



## Clinical Paper

# Geographic factors are associated with increased risk for out-of-hospital cardiac arrests and provision of bystander cardio-pulmonary resuscitation in Singapore<sup>☆</sup>



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## ABSTRACT

**Background:** Bystander Cardio-Pulmonary Resuscitation (BCPR) can improve survival for Out-of-Hospital Cardiac Arrest (OHCA). This study aimed to investigate the geographic variation of BCPR provision and survival to discharge outcomes among residential OHCA cases, evaluate this variation with individual and population characteristics and identify high-risk residential areas with low relative risk (RR) of BCPR and high RR of OHCA at the development guide plan (DGP) census tract levels in Singapore.

**Methods:** This was a retrospective, secondary analysis of two prospectively-collected registries in Singapore from 2001 to 2011. We used Bayesian conditional autoregressive spatial models to examine predictors at the DGP level and calculate smoothed RR to identify high-risk areas. We used multi-level mixed-effects logistic regression models to examine the independent effects of individual and neighborhood factors.

**Results:** We found a total of 3942 OHCA with a BCPR rate of 20.3% and a survival to discharge rate of 1.9% and 3578 cases eligible for BCPR. After adjusting for age, witnessed status, presumed cardiac etiology and longer response time, the risk of BCPR provision significantly increased by 0.02% for every 1% increase in the proportion of household size 5 and above in the DGP area (odds ratio 1.02, 95%CI = 1.002–1.038,  $p < 0.026$ ). We identified 10 high-risk residential areas with low RR of BCPR and high RR of OHCA.

**Abbreviations:** OHCA, out-of-hospital cardiac arrests; EMS, emergency medical services; CPR, cardiopulmonary resuscitation; BCPR, bystander cardiopulmonary resuscitation; PAD, public access defibrillation; RR, relative risk; DGP, development guide plan; SCDF, Singapore Civil Defence Force; AED, automated external defibrillators; CARE, Cardiac Arrest and Resuscitation Epidemiology; PAROS, Pan-Asian Resuscitation Outcomes; CAR, conditional autoregressive; ROSC, return of spontaneous circulation; ED, emergency department; OR, odds ratio; MOR, median odds ratio; SED1, socio-economic disadvantage index.

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*Conclusion:* This study informed that neighborhood household size could have played a significant role in the provision of BCPR and occurrence of high-risk areas. It demonstrates the public health potential of combining geospatial and epidemiological analysis for improving health.

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## 1. Introduction

Sudden cardiac death, mainly attributable to underlying cardiovascular diseases, is a major cause of mortality in Singapore and the rest of the world.<sup>1</sup> Nearly 383,000 out-of-hospital cardiac arrests (OHCA) occur annually in the United States and 88 percent of cardiac arrests occur at home.<sup>2</sup> The chances of survival of OHCA will decrease by 10% if unattended for every minute.<sup>3</sup> The survival rate from OHCA in Singapore was only 2.7% between 2001 and 2002.<sup>4</sup> Survival outcomes from sudden cardiac arrest can improve when a particular sequence of events (recognition of cardiac arrest, activation of emergency medical services (EMS), early cardiopulmonary resuscitation (CPR), early defibrillation and early advanced life support) in the 'chain of survival' concept occurs.<sup>5</sup> Bystander CPR (BCPR) is defined as the performance of CPR by a layperson which is not part of the EMS system.<sup>6</sup> Studies have reported initiation of BCPR can increase survival by three-folds and early BCPR initiated less than 4 min after cardiac arrest can increase the odds of survival by 4.5 times.<sup>7</sup>

Previous evidence suggested a significant regional variation in the incidence of OHCA events in Singapore.<sup>8</sup> One local study reported significantly poor survival outcomes among residential OHCA cases.<sup>9</sup> However, the extent to which areas vary in BCPR and survival rates among residential OHCA cases remains unknown in Singapore. Therefore, understanding the neighborhood factors explaining the non-provision of BCPR and identifying different risk areas are vital to help the public health system deal with the characteristics of each region specifically and prioritize neighborhood-based interventions (public education, CPR training, automated external defibrillation (AED) placement, allocation of EMS resources) in high-risk residential areas.

Previous studies reported health behaviors tend to be clustered within individuals and some of this clustering could be linked to shared neighborhood characteristics.<sup>10</sup> Therefore, we assumed that likelihood of providing BCPR could depend on the neighborhood in which the cardiac arrest occurs. Multilevel analysis allows us to examine both individual-level and macro-level determinants of health behaviors such as BCPR provision in residential areas and elucidate their independent effect.<sup>11</sup> The census tracts in Singapore are categorized as development guide planning (DGP) areas by the urban redevelopment authorities (URA) for town planning purposes.<sup>12,13</sup> Therefore, this study aimed to investigate the geographic variation of BCPR provision and survival to discharge outcomes among residential OHCA cases, evaluate this variation with individual and population characteristics and identify high-risk residential areas with low relative risk (RR) of BCPR and high RR of OHCA at the DGP census tract levels in Singapore.

## 2. Methods

### 2.1. Study setting and design

Singapore encompasses 137 km with a population of 5.1 million in 2011.<sup>14</sup> Singapore's EMS system is activated by a universal, centralized, enhanced 995 dispatching system run by the Singapore Civil Defence Force (SCDF). At the time of the study, SCDF operated 36 ambulances based in 14 fire stations and 10 satellite stations. It is primarily a single-tier system, which handled about 140,000 calls

in 2011. The paramedics are trained to provide basic life support and defibrillation with AED.

This was a retrospective secondary data analysis from 2 cardiac arrest registry-based cohorts, the Cardiac Arrest and Resuscitation Epidemiology in Singapore (CARE) study and the Pan-Asian Resuscitation Outcomes Study (PAROS) study. CARE is a prospective observational study including non-traumatic OHCA patients conveyed by SCDF ambulances from October 1, 2001, to October 14, 2004. The Pan-Asian Resuscitation Outcomes Study (PAROS) network of hospitals was established in 2009 as an international, multicenter, prospective registry of OHCA across the Asia-Pacific region. Both CARE and PAROS registries included all OHCA patients in Singapore presenting to EMS "995" (universal access number in Singapore) and emergency departments (ED) during their study periods, as confirmed by the absence of pulse, unresponsiveness, and apnoea. It excluded those patients immediately pronounced dead and for whom resuscitation was not attempted, including decapitation, rigor mortis, and dependent lividity. This study included all OHCA cases from the CARE data set between October 1, 2001, and October 14, 2004, and the PAROS data set between April 2010 and June 2011. We excluded cases if arrest was witnessed by EMS and BCPR performance (Yes/No) was unknown.

Census demographic and socio-economic variables at DGP areas were obtained from the 'Singapore Population Census 2010'.<sup>13</sup> The census is conducted every 10 years.<sup>14</sup> The census contains population counts of all Singapore residents, including citizens and permanent residents, but excludes foreign workers with work passes, foreign students and transient students. Ethics approval was obtained from the Institutional Review Board to conduct this study.

### 2.2. Data processing and analysis

Based on the address from where the cardiac arrest occurred, each case was assigned to a DGP based on the URA Master Plan 2008.<sup>12</sup> Incomplete street addresses were mapped using an online street directory.

Using WinBUGS (version 1.4, Imperial College and Medical Research Council, UK), we analyzed Bayesian conditional autoregressive (CAR) spatial models to examine predictors at the DGP level and calculate smoothed RR to identify high-risk areas.<sup>15</sup> CAR models have been widely used to map health outcomes at a population level and to identify relations with covariates.<sup>8,15,16</sup> Individuals living in close proximity are more likely to have the same outcome than individuals living farther apart. Unlike Bayesian hierarchical modeling, traditional regression methods fail to account for such spatial correlation patterns which could lead to bias in regression parameter estimates, under-estimation of standard errors, very narrow confidence intervals and potentially incorrect inferences regarding exposure-outcome associations.<sup>17</sup> A Poisson model that incorporated both a spatially structured random-effects term and a spatially unstructured random term was fitted to allow for a spatial correlation, commonly known as a CAR convolution prior model. We included observed and expected counts of BCPR and also values of covariates in the model. We did 2 different analyses, one analyzing overall OHCA and the other examining OHCA that occurred only at home to relate with census level characteristics of a resident population. Out of the 55 DGP areas in Singapore, we included 36 DGP areas with available census data in our analysis.

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