Long term survival and disease burden from out-of-hospital cardiac arrest in Singapore: a population-based cohort study

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Abstract

Background: Understanding the long-term outcomes after out-of-hospital cardiac arrest (OHCA) is important to understand the overall health burden of OHCA. Disability-adjusted life years (DALY) have recently been utilised to measure disease burden in OHCA, but data in Asia remains limited. We aimed to quantify long-term survival in OHCA and the annual disease burden of OHCA estimated using DALYs in a national multi-ethnic Asian cohort.

Methods: We conducted an open cohort study through linking the Singapore Pan-Asian Resuscitation Outcomes Study (PAROS) and the Singapore Registry of Births and Deaths from 2010 to 2019. We quantified long-term survival using standardised mortality ratio (SMR) for each year of follow up and the annual disease burden using DALYs. Predictors of long-term survival were identified using Cox-proportional hazards models.

Results: We included 802 cases in the analysis. The mean age was 56.0 (SD 17.8) and the majority was male (631 cases, 78,7%) and of Chinese ethnicity (552 cases, 68.8%). At one year, the SMR was 14.9 (95%CI: 12.5-17.8), and this decreased to 1.2 (95%CI: 0.7-1.8) at three years, and 0.4 (95%CI: 0.2-0.8) at five years. Age at arrest (HR:1.03, 95%CI: 1.02-1.04, p<0.001), shockable first arrest rhythm (HR:0.75, 95%CI: 0.52-0.93, p=0.015) and CPC category (HR:4.62, 95%CI: 3.17-6.75, p<0.001) were independently associated with mortality. The annual DALYs due to OHCA varied from 304.1 in 2010 to 849.7 in 2015, then to 547.1 in 2018. The mean DALY decreased from 12.162 in 2010 to 3.599 in 2018.

Conclusions: OHCA survivors had an increased mortality rate compared to the general population for the first three years, which subsequently normalised to that of the general population. Annual disease burden of OHCA in DALY trended downwards from 2010 to 2018. Improved surveillance and OHCA treatment strategies may improve long-term survivorship and decrease the global burden of OHCA.

Introduction

Out-of-hospital cardiac arrest (OHCA), or sudden cardiac arrest, is one of the leading causes of mortality worldwide[1]. The global incidence of emergency medical services (EMS)-treated OHCA is estimated to be between 34.4–59.4 per 100,000 person-years, of which the percentage who survive to discharge is estimated to be between 3.0% – 9.7%[1–3]. In Singapore, the age-adjusted incidence of OHCA was approximately 50.0 per 100,000 population and was increasing between 2011 and 2016, with survival rates of approximately 1.0–3.0% during this time[4,5]. Thus, OHCA is an extensive problem that poses a large health burden both locally and internationally.

OHCA is defined as the loss of functional cardiac mechanical activity in association with an absence of systemic circulation, occurring outside of a hospital setting[1]. The causes of OHCA may be broadly categorised into cardiac (including ischemic heart disease, non-atherosclerotic coronary artery disease, arrhythmia, cardiomyopathy, valvular heart disease, and congenital heart disease), as well as non-cardiac causes (including trauma, malignancy, non-traumatic bleeding, hypoxia, epilepsy, and toxic-metabolic causes)[1,6]. Extensive research has been conducted on factors associated with survival following OHCA, of which the strongest relationships in the existing literature include age, ethnicity, comorbidity, socioeconomic status, heart rhythm, witness status, bystander cardiopulmonary resuscitation (CPR), time to CPR, and time to defibrillation[7–9].

Recently, increased focus has been placed on the long-term outcomes of OHCA including survival after one year, as well as the health-related quality of life during these additional years of life lived[10–13]. These long-term outcomes are important to evaluate the natural history and long-term impact of OHCA on the health burden of society[13–15]. To quantify both the fatal and non-fatal disease burden of OHCA, several recent articles had applied the concept of disability-adjusted life years (DALYs) to OHCA[15–17]. The DALY of a case is defined as the sum of the number of years of life lost (YLL) and the number of years lived with disability (YLD)[18]. Thus, one DALY is equal to one year of healthy life lost. The estimated annual DALYs after adult nontraumatic EMS-treated OHCA in the United States was 4,354,192 in 2016, with a rate of 1347 OHCA DALYs per 100,000 population (third highest cause of DALYs in the US)[17].

To our knowledge, data on the long-term outcomes of OHCA in Asia has been limited[13]. Furthermore, DALYs specific to OHCA in an Asian cohort has not been reported in the existing international literature. We aimed to quantify the annual disease burden of OHCA estimated using DALYs in a national multi-ethnic Asian cohort as well as to quantify and identify predictors of long-term survival (up to 10 years follow up).

Methods

Study design

We conducted an open cohort study through the linkage of two national datasets, the Singapore data from the Pan-Asian Resuscitation Outcomes Study (PAROS)[19], and the Singapore Registry of Births and Deaths (henceforth, the “death registry”)[20] from 2010 to 2019. PAROS is an international, multicentre, prospective registry of OHCA in nine countries across the Asia-Pacific region established in 2009[19]. The death registry is maintained by the Ministry of Home Affairs Immigration and Checkpoints Authority and includes data on the cause and date of death of all Singaporeans and permanent residents residing in Singapore[20]. Data linkage was performed using the National Registration Identity Card (NRIC) numbers of each case, which is the unique national identification number in Singapore.

Setting

This study was conducted in Singapore, an urbanized, multi-ethnic, densely populated island city-state located in Southeast Asia with a population of 5.7 million over a land area of 725.7 km^2 (population density of 7810 per km^2)[21]. The Singapore Civil Defence Force (SCDF) provides nationwide EMS in Singapore and is a fire-based system activated by a centralized “995” dispatch system[2222]. All ambulances have mechanical CPR devices, and all ambulance personnel are proficient in basic life support skills and can administer automated external defibrillators[22].

Study population and data collection

We included all cases with OHCA in the PAROS dataset in this study, defined as any OHCA conveyed by EMS or presenting at emergency departments, as confirmed by the absence of pulse, unresponsiveness, and apnea[19]. As this study investigated the long-term outcomes of OHCA, we excluded all cases that demised within 30 days of the date of OHCA. We also excluded cases that had no documented cause or date of death after linkage with the Singapore Death Registry. The date of OHCA was taken as the event date and the registry data were subject to annual audits for accuracy and inter-rater reliability. Outlier and illogical data were flagged and reviewed for final consensus among the registry coordinators. The study was approved by the Centralised Institutional Review Board (CIRB ref: 2018/2937) and qualified for exemption from full review as it analyzed de-identified data, with the Ministry of Health's Unit for Prehospital Emergency Care acting as a trusted third party.

Data collected from linkage of the two national databases included case demographics (age, sex, race), details of OHCA, initiation of hypothermia therapy, and date and cause of death. Details of OHCA included the first arrest rhythm (categorised as shockable, non-shockable, and unknown rhythm), the presence of a witness during the OHCA, the provision of bystander CPR, EMS response time (defined as time the call was received at dispatch to the time the ambulance arrived on scene and dichotomised to greater than 8 mins and lesser than or equal to 8 mins) and Cerebral Performance Category (CPC) categorised to CPC grades 1 and 2 versus CPC grades 3 and 4.

The primary outcome of interest was duration of survival after OHCA and was computed as the time from 30 days after the date of OHCA to the date of death as documented by the Singapore death registry. For the time-to-event analysis, the date of censoring was taken as the 30th of June 2020. The cause of death was determined from the death registry and was collected based on ICD 9 and ICD 10 codes reported by Singapore registered medical practitioners who announced the patient's death. ICD 9 and ICD 10 codes were harmonised using an open source R package, *icdcoder*[23].

Statistical analyses

Baseline characteristics were presented as frequencies and proportions for categorical variables, and median (interquartile range) or mean (standard deviation) for continuous variables, as appropriate for the distribution of the data. Hypothesis testing was conducted using the Pearson Chi-squared test and the independent student t-test to compare baseline characteristics by death status at one year follow up.

To investigate the long-term survival of patients with OHCA, we conducted survival analyses and computed Cox proportion regression models to identify factors that were significantly and independently associated with survival. Covariates included in the cox-proportional models were demographics (age, sex, and race), details of OHCA (first arrest rhythm, witnessed arrest, bystander CPR, EMS response time, and CPC category), and the initiation of hypothermia therapy. The proportional hazards assumption was assessed. Missing data within variables was kept as a separate category to preserve the overall sample size. Kaplan-Meier survival curves were constructed for the overall population, and by key characteristics. The proportion surviving (and 95% CI) was calculated annually for up to eight years post-OHCA.

For the final model, we started with the most significant covariate identified on univariate analysis and used the likelihood ratio to assess whether inclusion of the next most significant variable would improve the fit of the model. This was done sequentially until all variables had been assessed. The proportional hazards assumption was assessed. Missing data within variables was kept as a separate category to preserve the overall sample size. Interaction effects were also assessed for the variables in the multivariate model. A stratified analysis was performed by CPC category as we found significant interaction effects. Kaplan-Meier survival curves were constructed for the overall population, and by key characteristics. The proportion surviving (and 95% CI) was calculated for up to eight years post-OHCA.

We calculated the standardised mortality ratio (SMR) for each year of follow up (computed as the ratio of the observed number of deaths divided by the expected number of deaths). The expected number of deaths was defined as the age and sex indirect standardised, with the expected death rates at each year of OHCA and follow up year calculated from the Complete Life Table for Singapore Residents 2019[24]. The top 10 causes of death categorized by ICD10 categories were tabulated.

To quantify the annual disease burden of OHCA in Singapore, the DALY following OHCA was calculated for each case as follows: for those who died, the YLL was calculated from the remaining standard life expectancy at the age of death, stratified by gender. This data was obtained from Life Expectancy Tables from the department of Statistics, Singapore[24]. For those who were alive, the YLD was calculated by assigning a disability weight (DW) based on their CPC score[15]. Those with CPC 1 were assigned a weight of 0.049, CPC 2 = 0.138, CPC 3 = 0.425 and CPC 4 = 0.673[15]. These weights were chosen following the method used by Coute et al.[16], where the DW for a CPC 1 patient was assigned based on the average DW of 77 survivors with a CPC of 1. The DALY was a summation of YLL and YLD[16]. The sum and average DALY, along with YLL and YLD was calculated annually from 2010–2018. The level of significance was set at 5% and the analysis was performed using Stata V16 (Stata Corp, College Station, Tx, USA).

Results

We included 802 cases in the analysis. 17,473 cases were excluded because they died within 30 days of OHCA, and 41 cases were excluded because these were foreigners with no cause of death or death date. The detailed population flowchart may be found in Supplementary Figure S1. 126 cases had demised at one-year follow up. The mean age of the cohort was 56.0 (SD 17.8) and majority of the cohort was male (631 cases, 78.7%) and of Chinese ethnicity (552 cases, 68.8%). OHCA survivors who died at one year of follow up had significantly older age, a lower proportion of shockable first arrest rhythm, and higher CPC category at baseline (Table 1).

Table 1
Baseline demographics and clinical characteristics of the OHCA cohort stratified by mortality at one year follow up

Factor	Whole Cohort (%)	Alive at 1 Year (%)	Died at 1 Year (%)	P-Value
Total N	802	676	126	
Gender				0.054
Male	631 (78.7%)	540 (79.9%)	91 (72.2%)	
Female	171 (21.3%)	136 (20.1%)	35 (27.8%)	
Age, mean (SD)	56.0 (17.8)	54.4 (17.5)	64.9 (16.7)	< 0.001*
Race				0.99
Chinese	552 (68.8%)	455 (67.3%)	97 (77.0%)	
Malay	96 (12.0%)	83 (12.3%)	13 (10.3%)	
Indian	114 (14.2%)	100 (14.8%)	14 (11.1%)	
Other	40 (5.0%)	38 (5.6%)	2 (1.6%)	
Bystander CPR				0.39
No	316 (39.4%)	262 (38.8%)	54 (42.9%)	
Yes	486 (60.6%)	414 (61.2%)	72 (57.1%)	
Arrest witnessed				0.35
No	136 (17.0%)	111 (16.4%)	25 (19.8%)	
Yes	666 (83.0%)	565 (83.6%)	101 (80.2%)	
Hypothermia therapy initiated				0.42
No	554 (69.2%)	463 (68.6%)	91 (72.2%)	
Yes	247 (30.8%)	212 (31.4%)	35 (27.8%)	
EMS ambulance response time				
≤ 8 mins	381 (47.5%)	319 (47.2%)	62 (49.2%)	0.59
> 8 mins	393 (49.0%)	335 (49.6%)	58 (46.0%)	
Missing	28 (3.5%)	22 (3.3%)	6 (4.8%)	

OHCA: Out-of-hospital cardiac arrest; SD: Standard deviation; CPR: Cardiopulmonary resuscitation; EMS: Emergency medical services. *P value < 0.05.

Factor	Whole Cohort (%)	Alive at 1 Year (%)	Died at 1 Year (%)	P-Value
Shockable first arrest rhythm				
Non-shockable	167 (20.8%)	121 (17.9%)	46 (36.5%)	< 0.001*
Shockable	577 (71.9%)	503 (74.4%)	74 (58.7%)	
Unknown	58 (7.2%)	52 (7.7%)	6 (4.8%)	
Cerebral Performance Category				
Grouped				< 0.001*
1–2	540 (67.5%)	500 (74.2%)	40 (31.7%)	
3–4	257 (32.1%)	171 (25.4%)	86 (68.3%)	
Missing	3 (0.4%)	3 (0.4%)	0 (0.0%)	
OHCA: Out-of-hospital cardiac arrest; SD: Standard deviation; CPR: Cardiopulmonary resuscitation; EMS: Emergency medical services. *P value < 0.05.				

In the univariate cox proportional hazards model, age at arrest (HR 1.04, 95% CI: 1.03–1.05, $p < 0.001$), female sex (HR 1.35, 95% CI: 1.01–1.81, $p = 0.046$), and CPC category 3–4 (HR 4.20, 95% CI: 3.23–5.46, $p < 0.001$) were found to be significantly associated with mortality while shockable first arrest rhythm (HR 0.44, 95% CI: 0.33–0.58, $p < 0.001$) and ‘other’ race (HR 0.26, 95% CI: 0.10–0.69, $p < 0.007$) were significantly associated with survival (Table 2). Figure 1A shows the overall survival curve, and Figs. 1B and 1C show the curves for subgroups by CPC category and shockable rhythm.

Table 2
Demographic and clinical factors associated with survival on Cox-proportional hazards models

Covariate	Univariate analysis			Adjusted analysis		
	HR	95% CI	P-Value	HR	95% CI	P-Value
Gender						
Male	Reference					
Female	1.35	1.01–1.81	0.046*			
Age, every year increase	1.04	1.03–1.05	< 0.001*	1.03	1.02–1.04	< 0.001*
Race						
Chinese	Reference					
Malay	0.68	0.43–1.05	0.085			
Indian	0.90	0.62–1.31	0.589			
Other	0.26	0.10–0.69	0.007*			
Bystander CPR						
No	Reference					
Yes	0.89	0.68–1.15	0.362			
Arrest witnessed						
No	Reference					
Yes	0.96	0.68–1.34	0.793			
Hypothermia therapy initiated						
No	Reference					
Yes	0.90	0.68–1.20	0.482			
EMS ambulance response time						

HR: Hazard ratio; 95% CI: 95% confidence interval; CPR: Cardiopulmonary resuscitation; EMS: Emergency medical services. *P value < 0.05.

Covariate	Univariate analysis			Adjusted analysis		
≤ 8 mins	Reference					
> 8 mins	0.95	0.73–1.24	0.713			
Shockable first arrest rhythm						
Non-shockable	Reference			Reference		
Shockable	0.44	0.33–0.58	< 0.001*	0.70	0.52–0.93	0.015*
Unknown	0.40	0.22–0.73	0.003*	0.45	0.24–0.82	0.010*
Cerebral Performance Category						
1–2	Reference			Reference		
3–4	4.20	3.23–5.46	< 0.001*	4.62	3.17–6.75	< 0.001*

HR: Hazard ratio; 95% CI: 95% confidence interval; CPR: Cardiopulmonary resuscitation; EMS: Emergency medical services. *P value < 0.05.

In the multivariate cox proportional hazards model age at arrest (HR 1.03, 95% CI: 1.02–1.04, $p < 0.001$) and CPC category 3–4 (HR 4.62, 95% CI: 3.17–6.75, $p < 0.001$) were independently associated with mortality while shockable first arrest rhythm (HR 0.75, 95% CI: 0.52–0.93, $p = 0.015$) was significantly associated with survival (Table 2). We found a significant interaction effect between CPC category and age ($p < 0.001$), as well as CPC category and a shockable first rhythm ($p < 0.001$). A stratified analysis was shown in **Supplementary Table S1**. Amongst those with CPC grades 1–2, age had a stronger effect on mortality (HR 1.05, 95% CI: 1.03–1.07) as compared to those with CPC grades 3–4 (HR 1.02, 95% CI: 1.01–1.03). In addition, amongst those with CPC grades 1–2, a shockable first rhythm had a significant protective effect (HR 0.36, 95% CI: 0.23–0.58) compared to those with CPC grades 3–4 (HR 1.02, 95% CI: 0.72–1.45).

The long-term survivorship of OHCA was reported for each year of follow up (Table 3). The proportion surviving at one year of follow up was 0.84 (95% CI: 0.81–0.87), at five years of follow up was 0.68 (95% CI 0.65–0.72), and at ten years of follow up was 0.62 (95% CI 0.57–0.67). The top three causes of death after OHCA based on ICD10 categories were pneumonia, chronic ischemic heart disease, and acute myocardial infarction (Table 4). The age-sex SMR of the OHCA cohort compared to the standard Singapore population was shown in Fig. 2. At one year of follow up, the SMR was 14.9 (95% CI: 12.5–17.8) and this decreased to 1.2 (95% CI: 0.7–1.8) at three years follow up, and 0.4 (95% CI: 0.2–0.8) at five years follow up.

Table 3
Survival by follow-up period of the out-of-hospital cardiac arrest cohort

Follow-up year	Population at risk	Deaths	Proportion surviving	95% CI	
1	675	127	0.84	0.81	0.87
2	539	50	0.78	0.75	0.80
3	414	23	0.74	0.71	0.77
4	296	13	0.71	0.68	0.75
5	196	11	0.68	0.65	0.72
6	129	5	0.66	0.62	0.70
7	89	3	0.65	0.60	0.69
8	49	2	0.62	0.57	0.67
9	26	0	0.62	0.57	0.67
10	3	0	0.62	0.57	0.67

95% CI: 95% confidence interval.

Table 4
Survival by follow-up period of the out-of-hospital cardiac arrest cohort

Rank	Cause	Total N	Year of follow-up									
			1	2	3	4	5	6	7	8	9	10
1	PNEUMONIA, UNSPECIFIED	58	27	15	5	4	3	2	1	1	0	
2	CHRONIC ISCHAEMIC HEART DISEASE	49	28	11	2	5	2	1				
3	ACUTE MYOCARDIAL INFARCTION	10	7	2	1							
4	URINARY TRACT INFECTION	8	5	1	2							
5	ISCHAEMIC CARDIOMYOPATHY	7	5				1	1				
6	ACUTE ISCHAEMIC HEART DISEASE	5	4	1								
7	END-STAGE RENAL DISEASE	5	1		1		1		1	1		
8	CARDIORESPIRATORY FAILURE	4	4									
9	MALIGNANT NEOPLASM: BRONCHUS OR LUNG	4	3						1			
10	SEQUELAE OF STROKE	4	1	2	1							

The annual disease burden of OHCA in Singapore measured using DALYs were reported from 2010 to 2018 in Table 5. The total YLL increased from 303.1 in 2010 to 844.2 in 2015, followed by decreasing to 538.5 in 2018. The total YLD increased from 1.0 in 2010 to 8.6 in 2018. The total DALY increased from 304.1 in 2010 to 849.7 in 2015, followed by decreasing to 547.1 in 2018. The mean DALY decreased from 12.162 in 2010 to 3.599 in 2018.

Table 5
Disability-adjusted life years lost for the out-of-hospital cardiac arrest cohort from 2010 to 2018

Year	Total YLL	Total YLD	Total DALY	YLL		YLD		DALY	
				Mean	95% CI	Mean	95% CI	Mean	95% CI
2010	303.1	1.0	304.1	27.6	16.4–38.7	0.07	0.05–0.09	12.2	4.9–19.4
2011	310.2	1.8	312.0	22.2	15.7–28.6	0.07	0.06–0.09	8.0	3.9–12.1
2012	371.4	1.8	373.2	18.6	15.1–22.1	0.06	0.05–0.08	7.8	4.8–10.8
2013	550.8	2.9	553.7	19.7	13.8–25.5	0.08	0.06–0.09	8.4	5.0–11.8
2014	624.8	2.8	627.6	21.5	17.8–25.3	0.06	0.05–0.07	8.0	5.3–10.8
2015	844.2	5.5	849.7	22.2	17.1–27.3	0.07	0.06–0.08	7.5	4.9–10.1
2016	731.6	7.7	739.3	18.8	14.7–22.8	0.07	0.06–0.07	4.8	3.2–6.4
2017	685.3	6.0	691.3	23.6	18.4–28.9	0.06	0.06–0.07	5.6	3.5–7.8
2018	538.5	8.6	547.1	20.7	16.3–25.2	0.07	0.06–0.07	3.6	2.2–5.0

YLL: Years of life lost; YLD: Years of healthy life lost due to disability; DALY: Disability-adjusted life years; 95% CI: 95% confidence intervals.

Discussion

We investigated the long-term survival of a large national Asian cohort who survived to 30 days after OHCA. The key findings of this study were that (a) long-term survivorship of the OHCA cohort decreased from 0.84 at one year of follow up to 0.62 at 10 years of follow up, (b) SMR decreased from 14.9 at one year of follow up to 1.2 and 0.4 and three and five years of follow up respectively, and (c) total DALY attributable to OHCA varied from 304.1 in 2010 to 849.7 in 2015 and finally to 547.1 in 2018, although mean DALY decreased from 12.2 in 2010 to 3.6 in 2018. To our knowledge, this is the first national Asian study to quantify the annual disease burden of OHCA over time using DALY and to describe the long-term survival of OHCA patients for up to 10 years, hence representing a significant contribution to the growing body of literature on the public health burden and long-term outcomes of OHCA.

In the Singapore Burden of Disease Study[25], cardiovascular diseases including OHCA were ranked as the leading cause of DALY, largely driven by YLL. However, the overall decrease in the mean DALY from 2010 to 2018 in our study suggests that the long-term burden per OHCA patient has improved in Singapore over time, contrary to international data which demonstrated an increasing burden of disease due to OHCA from 2013 to 2018 (suggested to be due to more precise national OHCA surveillance in the later years)[16]. This result from a cohort of initial OHCA survivors in a small city-state may have been influenced by nation-wide improvements to OHCA interventions[26], ranging from community interventions such as the MyResponder phone application to improve rates of bystander CPR and AED use[27] to post-resuscitation interventions including coronary angiography (CAG) with percutaneous coronary intervention (PCI)[28] and targeted temperature management (TTM)[29–31]. Although bystander CPR was not significantly associated with long-term survival in this study, the sum effect of these interventions may have improved short-term neurological outcomes, which was significantly associated with long-term survival here and elsewhere[32]. Yet, this encouraging result should not imply that OHCA has a decreasing public health burden, since total DALY may increase in the future considering Singapore's aging population and the association between older age and poorer long-term survival.

Our results on long-term survival were similar to various international studies, including a Victorian cohort of 3449 OHCA survivors, which had a 10-year absolute survival of 70% and an SMR that approached that of the general population after 5-years of follow up[11]. These results support the hypothesis that mortality in initial OHCA survivors is greatest during the immediate period after OHCA, but improves in the later years[33], such that long-term survivors would experience similar life spans to the age and sex-matched general population[14,31,34]. Our findings that age at arrest, non-shockable first arrest rhythm, and CPC category 3–4 were independently associated with higher risk of mortality are largely consistent with other studies worldwide[35,36]. It has been previously hypothesised that traditional factors such as witnessed arrest, bystander CPR, and EMS response time influence long-term survival to a lesser degree than short-term survival[11]. As Singapore is a small, developed, and densely populated city-state with a mature healthcare system[37], geographical factors in our study related to location of arrest and access to PCI-capable hospitals were also less of a concern compared to other countries[1,11]. Lastly, we identified CPC grade to be an effect modifier of the association between age or shockable first rhythm and mortality. Our results suggest that older age and non-shockable first rhythm had stronger effects on mortality in OHCA survivors with CPC grades 1–2 as compared to those with CPC grades 3–4. Hence, in patients with CPC grades 3–4, poor neurological recovery may be the most important predictive factor for mortality in the long-term[11,38].

The importance of short-term good neurological outcome to long-term survival implies that interventions to improve short-term neurological outcomes such as CAG, PCI, intensive care, and other post-resuscitation care strategies may in turn improve longer term outcomes. More data about the long-term complications of OHCA, such as acute myocardial infarction (which was the third-most common cause of mortality in this study) or recurrent cardiac arrest, are needed to guide the long-term management of OHCA survivors[39]. Further research into these gaps, national OHCA surveillance, and other OHCA treatment strategies will be important to elucidate the reasons behind changes in the burden of OHCA over the years, although much remains unknown about the global burden of OHCA in terms of DALY and what may ease this burden in the future.

Strengths And Limitations

Our study is the first population-based Asian study to quantify the long-term survivorship and national burden of OHCA. The strengths of our study included comprehensive case capture via the linkage of two national cohorts using a nationalised identification number, and the prospective ascertainment of exposure, outcomes and follow up time in the cohort. Our study was limited by the exclusion of foreigners treated in Singapore that had no date of death recorded or whose deaths were not captured as they were overseas, and by the exclusion of cases with 2nd episode cardiac arrest as these were not captured by the database. The choice of DW to calculate the YLD for individual patients also influenced our study findings, although this choice was made to improve comparability of results and reflects current understanding of how cardiac arrest impacts long-term quality of life. Importantly, the observational design of this study implies our results are limited to observed associations and cannot establish a causal link between covariates and outcomes. Furthermore, our results are vulnerable to confounding, although efforts to minimise these effects were made through our adjusted analyses.

Conclusion

Adult OHCA has a large burden of disease and should be a focus of public health policy. In this national study, initial survivors of OHCA had an increased mortality rate compared to the general population for the first three years, but subsequently normalised to that of the general population, while the annual disease burden of OHCA quantified using DALYs showed decreasing trends from 2010 to 2018. Further improvements in the surveillance and OHCA treatment strategies are needed to improve long-term survivorship and to decrease the global burden of OHCA.

Declarations

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Ethics approval and Consent to participate

The study was approved by the Centralised Institutional Review Board (CIRB ref: 2018/2937) and qualified for exemption from full review as it analyzed de-identified data, with the Ministry of Health's Unit for Prehospital Emergency Care acting as a trusted third party.

Data availability statement

The data that support the findings of this study are available from the PAROS investigators and National Registry of Diseases Office. Restrictions apply to the availability of these data, which were used under license for this study. Data are available from the authors with the permission of the PAROS investigators and National Registry of Diseases Office.

Authors' contributions

AFWH, MJRL, and MEHO were involved in conceptualisation.

AFWH, MJRL, AE, and MEHO were involved in data collection.

AFWH, MJRL, and AE were involved in data analysis.

AFWH and MJRL were involved in manuscript drafting.

All authors were involved in manuscript review.

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Conflict of interest

MEH Ong reports funding from the Zoll Medical Corporation for a study involving mechanical cardiopulmonary resuscitation devices; 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;

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Figures

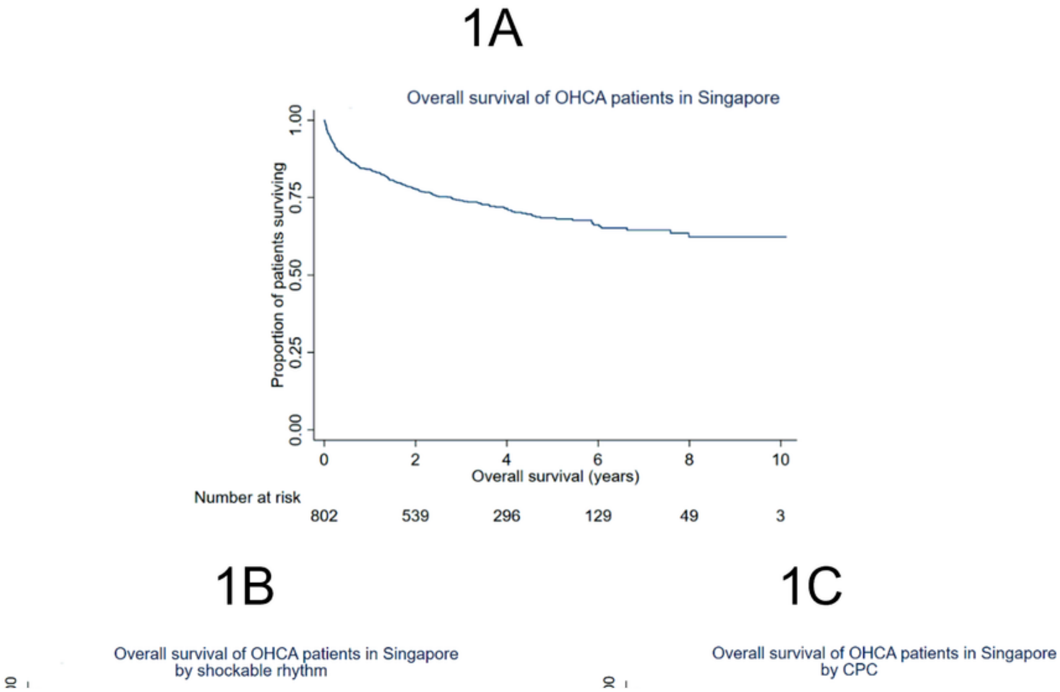

Figure 1

Overall survival of out-of-hospital cardiac arrest patients in Singapore, in total, by shockable rhythm, and by Cerebral Performance Category

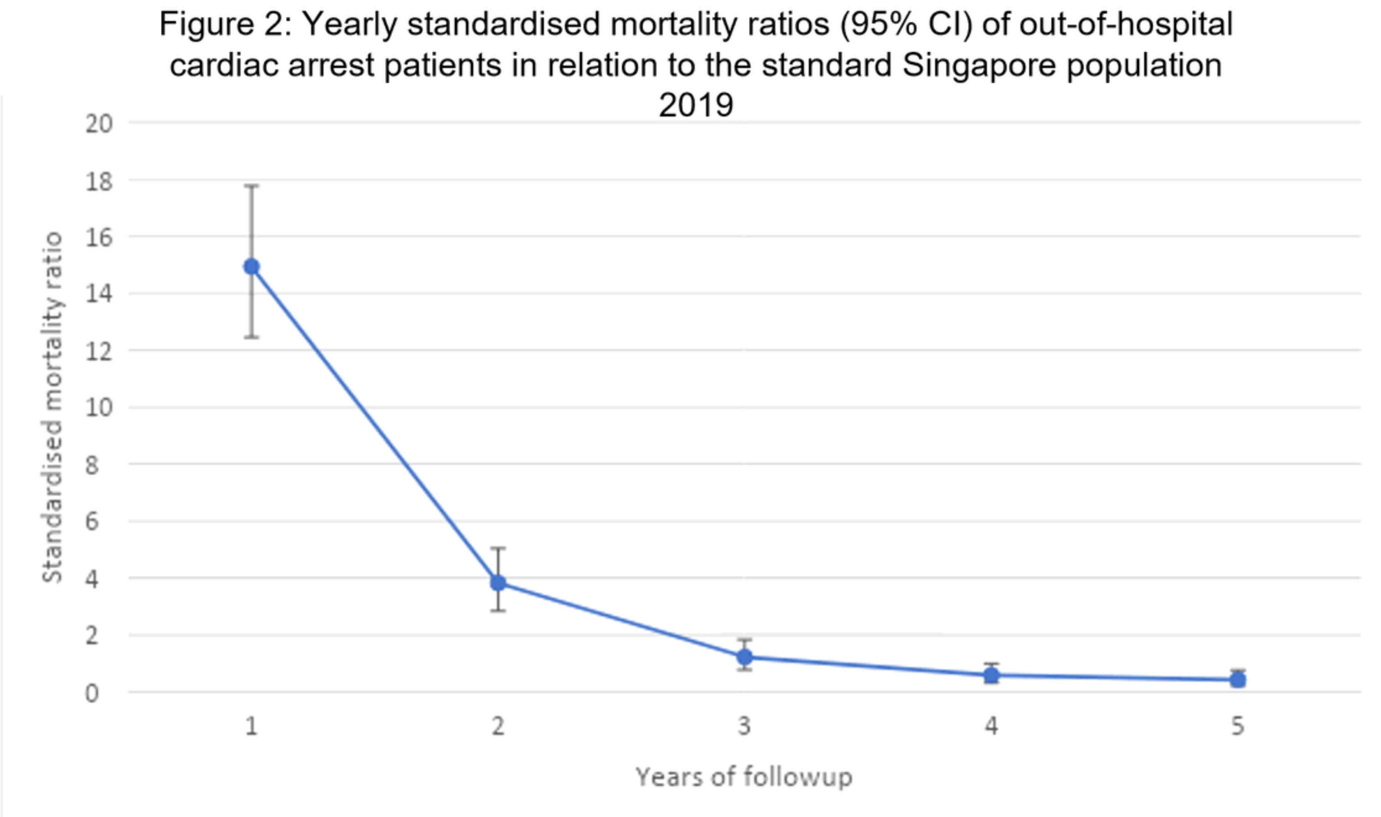

Figure 2

Yearly standardised mortality ratios (95% confidence interval) of out-of-hospital cardiac arrest patients in relation to the standard Singapore population in 2019

Supplementary Files

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