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Examining the Contextual Effects of Neighborhood on Out-of-Hospital Cardiac Arrest and the Provision of Bystander Cardiopulmonary Resuscitation

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Abstract

Objective—To understand the association between neighborhood and individual characteristics in determining whether or not bystanders perform cardiopulmonary resuscitation (CPR) in cases of out-of-hospital cardiac arrest (OHCA).

Methods—Between October 1, 2005 to November 30, 2008, 1,108 OHCA cases from Fulton County (Atlanta), Georgia were eligible for bystander CPR. We conducted multi-level non-linear regression analysis and derived Empirical Bayes estimates for bystander CPR by census tract.

Results—279 (25%) cardiac arrest victims received bystander CPR. Provision of bystander CPR was significantly more common in witnessed events (odds ratio [OR] 1.64; 95% confidence interval [CI] 1.21 to 2.22, p value <0.001) and those that occurred in public locations (OR 1.67; 95% CI 1.16 to 2.40, p value <0.001). Other individual-level characteristics were not significantly associated with bystander CPR. Cardiac arrests in the census tracts that rank in the highest income quintile, as compared to the lowest income quintile were much more likely (OR 4.98; 95% CI 1.65 to 15.04) to receive bystander CPR.

Conclusion—Cardiac arrest victims in the highest income census tracts were much more likely to receive bystander CPR than in the lowest income census tracts, even after controlling for individual and arrest characteristics. Low-income neighborhoods may be particularly appropriate targets for community-based CPR training and awareness efforts.

Striking geographic variation in out-of-hospital cardiac arrest (OHCA) outcomes have been observed,¹ with survival rates varying from 0.2% in Detroit, Michigan² to 15.3% in Seattle, Washington.³ It is well established that timely provision of certain interventions can substantially improve a victim's odds of survival with a favorable neurologic outcome. The collective impact of these interventions has been termed the "chain of survival."^{4, 5} Recent evidence-based guidelines for OHCA management have placed more emphasis on basic life support, including early provision of CPR and early defibrillation as key steps in resuscitating victims of OHCA. For every 24 to 36 people who receives bystander CPR, one life will be saved.⁶ This means that in the United States alone, if we could raise the national average rate of bystander CPR from 20%^{1, 7} to the nearly 50% rate of bystander CPR typical of cities such as Seattle,⁸ a minimum of 2,500 to 3,000 lives would be saved each year.

Studies conducted in Memphis,⁹ Chicago,¹⁰ New York City,¹¹ and Canada¹² have demonstrated racial and economic disparities in outcomes following cardiac arrest. Patients who are African-American and/or lower socioeconomic status are less likely to receive bystander CPR and to survive an OHCA. No single explanation for these differences has been identified. However, these studies examined decontextualized events, ignoring the potential effects neighborhood may have on both bystander CPR initiation and survival following cardiac arrest. Neighborhoods have been shown to exert an independent and consequential influence on disease incidence, processes of care and outcomes in other life-threatening conditions, such as myocardial infarction and stroke.^{13–17} These neighborhood effects can be of many forms. For CPR provision, the mechanism of neighborhood effects may be particularly straightforward – someone other than the cardiac arrest victim must provide the CPR and initiate the chain of survival. We expect that a major determinant of who is nearby to provide CPR is the neighborhood in which the cardiac arrest occurs.

While it is certainly plausible that neighborhoods might influence cardiac arrest outcomes, there is a paucity of data and there have been no focused interventions with neighborhoods as their targets. Data from Chicago in the 1980's¹⁸ suggested that neighborhood factors influence CPR provision rates. But there have been no subsequent studies that integrate neighborhood characteristics with modern statistical techniques¹⁹ to address a key question that must be answered to motivate neighborhood-based interventions: Are there characteristics that can identify neighborhoods particularly at risk for failing to provide CPR, and consequently suffering unnecessarily poor cardiac arrest outcomes?

METHODS

This is a secondary data analysis of the out-of-hospital cardiac arrest surveillance registry CARES (Cardiac Arrest Registry to Enhance Survival). Detailed information about this registry is published elsewhere.^{7, 20}

From October 1, 2005 to November 30, 2008, CARES captured all 911-activated cardiac arrest events that took place in Fulton County, Georgia. Fulton County has a population of 936,676 people; is primarily biracial, with 48.3% of citizens classified as white and 42.4% African-American by the US Census Bureau.²¹ CARES analysts confirmed the capture of all cardiac arrests by each city's 911-center during the data review process. Grady EMS (which is the largest hospital-based EMS system in the country) and Rural Metro Ambulance Services (privately-owned ambulance service) cover 95% of Fulton County. Both agencies prospectively submitted data in accordance with the CARES user agreement. Both EMS agencies have similar standards for response intervals and both have the same EMS protocols.

All cases submitted to the registry during the study interval (n=2,028) were eligible for study if they met inclusion criteria. A case was excluded if 1) the patient was not eligible for bystander CPR by a non-healthcare professional because of the ready availability of healthcare professionals (*e.g.*, patient's arrest occurred in a medical facility such as a nursing home or medical clinic) or the event was witnessed by EMS (n=468); 2) EMS personnel determined that the arrest was due to a non-cardiac etiology (*e.g.*, trauma, electrocution, drowning, or respiratory) (n=283); or 3) prehospital resuscitation was not attempted based on local EMS protocols (*e.g.*, obvious signs of death such as rigor mortis, decomposition, lividity) (n=66). We also excluded cases if: 4) data documenting the patient's clinical outcome was missing (n=24) 5) the patient's cardiac arrest location address could not be mapped (n=60), or 6) the event occurred in Atlanta's Hartsfield-Jackson International Airport, a public facility that is heavily monitored, has numerous trained rescuers and an ample supply of public access defibrillators (n=19 cases).

The CARES dataset was geocoded based upon the address of the cardiac arrest event using ArcGIS and Spatial Analyst Extension Software (Environmental Systems Research Institute (ESRI), Redlands, CA). We used census tracts as proxies for neighborhoods, as they tended to represent social and economically homogenous groups of approximately 4000–7000 people.²² Census tract variables were linked to each geocoded address using the 2000 US Census Summary files.²³ All statistical analyses were conducted using STATA version 10.2 (College Station, TX).

Patient-level factors were obtained from the CARES registry. They included: age, gender, race (as coded by the EMS provider), location of arrest (public location versus private residence), witnessed arrest (arrest witnessed by someone other than the first responder/EMS provider), who initiated CPR (as coded by the EMS provider), receiving emergency department and neurological outcome at the time of hospital discharge. Any bystander, who was not part of the medical or EMS team, was considered eligible to initiate bystander CPR. Individual level race was coded as unknown in approximately 40% of our sample. To control for non-response, we categorized these patients as a separate "missing" or "unknown" racial category, rather than dropping them from the sample or attempting to impute race. Neurological outcome was coded by the hospital contact, using the 5-level Cerebral Performance Categories Scale (CPCS).²⁴

To determine the association of individual and neighborhood-level characteristics on the likelihood that an OHCA victim would receive bystander CPR, we conducted a hierarchical non-linear regression (HLM). HLM allowed us to statistically account for 1,108 individual

cardiac arrest victims being nested within 161 census tracts. To determine the extent to which neighborhoods have associations independent of individual characteristics, we used a random intercept model (empty model) to partition the variance between neighborhoods (defined as census tracts) and the individual-level characteristics. Individual level (model 1) and neighborhood level characteristics (model 2) were then added as fixed effects to the model to examine their independent contributions. Because odds ratios can be difficult to present in a two level model, we conducted posterior predictions to illustrate the effect of neighborhood factors on the provision of bystander CPR. In addition, we chose to use median household income of the census tract as a categorical variable with 5 values, in order to better determine the effect of income on an individual's likelihood of receiving bystander CPR or surviving an OHCA.

For this analysis, we characterized Atlanta neighborhoods as homogeneously white or black if greater than 90% of the census tract's residents identified themselves as members of one racial group or the other. If the proportions of the two groups were less skewed, we described the neighborhood as integrated. Because there was a high degree of correlation between income levels and the prevalence of the three racial categories (White, Black and not reported), we were unable to assess whether observed differences by census tract are due to differences in race or median income. We chose to include the median income of each census tract in the final model, but we also ran models analyzing differences in race and mean income, available in the appendices (A& B).

We then used Empirical Bayes methods to calculate rates of bystander CPR by census tract and then stratified by the median household income tertiles in order to graphically depict the differences in adjusted rates of bystander CPR provision by census tract. We chose to display the map in tertiles of income, rather than the quintiles used for the main regression, for ease of interpretation.

Several sensitivity analyses are reported in Appendix C. We considered a neighborhood's racial homogeneity rather than neighborhood median income as an explanatory variable, as including both variables in the model was not possible due to collinearity. We also varied the percentage thresholds used to define racial homogeneity and stratified analyses based on different levels of neighborhood racial homogeneity.

This registry is used for public health surveillance and continuous quality improvement. Because it contains only de-identified data, our study was considered exempt research by the University of Michigan Institutional Review Board.

RESULTS

1,108 cardiac arrests met study criteria as eligible to receive bystander CPR. Forty-one patients (3.7%) survived to hospital discharge. Table 1 displays the row percentages of the eligible arrests from the bystander and non-bystander CPR groups who have certain demographic, clinical and EMS statistics of the eligible arrests. Twenty of the 41 survivors received bystander CPR. Eleven of these 20 were from neighborhoods in the highest median income quintile of Atlanta census tracts.

Figure 1 displays the geographic distribution of bystander CPR rates in Fulton County. Bivariate analysis confirmed that there were marked differences between arrest victims who did and did not receive bystander CPR (Table 1). Arrest victims who received bystander CPR were more likely to be male, white, arrest in a public location, or have a witnessed cardiac arrest. Not surprisingly, they were also more likely to be found with a shockable rhythm such as ventricular fibrillation or ventricular tachycardia (VF/VT).

Table 2 displays the unadjusted and adjusted odds ratios for provision of bystander CPR. At the individual level, OHCA events that were witnessed (odds ratio [OR] 1.64; 95% confidence interval [CI] 1.21 to 2.22) or occurred in a public location (OR 1.67; 95% CI 1.16 to 2.40) were more likely to receive bystander CPR. Cardiac arrests in the census tracts that rank in the highest quintile of median household income were more likely (OR 4.98; 95% CI 1.65 to 15.04) to receive bystander CPR than the reference group in the lowest median quintile of median household income. Although differences between the other three quintiles were not statistically significant, a dose response relationship between neighborhood income and higher rates of bystander CPR was evident in the top 3 income quintiles. We also display the distribution of the quintiles of median household income by census tract and quintiles of adjusted rates of bystander CPR by census tract in Figure 1 & 2. This pictorially displays the wide variation that is seen in both median household income and bystander CPR throughout Fulton County. In addition, for every 10 percent increase in single person households within a census tract, the odds of receiving bystander CPR increased 30 percent (OR 1.30; 95% CI 1.09 to 1.54). Including census tract level variables in the model explained more than 3/4 of the total variance between census tracts.

Despite a relatively small number of survivors (n=41), we identified a trend between census tract median household income and the likelihood of survival to hospital discharge. Specifically, those events that occurred within the highest median income census tract had an OR for survival of 9.11 (95% CI 1.17 to 71.00, Table 2) as compared to those in the lowest income census tract. We did examine the influence of adding bystander CPR and shockable rhythm to the model, however this did not significantly alter the final results.

To illustrate the magnitude of census tract effects on the provision of CPR, we calculated the predicted probability of receiving CPR stratified by individual factors such as whether or not the arrest was witnessed (Table 3). All other things being equal, OHCA victims who were witnessed to collapse in a public setting in a neighborhood in the highest income quintile were more likely to receive bystander CPR (adjusted probability 0.55; 95% CI 0.35 to 0.80) than patients in similar circumstances who collapsed in a neighborhood ranked in the lower quintiles for income (adjusted probability 0.35; 95% CI 0.21 to 0.50).

Sensitivity Analysis

Due to the collinearity of the census tract median household income and racial composition variables, we performed a sensitivity analysis of the data using homogeneity of the census tract to identify those neighborhoods that were greater than 80% (Appendix B) or 90% (Appendix C) White or Black. Regression analyses were done using homogeneity of the census tract in addition to the median household income variable for both the 80% and 90% threshold for homogeneity of the census tract. The homogeneity of the census tract was significant without median household income included in the analysis, but upon adding this variable no longer became significant. Only the highest median household income quintile was significant in the final model, however the increasing trend of likelihood of CPR as the median household income increased was similar to the model included in the primary analysis.

DISCUSSION

We found that a patient's likelihood of receiving bystander CPR was almost two times greater in the highest income neighborhoods, even after controlling for differences in cardiac arrest characteristics. Our research shows, building on previous work,^{12, 18, 25} that neighborhood characteristics have a profound effect on the likelihood that an OHCA victim will receive bystander CPR and whether that victim will ultimately survive cardiac arrest. Differences in CPR rates between the wealthiest and the poorest neighborhoods are of nearly

the same magnitude as differences between witnessed and unwitnessed arrests. This information could help policy-makers, public health officials and community planners do a better job of allocating limited healthcare resources, such as CPR training. Rather than blanketing a city with CPR training, which is costly and time-consuming, our research suggests that evidence-based community interventions can be designed that will specifically target those neighborhoods that are most at need. Based on our previous work,²⁶ we know that certain neighborhoods, year after year, can be identified that have a higher incidence of cardiac arrest and lower prevalence of CPR. This has implications for all cities, both nationally and internationally. Quantitative data, such those provided by CARES, may be combined with other public health datasets to identify neighborhoods at risk for low bystander CPR rates, and then develop targeted interventions that can boost rates of bystander CPR and therefore, improve community wide rates of survival.

Almost half of those who survived to hospital discharge received bystander CPR, as has been true elsewhere^{9–12}. More than half of the survivors were from neighborhoods in the highest income quintile. In our study, if we were able to improve rates of bystander CPR for the entire sample to the current bystander CPR rates in the highest SES groups, an additional 97 people would receive CPR. An estimated additional (relative) 17% increased survival could be realized. This underscores the importance of bystander CPR in cases of OHCA, as well as the need to bridge the gap between the lowest and highest quintile neighborhoods for household income.

Our study has several important limitations. Individual level race was missing or coded as “unknown” in approximately 40% of our sample. The fact that “race unknown” was associated with an odds ratio for bystander CPR that was closer to those of blacks suggests that non-reporting was not a random event. After census-tract level variables were taken into consideration, victim race did not have an independent effect on bystander CPR or survival. This may suggest that an individual’s race may be less relevant for predicting bystander CPR than the neighborhood in which the OHCA occurs. Future studies in other cities may be able to examine the relative impact of race at the individual and neighborhood level, particularly in places with more diverse racial and ethnic compositions. We were unable to distinguish between the effects of neighborhood socioeconomic status versus racial composition on the provision of CPR as they are highly correlated in Fulton County. Previous studies in Canada¹² and Seattle²⁵ have found that OHCA patients who collapse in higher socioeconomic status homes or areas associated with higher educational attainment are more likely to receive CPR. In contrast, data from Chicago in the 1980’s suggested that racial homogeneity, but not neighborhood income, was an important predictor of the likelihood of receiving bystander CPR.¹⁸ Further exploration of the larger OHCA surveillance data from other US cities and qualitative research methods may disentangle the explanatory effects of neighborhood income versus racial composition in OHCA treatment and outcomes.

Many factors have been offered to explain location-specific differences in OHCA outcome, including variations in underlying illness,^{27, 28} differences in risk factors and lifestyles,^{29–33} lower quality of hospital care in poor neighborhoods,^{34–36} and a lower likelihood of receiving interventions such as thrombolytics and cardiac catheterization.^{37–40} We found that low-income neighborhoods have markedly lower rates of bystander CPR – an intervention known to improve outcomes – than high-income neighborhoods. There may be several explanations for this phenomenon. These include lack of CPR training classes in low-income areas, baseline health differences, a relative lack of social capital (distrust of neighbors, social isolation), and perhaps fear of acquiring a communicable disease from mouth-to-mouth ventilation. With the recent shift to chest compression only bystander CPR, the reasons for lack of CPR may change.⁴¹ Future research will need to examine whether the

trends we have seen in Fulton County persist across time with the change to compression-only bystander CPR. These issues of spatial, contextual and psychosocial environmental effects on OHCA occurrence are a relatively untapped area of research and will require further exploration.

CONCLUSION

Disparities in the provision of CPR exist within Fulton County, Georgia despite national and local efforts to educate the public about the importance of early chest compressions for survival from OHCA. This study validates the work conducted in Chicago over twenty years ago, specifically that neighborhood level factors play an important role in determining the provision of bystander CPR and may be important targets for focused community-based educational interventions. Further research considering the impact of the neighborhood when designing, implementing and evaluating CPR interventions, as well as improving the individual's access to timely EMS care and interventional resources (i.e. cardiac catheterization⁴² or resuscitation centers⁴³) may be important in attempting to improve a stagnant rate of OHCA survival.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.
Distribution of Median Household Income by Census Tract in Fulton County, Atlanta
Georgia

Figure 2.
Distribution of Adjusted Bystander CPR Prevalence by Census Tract in Fulton County,
Atlanta Georgia

Table 1

Patient Demographics & Cardiac Arrest Characteristics

	Bystander CPR (n=279)	No bystander CPR (n=829)	P value
Age (SD) (n=1082)	60.8 years	62.5 years	0.17
Sex			
Female (n=466)	20.8%	79.2%	0.011
Male (n=640)	28.4%	71.6%	
Race			
White (n=209)	36.4%	63.6%	0.001
Black (n=396)	21.7%	78.3%	
Other (n=27)	25.9%	74.1%	
Unknown (n=476)	23.1%	76.9%	
Witnessed Arrest (n=489)	32.1%	67.9%	<0.001
Unwitnessed Arrest (n=615)	19.7%	80.3%	
Location of Arrest			
Private (n=847)	20.8%	79.2%	<0.001
Public Location (n=261)	39.5%	60.5%	
Presenting Rhythm			
VF/VT/Unknown Shockable (n=257)	35.8%	64.2%	<0.001
Unknown Unshockable (n=79)	20.2%	79.8%	
Asystole=564)	24.5%	75.5%	
Pulseless Electrical Activity(n=208)	15.9%	84.1%	
Who First Applied Bystander (n=29)	96.5%	3.5%	<0.001
First Responder	22.2	77.8%	
EMS (n=685)	23.9%	76.1%	
Overall Survival to Hospital Discharge (n=41)	7.2%	2.5%	

TABLE 2

Adjusted Odds Ratios for Provision of Bystander CPR and Survival to Hospital Discharge

	PROVISION OF BYSTANDER CPR FINAL MODEL	SURVIVAL TO HOSPITAL DISCHARGE FINAL MODEL
INDIVIDUAL LEVEL VARIABLES		
Age per 10-Year Increment	0.95 (0.87–1.04)	1.05 (0.85–1.29)
Female	0.81 (0.59–1.10)	1.35 (0.64–2.85)
Race White	Reference Group	Reference Group
Race Black	0.82 (0.52–1.30)	0.30 (0.11–0.82) *
Race Other	0.74 (0.28–1.93)	0.78 (0.09–6.78)
Race Unknown	0.71 (0.47–1.08)	0.47 (0.21–1.05)
Witnessed Arrest	1.64 (1.21–2.22) **	3.13 (1.41–6.95) *
Public Location	1.67 (1.16–2.40) **	6.80 (3.06–15.11) **
CENSUS TRACT VARIABLES		
Med Inc <\$21,600	Reference Group	Reference Group
Med Inc \$21,601–\$30,500	0.94 (0.49–1.81)	2.72 (0.72–10.27)
Med Inc \$30,501–\$42,000	1.57 (0.72–3.40)	2.49 (0.49–12.69)
Med Inc \$42,001–\$62,000	2.02 (0.83–4.93)	2.30 (0.48–10.99)
Med Inc >\$62,001	4.98 (1.65–15.04) *	9.11 (1.17–71.00) *
Percent Single Householder	1.30 (1.09–1.54) *	1.11 (0.79–1.57)
Med Age of Census Tract	0.99 (0.96–1.04)	0.94 (0.86–1.03)
Percent HS Education and Above	0.81 (0.65–1.01)	0.97 (0.65–1.45)
Percent Adults Below PS	0.92 (0.61–1.38)	1.58 (0.78–3.19)

P value * <0.05 ** <.001

MODEL – Age (Decades), Gender, Race, Witnessed Arrest, Public Location, Quintile of Median Household Income, Percent of Single Person Householder, Median Age of Census Tract, Percent of High School Education and Above, Percent of Adults Below Poverty Status.

TABLE 3

Rates of Bystander CPR Risk Adjusted for Neighborhood and Individual Level Patient Factors

	N	Crude Rate	Adjusted Rate	95% Confidence Interval
Private Unwitnessed (overall mean=0.18)				
Median Income <\$21,600	120	0.14	0.15	(0.07–0.31)
Median Income \$21,601–\$30,500	97	0.10	0.14	(0.08–0.23)
Median Income \$30,501–\$42,000	118	0.18	0.15	(0.09–0.37)
Median Income \$42,001–\$62,000	93	0.24	0.19	(0.12–0.39)
Median Income >\$62,000	88	0.25	0.28	(0.15–0.62)
Private Witnessed (overall mean=0.25)				
Median Income <\$21,600	70	0.23	0.23	(0.14–0.49)
Median Income \$21,601–\$30,500	73	0.16	0.20	(0.12–0.30)
Median Income \$30,501–\$42,000	65	0.17	0.22	(0.14–0.46)
Median Income \$42,001–\$62,000	57	0.26	0.29	(0.17–0.48)
Median Income >\$62,000	62	0.47	0.38	(0.20–0.65)
Public Unwitnessed (overall mean=0.29)				
Median Income <\$21,600	20	0.35	0.28	(0.15–0.48)
Median Income \$21,601–\$30,500	20	0.15	0.25	(0.15–0.37)
Median Income \$30,501–\$42,000	23	0.39	0.30	(0.17–0.47)
Median Income \$42,001–\$62,000	18	0.28	0.38	(0.21–0.56)
Median Income >\$62,000	18	0.28	0.41	(0.26–0.71)
Public Witnessed (overall mean=0.46)				
Median Income <\$21,600	31	0.42	0.41	(0.21–0.55)
Median Income \$21,601–\$30,500	27	0.41	0.35	(0.21–0.50)
Median Income \$30,501–\$42,000	23	0.30	0.44	(0.26–0.64)
Median Income \$42,001–\$62,000	42	0.43	0.48	(0.29–0.75)
Median Income >\$62,000	39	0.64	0.55	(0.35–0.80)

* Four patients with unknown locations of arrests (50% received bystander CPR), so their information is not displayed in this table