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Clinical paper

Nationwide trends in residential and non-residential out-of-hospital cardiac arrest and differences in bystander cardiopulmonary resuscitation

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Abstract

Aims: Singapore is highly-urbanized, with >90% of the population living in high-rise apartments. She has implemented several city-wide interventions such as dispatcher-assisted CPR, community CPR training and smartphone activation of volunteers to increase bystander CPR (BCPR) rates for out-of-hospital cardiac arrest (OHCA). These may have different impact on residential and non-residential OHCA. We aimed to evaluate the characteristics, processes-of-care and outcome differences between residential and non-residential OHCA and study the differences in temporal trends of BCPR rates.

Methods: This was a national, observational study in Singapore from 2010 to 2016, using data from the prospective Pan-Asian Resuscitation Outcomes Study. The primary outcome was survival (to-discharge or to-30-days). Multivariate logistic regression was performed to determine the effect of location-type on survival and a test of statistical interaction was performed to assess the difference in the temporal relationship of BCPR rates between location-type.

Results: 8397 cases qualified for analysis, of which 5990 (71.3%) were residential. BCPR and bystander automated external defibrillator (AED) rates were significantly lower in residential as compared to non-residential arrests (41.0% vs 53.6%, $p < 0.01$; 0.4% vs 10.8%, $p < 0.01$ respectively).

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Residential BCPR increased from 15.8% (2010) to 57.1% (2016). Residential cardiac arrests had lower survival-to-discharge (2.9% vs 10.1%, $p < 0.01$). Multivariate logistic regression analysis showed that location-type had an independent effect on survival, with residential arrests having poorer survival compared to non-residential cardiac arrests (adjusted OR 0.547 [0.435–0.688]). A test of statistical interaction showed a significant interaction effect between year and location-type for bystander CPR, with a narrowing of differences in bystander CPR between residential and non-residential cardiac arrests over the years.

Conclusion: Residential cardiac arrests had poorer bystander intervention and survival from 2010 to 2016 in Singapore. BCPR had improved more in residential arrests compared to non-residential arrests over a period of city-wide interventions to improve BCPR.

Keywords: Cardiac arrest, Residential, Cardiopulmonary resuscitation, Bystander CPR

Introduction

Out-of-hospital cardiac arrest (OHCA) represents a significant public health issue globally, with survival rates ranging from 3.4% to 22% in the United States.[1] A 2015 study showed that survival-to-discharge rates for witnessed cardiac arrests with initial shockable rhythms was only 9.7% in Singapore, compared to other Asian sites – 31.2% in Japan, 29.6% in Korea and 18.0% in Taiwan.[2] Variations in OHCA outcomes between communities have been shown to relate to differences between emergency care system characteristics like rates of bystander cardiopulmonary resuscitation (BCPR). More recently, there is increased recognition of elements not confined to the traditional sphere of influence of the Emergency Medical Services (EMS) in optimizing OHCA care, including cultural views, political commitment, legislative environment and traffic congestion solutions – these were encapsulated under the Modified Frame of Survival framework by the Global Resuscitation Alliance.[3,4]

There is increasing recognition on the effect of spatial considerations for OHCA outcomes. For instance, some studies showed that OHCAs occurring in public places were more likely to be witnessed, and survival was greater than in residential places.[5] Also, in highly urbanized cities, the vertical distance from the ground in high-rise buildings was correlated with survival in a dose-dependent manner.[6–8] Organizing the community and prehospital response to OHCA in high-rise buildings poses challenges due to rapid urbanization like delayed recognition, reduced bystanders to intervene, increased time for paramedics to reach patient site and CPR interruptions while navigating corridors and elevators. There is hence value in studying the characteristics of residential arrests and the impact of interventions in this group.

We aim to study the characteristics of OHCA occurring in residential areas and the differences in BCPR improvement between residential and non-residential arrests, as we hypothesize that interventions during this period such as dispatcher-assisted CPR (DA-CPR) may preferentially improve BCPR in residential areas.

Materials and methods

Setting

Singapore has approximately 5.6 million people and a geographical area of 721.5 km^2. EMS provided by the Singapore Civil Defence Force (SCDF) since 1989 is a nationally-funded, multi-tiered, fire-based EMS system,[9,10] transporting close to 165,853 cases per year.[11] More than 90% of the population live in high-rise apartments in 2015.[12]

Over the past decade, the introduction of city-wide interventions have improved prehospital OHCA response in Singapore. Specifically targeting bystander-CPR are interventions such as DACPR introduced in July 2012. DACPR allows for timely provision of compression-only bystander CPR, as directed by a trained dispatcher over the telephone. A 2016 before-and-after interventional trial showed that DACPR significantly improved bystander CPR, return of spontaneous circulation (ROSC) and survival at 30 days rates.[13] Singapore also introduced the Dispatcher-Assisted First Responder programme (DARE) in April 2014, encompassing a one-hour education designed by the Ministry of Health to empower Singaporeans with basic CPR and defibrillation skills, in an effort to improve bystander CPR rates in the community. The myResponder mobile phone application was introduced in April 2015 by SCDF to alert passers-by with CPR skills on nearby cardiac arrest cases, accompanied with a "Call 995" button for users to send their geolocation to SCDF's 995 Operations Centre, enabling efficient dispatch of EMS to the scene.

Pan-Asian Resuscitation Outcomes Study

This was a population-based observational study of OHCA across Singapore from April 2010 to December 2016, using data from the Pan Asian Resuscitation Outcomes Study (PAROS). PAROS was a prospective cardiac arrest registry across 7 countries.[2] All OHCA cases – confirmed by absence of pulse, unresponsiveness and apnea – conveyed by Singapore EMS or presenting at the emergency department (ED) were included in the registry. Each patient had a unique case number and no patient identifiers were included in the dataset to maintain patient confidentiality.[14] Data was extracted from EMS records, ED notes and hospital discharge notes. EMS response timings were extracted from a centralized dispatch system and ambulance records. In this paper, data was used specifically from the Singapore cohort.[15]

The data taxonomy collected was based on the Utstein style, and aligned taxonomy with the North American Cardiac Arrest Resuscitation Outcomes Study allows valid comparisons with international cohorts.[16] The registry included information on patient demographics, arrest characteristics (witness status, various EMS response times, bystander CPR and AED rates and providers, first arrest rhythm), prehospital processes of care (i.e. mechanical CPR, defibrillation, advanced airway and drug administration), hospital processes-of-care (aetiology of arrest, patient status on arrival to ED, advanced airway, drug administration, emergency procedures and post-resuscitation disposition and care) as well as the outcomes (i.e. survival to discharge, survival to 30th day post-arrest, neurological outcome).

Variables and outcomes

The primary outcome was survival to hospital discharge or survival in hospital at 30th day post-arrest. Secondary outcomes included ROSC and neurological status at hospital discharge or at the 30th day post-arrest. Neurological status was defined using the Cerebral Performance Category (CPC) score, with "favourable" defined as CPC 1 or 2.

Location of arrest, divided into residential and non-residential areas, was the location patient was found at the time of arrest, where majority of Singaporeans reside in high-rise buildings. Non-residential areas were any location outside residences – including institutional buildings (i.e. nursing homes, healthcare facilities), public or commercial buildings, streets or highways and places of recreation (i.e. public parks). EMS-related time intervals was divided into 3 parts – time from call to arrival at scene, time from arrival at scene to arrival at patient's side and total time from call to arrival at patient's side. Bystanders were defined as laypersons who were at the scene of an OHCA.

Statistical methods

Data was processed using Microsoft Excel version 16.16.11. Analysis was performed using the IBM SPSS Statistics version 25.

The Kruskal–Wallis test was performed for continuous variables and the chi-square test for categorical variables to assess differences in patient characteristics, EMS characteristics and patient outcomes according to the location of arrest. Univariate and multivariate logistic regression were then used to assess the contribution of location-type to favourable survival outcome. The covariates used for multivariate logistic regression were selected based on previous literature.[17–20] They were age, gender, presence bystander CPR and bystander AED, witness status, EMS response time and first arrest rhythm. Odds ratio, adjusted odds ratio (AOR) and 95% confidence interval (CI) were reported.

A test of interaction was also performed to analyze if there is a significant interaction effect between Year of incident and Location-type for bystander CPR. A *p*-value of <0.05 was considered statistically significant.

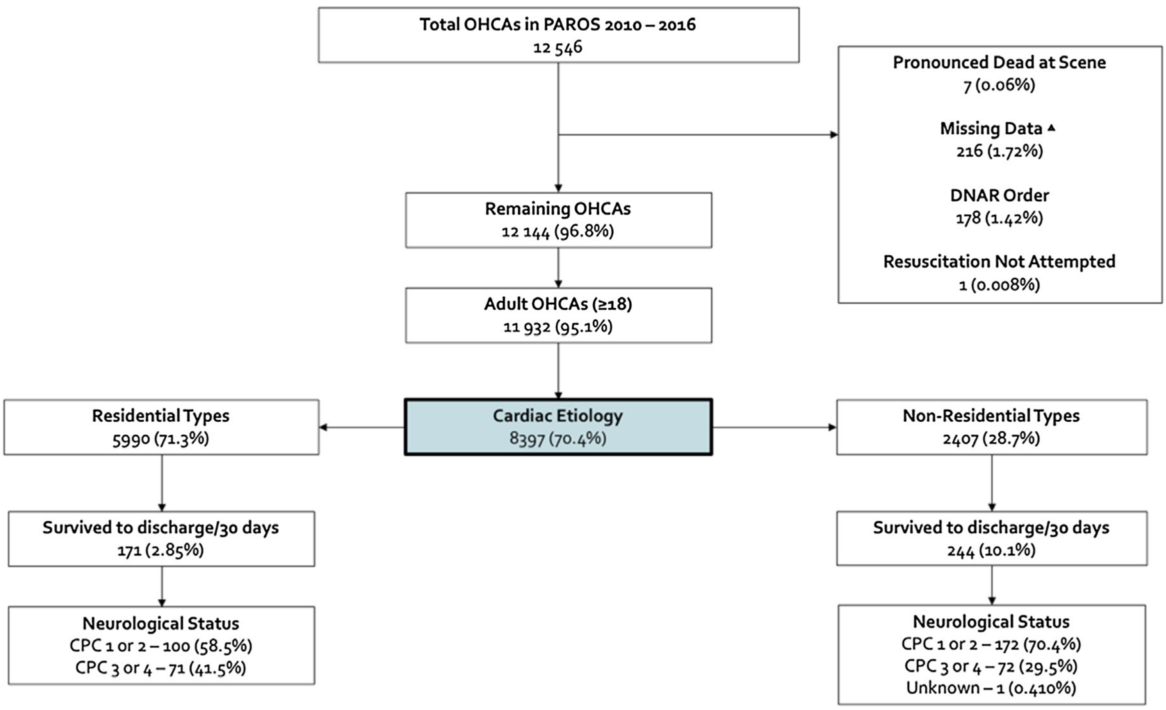
Ethics approval

The Centralized Institutional Review Board and Domain Specific Review Board of individual study sites granted approval for this study with a waiver of patient consent.

Results

Patient characteristics

Fig. 1 shows the population flow of the study. From April 2010 to December 2016, a total of 12,546 cases were included in PAROS. We excluded patients with existing Do Not Attempt Resuscitation (DNAR) order (178, 1.42%), pronounced dead at scene (7, 0.06%), who had missing data (216, 1.72%) and whom resuscitation was not attempted (1, 0.008%). In the remaining 11,932 cases, we only included patients aged 18 years and above, with arrests of cardiac aetiology, leaving 8397 cases eligible for analysis. Of these cases, close to three-quarter were residential cardiac arrests (5990 cases,



PAROS=Pan Asian Resuscitation Outcome Study; DNAR=Do-Not-Attempt Resuscitation; OHCA=Out-of-Hospital Cardiac Arrest; CPC= Cerebral Performance Category
▲ Missing data: missing location information

Fig. 1 – Population selection. PAROS = Pan Asian Resuscitation Outcome Study; DNAR = Do-Not-Attempt Resuscitation; OHCA = Out-of-Hospital Cardiac Arrest; CPC = Cerebral Performance Category. ▲ Missing data: missing location information.

71.3%) as compared to non-residential cardiac arrests (2407 cases, 28.7%).

Fig. 2 shows the breakdown of cardiac arrests by location-type. The distribution of non-residential arrests, in decreasing order of frequency, included public/commercial buildings (9.3%), street/ highway (3.8%), healthcare facilities (3.2%), nursing homes (3.2%), industrial places (2.6%), place of recreation (2.2%), in EMS/private ambulances (2.1%).

Demographic and clinical differences according to location-type

Table 1 shows the characteristics of patients in residential and non-residential cardiac arrests. In terms of patient demographics, residential cardiac arrest patients were older (70.0 years [59.0−81.0] vs 61.0 years [51.0−71.0], $p < 0.01$), were less likely to be males (61.8% vs 82.2%, $p < 0.01$) and more likely to be Chinese (67.0% vs 64.1%, $p < 0.01$).

In terms of OHCA response characteristics, residential cardiac arrests had a longer total EMS response time (10:43 min [08:39−13:14] vs 10:23 min [08:27−13:18], $p < 0.01$) and were less likely to be witnessed (3358, 56.1% vs 1683, 69.9%, $p < 0.01$), to receive bystander CPR (2455, 41.0% vs 1290, 53.6%, $p < 0.01$) and bystander AED application (23, 0.4% vs 259, 10.8%, $p < 0.01$), and to have a shockable initial arrest rhythm (1053, 17.5% vs 928, 38.5%, $p < 0.01$).

In terms of outcomes, residential cardiac arrests had significantly lower rates of survival outcome (2.9% vs 10.1%, $p < 0.01$), ROSC (27.4% vs 34.0%, $p < 0.01$) and favourable neurological outcome (58.5% vs 70.8%, $p < 0.01$).

Survival outcomes among residential and non-residential cardiac arrests

A multivariate logistic regression analysis was performed to assess if location-type had a significant independent effect on survival (Table 2). After adjustment for confounders, residential arrest was associated with poorer survival to discharge and 30th day outcome (AOR 0.547 [0.213−0.319]) as compared to non-residential. Other significant prognosticate factors were presence of bystander AED (AOR 1.83 [1.23−2.71]), witnessed arrests (AOR 2.35 [1.75−3.15]) and having a shockable first arrest rhythm (AOR 11.3 [8.66−14.8]).

Interaction between year and bystander CPR rate

Fig. 3 shows the trend in bystander CPR rates from 2010 to 2016. The graph shows a steady rise in overall bystander CPR rates from year 2011 (21.5−59.2%), and that most of this rise may be attributed to increases seen in residential cardiac arrests (14.6−57.1% vs 39.6−65% in non-residential).

A univariate, multivariate and test of interaction analysis was also performed, and the results can be seen in Table 3. We note that there was a significant change in bystander CPR rates, particularly between year 2011 and 2012 in the residential cardiac arrests (AOR 0.93 [0.68−1.26] vs AOR 2.15 [1.61−2.86]).

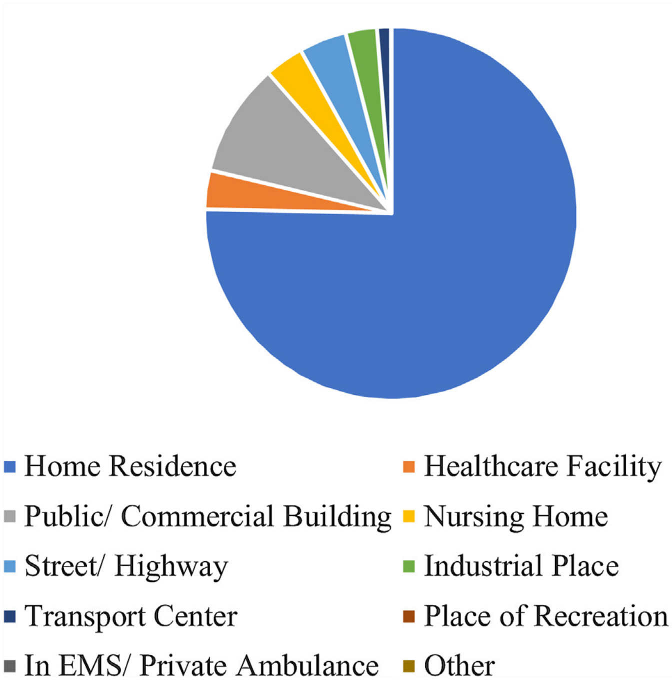
Discussion

Summary of findings

This national observational study of OHCA in Singapore from 2010 to 2016 had several interesting findings.

Community response in residential versus non-residential cardiac arrests

First, residential OHCA had lower provision of community interventions namely BCPR and bystander AED. The lower incidence of shockable initial rhythm may be a consequence of delayed recognition and activation of EMS. This was not surprising as there are fewer



Location	%
Home Residence	71.3
Healthcare Facility	3.2
Public/Commercial Building	9.3
Nursing Home	3.2
Street/ Highway	3.8
Industrial Place	2.6
Transport Center	1.1
Place of Recreation	2.2
In EMS/Private ambulance	2.1
Other	1.2

Fig. 2 – Cardiac arrests stratified by location.

Table 1 – Characteristics of cardiac arrest patients based on location.

Variable, *n* (%)	Residential (*n* = 5990)	Non-residential (*n* = 2407)	*P*-value
Age, median (IQR)	70.0 (59.0–81.0)	61.0 (51.0–71.0)	<0.01
Gender, male	3703 (61.8%)	1979 (82.2%)	<0.01
Race	<0.01		
Chinese	4011 (67.0%)	1543 (64.1%)	
Malay	1036 (17.3%)	334 (13.9%)	
Indian	682 (11.4%)	324 (13.5%)	
Eurasian	19 (0.3%)	14 (0.6%)	
Others	242 (4.0%)	192 (8.0%)	
EMS Response Times (mm:ss)			
Call to arrival at scene			0.58
Median	08:36	08:41	
Interquartile range	06:40–11:05	06:34–11:21	
Scene to patient's side			<0.01
Median	02:00	01:27	
Interquartile range	01:03–03:04	00:36–02:47	
Call to patient's side			<0.01
Median	10:43	10:23	
Interquartile range	08:39–13:14	08:07–13:18	
Bystander CPR	2455 (41.0%)	1290 (53.6%)	<0.01
Bystander AED	23 (0.4%)	259 (10.8%)	<0.01
Collapsed witnessed	<0.01		
Bystander	3040 (50.8%)	1428 (59.3%)	
EMS	318 (5.3%)	255 (10.6%)	
Not witnessed	2632 (43.9%)	724 (30.1%)	
First arrest rhythm	<0.01		
Shockable			
VF	967 (16.1%)	781 (32.4%)	
VT	24 (0.4%)	18 (0.7%)	
Unknown shockable	62 (1.0%)	129 (5.4%)	
Unshockable			
PEA	1582 (26.4%)	569 (23.6%)	
Asystole	3121 (52.1%)	810 (33.7%)	
Unknown non-shockable	224 (3.7%)	89 (3.7%)	
Unknown	10 (0.2%)	11 (0.5%)	
Any ROSC	1641 (27.4%)	819 (34.0%)	<0.01
(either en-route or at ED)			
Survival outcomes	<0.01		
Discharged Alive or Survived until 30 days post-arrest	171 (2.9%)	244 (10.1%)	
Favourable neurological outcome (CPC 1 or 2)	100 (58.5%)	172 (70.8%)	<0.01

people in a typical residential setting, leading to a lower likelihood of having a bystander trained in Basic Life Support (BLS).[15] The lower bystander AED application could be explained by the fact that few households own an AED.

However, it is important to note that BCPR has improved in both residential and non-residential arrests, with a greater increase in residential arrests (test of interaction was significant). There are three possible explanations for this. First, the low baseline BCPR rate in this group may itself allow more drastic improvements as there is a greater proportion of potential BCPR providers that remain targetable. Second, there may be regression to the mean where additional data points simply regress to a true mean. Third, it is possible that some of the BCPR interventions (namely, DA-CPR, DARE and the myResponder crowdsourcing app) preferentially improved rates in residential areas. We postulate that DA-CPR is most subjected to this effect. DA-CPR is less likely to be needed in a non-residential area where there is higher likelihood of BCPR even before the call to the dispatch centre.[21] This postulation is supported by the sharp increase in BCPR rate in 2011–2012 only in the residential group (Fig. 3), coinciding with the introduction of DA-CPR in July 2012.

EMS care characteristics in residential versus non-residential cardiac arrests

Second, residential OHCA had poorer EMS care characteristics. Response time was longer, likely contributed by the interval between EMS reaching the building and the patient. This exemplifies the challenges of coordinating OHCA care in a highly-urbanized setting with dense high-rise buildings. The need to navigate apartment blocks including waiting for lifts can delay the arrival of EMS. The detrimental effect of this is magnified due to lower rates of bystander interventions. In addition, while our data does not have the granularity to demonstrate this, it is postulated that the journey back to the ambulance would be problematic, with the additional need to manoeuvre a gurney through tight passage-ways and small elevators. The ability to provide adequate chest compression in a sitting position is an area requiring further research and may be a use-case where mechanical chest compression devices may be advantageous. Also, the presence of patients in healthcare facilities and nursing homes in the non-residential group may explain some of the better resuscitation treatment characteristics due to increase likelihood of staff being trained in BLS.

Table 2 – Unadjusted and adjusted odds ratio (OR) for survival to discharge and 30th day.

Variable	Number with survival outcome (%)	Unadjusted OR	95% CI	Adjusted OR	95% CI
Location					
Residential	175 (2.8%)	0.261	(0.213–0.319)	0.547	(0.435–0.688)
Non-residential	240 (11.2%)	Reference		Reference	
Age[a]	–	0.964	(0.958–0.970)	0.984	(0.976–0.992)
Gender					
Male	344 (6.1%)	2.40	(1.85–3.11)	0.976	(0.731–1.30)
Female	71 (2.6%)	Reference		Reference	
Bystander CPR					
Yes	234 (6.2%)	1.65	(1.35–2.00)	1.07	(0.852–1.34)
No	181 (3.9%)	Reference		Reference	
Bystander AED					
Yes	48 (17.0%)	4.33	(3.12–6.01)	1.83	(1.23–2.71)
No	367 (4.5%)	Reference		Reference	
Witness status					
Witnessed	356 (7.1%)	4.25	(3.21–5.61)	2.35	(1.75–3.15)
Not witnessed	59 (1.8%)	Reference		Reference	
EMS response time					
<8 min	218 (6.2%)	1.55	(1.27–1.89)	1.51	(1.22–1.88)
≥8 min	398 (4.1%)	Reference		Reference	
First arrest rhythm					
Shockable	340 (17.2%)	17.5	(13.6–22.6)	11.3	(8.66–14.8)
Non-shockable	75 (1.2%)	Reference		Reference	

Factors selection guided by literature review.
[a] Analyzed as continuous variable.

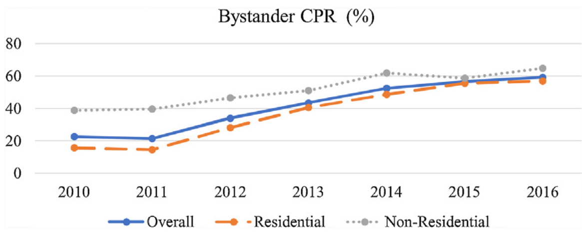


Fig. 3 – CPR rates over year, stratified by location.

Comparison with 2010 study

This study provided an updated analysis of residential OHCA in Singapore from a previous study based on the CARE study from 2001 to 2014.[5] There are important differences in the findings compared to the current study performed 10 years ago. Within the limitations of having subtle data collection and analytic differences between the two studies, comparison of results yielded some observations. First, unlike our study, Goh et al. found that location alone did not demonstrate an independent effect on survival outcome. This could be due to their smaller sample size across a shorter study period. Also, their proportion of survival was far lower, which reduces the efficiency of the logistic regression model. Another possible explanation is that they have adjusted for ground level arrest, an unmeasured confounder in our study as ground level arrest may have characteristics closer to non-residential and high-rise arrests.

In our population, residential location did have an independent effect on survival outcome, congruent with several other populations.[22–25] The effect on survival remained despite adjusting for demographics, BCPR and bystander AED. As OHCA occurring in residential and non-residential locations are the same disease (and same pathophysiology), it follows that there are unmeasured confounders driving the survival disadvantage. As earlier discussed, one of these confounders could be reduced resuscitation quality while journeying from patient's home back to the ambulance. This needs to be clarified in future studies, so that solutions and devices can be tested or developed in this high-rise setting.

Of note, BCPR remained a powerful positive prognostic factor in both studies.

Implications of the study

First, this study found that bystander AED application continues to remain low in residential arrests. This may support the need for targeted training of household members of patients who are at-risk of OHCA, such as heart failure patients. This could include BLS or simply knowing where the nearest AED is located in their residence.

Second, despite the improvements achieved, residential arrests continue to have lower survival. This reinforces the need for continued education to residential populations. An example would be the 2015 Save-A-Life Initiative (SAL) – a holistic educational effort to enhance community first response to cardiac arrest cases in the heartlands, entailing 3 main components: Hardware, Heartware and Software. “Hardware” involves the installation of more than a thousand AED devices in HDB estates nationwide, complementing the function of myResponder crowdsourcing app. “Heartware” involves nationwide, readily accessible education to the general public on life-saving BLS measures. Lastly, “Software” entails the development of a myResponder application to notify the community of any potential cardiac arrests within 400 metres. It is also linked the national AED registry and updates first responders on the nearest AED, enabling them to contribute to BLS prior to EMS arrival.

Table 3 – Unadjusted and adjusted OR and interaction effect for bystander CPR.

	Residential				Non-residential				Interaction effect			
	UOR	p	AOR	p	UOR	p	AOR	p	Ratio of UOR	p	Ratio of AOR	p
Age ≥65	1.04 (0.94–1.16)	0.43	1.15 (1.02–1.29)	0.02	0.98 (0.83–1.16)	0.83	1.00 (0.84–1.19)	0.98	0.94 (0.77–1.15)	0.54	0.87 (0.71–1.07)	0.19
Male	0.99 (0.89–1.10)	0.82	0.97 (0.87–1.09)	0.62	1.0 (0.81–1.23)	0.97	1.04 (0.83–1.29)	0.76	1.01 (0.80–1.28)	0.95	1.07 (0.83–1.37)	0.62
Witnessed arrest	1.06 (0.95–1.17)	0.28	1.12 (1.01–1.25)	0.04	0.96 (0.81–1.14)	0.66	1.03 (0.86–1.24)	0.73	0.91 (0.74–1.11)	0.35	0.92 (0.75–1.14)	0.44
Year												
2010	Reference		Reference		Reference		Reference		Reference		Reference	
2011	0.91 (0.667–1.24)	0.55	0.93 (0.68–1.26)	0.65	1.03 (0.722–1.47)	0.87	1.04 (0.73–1.49)	0.84	1.13 (0.71–1.82)	0.6	1.12 (0.70–1.80)	0.64
2012	2.10 (1.57–2.80)	<0.01	2.15 (1.61–2.86)	<0.01	1.36 (0.963–1.93)	0.081	1.37 (0.97–1.94)	0.08	0.65 (0.41–1.02)	0.061	0.64 (0.41–1.01)	0.05
2013	3.65 (2.78–4.79)	<0.01	3.74 (2.85–4.92)	<0.01	1.64 (1.16–2.31)	<0.01	1.65 (1.17–2.33)	<0.01	0.45 (0.29–0.7)	<0.01	0.44 (0.28–0.69)	<0.01
2014	5.07 (3.89–6.62)	<0.01	5.21 (4.00–6.81)	<0.01	2.54 (1.81–3.57)	<0.01	2.57 (1.82–3.61)	<0.01	0.5 (0.33–0.77)	<0.01	0.49 (0.32–0.76)	<0.01
2015	6.70 (5.15–8.72)	<0.01	6.91 (5.30–9.00)	<0.01	2.24 (1.61–3.10)	<0.01	2.26 (1.62–3.14)	<0.01	0.33 (0.22–0.51)	<0.01	0.33 (0.21–0.50)	<0.01
2016	7.09 (5.46–9.21)	<0.01	7.33 (5.64–9.53)	<0.01	2.92 (2.09–4.07)	<0.01	2.94 (2.11–4.11)	<0.01	0.41 (0.27–0.63)	<0.01	0.40 (0.26–0.61)	<0.01

Limitations of study

Limitations of this study include the lack of vertical distance data in the registry which does not allow us to make conclusive observations about the effect of high-rise OHCA. For example, those living on landed property may not be subjected to limitations of responding to a high-rise location. However, this is a minor limitation as 80% of Singapore resides in high-rise apartments. Secondly, there are unmeasured confounders in our study, implied by the residual survival advantage in the non-residential group after multivariable adjustment. While this likely reflects unmeasured negative prognostic factors in the residential group confounding the analysis (such as poorer CPR quality while navigating tight urban spaces), it is also possible that there is underlying etiological and physiological disease differences in the two group. Thirdly, while the improvements in BCPR were seen during the same period where several city-wide interventions were implemented, this may not have a causative effect.

Conclusion

Residential location is an independent predictor of survival in OHCA in Singapore from 2011 to 2016. Patients from residential-type arrests continue to have poorer rates of BCPR, bystander AED and EMS response. There was improvement in BCPR during in this period, with greater improvements amongst the residential arrest group.

Conflict of interest

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REFERENCES

1. Mcnally B, Abella B, Sasson C, Arbor A. Regional variation in out-of-hospital cardiac arrest survival in the United States. . p. 319–56.
2. Li WY, Ko PC-I, Song KJ, et al. Outcomes for out-of-hospital cardiac arrests across 7 countries in Asia: the Pan Asian Resuscitation Outcomes Study (PAROS). Resuscitation 2015;96:100–8.
3. Chong SL, Laerdal T, Cordero J, et al. Global resuscitation alliance consensus recommendations for developing emergency care

systems: Reducing perinatal mortality. Resuscitation [Internet] 2018;133:71–4 Available from: https://doi.org/10.1016/j.resuscitation.2018.09.027.
4. Nadarajan GD, Tiah L, Ho Ho AFW, et al. Global resuscitation alliance utstein recommendations for developing emergency care systems to improve cardiac arrest survival. Resuscitation [Internet] 2018 Available from: https://linkinghub.elsevier.com/retrieve/pii/S0300957218307998 [cited 11 September 2018].
5. Shaun Goh E, Liang B, Fook-Chong S, et al. Effect of location of out-of-hospital cardiac arrest on survival outcomes. Ann Acad Med Singapore 2013;42:437–44.
6. Morrison LJ, Angelini MP, Vermeulen MJ, Schwartz B. Measuring the EMS patient access time interval and the impact of responding to high-rise buildings. Prehospital Emerg Care 2005;9:14–8.
7. Lateef F, Anantharaman V. Delays in the ems response to and the evacuation of patients in high-rise buildings in Singapore. Prehospital Emerg Care 2005;4:327–32.
8. Lian TW, Allen JC, Ho AFW, et al. Effect of vertical location on survival outcomes for out-of-hospital cardiac arrest in Singapore. Resuscitation [Internet] 2019;139:24–32 Available from: https://linkinghub.elsevier.com/retrieve/pii/S0300957218309134.
9. Kudenchuk PJ, Stuart R, Husain S, Fahrenbruch C, Eisenberg M. Treatment and outcome of out-of-hospital cardiac arrest in outpatient health care facilities. Resuscitation 2015;97:97–102.
10. Ho AFW, Chew D, Wong TH, et al. Prehospital trauma care in Singapore. Prehospital Emerg Care 2015;19:409–15.
11. SCDF Home Page.
12. Statistics Singapore – Department of Statistics Singapore [Internet]. Available from: http://www.singstat.gov.sg/statistics/latest_data.html#14.
13. Harjanto S, Na MXB, Hao Y, et al. A before-after interventional trial of dispatcher-assisted cardio-pulmonary resuscitation for out-of-hospital cardiac arrests in Singapore. Resuscitation [Internet] 2016;102:85–93, doi:http://dx.doi.org/10.1016/j.resuscitation.2016.02.014.
14. Ong ME, Cho J, Ma MHM, et al. Comparison of emergency medical services systems in the pan-Asian resuscitation outcomes study countries: report from a literature review and survey. EMA – Emerg Med Australas 2013;25:55–63.
15. Doctor N, Ahmad N, Pek P, Yap S, Ong M. The Pan-Asian Resuscitation Outcomes Study (PAROS) clinical research network: what, where, why and how. Singapore Med J 2017;58:456–8.
16. Cummins RO, Chamberlain DA, Abramson NS, et al. Recommended guidelines for uniform reporting of data from out-of-hospital cardiac arrest: the Utstein Style. A statement for health professionals from a task force of the American Heart Association, the European Resuscitation Council, the Heart and Stroke Foundation of Canada, and the Australian Resuscitation Council. Circulation 1991;84:960–75.
17. Ho AFW, Hao Y, Pek PP, et al. Outcomes and modifiable resuscitative characteristics amongst pan-Asian out-of-hospital cardiac arrest occurring at night. Medicine (Baltimore) [Internet] 2019;98:e14611 Available from: http://insights.ovid.com/crossref?an=00005792-201903080-00015.
18. Tan TXZ, Hao Y, Ho AFW, et al. Inter-hospital variations in resuscitation processes and outcomes of out-of-hospital cardiac arrests in Singapore. J Emerg Crit Care Med [Internet] 2019;3:21 Available from: http://jeccm.amegroups.com/article/view/5118/html.
19. Wah W, Wai KL, Pek PP, et al. Conversion to shockable rhythms during resuscitation and survival for out-of hospital cardiac arrest. Am J Emerg Med [Internet] 2017;35:206–13 Available from: https://linkinghub.elsevier.com/retrieve/pii/S0735675716307380.
20. Ng YY, Wah W, Liu N, et al. Associations between gender and cardiac arrest outcomes in Pan-Asian out-of-hospital cardiac arrest patients. Resuscitation 2016;102:116–21.
21. Idris AH, Roppolo L. Barriers to dispatcher-assisted telephone cardiopulmonary resuscitation. Ann Emerg Med 2003;42–6.
22. Iwami T, Hiraide A, Nakanishi N, et al. Outcome and characteristics of out-of-hospital cardiac arrest according to location of arrest: a report from a large-scale, population-based study in Osaka, Japan. Resuscitation 2006;69:221–8.
23. Sondergaard KB, Wissenberg M, Gerds TA, et al. Bystander cardiopulmonary resuscitation and long-term outcomes in out-of-hospital cardiac arrest according to location of arrest. Eur Heart J 2019;40:309–18.
24. McNally B, Tanaka H, Lee SC, et al. Effect of dispatcher-assisted cardiopulmonary resuscitation program and location of out-of-hospital cardiac arrest on survival and neurologic outcome. Ann Emerg Med 201669: 52-61.e1.
25. Okabayashi S, Matsuyama T, Kitamura T, et al. Outcomes of patients 65 years or older after out-of-hospital cardiac arrest based on location of cardiac arrest in Japan. JAMA Netw Open 2019;2:e191011.