RESUSCITATION PLUS 17 (2024) 100573

Available online at www.sciencedirect.com

Resuscitation Plus

journal homepage: www.elsevier.com/locate/resuscitation-plus

Clinical paper

Increasing neurologically intact survival after out-of-hospital cardiac arrest among elderly: Singapore Experience

Chloe Alexis Ong[a,1], *Gayathri Devi Nadarajan*[b,1], *Stephanie Fook-Chong*[c], *Nur Shahidah*[b,c,*], *Shalini Arulanandam*[d], *Yih Yng Ng*[a,e,f], *Michael YC Chia*[g], *Ling Tiah*[h], *Desmond R Mao*[i], *Wei Ming Ng*[j], *Benjamin SH Leong*[k], *Nausheen Doctor*[l], *Marcus EH Ong*[b,m], *Fahad J Siddiqui*[c]

Abstract

Objectives: With more elderly presenting with Out-of-Hospital Cardiac Arrests (OHCAs) globally, neurologically intact survival (NIS) should be the aim of resuscitation. We aimed to study the trend of OHCA amongst elderly in a large Asian registry to identify if age is independently associated with NIS and factors associated with NIS.

Methods: All adult OHCAs aged ≥18 years attended by emergency medical services (EMS) from April 2010 to December 2019 in Singapore was extracted from the Pan-Asian Resuscitation Outcomes Study (PAROS) registry. Cases pronounced dead at scene, non-EMS transported, traumatic OHCAs and OHCAs in ambulances were excluded. Patient characteristics and outcomes were compared across four age categories (18–64, 65–79, 80–89, ≥90). Multivariable logistic regression analysis determined the factors associated with NIS.

Results: 19,519 eligible cases were analyzed. OHCA incidence increased with age almost doubling in octogenarians (from 312/100,000 in 2011 to 652/100,000 in 2019) and tripling in those ≥90 years (from 458/100,000 in 2011 to 1271/100,000 in 2019). The proportion of patients with NIS improved over time for the 18–64, 65–79- and 80–89-years age groups, with the greatest improvement in the youngest group. NIS decreased with each increasing year of age and minute of response time. NIS increased in the arrests of presumed cardiac etiology, witnessed and bystander CPR.

Conclusions: Survival with good outcomes has increased even amongst the elderly. Regardless of age, NIS is possible with good-quality CPR, highlighting its importance. End-of-life planning is a complex yet necessary decision that requires qualitative exploration with elderly, their families and care providers.

Keywords: Elderly, Out-of-hospital cardiac arrest, Quality of life, Epidemiology, Cardiopulmonary resuscitation

Introduction

Globally, many societies face ageing populations.[1] With the demographic shift, more elderly are experiencing out-of-hospital cardiac arrests (OHCAs) and surviving.[2–5] The proportion of elderly (defined as ≥65 years in this paper) with neurologically intact survival (NIS) (as defined by survival to discharge or 30th day post arrest with Cerebral Performance Category (CPC) ≤2) varies globally, with some reports more promising than others. A study in the Netherlands found that 7.3% of elderly OHCA patients achieved NIS,[6] while this was 0.88% in Japan.[5] As populations continue to age, the likely trajectory will result in an increasing number of elderly OHCA patients requiring care provided by emergency medical services (EMS) and hospital systems. Understanding the trend and factors associated with NIS can help guide clinical decisions regarding resuscitation in the elderly.

Similar to other developed countries,[7] Singapore's population is ageing, with the proportion of residents aged 65 and over increasing from 9.0% in 2011 to 14.4% in 2019.[8] With 108.3 disability adjusted life-years per 1,000 adults aged 25 and older, Singapore possesses

* Corresponding author at: Department of Emergency Medicine Singapore General Hospital Outram Road, Singapore 169608, Singapore.
E-mail address: nur.shahidah.ahmad@singhealth.com.sg (N. Shahidah).

[1] Joint first author. For the Singapore PAROS Investigators.

https://doi.org/10.1016/j.resplu.2024.100573
Received 30 November 2023; Received in revised form 10 January 2024; Accepted 23 January 2024

one of the lowest age-related disease burden rates globally.[9] Nonetheless, an ageing population is placing a strain on the country's resources. The elderly have more comorbidities and require more medical attention.[10] The dependency ratio has also increased from 12.6 in 2011 to 20.4 in 2019.[8] Overall healthcare expenditure had increased four-fold over 10 years, from S$2 billion (US$1.5 billion) in 2006 to S$8.5 billion (US$6.4 billion) in 2015. To keep up with the ageing population, it was estimated that an additional S$3 billion (US$2.3 billion) would be needed over the following five years.[11].

The relatively low proportion of NIS in elderly OHCA survivors found in countries with ageing populations,[5,6] has an impact on healthcare resources, individuals and their families. Besides this, counselling patients regarding advance care plans (ACPs) or deciding when not to conduct cardiopulmonary resuscitation (CPR) remains challenging due to the difficulties in determining the chances of NIS in elderly patients.

This study aims to describe the relationship between age and OHCA survival with good neurological outcomes in the elderly by retrospectively examining the characteristics of geriatric OHCA cases in Singapore. The primary objectives of this study are firstly, to establish the trend of geriatric OHCA in Singapore over time and secondly, determine the proportion of NIS in both non-geriatric and geriatric OHCA patients. We also aimed to determine the factors associated with NIS that need to be considered to make a decision of not providing CPR in geriatric OHCA patients.

Methods

Setting

The metropolitan Southeast Asian city-state of Singapore has a population of 5.7 million [8] and a gross domestic product (GDP) of US $374 million.[12] Life expectancy is 83.7 years[13] and as of 2019, elderly people aged 65 years and above comprise 14.4% of the resident population.[14] Pre-hospital EMS are provided nationwide by the Singapore Civil Defence Force (SCDF), activated by a centralized dispatch system,[15] which routinely initiates dispatcher-assisted CPR.

Pan-Asian resuscitation outcomes study (PAROS) registry

Data from Singapore in the Pan-Asian Resuscitation Outcomes Study (PAROS) registry was used. The PAROS network is an Asia-Pacific collaborative research network, founded in 2009 to address gaps in pre-hospital and OHCA management among Asian countries. This multi-center prospective registry records over 60 variables for each OHCA event and EMS response descriptors, pre-hospital and in-hospital interventions and outcomes. The PAROS methodology has been described in a previous study[16] and all data collected are in accordance with Utstein Style.[17] Sources of PAROS data elements include dispatch notes, ambulance record notes, hospital emergency department and inpatient notes.

Study population

All EMS-attended OHCA patients aged 18 years and above from April 2010 to December 2019 were included in this study. We excluded cases not transported by SCDF, patients who were pronounced dead at the scene, traumatic OHCA and cardiac arrests that occurred in the ambulance.

Definitions of key variables

Our primary outcome was neurologically intact survival (NIS), defined as a CPC score of 1 or 2 (CPC 1/2) at hospital discharge or 30-days post-arrest, whichever occurred first. Utstein guidelines recommend the use of the CPC score to measure neurologic function in cardiac arrest survivors. It is a five-point scale ranging from good cerebral performance (CPC 1) to brain death (CPC 5) and a score of 1 or 2 is generally regarded as a "good" outcome.[18]

Henceforth, the abbreviations NIS and CPC 1/2 are used interchangeably to refer to the primary outcome. The CPC score evaluates cerebral performance capabilities and neurological outcomes. Information on neurological outcomes were extracted from inpatient clinical documentations by attending physicians or specialists, and scores were derived using Glasgow-Pittsburg Outcome Categories. The best-case scenario refers to OHCA cases that were witnessed, with a presumed cardiac cause of arrest and bystander CPR.

Ethics statement

SingHealth Centralised Institutional Review Board (CIRB ref: 2013/604/C and 2018/2937) and National Healthcare Group Domain Specific Review Board (ref: C/10/545 and 2013/00929) granted approval for this study with a waiver of informed consent.

Statistical analysis

All analyses were conducted using Stata version 16.1. For the purposes of comparison, the cases studied were divided into four age groups, namely 18 to 64 years, 65 to 79 years, 80 to 89 years, and 90 years and above. We summarized the characteristics of individuals in the four age groups using median (interquartile range) and count (percentage) as appropriate. To calculate OHCA incidence, we obtained the total population size of each age group from the Singapore Department of Statistics.[8] Graph of OHCA incidence over the years was plotted starting from year 2011 instead of 2010 as we did not have a full year of OHCA cases available for 2010. We used the Mantel-Haenszel test to test for any linear trend in proportion of patients with NIS over time.

A multivariable logistic regression of NIS on restricted cubic splines (RCS) terms of age with four knots at 5th, 35th, 65th and 95th percentiles of age was performed. Potential confounders that were adjusted in the model were those known to be biologically plausible, namely age, year, gender, location of arrest, witness status, bystander CPR, bystander automated external defibrillator (AED) use, presumed cardiac cause of arrest, response time and the number of medical comorbidities. The predictive power of the model was assessed in terms of area under the curve (AUC) index and a calibration plot. Internal validation with 200 bootstrap resamples were drawn to obtain a bias-corrected regression model. The marginal prediction plot of NIS was computed separately for the subset of best-case scenario and another subset that comprised the remaining OHCA cases. Two models were built a) using all cases; and b) for the arrests that were witnessed, were cardiac in origin and received CPR (best-case scenario).

Results

Between 1 April 2010 and 31 Dec 2019, a total of 21,592 OHCAs were reported and registered in the PAROS database. We analyzed 19,519 OHCA cases after excluding arrests in patients who were privately transported, traumatic in etiology, occurred in ambulances or where the patient was below 18 years of age. Fig. 1 illustrates the patient flow diagram of the outcomes of OHCA in the various age groups.

Fig. 2 shows the incidence of OHCA increasing steadily from 2011 to 2019, from 44 cases per 100,000 Singapore population in 2011 to almost double at 86 per 100,000 in 2019. This increase has occurred despite the growing population of elderly over time. Across all 9 years, OHCA incidence was consistently higher among the older age groups. Moreover, the increase in incidence rate was fastest for the two oldest age groups, with incidence almost doubling in 80–89 years age group (from 312 per 100,000 in 2011 to 652 per 100,000 in 2019) and tripling in the $\geq$90 years age group (from 458 per 100,000 in 2011 to 1271 per 100,000 in 2019).

The proportion of NIS improved over time for patients in the 18 to 64 years, 65 to 79 years, and 80 to 89 years age groups ($p < 0.05$, Fig. 3). The greatest improvement was seen in the youngest group (18–64 years), with an increase from 2.8% in 2011to 10% in 2019 (not shown in Fig. 3). However, no increase in the proportion of NIS was observed in the oldest group ($\geq$90 years, yellow line).

From the youngest to oldest age group, it was observed that there were increasingly fewer males, more Chinese, lower frequency of initial shockable rhythm, more OHCAs occurring at home, fewer bystander witnessed arrests, lesser bystander AED administered, lesser cases with cardiac cause of arrest and a higher number of medical comorbidities in patients. The proportions of receipt of bystander CPR and response time (within 8 minutes) were comparable across all age groups. The trend in the rates of ROSC, survival to hospital admission, survival to hospital discharge and proportion of NIS were decreasing significantly with increasing age ($p < 0.001$ for trend, for all four outcomes, Table 1).

Multivariable logistic regression analysis of NIS is presented in Table 2. The spline function 1 of age was simply the linear term of age. A test for null hypothesis that the coefficients for spline terms 2 and 3 are jointly zero was rejected. This confirmed that the relationship between age and survival was non-linear.

The chance of NIS decreased for every year increase in age and each minute delay in response time. The chance of NIS was also lower for females. Contrarily, chances of NIS increased for each passing calendar year, for arrests occurring in healthcare facilities or public locations compared to home, for scenarios where the arrests were witnessed, had bystander CPR or AED administration or a presumed cardiac cause of arrest. The number of comorbidities was not significantly associated with NIS after adjustment for confounders (Table 2).

Internal validation with 200 bootstrap resamples yielded a similar model to the one depicted in Table 2. The derived model performed well in separating good neurological survival from poor with AUC

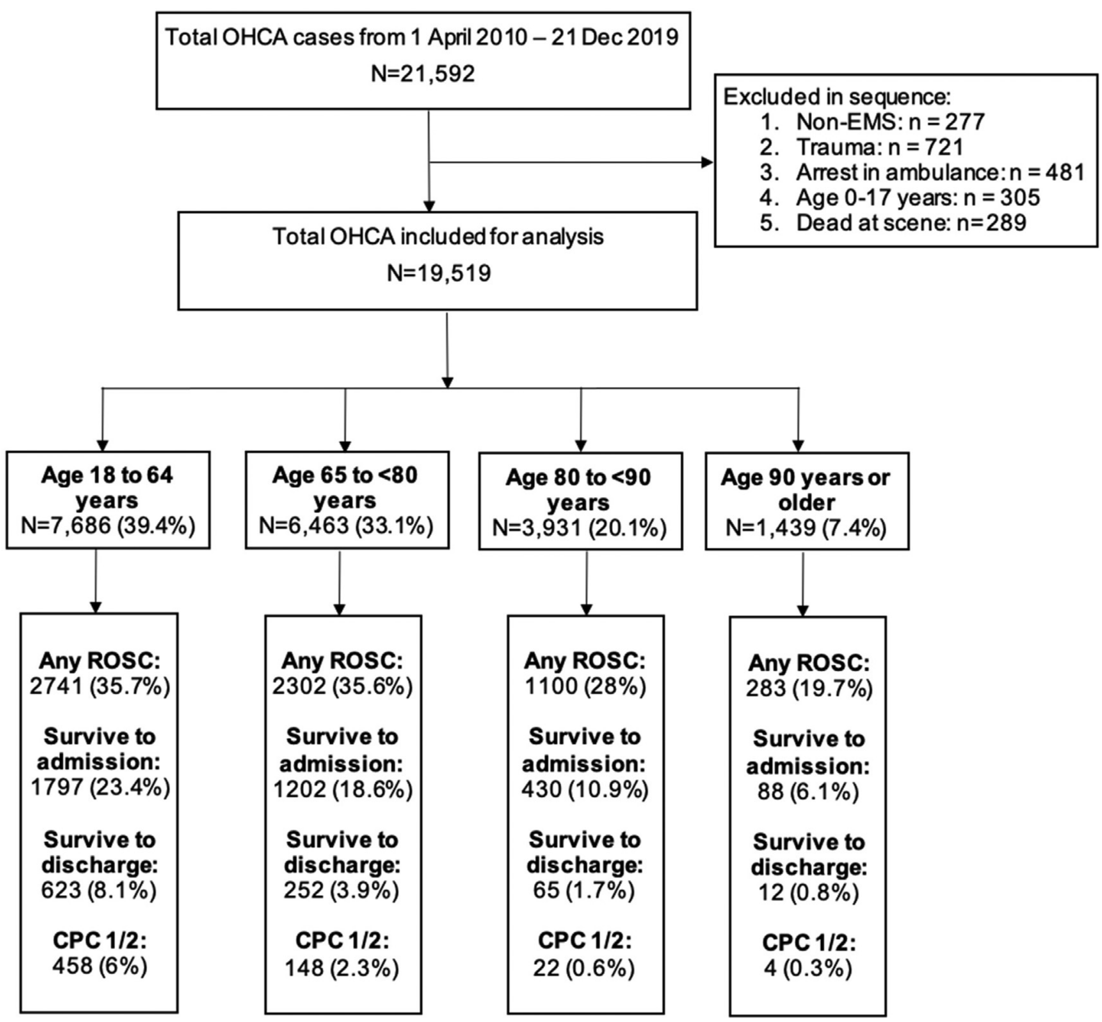

Fig. 1 – Patient flowchart.

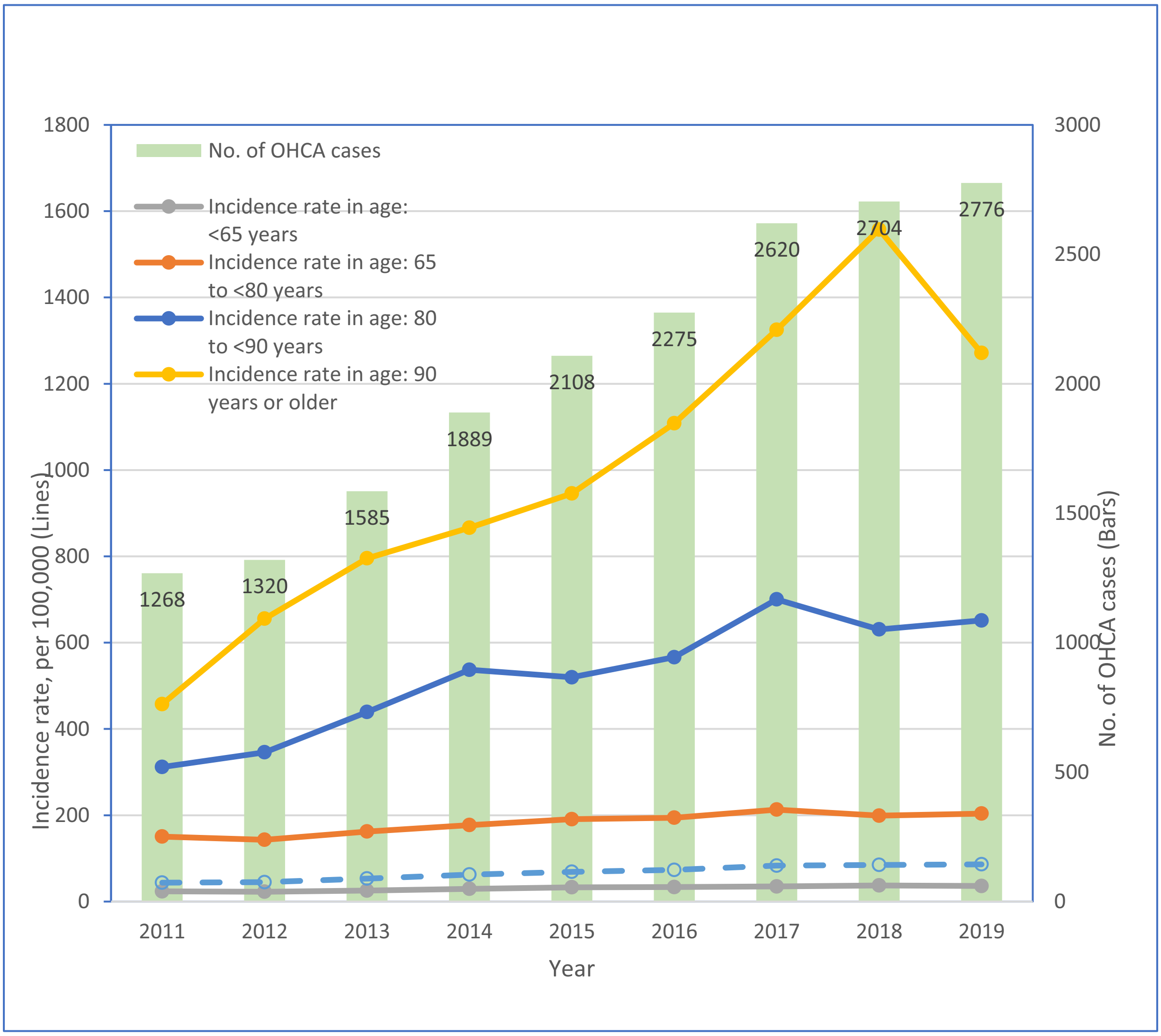

Fig. 2 – Number and incidence rate of OHCA (per 100,000 residents) for various age groups over time.

(95% CI) of 0.83 (0.82, 0.85). Correspondence between observed and expected frequencies was excellent as seen in the calibration plot (Appendix 1).

Fig. 4 shows the predicted probability of NIS according to age and best-case scenario. For the OHCA cases that meet the best-case criteria, even up to 115 years of age, NIS was still above the arbitrary futility cut-off of 1% by extrapolating from the lower 95% confidence bound of survival probability. By similar extrapolation for the OHCA cases that do not fulfil the best-case criteria, NIS fell below the cut-off after 84 years of age. Thus, we observed that even octogenarian OHCA patients can still experience NIS when resuscitated under favorable circumstances.

Discussion

This study showed an overall increase in the incidence of OHCA amongst the elderly. This increase in OHCA incidence is primarily driven by elderly of age ≥80 years. With the recent healthcare advances the comorbidities are better managed increasing the longevity by pushing occurrence of OHCA events forward yet happening eventually. We also observed an increasing proportion of NIS over the years in Singapore between the years 2011 to 2019. The young elderly (65 – <89 years) contributed to this increase, while the oldest experienced minimal improvement. It was further observed that the proportion of elderly with NIS declined with increasing age. OHCA occurring in healthcare facilities or public locations under the best-case scenario were independently associated with NIS.

Our study showed improving outcomes over the years across most age groups. Various initiatives have been introduced as part of a five-year national improvement plan for prehospital emergency care in Singapore that led to an increase in survival rates from 2011 to 2019.[19] With the Dispatcher-Assisted first REsponder (DARE) program (April 2014)[20] and Save-A-Life Initiative (April 2015),[21] there was increased awareness and training, and bystanders were more willing to render help when OHCAs occur.[22] The Fire Bikers Scheme (April 2012),[23] dispatcher-assisted CPR (July 2012),[24] intraosseous adrenaline infusion devices on ambulances (April 2014),[25] large-scale deployment of AED in residential areas (April 2015),[26] and crowd-sourced community rescuer app (April 2015)[26] helped improve NIS among elderly.

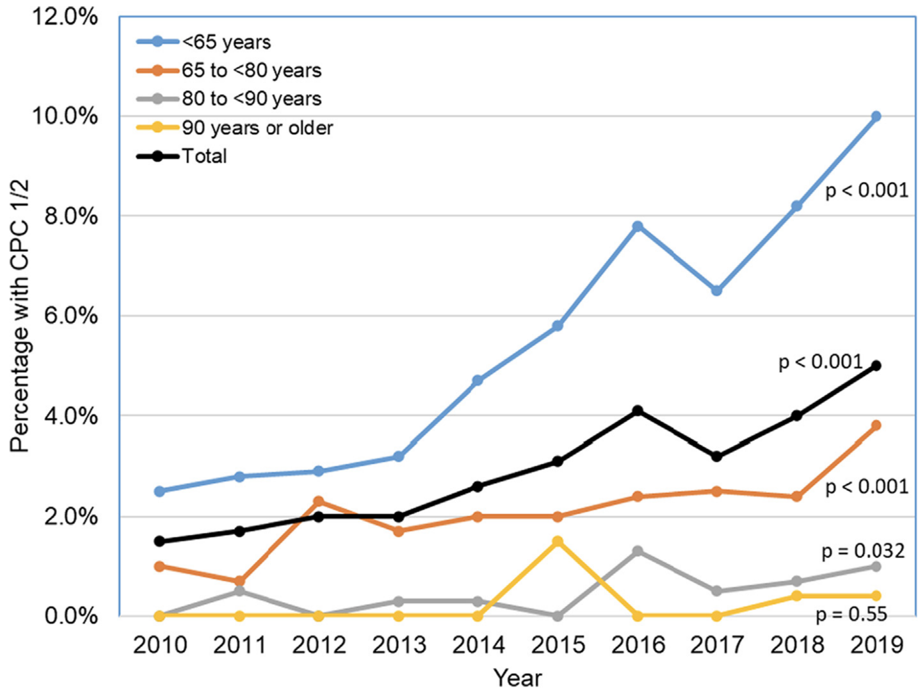

Fig. 3 – Time tend of percentage of neurologically favorable survival to hospital discharge, stratified by age groups.

Our study found that advanced age is independently associated with lower chances of NIS, which is in keeping with other studies.[6,27–32] In addition, an Australian study[32] found that increasing age is associated with reduced functional outcomes at 12 months and reduced odds of living independently. The reasons for poorer prognosis in the elderly are likely to be multifactorial, possibly related to the different characteristics of OHCA, biological changes during ageing and limitations of CPR in this population.[33] OHCA characteristics may include living alone resulting in the absence of bystander CPR, initial non-shockable rhythm or even delays in OHCA response due to subconscious age biases. Further qualitative research should be conducted to examine how these various elements affect OHCA outcomes. Our results also demonstrate that female gender is negatively associated with NIS. This is in line with findings from other studies, showing that women, in general, tend to have poorer outcomes in OHCAs.[34,35] While the gender-based differences in outcomes were not explored in our study, some proposed reasons for the difference include the older age of female patients due to their longer life expectancy[13], lack of self and public awareness that OHCAs are prevalent in women[36] and bystander unwillingness to perform CPR on female patients[37]. Further analysis can be performed in future studies to determine the reasons for the gender-based differences outcomes in OHCAs for our local context.

Nevertheless, our study also showed that in the best-case scenario, the chance of NIS is >1%, even in the super elderly (≥90 years). This percentage can account for a large absolute number of people in an ageing society. Denying good-quality CPR can lead to losing 1 out of 100 lives and hence it is not futile to resuscitate the elderly. Other studies too have suggested that the decision to resuscitate should not be based on age alone. A US-based study showed that amongst the elderly survivors of in-hospital cardiac arrest, nearly 60% were alive at 1 year post-cardiac arrest, and the rate of 3-year survival was similar to that of patients with heart failure.[38] Another study showed that among elderly who survived an OHCA, 1-year mortality was only 32%.[39] It was also found that age has a less profound impact[40] on the success of resuscitation compared to other factors such as witnessed arrest, presence of initial shockable rhythm and early CPR (the best-case scenario).[27,41] In this study population, 17.3% (249/1439) of the super elderly experienced 'best-case scenario' hence the frequency is non-negligible. Furthermore, the proportion of NIS has also been increasing over time, even amongst the elderly, which was also reported from Japan.[42] These findings reinforce that it is not always futile to resuscitate the super elderly. They should not be deprived of CPR efforts based on their age alone. The blanket policy of 'do not resuscitate super elderly' is, therefore not, supported. Furthermore, the way we defined the 'best-case scenario' facilitates the rescuers to promptly decide about continuing the resuscitation on a case-by-case basis if allowed.

These findings may have implications on termination of resuscitation efforts (TOR) and end-of-life (EOL) discussions. Currently, age is not a criterion in any of the EMS TOR protocols and perhaps is better kept as such. EOL discussions are complex as ethical considerations, personal and societal values and especially in an Asian context, family's wishes, heavily influence EOL plans and vary across individuals. Our findings may provide supporting evidence to clinicians as they guide patients and relatives through EOL planning. Though the chances of NIS are smaller in the more elderly patients, it may still be meaningful for patients and families, and they may prefer to have CPR performed in the event of an OHCA. Others may choose not to be resuscitated to avoid the possibility of poor neurological outcomes if they survive after receiving poor-quality CPR.

Arrests occurring in healthcare facilities or public locations, witnessed arrests, presumed cardiac cause of arrest, administration of bystander CPR and AED increased the chances of NIS, even

Table 1 – Patient and EMS characteristics, and outcomes by age groups.

Factor		All N = 19,519 (100%)	<65 years N = 7,686 (39.4%)	65 to <80 years N = 6,463 (33.1%)	80 to <90 years N = 3,931 (20.1%)	90 years or older N = 1,439 (7.4%)	p-value[b]
Age (years)		69 (58, 81)	55 (47, 60)	72 (68, 76)	84 (82, 87)	93 (91, 95)	NA
Gender	Male	12,522 (64.2)	5851 (76.1)	4189 (64.8)	1934 (49.2)	548 (38.1)	< 0.001
Race	Chinese	13,381 (68.6)	4322 (56.2)	4663 (72.1)	3142 (79.9)	1254(87.1)	< 0.001
	Malay	3034 (15.5)	1637 (21.3)	936 (14.5)	378 (9.6)	83 (5.8)	
	Indian	2157 (11.1)	1152 (15)	612 (9.5)	325 (8.3)	68 (4.7)	
	Others	947 (4.9)	575 (7.5)	252 (3.9)	86 (2.2)	34 (2.4)	
First arrest rhythm	Shockable	3411 (17.5)	2100 (27.3)	979 (15.1)	294 (7.5)	38 (2.6)	< 0.001
Location of arrest	Home residence	14,804 (75.8)	5011 (65.2)	5154 (79.7)	3406 (86.6)	1233 (85.7)	< 0.001
	Nursing home	902 (4.6)	133 (1.7)	313 (4.8)	293 (7.5)	163 (11.3)	
	Healthcare facility	599 (3.1)	301 (3.9)	190 (2.9)	83 (2.1)	25 (1.7)	
	Public place	3065 (15.7)	2130 (27.7)	768 (11.9)	149 (3.8)	18 (1.3)	
	Others	149 (0.8)	111 (1.4)	38 (0.6)	0 (0)	0 (0)	
Arrest witnessed by	EMS/Private Ambulance	1231 (6.3)	470 (6.1)	424 (6.6)	247 (6.3)	90 (6.3)	< 0.001
	Not witnessed	8333 (42.7)	3065 (39.9)	2749 (42.5)	1835 (46.7)	684 (47.5)	
	Bystander	9955 (51)	4151 (54)	3290 (50.9)	1849 (47)	665 (46.2)	
Bystander CPR		10,354 (53)	4126 (53.7)	3324 (51.4)	2114 (53.8)	790 (54.9)	0.613
Bystander AED		1054 (5.4)	566 (7.4)	296 (4.6)	142 (3.6)	50 (3.5)	< 0.001
EMS response time (≤8 minutes)		9065 (46.4)	3523 (45.8)	3066 (47.4)	1820 (46.3)	656 (45.6)	0.243
Presumed cardiac cause of arrest		14,014 (71.8)	5725 (74.5)	4656 (72)	2669 (67.9)	964 (67)	< 0.001
Medical History – Heart Disease		7180 (36.8)	2145 (27.9)	2734 (42.3)	1718 (43.7)	583 (40.5)	< 0.001
Medical History – Hypertension		10,781 (55.2)	2971 (38.7)	4160 (64.4)	2698 (68.6)	952 (66.2)	< 0.001
Medical History – Hyperlipidemia		7822 (40.1)	2153 (28)	3096 (47.9)	1952 (49.7)	621 (43.2)	< 0.001
Medical History – Stroke		2611 (13.4)	450 (5.9)	1028 (15.9)	823 (20.9)	310 (21.5)	< 0.001
Medical History – Diabetes		6504 (33.3)	2055 (26.7)	2637 (40.8)	1429 (36.4)	383 (26.6)	< 0.001
Medical History – Cancer		2042 (10.5)	627 (8.2)	791 (12.2)	493 (12.5)	131 (9.1)	< 0.001
Medical History - Renal Disease		2900 (14.9)	839 (10.9)	1109 (17.2)	720 (18.3)	232 (16.1)	< 0.001
Medical History - Respiratory Disease		2362 (12.1)	676 (8.8)	868 (13.4)	602 (15.3)	216 (15)	< 0.001
Medical History – HIV		38 (0.2)	28 (0.4)	9 (0.1)	1 (0)	0 (0)	< 0.001
Medical History – Other		9824 (50.3)	2726 (35.5)	3414 (52.8)	2639 (67.1)	1045 (72.6)	< 0.001
No. of comorbidities[a]		3 (1, 4)	1 (0, 3)	3 (2, 5)	3 (2, 5)	3 (2, 4)	< 0.001
Response time (mins)		8.3 (6.5, 10.4)	8.3 (6.5, 10.5)	8.2 (6.5,10.3)	8.3 (6.6, 10.4)	8.3 (6.6, 10.4)	0.184
Outcomes							
Survival to hospital admission		3517 (18)	1797 (23.4)	1202 (18.6)	430 (10.9)	88 (6.1)	< 0.001
Survival to hospital discharge or 30-day post-arrest		952 (4.9)	623 (8.1)	252 (3.9)	65 (1.7)	12 (0.8)	< 0.001
Any ROSC		6426 (32.9)	2741 (35.7)	2302 (35.6)	1100 (28)	283 (19.7)	< 0.001
CPC ½		632 (3.2)	458 (6)	148 (2.3)	22 (0.6)	4 (0.3)	< 0.001

CPR: Cardiopulmonary resuscitation; AED: Automated external defibrillator; EMS: Emergency medical services; ROSC: Return of spontaneous circulation; CPC: Cerebral performance category.

[a] Comorbodities include heart disease, hypertension, hyperlipidemia, stroke, diabetes, renal disease, and others. Results reported in the table are count (%) for categorical data and median (Q1, Q3) for continuous data.

[b] p-values are from comparison test of the 4 age groups using Chi-square test or Mann-Whitney test as appropriate.

amongst the elderly. This is in keeping with previous studies.[43–46] These findings are reflected in the best-case scenario of Fig. 3. This reinforces the importance of resuscitation and that all patients should receive the elements of CPR in a timely manner, regardless of age, to increase their chances of NIS. At the same time, there is a need to explore reasons for poor outcomes in OHCA happening at home, with the aim of improving it as most OHCAs in elderly occur at home.

It is important to improve the quality of CPR for all, despite their age as survival with a poor CPC can drain society's resources. The incapacitated OHCA survivor may be in a comatose state for pro-

Table 2 – Multivariate logistic regression analysis of neurologically intact survival (CPC ≤2).

Factor	OR (95% CI)[e]	p-value
Spline function 1 of Age[a]	0.984 (0.971, 0.997)	0.013
Spline function 2 of Age[a]	0.957 (0.92, 0.997)	0.035
Spline function 3 of Age[a]	0.997 (0.763, 1.302)	0.981
Year (calendar)	1.15 (1.111, 1.191)	< 0.001
Female	0.669 (0.533, 0.84)	0.001
Location of arrest		
Home residence	Reference	
Nursing home	0.687 (0.367, 1.286)	0.241
Healthcare facility	3.247 (2.378, 4.433)	< 0.001
Public place	2.471 (2.015, 3.029)	< 0.001
Others	1.45 (0.705, 2.983)	0.313
Witnessed arrest[b]	3.069 (2.474, 3.805)	< 0.001
Bystander AED[c]	2.568 (2.024, 3.258)	< 0.001
Bystander CPR[d]	1.304 (1.077, 1.58)	0.007
Cardiac cause of arrest	1.452 (1.163, 1.814)	0.001
Response time (mins)	0.908 (0.882, 0.934)	< 0.001
No. of comorbidities	1.046 (0.998, 1.096)	0.063

[a] From the restricted cubic splines (RCS) involving knots. The 4 RCS knots were at age = 39, 62, 76, 91 years.
[b] Witnessed arrest comprised of bystander witnessed cases.
[c] AED: Automated external defibrillator.
[d] CPR: Cardiopulmonary resuscitation
[e] CI: Confidence interval.

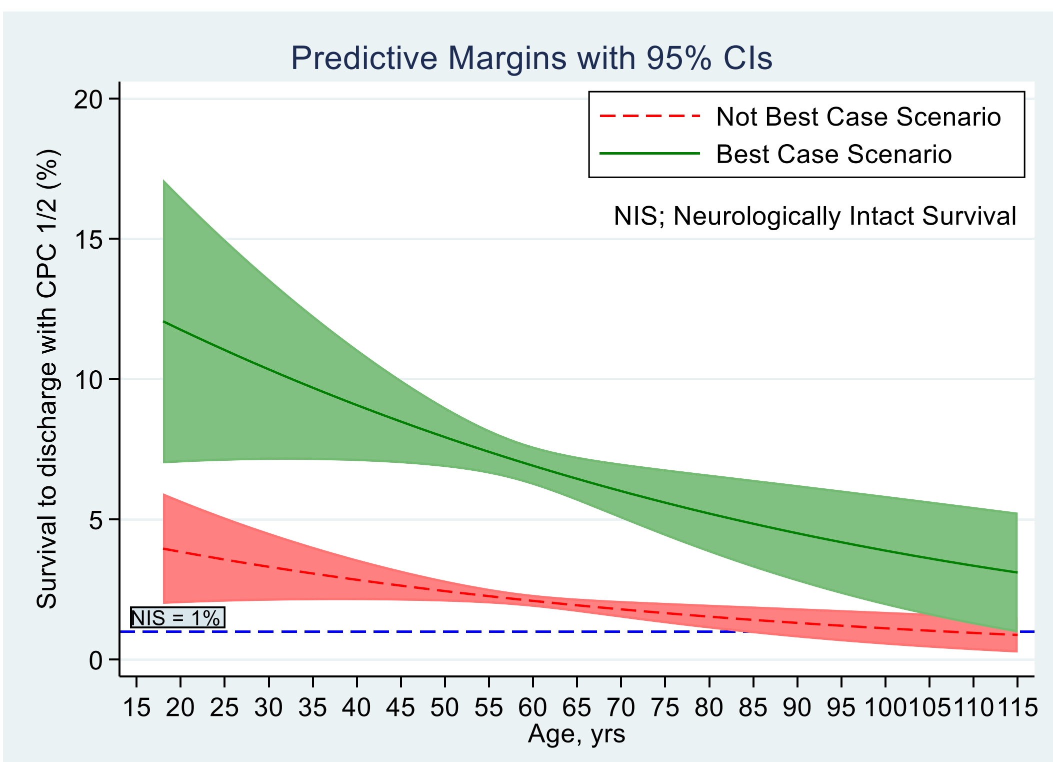

Fig. 4 – Plot of neurologically intact survival with 95% CI according to age, stratified by subgroup of best-case scenario.

longed periods, drawing resources within the healthcare system. They may also have a poor quality of life (QoL) and become a burden to the family. Hence, the need to reinforce good-quality CPR delivery despite the age.

Limitations

The patients' premorbid medical conditions were broadly classified rather than stated as specific medical conditions. Furthermore, the severity of these conditions was not available. There are other comorbidities that can influence NIS, such as mental health, premorbid frailty, and activities of daily living (ADLs), however, these were not available in the registry for adjustment in the data analysis stage. Another drawback is the lack of information about health related (HRQoL), which limits the interpretation of the patients' holistic QoL post-cardiac arrest. The applicability of the results is limited to the setting very similar to Singapore, however an analysis based on wider dataset is underway.

Furthermore, the data does not indicate the quality of bystander CPR, which would have been useful to fully assess the impact of bystander CPR. However, we have adjusted our results for the calendar year, which indirectly accounts for the influence of improving CPR quality over the years due to community CPR trainings and the introduction of dispatcher-assisted CPR (in 2012). We used an arbitrary futility cut-off of 1%. Changing this cut-off will have an impact on the conclusions. This value is a matter of deliberations and further research. Lastly, there is a lack of long-term survival data, such as data from three months, one year and three years survival post-hospital discharge.

Conclusion and implications

Though age appears to be associated with survival in OHCAs, survival with good outcomes has been increasing even amongst the elderly over the years. In favorable circumstances, NIS is possible among super elderly. Hence, the importance of prompt initiation of bystander CPR, regardless of age. At the same time, this study supports the importance of EOL planning as some may argue the chances of good NIS survival is too small. This is a complex decision involving multiple factors, which will need to be explored qualitatively through conversations with the elderly, their families and home and hospital care providers.

Singapore PAROS investigators

Han Nee Gan (Changi General Hospital, Singapore); Andrew FW Ho (Singapore General Hospital, Singapore); Wei Ling Tay (Ng Teng Fong General Hospital, Singapore); Si Oon Cheah (Urgent Care Clinic International, Singapore); Shun Yee Low (Sengkang General Hospital, Singapore); Lai Peng Tham (KK Women's and Children's Hospital, Singapore); Shir Lynn Lim (National University Heart Centre Singapore, Singapore).

Sources of funding

This study was funded by National Medical Research Council, Clinician Scientist Awards, Singapore (NMRC/CSA/024/2010, NMRC/CSA/0049/2013 and NMRC/CSA-SI/0014/2017) and Ministry of Health, Health Services Research Grant, Singapore (HSRG/0021/2012).

Data sharing statement

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

CRediT authorship contribution statement

Chloe Alexis Ong: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Data curation. **Gayathri Devi Nadarajan:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Stephanie Fook-Chong:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation. **Nur Shahidah:** Writing – review & editing, Resources, Project administration, Methodology, Investigation, Data curation. **Shalini Arulanandam:** Writing – review & editing, Resources. **Yih Yng Ng:** Writing – review & editing, Resources. **Michael YC Chia:** Writing – review & editing, Resources. **Ling Tiah:** Writing – review & editing, Resources. **Desmond R Mao:** Writing – review & editing, Resources. **Wei Ming Ng:** Writing – review & editing, Resources. **Benjamin SH Leong:** Writing – review & editing, Resources. **Nausheen Doctor:** Writing – review & editing, Resources. **Marcus EH Ong:** Writing – review & editing, Supervision, Resources, Methodology, Funding acquisition, Conceptualization. **Fahad J Siddiqui:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: MEH Ong reports grants from the Laerdal Foundation, Laerdal Medical, and Ramsey Social Justice Foundation for funding of the Pan-Asian Resuscitation Outcomes Study; an advisory relationship with Global Healthcare SG, a commercial entity that manufactures cooling devices. MEH Ong has a licensing agreement with ZOLL Medical Corporation and patent filed (Application no: 13/047,348) for a "Method of predicting acute cardiopulmonary events and survivability of a patient." He is also the co-founder and scientific advisor of TIIM Healthcare, a commercial entity which develops real-time prediction and risk stratification solutions for triage. All other authors have no conflict of interest to disclose.

Acknowledgements

The authors would like to thank Ms Pek Pin Pin and the late Ms Susan Yap from Department of Emergency Medicine, Singapore General Hospital; Ms Nurul Asyikin, Ms Liew Le Xuan, Ms Noor Azuin and Ms Joann Poh from Unit for Prehospital Emergency Care, Singapore General Hospital; Ms Woo Kai Lee from Department of Cardiology, National University Heart Centre Singapore and Ms Charlene Ong previously from Accident & Emergency, Changi General Hospital for their contributions and support to the Singapore OHCA registry

Author details

[a]Lee Kong Chian School of Medicine, Nanyang Technological University of Singapore, Singapore [b]Department of Emergency Medicine, Singapore General Hospital, Singapore [c]Pre-hospital & Emergency Research Centre, Duke-NUS Medical School, Singapore [d]Military Medicine Institute, Singapore Armed Forces Medical Corps, Singapore[e]Digital and Smart Health Office, Ng Teng

Fong Centre for Healthcare Innovation, Tan Tock Seng Hospital, Singapore [f]Department of Preventive and Population Medicine, Tan Tock Seng Hospital, Singapore [g]Emergency Department, Tan Tock Seng Hospital, Singapore [h]Accident & Emergency, Changi General Hospital, Singapore [i]Department of Acute and Emergency Care, Khoo Teck Puat Hospital, Singapore [j]Emergency Medicine Department, Ng Teng Fong General Hospital, Singapore [k]Emergency Medicine Department, National University Hospital, Singapore [l]Department of Emergency Medicine, Sengkang General Hospital, Singapore [m]Health Services & Systems Research, Duke-NUS Medical School, Singapore

REFERENCES

1. Christensen K, Doblhammer G, Rau R, Vaupel JW. Ageing populations: the challenges ahead. Lancet Lond Engl 2009;374:1196–208.
2. Deasy C, Bray JE, Smith K, et al. Out-of-hospital cardiac arrests in the older age groups in Melbourne, Australia. Resuscitation 2011;82:398–403.
3. SOS-KANTO 2012 Study Group. Changes in treatments and outcomes among elderly patients with out-of-hospital cardiac arrest between 2002 and 2012: A post hoc analysis of the SOS-KANTO 2002 and 2012. Resuscitation 2015;97:76–82.
4. Fukuda T, Ohashi-Fukuda N, Matsubara T, et al. Trends in outcomes for out-of-hospital cardiac arrest by age in Japan: an observational study. Medicine (Baltimore) 2015;94:e2049.
5. Funada A, Goto Y, Maeda T, Teramoto R, Hayashi K, Yamagishi M. Improved survival with favorable neurological outcome in elderly individuals with out-of-hospital cardiac arrest in Japan – a nationwide observational cohort study. Circ J 2016;80:1153–62.
6. Hiemstra B, Bergman R, Absalom AR, et al. Long-term outcome of elderly out-of-hospital cardiac arrest survivors as compared with their younger counterparts and the general population. Ther Adv Cardiovasc Dis 2018;12:341–9.
7. World Health Organization. World health statistics 2013. (Accessed 15 Nov 2021, at https://apps.who.int/iris/handle/10665/81965).
8. Department of Statistics Singapore. Population and Population Structure 2020. (Accessed 15 Nov 2021, at https://www.singstat.gov.sg/find-data/search-by-theme/population/population-and-population-structure/latest-data).
9. Chang AY, Skirbekk VF, Tyrovolas S, Kassebaum NJ, Dieleman JL. Measuring population ageing: an analysis of the Global Burden of Disease Study 2017. Lancet Public Health. 2019;4:e159–67.
10. Jaul E, Barron J. Age-related diseases and clinical and public health implications for the 85 years old and over population. Front Public Health 2017;5:335.
11. Chen C, Lim JT, Chia NC, et al. The long-term impact of functional disability on hospitalization spending in Singapore. J Econ Ageing 2019;14 100193.
12. The World Bank. GDP (Current US$) – Singapore. (Accessed 15 Nov 2021, at https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=SG).
13. Department of Statistics Singapore. Death and Life Expectancy 2020. (Accessed 15 Nov 2021, at https://www.singstat.gov.sg/find-data/search-by-theme/population/death-and-life-expectancy/latest-data).
14. Department of Statistics Singapore. Elderly, Youth and Gender Profile 2020. (Accessed 15 Nov 2021, at https://www.singstat.gov.sg/find-data/search-by-theme/population/elderly-youth-and-gender-profile/latest-data).
15. Ho AFW, Chew D, Wong TH, et al. Prehospital Trauma Care in Singapore. Prehosp Emerg Care 2015;19:409–15.
16. Ong MEH, Shin SD, Tanaka H, et al. Pan-Asian Resuscitation Outcomes Study (PAROS): rationale, methodology, and implementation. Acad Emerg Med 2011;18:890–7.
17. Perkins GD, Jacobs IG, Nadkarni VM, et al. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update of the Utstein Resuscitation Registry Templates for Out-of-Hospital Cardiac Arrest: a statement for healthcare professionals from a task force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian and New Zealand Council on Resuscitation, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Southern Africa, Resuscitation Council of Asia); and the American Heart Association Emergency Cardiovascular Care Committee and the Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. Circulation 2015;132:1286–300.
18. Grossestreuer AV, Abella BS, Sheak KR, et al. Inter-rater reliability of post-arrest cerebral performance category (CPC) scores. Resuscitation 2016;109:21–4.
19. Ho AFW, De Souza NNA, Blewer AL, et al. Implementation of a national 5-year plan for prehospital emergency care in Singapore and impact on out-of-hospital cardiac arrest outcomes From 2011 to 2016. J Am Heart Assoc 2020;9:e015368.
20. Global Resuscitation Alliance. DARE: The Dispatcher-Assisted First REsponder Program in Singapore. 2019. (Accessed 20 Mar 2022 at, https://www.globalresuscitationalliance.org/wp-content/uploads/2019/12/Singapore_Community_Training_Update%20.pdf).
21. Singapore Heart Foundation. Save A Life Initiative.[cited 2022 Mar 20]. (Accessed 20 Mar 2022 at, https://www.myheart.org.sg/programmes/save-a-life-initiative/).
22. Singapore Heart Foundation. Knowledge, Attitudes & Practices (KAP) of CPR+AED Survey 2020. (Accessed 20 Mar 2022 at, https://www.myheart.org.sg/tools-resources/knowledge-attitudes-practices-of-cpraed-survey-2020/).
23. Singapore Civil Defence Force. Lifesavers on Bikes. (Accessed 20 Mar 2022 at, https://www.scdf.gov.sg/rescue995/archive/people/lifesavers-on-bikes).
24. Wong XY, Fan Q, Shahidah N, et al. Impact of dispatcher-assisted cardiopulmonary resuscitation andmyResponder mobile app on bystander resuscitation. Ann Acad Med Singapore 2021;50:212–21.
25. SingHealth Health Xchange. Delivering life-saving drugs through the veins or the bones: Evaluation of vascular access methods in the treatment of cardiac arrest patients. (Accessed 20 Mar 2022 at, https://www.healthxchange.sg:443/news/delivering-life-saving-drugs-through-the-veins-or-the-bones-evaluation-of-vascular-access-methods-in-the-treatment-of-cardiac-arrest-patients).
26. Chua S, Ng Y, Ong M. Getting R-AEDI to save lives in Singapore. Singapore Med J 2020;61:60–2.
27. Libungan B, Lindqvist J, Strömsöe A, et al. Out-of-hospital cardiac arrest in the elderly: a large-scale population-based study. Resuscitation 2015;94:28–32.
28. Fan KL, Leung LP. Outcomes of cardiac arrest in residential care homes for the elderly in Hong Kong. Prehosp Emerg Care 2017;21:709–14.
29. Nakamura F, Kajino K, Kitamura T, et al. Impact of age on survival of patients with out-of-hospital cardiac arrest transported to tertiary emergency medical institutions in Osaka, Japan. Geriatr Gerontol Int 2019;19:1088–95.
30. Grimaldi D, Dumas F, Perier MC, et al. Short- and long-term outcome in elderly patients after out-of-hospital cardiac arrest: a cohort study. Crit Care Med 2014;42:2350–7.
31. Terman SW, Shields TA, Hume B, Silbergleit R. The influence of age and chronic medical conditions on neurological outcomes in out of hospital cardiac arrest. Resuscitation 2015;89:169–76.
32. Andrew E, Mercier E, Nehme Z, Bernard S, Smith K. Long-term functional recovery and health-related quality of life of elderly out-of-hospital cardiac arrest survivors. Resuscitation 2018;126:118–24.
33. Murphy DJ. Outcomes of cardiopulmonary resuscitation in the elderly. Ann Intern Med 1989;111:199.

34. Mody P, Pandey A, Slutsky AS, et al. Gender-based differences in outcomes among resuscitated patients with out-of-hospital cardiac arrest. Circulation 2021;143:641–9.
35. Blom MT, Oving I, Berdowski J, van Valkengoed IGM, Bardai A, Tan HL. Women have lower chances than men to be resuscitated and survive out-of-hospital cardiac arrest. Eur Heart J 2019;40:3824–34.
36. Mosca L, Ferris A, Fabunmi R, Robertson RM. Tracking women's awareness of heart disease: an American Heart Association National Study. Circulation 2004;109:573–9.
37. Perman SM, Shelton SK, Knoepke C, et al. Public perceptions on why women receive less bystander cardiopulmonary resuscitation than men in out-of-hospital cardiac arrest. Circulation 2019;139:1060–8.
38. Chan PS, Nallamothu BK, Krumholz HM, et al. Long-term outcomes in elderly survivors of in-hospital cardiac arrest. N Engl J Med 2013;368:1019–26.
39. Chan PS, McNally B, Nallamothu BK, et al. Long-term outcomes among elderly survivors of out-of-hospital cardiac arrest. J Am Heart Assoc 2016;5:e002924.
40. Kim C, Becker L, Eisenberg MS. Out-of-hospital cardiac arrest in octogenarians and nonagenarians. Arch Intern Med 2000;160:3439.
41. Tanner R, Masterson S, Jensen M, et al. Out-of-hospital cardiac arrests in the older population in Ireland. Emerg Med J 2017;34:659–64.
42. Matsuyama T, Kitamura T, Kiyohara K, et al. Assessment of the 11-year nationwide trend of out-of-hospital cardiac arrest cases among elderly patients in Japan (2005–2015). Resuscitation 2018;131:83–90.
43. Sasson C, Rogers MAM, Dahl J, Kellermann AL. Predictors of survival from out-of-hospital cardiac arrest: a systematic review and meta-analysis. Circ Cardiovasc Qual Outcomes 2010;3:63–81.
44. Herlitz J, Ekström L, Wennerblom B, Axelsson A, Bång A, Holmberg S. Effect of bystander initiated cardiopulmonary resuscitation on ventricular fibrillation and survival after witnessed cardiac arrest outside hospital. Br Heart J 1994;72:408.
45. Stiell I, Nichol G, Wells G, et al. Health-related quality of life is better for cardiac arrest survivors who received citizen cardiopulmonary resuscitation. Circulation 2003;108:1939–44.
46. Holmberg MJ, Vognsen M, Andersen MS, Donnino MW, Andersen LW. Bystander automated external defibrillator use and clinical outcomes after out-of-hospital cardiac arrest: a systematic review and meta-analysis. Resuscitation 2017;120:77–87.