomic characteristics, we found that a different pattern emerged (Fig. 2). Presence or absence of a revascularization resource did not predict for neighborhood-level revascularization. Of note, Staten Island had revascularization odds at least 26% below the city average, and there was no hospital there with revascularization during the early 1990s.
- The model showed that although the neighborhood availability of hospitals with revascularization resources was not associated with revascularization use at

FIGURE 1. Smooth odds ratios of revascularization after AMI in NYC neighborhoods, 1988–1992.

FIGURE 2. Smooth odds ratios of revascularization after AMI in NYC neighborhoods, 1988–1992 (adjusted for covariate effect).

the neighborhood level, the percentage of patients admitted to such hospitals (i.e., “access”) was positively associated with revascularization use. For example, an acute MI patient who lives in a neighborhood with 20% higher percentage of patients admitted to hospitals with revascularization resources than the NYC average was about 41% more likely to be revascularized. For other characteristics in the model, only congestive heart failure (CHF) and hypertension were independently associated with revascularization odds (Table 2).

FIGURE 3. Smooth trends in ratio of revascularization after AMI in NYC neighborhoods, from 1988–1992 to 1998–2002 (adjusted for covariate effect).

TABLE 1. Descriptive summary of New York City neighborhoods with and without revascularization hospitals, 1998–2002

	Neighborhood with revascularizing hospital	
	Yes	No
Total number of neighborhoods	14	27
Total population	2,903,616	5,072,275
AMI hospitalizations	24,179	48,009
White (%)	40.2	32.0
Black (%)	20.4	26.8
Hispanic (%)	25.6	27.8
Median household income (\$)	44,769	40,884
Below poverty (%)	18.7	20.7
Physicians per 100,000 population	157.4	148.3
Age-adjusted total death rate (1/100,000)	671.2	735.1
Age-adjusted CVD death rate (1/100,000)	243.4	285.4

3. Change from 1990 to 2000.

From 1990 to 2000, the overall revascularization rate in NYC increased from 103 to 326 per 1,000 hospitalized acute MI patients. However, there was some variation in this increase of revascularization use by neighborhood (i.e., ranging from 2.1 to 6.2-fold increase). The odds ratio corresponding to the time trend (i.e., 1988–1992 vs 1998–2002) in each neighborhood, adjusting for other neighborhood characteristics, revealed that there was an increase in revascularization use in every neighborhood from 1988–1992 to 1998–2002. There was a moderate level of local autocorrelation, i.e., 0.73 with 95% credible interval from 0.21 to 0.99. In general, the emerging impression is that neighborhoods starting with high revascularization odds seem to stay relatively stable, while neighborhoods that started with low odds of revascularization show more increase over the years. Since only one hospital with revasculari-

TABLE 2. Odds ratios of revascularization associated with neighborhood-level covariates, New York City, 1998–2002

Covariate	OR	95% CI
Gender	1.00	(0.99, 1.02)
CHF	0.98	(0.97, 0.99)
Cardiogenic shock	0.99	(0.95, 1.03)
Diabetes	1.01	(0.98, 1.02)
Access	1.017	(1.01, 1.02)
Hyperlipidemia	1.00	(0.99, 1.02)
Hypertension	0.98	(0.97, 0.996)
Median HH income	1.09	(0.97, 1.14)
Obesity	1.02	(0.94, 1.10)
Pulmonary disease	1.00	(0.98, 1.02)
Renal disease	0.97	(0.92, 1.02)
Race	1.00	(0.99, 1.003)
Age	0.99	(0.98, 1.01)

All covariates except Median HH income and age are expressed as percentages. For instance, CHF is the percentage with congestive heart failure among those hospitalized for AMI.

zation resources was added during this period in Staten Island and the odds of revascularization for this neighborhood increased the least, the increase could not be explained by the opening of new hospitals with revascularization service in the neighborhoods. On the other hand, most neighborhoods with the highest increases in Brooklyn and Queens had no hospitals with revascularization resources (Fig. 3).

DISCUSSION

The principal finding of this study is that in NYC, residents in a neighborhood with high levels of access to coronary reperfusion resources—regardless of the presence of a hospital capable of revascularization in their neighborhood of residence—experienced significantly higher revascularization rates for acute MI compared to residents in neighborhoods where patients experience less likelihood of reaching these facilities, after accounting for other neighborhood-level sociodemographic characteristics.

Here, “access”—admitting to hospitals with revascularization resources—is not a matter of geographic proximity; rather, it reflects actual admission to a hospital capable of performing the needed procedure. Thus, for example, a patient living in a neighborhood lacking a revascularization facility might still be admitted to a hospital in another neighborhood of the city. In this case, s/he could access revascularization even though the facility is not located in her/his neighborhood. In fact, early studies at the individual level had revealed that 1) acute MI patients living in the neighborhood with revascularization resources were more likely to use the revascularization service,⁹ and 2) the availability of cardiac services in the hospital to which patients initially present strongly influences the likelihood of their use in the period following AMI.¹⁴ The current study, using a neighborhood-level approach, provides us a new pathway—getting the patients to a hospital with resources regardless of where they live. To achieve this, we can either build more hospitals with revascularization facilities or arrange a better transportation system to send the patients to the hospitals with resources. With limited health care dollars, the latter option would be more appealing.

Interestingly, the addition of one hospital with revascularization resources after 1992 in Staten Island was not associated with a significant increase in revascularization. At the same time, the observed increased revascularization rate from 1990 to 2000 in most New York City neighborhoods was not due to an increase in hospitals with revascularization facility. This provides further support for the notion that geographic proximity may not be the critical factor. In fact, residents of Staten Island have a lower revascularization rate than the NYC average, despite having higher socioeconomic status than the average New Yorker. This supports our finding here that after accounting for socioeconomic status, access to hospitals with revascularization services is the most important determinant of using revascularization. In the case of Staten Island, the limited access on the two connecting bridges prevents efficient transportation of patients from Staten Island to revascularization hospitals in other areas. On the other hand, the finding of low revascularization rates in Staten Island in 2000 may be the result of long-established referral patterns remaining strong determinants of revascularization use even though resources became available within the neighborhood.

Since early revascularization can improve survival to patients with acute MI, it should be the goal that every patient without contraindication should receive revascularization. Less frequent revascularization among patients with low socioeconomic status may be the cumulative result of multiple factors—i.e., less frequent admission to a hospital offering revascularization, less frequent revascularization even when admitted, or less frequent transfer or readmission to a performing hospital.¹⁵ By contrast, patients of higher socioeconomic status are more likely to be admitted to a high-technology hospital even though it is beyond their closest hospital.^{14,16}

Our data showed that those neighborhoods with the highest percentage of patients admitted to hospitals with revascularization resources were most likely to have high revascularization usage. This suggests, of course, that access to revascularization is the strongest predictor of revascularization use by patients with acute MI even after adjusting for neighborhood-level sociodemographic and clinical characteristics. Moreover, the substantial differences in the odd ratios for revascularization across neighborhoods are not explained by differences in socioeconomic status or race or the clinical mix of acute MI patients, since these characteristics were controlled for in the spatial model. Nevertheless, the key issue seems to be whether patients were admitted to hospitals with a revascularization service. It might be possible to increase admissions to appropriate hospitals by altering the ambulance delivery system. For example, Southwest Queens has no revascularization hospitals, yet revascularization use there was high. At the same time, Staten Island, having no hospital with revascularization capacity during 1988–1992, one hospital with revascularization added during the middle 1990s, and no other such hospital nearby, had the least revascularization use.

During the time period of this study, there was increased revascularization in all neighborhoods in NYC, but this varied substantially by neighborhood. The fact that neighborhoods with the lowest odds of revascularization at the beginning increased most—as well as that this increase was not explained by the addition of performing hospitals in the neighborhoods—suggests the possibility that improved ambulance service for patients with acute MI could have contributed to the increased revascularization.¹⁷

It is possible that revascularization is really not the principal explanation for difference in outcomes but merely serves as a surrogate for other determinants of health services, including the overall quality of cardiovascular and general medical care.¹⁸ In fact, other determinants of care, such as hospital teaching status, may be more important.¹⁹ Perhaps hospitals offering sophisticated cardiovascular services attract superior health care providers at all levels.

The study is limited by the use of an administrative database. Important clinical information such as the use of thrombolysis, which would affect treatment decisions and health outcomes, was not available from the data. Errors in diagnostic and procedure coding could also have affected our results. However, given the quality and standardized nature of the large SPARCS data,¹¹ we believe in their reliability and internal validity, as well as the validity associated with time changes.

These results suggest that, in New York City, ready access to a hospital capable of revascularization determines the likelihood of receiving the procedure, regardless of geographic location or socioeconomic status. Results here suggest that targeted improvement in the system for delivery of patients to appropriate cardiovascular care facilities can increase revascularization and thereby improve outcomes in patients with acute MI.

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APPENDIX

Specifically, we employed a Bayesian spatial model. Let Y_j denote the number of revascularizations for the j th neighborhood and N_j be the corresponding number of patients hospitalized for AMI; $j = 1, \dots, J$. Let θ_j represent the underlying revascularization rate for the j th neighborhood. Given the underlying revascularization rate θ_j , our model assumes the following binomial sampling distribution for the Y_j s:

$$Y_j/\theta_j \sim \text{Binomial}(N_j, \theta_j)$$

Considering a logit link function for the revascularization rates θ_j , we assumed that

$$\log\left(\frac{\theta_j}{1 - \theta_j}\right) = \beta_0 + \sum_{i=1}^I \beta_i z_i + b_j$$

Where β_0 represents the logarithm of ‘global’ mean odds of revascularization for New York City as a whole, the β_i s are regression coefficients capturing the effect of neighborhood-level covariates such as average household income or race, and the b_j s are random spatial effects representing log-odds ratio of the corresponding neighborhood after taking into account the effect of neighborhood-level covariates included in the model. Therefore, $\exp(b_j)$ is a relative odds ratio. We put a prior on the b_j s that allows dependency in the likelihood of revascularization among geographically adjacent neighborhoods. We specifically employed the conditional autoregressive (CAR) model.^{*,†} This model induces local smoothing by borrowing strength from adjacent neighborhoods. The CAR prior corresponds to the following conditional distribution of b_j :

$$b_j/b_{k \neq j} \sim \text{Normal}\left(\frac{\lambda}{1 - \lambda + \lambda n_j} \sum_{j:k} b_k, \frac{\sigma^2}{1 - \lambda + \lambda n_j}\right), j = 1, \dots, J$$

To carry out a full Bayesian analysis via the Markov Chain Monte Carlo (MCMC) method, we completed the model specification by assuming the following non-informative priors and hyperpriors:

$$\begin{aligned}\tau = \sigma^{-2} &\sim \text{Gamma}(0.001, 0.001) \\ \beta_i &\sim \text{Normal}(0.0, 0.001), i = 0, \dots, I \\ \lambda &\sim \text{Uniform}(0, 1)\end{aligned}$$

* MacNab YC. Hierarchical Bayesian spatial modelling of small-area rates of non-rare disease. *Stat Med*. 2003;22:1761–1773.

† Banerjee S, Carlin BP, Gelfand AE. *Hierarchical Modeling and Analysis for Spatial Data*. Boca Raton, FL: Chapman and Hall/CRC Press; 2004.

Where n_j denotes the number of neighbors for area j , $j \sim k$ indicates that area j is a neighbor of area k and λ is a spatial autocorrelation parameter.

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