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Clinical paper

# Neighborhood-level out-of-hospital cardiac arrest risk and the impact of local CPR interventions

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## Abstract

**Introduction**: It is unclear how best to identify "high-risk" areas for out-of-hospital cardiac arrest (OHCA) and if neighborhood-level interventions improve bystander cardiopulmonary resuscitation (BCPR). Our objectives were to 1) identify and compare community characteristics between high and low-risk neighborhoods; and 2) examine change in BCPR after a targeted hands-only CPR intervention.

**Methods**: This was a cross-sectional analysis of OHCA events in Franklin County, Ohio between 1/1/2010–12/31/2017. Adult (≥18 years) OHCAs in a non-healthcare setting with emergency medical services resuscitation attempted were included. High-risk neighborhoods based on OHCA incidence and BCPR rates were identified using global Empirical Bayes, Local Moran's I, and spatial scan statistic. We compared characteristics of high and low-risk neighborhoods and examined change in BCPR.

**Results**: From the 3,841 included OHCAs, the mean adjusted OHCA incidence per census tract was 0.81 per 1,000, BCPR rate was 37.2%, and survival to hospital discharge was 11.5%. Of the 35 census tracts identified as high-risk, ten persisted from previous work. OHCA incidence was higher in high-risk neighborhoods (1.30 per 1,000 vs. 0.73, $p < 0.001$) and BCPR rates were lower (30.2% vs. 38.5%, $p < 0.001$). There were significant differences in characteristics between high and low-risk neighborhoods (e.g., Black population: 45.3% vs. 25.7%, $p < 0.001$). The neighborhoods targeted for the community education intervention had similar pre- and post-intervention BCPR rates.

**Conclusions**: Demographic and socioeconomic characteristics differed between high- and low-risk neighborhoods. BCPR rates were lower in high-risk neighborhoods despite a targeted BCPR intervention. Educational interventions may be necessary, but not sufficient, to improve OHCA outcomes.

**Keywords**: Emergency medical services, Out-of-hospital cardiac arrest, Bystander cardiopulmonary resuscitation

## Introduction

Despite concerted efforts to improve survival, the approximately 395,000 adults who suffer out-of-hospital cardiac arrest (OHCA) annually have about an 11% survival to hospital discharge. Although national resuscitation guidelines exist, OHCA survival varies regionally between 3–22%.[1–4] Much of this variation in survival is thought to be associated with the provision of bystander cardiopulmonary resuscitation (BCPR), which has been shown to improve survival and outcomes for patients.[5,6] Willingness to provide CPR as a bystander is related to many factors, including the sex, race, and ethnic origin of the victim, the community socioeconomic status, and a lack of understanding about OHCA and how to perform CPR.[7–10]

Many communities have implemented interventions to increase bystander CPR rates as a means to improve OHCA survival.[11,12] Based on previous work by Sasson et al. (2012) and Semple et al. (2012),[13,14] a targeted community intervention was launched in 2013 in the Columbus/Franklin County, Ohio area in specific neighborhoods that were identified as "high-risk." There is no standard definition of what constitutes a high-risk area, though this is often considered a neighborhood with a high incidence of OHCA and low prevalence of BCPR. The community intervention focused on training laypeople in hands-only CPR with encouragement for trained bystanders to then train family and friends with the provided training materials.[15,16] However, population and demographic shifts occurred over the intervening years. It is unclear if the incidence of OHCA, prevalence of BCPR, and survival to hospital discharge changed in the Columbus area overall and especially among those areas previously identified as high-risk.

Therefore, our objectives for this study were to 1) identify and compare community characteristics between low and high-risk

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neighborhoods; and 2) examine change in BCPR rates after a targeted community intervention in 2013.

## Methods

### Study design & data source

This was a retrospective cross-sectional analysis of OHCA data from patients treated by Columbus Division of Fire in Franklin County, Ohio. Data came from the Columbus Division of Fire's submissions to the Cardiac Arrest Registry to Enhance Survival (CARES) program for the period of January 1, 2010 to December 31, 2017. CARES, which is funded by the Center for Disease Control and Prevention and maintained by Emory University School of Medicine, began in 2005 to provide a means for communities to track and benchmark their OHCA care performance.[17] Detailed information about CARES has been published previously.[17–19] This study was approved by the Institutional Review Board of American Institutes of Research. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines.[20].

### Setting & population

The study population consisted of cardiac arrests that occurred in the Franklin County, Ohio limits. Franklin County, which includes the city of Columbus, had a population of approximately 1.3 million people in 2020 and covers approximately 532 square miles.[21] About 67% of the population identifies as non-Hispanic white, 24% as African American/Black, and 6% as Hispanic ethnicity. EMS response to 9-1-1 activations for most of the county are provided by the all advanced life support ambulances from Columbus Fire, with 128,893 EMS and rescue responses in 2017.[22] Ambulances and fire apparatus are staffed with at least one paramedic.

OHCA events with 9-1-1 activation treated by Columbus Fire that occurred in the Franklin County limits are captured in CARES. Initially, only cardiac arrests with a presumed cardiac aetiology were recorded, but this methodology changed in 2013 to include all non-traumatic cardiac arrests.[23] Trained data analysts review and perform quality checks for all submitted patient care reports. Follow up with the receiving hospital staff is also conducted to obtain hospital clinical course and outcome information. Cases are de-identified in the registry database, though geographic information of the event is maintained.

All cases for patients aged 18 and older that were submitted to the registry during the study period (n = 4,964) were eligible for inclusion. We included patients $\geq$ 18 years from 2010-2017 that had an OHCA event with resuscitation attempted by EMS in a non-healthcare setting within Franklin County. Cases were excluded for the following reasons: 1) prehospital resuscitation by EMS was not attempted based on local protocols (n = 9); 2) clinical outcome data were missing (n = 174); or 3) the cardiac arrest location could not be geocoded or mapped or was outside of the Franklin County limits (n = 92). We also excluded cases that occurred in a healthcare setting (i.e., nursing home or medical facility) (n = 860). For calculation of BCPR rates, events that were witnessed by EMS were excluded (n = 559). Cases may have met more than one exclusion criteria.

### Community intervention

The community education intervention, as part of the "Identifying High Arrest Neighborhoods to Decrease Disparities in Survival" (HANDDS) project,[15,16] occurred in three high-risk neighborhoods from 2013-2014. Firefighters and other trained personnel held classes in variety of locations (e.g., fire stations, community centers, libraries, restaurants, and street festivals) in the targeted neighborhoods to train community members in hands-only CPR. Participants also received a free CPR Anytime kit and DVD to bring home and train a family member or friend.

### Measures

Patient characteristics were obtained from the registry including age, sex, race/ethnicity, and address of the OHCA event. Clinical characteristics included location of the arrest (e.g., at home or in a public location), who witnessed the arrest (unwitnessed, EMS or first responder witnessed, or bystander witnessed), who initiated CPR (bystander, EMS/first responder), use of a public access defibrillator prior to EMS or first responder arrival, and presenting cardiac rhythm. Outcome information, including survival to hospital discharge, was also documented. We considered first responders as firefighters and police officers, while we defined bystanders as anyone other than first responders or the responding EMS crew. The patient's race and ethnicity were documented by the EMS crew treating the patient and may represent their perception, rather than how the patient identified. A total of 6.6% of the sample had a race of unknown or missing documented, which we included as a separate category.

Community characteristics were defined on the level of census tracts. While census tracts may not reflect the geographic boundaries of established neighborhoods, they are generally a stable method of subdividing geography to describe relatively homogeneous populations of between 1,200 and 8,000 people.[24] We obtained census tract shapefiles and population estimates from the U.S. Census Bureau. Population estimates from the 2010 Census included the total number of people per census tract and the racial, sex, and age breakdowns of those estimates. Community-level characteristics for each census tract were obtained from the 2014 American Community Survey (ACS) 5-year estimates covering the time period of 2010–2014.[25] These characteristics included median household income, families living in poverty, and health insurance status. Census tracts where no cases were observed over the 8-year study period (n = 50) were excluded from the spatial analysis.

### Data analysis

Variable generation and patient-level descriptive analysis, overall and stratified by time period, was conducted using STATA IC 15.1 (StataCorp, LLC., College Station, Texas). Cases were geocoded to census tract using ArcGIS Desktop 10.7 (Environmental Systems Research Institute Inc. [ESRI], West Redlands, California). Layers were downloaded from the Columbus, Ohio GIS Open Data Portal (http://data-columbus.opendata.arcgis.com/) and the ESRI website.

Following the methodology of Sasson et al. (2012),[7] we identified high-risk census tracts in three ways: global Empirical Bayes smoothed rates, Local Moran's I using spatial Empirical Bayes smoothed rates, and a spatial scan statistic. We used the spatial statistics software Geoda 1.16 (http://geodacenter.github.io) to calculate adjusted incidence rates from global and spatial Empirical Bayes smoothed rates of OHCA and BCPR. Empirical Bayes smoothed rates account for the small area statistical problem by adjusting potentially unstable estimates towards the mean of surrounding areas.[26] Global Empirical Bayes smoothing adjusts rates toward to global mean of the observed data, whereas spatial Empirical Bayes smoothing adjusts rates towards to the average surrounding areas.[27] Estimates for the 18-year and older population per census tract was multiplied by the duration of the study period to determine the population at risk for the adjusted incidence rate of OHCA and survival to hospital discharge. For example, to calculate the overall incidence of OHCA in Franklin County over the 8-year study period, the population estimates were multiplied by 8. The total number of bystander eligible cardiac arrest events (OHCA not witnessed by first responder or EMS) was used to calculate the adjusted rate of BCPR per census tract.

*Global Empirical Bayes smoothed rate analysis*

We calculated the global Empirical Bayes smoothed rates of OHCA and BCPR as described above. The adjusted rates were mapped for each using ArcGIS to identify those census tracts in the highest quartile for OHCA incidence and lowest quartile for BCPR. The overlapping areas were defined as high-risk neighborhoods.

*Local Moran's I analysis*

We calculated spatial Empirical Bayes smoothed rates of OHCA and BCPR as described above. We used Geoda to calculate the Local Moran's I statistic separately for both OHCA and BCPR, using first order queen contiguity spatial weights. Local Moran's I is a technique to identify a "hot spot" or cluster based on the degree in which similar observations are spatially located near each other.[28] Clustering was identified if $p < 0.05$ from a nonparametric Monte Carlo simulation with 999 permutations. Using ArcGIS, we then overlaid the census tracts identified as clusters of high incidence of OHCA and low prevalence of BCPR to define high-risk neighborhoods.

*Spatial scan statistic analysis*

We used the SaTScan application (version 10.0, https://www.satscan.org) to conduct a spatial Poisson analysis. Centroids of each census tract were used to define the OHCA cases, assumed to be Poisson distributed, and population at-risk aggregated over the 8-year study period (rather than examining as space–time associations). SaTScan uses a spatial scan statistic to draw circular windows of varying sizes around each census tract centroid, containing up to 50% of the total cases being analyzed, to compare expected and observed observations in order to detect a spatial cluster of elevated OHCA incidence.[29] We used a Monte Carlo simula-

**Table 1 – Patient demographics and cardiac arrest characteristics.**

| Characteristic | Overall (n = 3,841) n (%) | 2010–2012 (n = 1,249) n (%) | 2013–2014 (n = 912) n (%) | 2015–2017 (n = 1,680) n (%) |
|---|---|---|---|---|
| Age (years), mean (SD) | 58.5 (16.8) | 59.2 (16.6) | 59.8 (16.0) | 57.3 (17.3) |
| Sex, female | 1,489 (38.8) | 470 (37.6) | 368 (40.4) | 651 (38.8) |
| Race | | | | |
| White | 2,204 (57.4) | 735 (58.9) | 503 (55.2) | 966 (57.5) |
| Black or African American | 1,294 (33.7) | 435 (34.8) | 302 (33.1) | 557 (33.2) |
| Other | 88 (2.3) | 19 (1.5) | 15 (1.6) | 54 (3.2) |
| Unknown | 255 (6.6) | 60 (4.8) | 92 (10.1) | 103 (6.1) |
| Presumed arrest etiology | | | | |
| Cardiac | 3,270 (85.1) | 1,155 (92.5) | 777 (85.2) | 1,338 (79.6) |
| Respiratory/asphyxia | 265 (6.9) | 16 (1.3) | 81 (8.9) | 168 (10) |
| Drug overdose | 173 (4.5) | 0 (0) | 26 (2.9) | 147 (8.8) |
| Trauma | 41 (1.1) | 28 (2.2) | 6 (0.7) | 7 (0.4) |
| Other | 92 (2.4) | 50 (4.0) | 22 (2.4) | 20 (1.2) |
| Bystander-witnessed arrest | 1,062 (27.7) | 355 (28.4) | 256 (28.1) | 451 (26.9) |
| EMS-witnessed arrest | 559 (14.6) | 149 (11.9) | 144 (15.8) | 266 (15.8) |
| Unwitnessed arrest | 2,220 (57.8) | 745 (59.7) | 512 (56.1) | 963 (57.3) |
| Location of arrest | | | | |
| Home | 3,238 (84.3) | 1,051 (84.2) | 754 (82.7) | 1,433 (85.3) |
| Public location | 299 (7.8) | 85 (6.8) | 79 (8.7) | 135 (8.0) |
| Street | 233 (6.1) | 78 (6.2) | 68 (7.5) | 87 (5.2) |
| Parking lot/vehicle | 16 (0.4) | 7 (0.6) | 3 (0.3) | 6 (0.4) |
| Place of recreation | 42 (1.1) | 18 (1.4) | 8 (0.9) | 16 (1.0) |
| Other | 13 (0.3) | 10 (0.8) | 0 (0) | 3 (0.2) |
| Presenting rhythm (n = 3,840) | | | | |
| VF/VT/unknown shockable | 870 (22.7) | 324 (26) | 203 (22.3) | 343 (20.4) |
| Unknown unshockable | 45 (1.2) | 6 (0.5) | 9 (1.0) | 30 (1.8) |
| Asystole | 2,029 (52.8) | 655 (52.5) | 474 (52) | 900 (53.6) |
| PEA | 896 (23.3) | 263 (21.1) | 226 (24.8) | 407 (24.2) |
| Public access defibrillator applied (n = 3,461) | 81 (2.3) | 18 (2.1) | 22 (2.4) | 41 (2.4) |
| Bystander CPR (n = 3,282*) | 1,161 (35.4) | 369 (33.6) | 301 (39.2) | 491 (34.7) |
| Outcome | | | | |
| Died in the field | 1,101 (28.7) | 348 (27.9) | 278 (30.5) | 475 (28.3) |
| Died in the ED | 1,530 (39.8) | 526 (42.1) | 365 (40.0) | 639 (38.0) |
| Died in the hospital | 795 (20.7) | 238 (19.1) | 175 (19.2) | 382 (22.7) |
| Survived to hospital discharge | 415 (10.8) | 137 (11.0) | 94 (10.3) | 184 (11.0) |

Abbreviations: CPR, cardiopulmonary resuscitation; ED, emergency department; EMS, emergency medical services; PEA, pulseless electrical activity; VF, ventricular fibrillation; VT, ventricular tachycardia.

* Denominator includes only OHCA events eligible to receive bystander CPR.

tion with 999 permutations to test for significance of a likelihood ratio test at $p < 0.05$. Secondary clusters were only allowed if not overlapping a more likely cluster. Using ArcGIS, census tracts identified as a cluster were then overlaid with those in the lowest quartile of BCPR and defined as high-risk neighborhoods.

We determined how many census tracts were identified as a high-risk neighborhood by one, two, or all three methods used. Comparisons of community-level characteristics from the 2014 ACS data between high and low-risk neighborhood were done with t-tests. Finally, we also examined OHCA incidence and BCPR rates in the three census tracts targeted for a previous community intervention for hands-only CPR training.[15,16] We looked at three time periods: pre-intervention (2010–2012), intervention (2013–2014), and post-intervention (2015–2017) to examine the change in incidence of OHCA, BCPR rate, and survival.

## Results

There was a total of 3,841 cardiac arrest cases included in the final sample with 3,282 cases that were eligible for BCPR. The mean age of patients was 58.5 years (SD 16.8) and 38.8% were female (Table 1). More than half (57.4%) of patients were documented as white and bystanders witnessed approximately one-quarter of the events. Patients were most commonly found at home (84.3%), with about half found initially in asystole. Bystander CPR was provided in 30.3% of the total events, with a crude BCPR rate (accounting for only the BCPR eligible events not witnessed by EMS) of 35.4%. The overall survival to hospital discharge in the sample was 10.8%. Patient characteristics were similar across time periods, though patients were slightly younger

**Table 2 – Incidence of OHCA and bystander CPR for census tracts identified as high-risk.**

| Census Tract | Methods* | Crude Incidence (per 1,000) | Adjusted† Incidence (per 1,000) | Crude Bystander CPR Rate (%) | Adjusted† Bystander CPR Rate (%) | Survival (%) |
|---|---|---|---|---|---|---|
| 3.10 | 1 | 1.21 | 1.17 | 15.8 | 32.2 | 8.3 |
| 3.30 | 2 | 1.27 | 1.28 | 13.3 | 25.8 | 5.6 |
| 4.10 | 1 | 0.30 | 0.37 | 0.0 | 46.9 | 0.0 |
| **7.30** | 3 | 1.45 | 1.58 | 9.1 | 21.1 | 8.0 |
| **8.20§** | 1 | 0.87 | 0.88 | 16.7 | 26.0 | 18.8 |
| **9.10** | 1 | 1.86 | 1.78 | 33.3 | 25.3 | 17.1 |
| **9.20§** | 1 | 1.20 | 1.21 | 18.2 | 18.1 | 7.1 |
| 16.00 | 2 | 1.12 | 1.07 | 0.0 | 25.4 | 10.0 |
| 18.20 | 1 | 0.36 | 0.41 | 16.7 | 43.8 | 0.0 |
| 22.00 | 1 | 0.60 | 0.64 | 14.3 | 40.6 | 0.0 |
| **25.10** | 2 | 1.86 | 1.78 | 22.2 | 29.7 | 16.1 |
| 27.40 | 1 | 1.10 | 1.07 | 20.0 | 34.8 | 6.3 |
| 27.50 | 1 | 2.13 | 1.99 | 23.8 | 29.1 | 7.4 |
| **27.70** | 1 | 1.61 | 1.57 | 22.2 | 28.4 | 21.1 |
| **29.00** | 1 | 2.15 | 2.07 | 23.5 | 34.6 | 13.0 |
| 32.00 | 1 | 0.54 | 0.58 | 22.2 | 45.2 | 33.3 |
| **36.00** | 1 | 2.00 | 1.95 | 17.6 | 30.6 | 11.1 |
| 55.00 | 1 | 2.30 | 2.17 | 20.0 | 24.3 | 9.3 |
| 56.10 | 1 | 1.96 | 1.83 | 21.4 | 25.6 | 10.5 |
| 56.20 | 2 | 2.00 | 1.85 | 20.8 | 26.0 | 24.1 |
| 58.10 | 1 | 0.60 | 0.67 | 12.5 | 33.2 | 18.2 |
| 58.20 | 1 | 1.44 | 1.47 | 33.3 | 24.5 | 14.3 |
| 59.00 | 1 | 1.39 | 1.95 | 35.0 | 26.6 | 0.0 |
| 60.00 | 1 | 1.81 | 1.78 | 21.1 | 28.1 | 0.0 |
| 61.00 | 1 | 2.67 | 2.22 | 23.5 | 31.9 | 5.3 |
| 68.22 | 1 | 0.79 | 0.73 | 0.0 | 27.9 | 0.0 |
| 69.33 | 1 | 0.89 | 0.85 | 19.0 | 35.2 | 3.8 |
| 69.43 | 1 | 0.89 | 0.87 | 20.0 | 32.6 | 4.3 |
| 75.11 | 3 | 1.41 | 1.41 | 0.0 | 18.6 | 7.1 |
| 75.20 | 1 | 0.59 | 0.70 | 12.5 | 24.9 | 10.0 |
| 77.10 | 1 | 0.79 | 0.68 | 22.2 | 29.7 | 5.0 |
| 77.22 | 1 | 0.54 | 0.75 | 12.5 | 36.4 | 18.2 |
| 83.30 | 1 | 0.83 | 0.94 | 11.1 | 39.2 | 0.0 |
| **93.33** | 1 | 2.04 | 1.82 | 27.3 | 24.7 | 0.0 |
| **93.34** | 1 | 1.09 | 1.31 | 16.7 | 30.4 | 11.1 |
| *Franklin County (overall)* | | *0.83* | *0.81* | *36.4* | *37.2* | *11.5* |

Abbreviations: CPR, cardiopulmonary resuscitation; OHCA, out-of-hospital cardiac arrest.

*Number of methods by which census tract was identified as high-risk (global Empirical Bayes smoothed rates, Local Moran's I using spatial Empirical Bayes smoothed rates, and SaTScan).

†Adjusted incidence or rate calculated from spatial Empirical Bayes smoothed rates.

§Neighborhood was part of the targeted intervention to improve bystander CPR rates. Tract 75.12 was also included but was not identified as high-risk in this analysis.

Bolding indicates previously identified as a high-risk neighborhood in Sasson et al. (2012).

with a higher proportion of arrests from a presumed drug overdose from 2015-2017.

The overall crude incidence of OHCA in Franklin County for the 8-year study period was 0.54 events per 1,000 population. After calculating the spatial Empirical Bayes smoothed rates (Table 2), the mean adjusted incidence of OHCA per census tract was 0.81 per 1,000 (SD 0.67) and the mean adjusted BCPR percentage per census tract was 37.2% (SD 9.2). The mean survival to hospital discharge per census tract was 11.5% (SD 14.5).

A total of 35 census tracts were identified as high-risk neighborhoods by at least one method (Fig. 1). These neighborhoods were geographically located near the center of the county and downtown Columbus area, generally located in portions of the North Linden, South Linden, Northeast, Near East, Near South, Hilltop, and Eastmoor/Walnut Ridge neighborhoods. A total of 2 census tracts (7.30 and 75.11, both in the South Linden neighborhood) were identified as high-risk by all three methods. Ten of the 35 census tracts had been previously identified as high-risk areas for the 2004–2009 time period (Table 2).[13] Not surprisingly, the incidence of OHCA in each of the high-risk census tracts was generally higher than Franklin County's overall, and BCPR rates were generally lower.

The mean adjusted OHCA rate in high-risk neighborhoods was 1.30 per 1,000 people compared to 0.73 per 1,000 people in the low-risk neighborhoods (Table 3). The mean adjusted prevalence of BCPR was significantly lower in high-risk neighborhoods with a prevalence of 30.2% compared to 38.5% in low-risk neighborhoods ($p < 0.001$). There were also significant differences in several of demographic and socioeconomic characteristics of high and low-risk neighborhoods. There was a significantly higher population density, proportion of population that was Black, living in poverty,

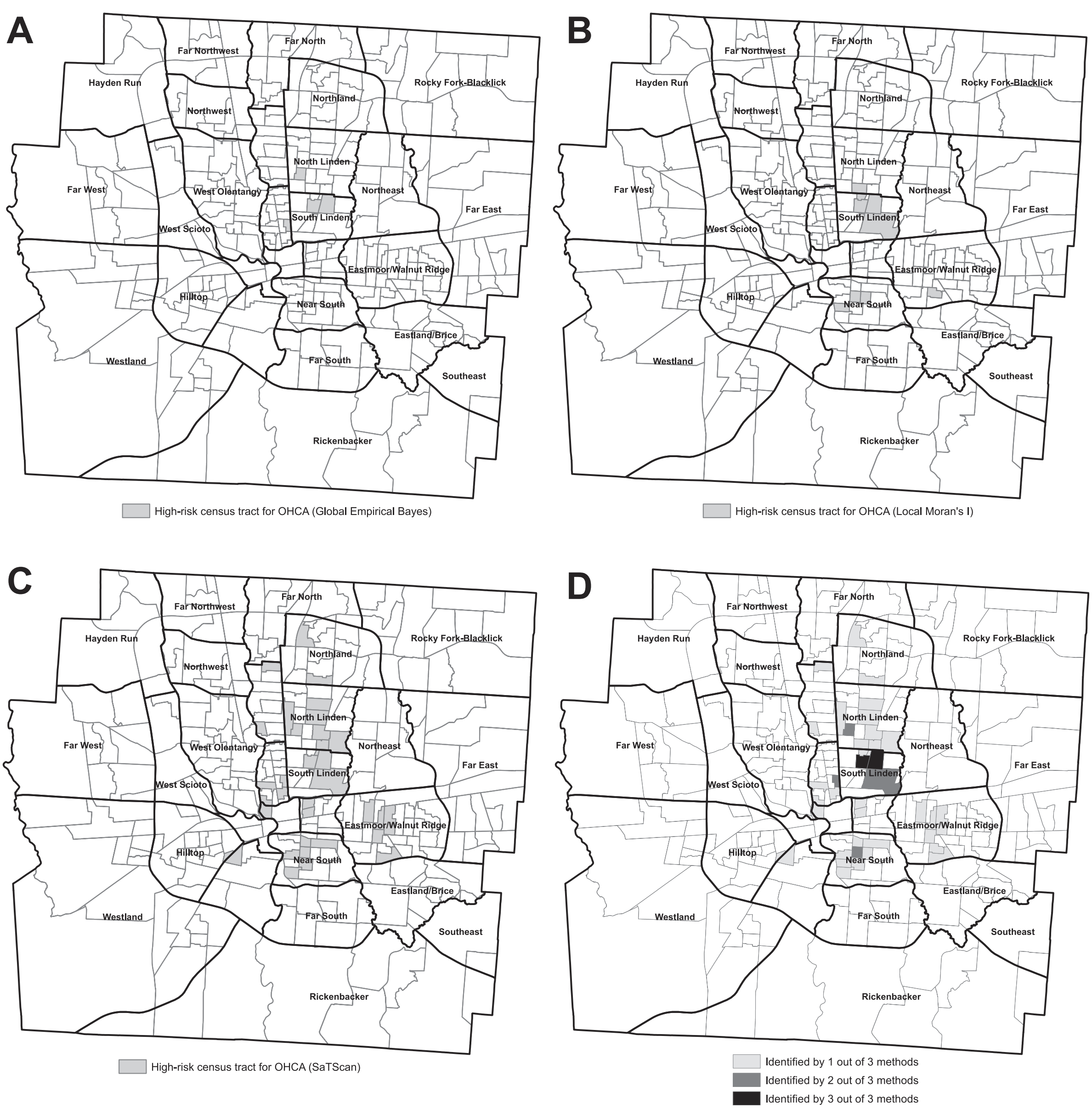


**Fig. 1 – High-risk areas in Franklin County, Ohio as identified by A) global Empirical Bayes smoothed rates; B) Local Moran's I using spatial Empirical Bayes rates; c) spatial scan statistic clusters; and D) in combination. Abbreviations: OHCA, out-of-hospital cardiac arrest.**

**Table 3 – Comparison of community characteristics at the census tract level stratified by high and low-risk neighborhood (presented as mean [SD] unless otherwise specified).**

| Characteristic | High-Risk Neighborhood (n = 35) | Low-Risk Neighborhood (n = 198) | p |
|---|---|---|---|
| OHCA rate per 1,000 (adjusted) | 1.30 (0.55) | 0.73 (0.65) | <0.001 |
| Bystander CPR rate (adjusted), % | 30.2 (7.0) | 38.5 (9.0) | <0.001 |
| Survival to hospital discharge, % | 9.3 (8.0) | 11.9 (15.4) | 0.33 |
| Urban area*, n (%) | 35 (100) | 209 (84.3) | 0.16 |
| Population density, per square mile | 6,091 (1,896) | 4,685 (3,842) | 0.001 |
| Median age, years | 34.4 (6.3) | 33.8 (5.5) | 0.61 |
| Male, % | 48.5 (3.1) | 49.0 (3.2) | 0.44 |
| 65 and older, % | 10.1 (4.2) | 10.0 (6.0) | 0.95 |
| Black, % | 45.3 (29.7) | 25.7 (25.1) | <0.001 |
| White, % | 45.7 (30.1) | 62.1 (25.0) | <0.001 |
| Median household income, $US | $33,279 ($13,256) | $47,635 ($23,577) | <0.001 |
| Families living in poverty, % | 26.7 (17.0) | 15.9 (14.0) | <0.001 |
| Uninsured, % | 13.1 (4.9) | 10.4 (5.8) | 0.01 |
| Has $\geq$ 1 emergency department, n (%) | 0 (0) | 16 (5.4) | 0.01 |

Abbreviations: CPR, cardiopulmonary resuscitation; OHCA, out-of-hospital cardiac arrest.

* Urban area (by land) determined using U.S. Census definition of urbanized areas and urban clusters. Shown are the proportion of census tracts that are 100% urban.

**Table 4 – Change in OHCA incidence and bystander CPR rates among the three targeted census tracts.**

| | 2010–2012 | 2013–2014 | 2015–2017 |
|---|---|---|---|
| Total OHCAs | 21 | 22 | 21 |
| Crude incidence (per 1,000) | 1.04 | 1.64 | 1.04 |
| Crude bystander CPR rate (%) | 28.6 | 16.7 | 28.0 |
| Crude survival (%) | 14.3 | 13.6 | 14.3 |

Abbreviations: CPR, cardiopulmonary resuscitation; OHCA, out-of-hospital cardiac arrest.

uninsured, and with a lower median household income in the high-risk neighborhoods (Table 3). The survival to hospital discharge rate was slightly lower in the high-risk neighborhoods (9.3% versus 11.9% in low-risk neighborhoods), but this difference was not statistically significance (p = 0.33).

Three census tracts were previously identified as high-risk neighborhoods and targeted for community intervention in 2013 (Table 4). In the pre-intervention (2010–2012) and post-intervention (2015–2017) periods, the overall crude BCPR rates were similar (around 28%), while survival to hospital discharge was 14.3% for both periods. In the 2-year intervention period (2013–2014), there was a lower BCPR rate (16.7%) and slightly lower survival rate (13.6%). Because of low case counts per census tract leading to unstable estimates, we did not examine the change in each targeted neighborhood individually.

## Discussion

Disparities in OHCA care have been identified throughout the US with variation based on geographic location and socioeconomic characteristics.[1,7] In this evaluation of OHCA events in the Franklin County, Ohio area, we identified 35 high-risk census tracts with ten areas persisting as high-risk over a period of time since a prior analysis.[14] The high-risk neighborhoods differed from low-risk neighborhoods in demographic and socioeconomic characteristics. Finally, BCPR rates were lower in high-risk neighborhoods despite a targeted intervention to train laypeople in hands-only CPR in key areas during the study period.

Defining high-risk neighborhoods is important to be able to identify areas in the community that may specifically benefit from interventions to improve BCPR rates and OHCA outcomes. There is no standard definition of what constitutes a high-risk area or neighborhood when considering OHCA. Similar to this evaluation, prior analyses have used incidence of OHCA and rates of BCPR to define these areas.[13,14] We noted that, though the outcome of survival to hospital discharge was similar, there were significant disparities in demographic and socioeconomic characteristics between high and low-risk neighborhoods. We propose that these additional factors could also be considered when determining target areas for future interventions, particularly since community characteristics and socioeconomic status has been found to be related to outcomes from OHCA.[7,30–32].

In 2013, there was a significant effort to increase BCPR through a community intervention in hands-only CPR training.[33] Barriers and facilitators of learning CPR in this community were identified so that programs could be tailored to improve BCPR performance.[15] Leveraging this work, a robust training program was developed and implemented in three key high-risk census tracts in Columbus to improve BCPR rates.[16] In this evaluation, we assessed the temporal impact of that intervention. Unfortunately, the targeted neighborhoods showed no increase in BCPR during the intervention period, though the pre- and post-intervention BCPR rates were similar. The causal mechanism for the increase in BCPR back to baseline after the intervention remains unclear. Thus, community interventions may be necessary but not sufficient to address underlying disparities in provision of BCPR and longer-term outcomes. Improving OHCA outcomes may require interventions addressing social determinants of health in addition to education programs to enhance CPR performance.

Compared to previous work,[13] ten census tracts persisted as high-risk neighborhoods. The transition between high to low risk over time could have been multifactorial. There may have been a change in the demographics (e.g., gentrification) of a census tract, leading to a demographically distinct population and change in the prevalence of OHCA in the neighborhood. There may have also been a change in BCPR rates in a neighborhood. Bystander CPR rates were statistically different—but clinically similar with less than a 10-percentage point difference—between the high and low-risk neighborhoods. The exact aetiology of the transition from high to low risk is still unclear from this analysis and will require further evaluation. Regardless of the reason, change in "high-risk" status over time should be considered and re-evaluated periodically to ensure these community-level interventions area targeted to the right areas.

There were several limitations to this work. These data came from a single EMS agency in one city. While Columbus Division of Fire is the primary agency providing prehospital care in Columbus, they do not have 100% coverage of the Franklin County limits, and other agencies may provide mutual aid. Thus, there may be missing OHCA cases. Over the study period there were changes in documentation of variables due to updated standards from CARES, though no changes were made for the specific variables examined in this study. There was also a loss of a small number of cases due to missing outcome information. Reasons for missing outcome information are unclear.

## Conclusions

Neighborhood-level variations in OHCA incidence and BCPR persisted over time and after a targeted community intervention to improve BCPR, with marked disparities in characteristics between high and low risk neighborhoods. Improving OHCA outcomes may require interventions beyond those targeting specific areas. In addition, we propose that demographic and socioeconomic characteristics of communities should be considered to reduce disparities when determining target areas for future interventions to improve BCPR rates and OCHA outcomes.

## Prior presentations

An abstract of this work was presented as a poster at the 2019 American Heart Association Resuscitation Science Symposium (November 2019, Philadelphia, PA).

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## CRediT authorship contribution statement

**Rebecca E. Cash:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Visualization. **Michelle Nassal:** Conceptualization, Writing – review & editing. **David Keseg:** Conceptualization, Resources, Writing – review & editing. **Ashish R. Panchal:** Conceptualization, Resources, Writing – review & editing, Supervision.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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