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ORIGINAL RESEARCH

Incidence and Outcomes of Out-of-Hospital Cardiac Arrest in Singapore and Victoria: A Collaborative Study

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BACKGROUND: Incidence and outcomes of out-of-hospital cardiac arrest (OHCA) vary between communities. We aimed to examine differences in patient characteristics, prehospital care, and outcomes in Singapore and Victoria.

METHODS AND RESULTS: Using the prospective Singapore Pan-Asian Resuscitation Outcomes Study and Victorian Ambulance Cardiac Arrest Registry, we identified 11 061 and 32 003 emergency medical services-attended adult OHCAs between 2011 and 2016 respectively. Incidence and survival rates were directly age adjusted using the World Health Organization population. Survival was analyzed with logistic regression, with model selection via backward elimination. Of the 11 061 and 14 834 emergency medical services-treated OHCAs (overall mean age±SD 65.5±17.2; 67.4% males) in Singapore and Victoria respectively, 11 054 (99.9%) and 5595 (37.7%) were transported, and 440 (4.0%) and 2009 (13.6%) survived. Compared with Victoria, people with OHCA in Singapore were older (66.7±16.5 versus 64.6±17.7), had less shockable rhythms (17.7% versus 30.3%), and received less bystander cardiopulmonary resuscitation (45.7% versus 58.5%) and defibrillation (1.3% versus 2.5%) (all $P<0.001$). Age-adjusted OHCA incidence and survival rates increased in Singapore between 2011 and 2016 ($P<0.01$ for trend), but remained stable, though higher, in Victoria. Likelihood of survival increased significantly ($P<0.001$) with arrest in public locations (adjusted odds ratio [aOR] 1.81), witnessed arrest (aOR 2.14), bystander cardiopulmonary resuscitation (aOR 1.72), initial shockable rhythm (aOR 9.82), and bystander defibrillation (aOR 2.04) but decreased with increasing age (aOR 0.98) and emergency medical services response time (aOR 0.91).

CONCLUSIONS: Singapore reported increasing OHCA incidence and survival rates between 2011 and 2016, compared with stable, albeit higher, rates in Victoria. Survival differences might be related to different emergency medical services practices including patient selection for resuscitation and transport.

Key Words: cardiac arrest ■ emergency medical services ■ survival

Out-of-hospital cardiac arrest (OHCA) is a significant public health problem. Despite advances in resuscitation science over the past few decades, outcomes remain poor worldwide.[1,2] Only a minority of patients experiencing OHCA are successfully resuscitated, and even fewer are discharged with minimal neurological impairment.

Significant variations have been observed in OHCA outcomes across communities,[2–8] and these are thought to be largely linked to differences in efficiency and efficacy of prehospital care and to some extent, case capture and definitional differences. Additionally, differences in population characteristics, community interventions, and healthcare system and delivery could contribute to variations in outcomes. Apart from a recent study by Dyson et al,[9] comparisons of OHCA incidences and outcomes have, thus far, been

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CLINICAL PERSPECTIVE

What Is New?

- Our study provided a comprehensive comparison of out-of-hospital cardiac arrest incidence and outcomes across distinct geographical and sociocultural borders, including a comparison of emergency medical services agencies serving Singapore and Victoria.
- Significant differences in emergency medical services practices, coupled with that in community interventions, may have contributed to the variations in survival outcomes observed.

What Are the Clinical Implications?

- Community interventions are crucial to out-of-hospital cardiac arrest outcomes; therefore, we should continue to encourage and enable lay people to intervene before arrival of emergency medical services.
- Refinement of prehospital management, through patient selection for resuscitation and strengthening the capabilities of emergency medical services system, may improve out-of-hospital cardiac arrest survival, particularly in Singapore.

Nonstandard Abbreviations and Acronyms

OHCA	out-of-hospital cardiac arrest
PAROS	Pan-Asian Resuscitation Outcomes Study
ROSC	return of spontaneous circulation
SAM	smartphone activated medics
SCDF	Singapore Civil Defence Force
VACAR	Victorian Ambulance Cardiac Arrest Registry

limited to that within the same country or continent. Understanding the influence of these regional characteristics and emergency medical services (EMS) systems beyond geographical confines could identify effective system and structural interventions that have been implemented in some communities, in improving survival after OHCA.

The island city-state of Singapore and the south-eastern Australian state of Victoria are fairly similar in population sizes and level of development but different in terms of EMS systems and geographical and sociocultural factors, thus presenting a unique opportunity for comparison. The purpose of this study was using population-based registries, to compare patient and event characteristics, prehospital interventions, and survival outcomes between Singapore and Victoria and to identify factors that improve OHCA outcomes. We hypothesized there would be significant regional variations in incidence and outcomes in OHCA, associated with patient, community, and system differences.

METHODS

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Study Design and Setting

This was a retrospective population-based cohort study of adult (defined ≥20 years of age), EMS-attended OHCA of all etiologies occurring in Singapore (Figure 1A) and Victoria (Figure 1B) between January 1, 2011 and December 31, 2016.

Singapore is an urbanized island city-state located in Southeast Asia with a population of 5.6 million over a land area of 719.1 square kilometres (km^2), giving a population density of 7787 people per km^2.[10] The Singapore Civil Defence Force (SCDF) provides nationwide EMS in Singapore.[11] It is a fire-based system activated by a centralized “995” dispatch system. All ambulances have mechanical cardiopulmonary resuscitation (CPR) devices.

The state of Victoria, Australia has a population of 6.2 million over a land area of 227 000 square kilometres, most of whom (>4 million) live in the capital city of Melbourne. This translates to a population density of 28 people per km^2.[12] Victoria operates a single statewide EMS system (Ambulance Victoria); access to EMS is provided through a single nationwide telephone number (ie, 000).[13] Patients experiencing OHCA are managed according to Ambulance Victoria clinical practice guidelines,[14] which are based on recommendations by the Australian Resuscitation Council.[15]

Data Sources

The PAROS (Pan-Asian Resuscitation Outcomes Study) is an ongoing clinical research network for OHCA in the Asia-Pacific whose methodology had been previously described.[16] In brief, it is a prospective, multicenter registry designed to provide baseline information on OHCA epidemiology, management, and outcomes; describe variations among EMS systems; and compare systemic and structural interventions in the Asia-Pacific region. Data were extracted from emergency dispatch records, ambulance case notes, and emergency department and in-hospital records. Quality assurance data checks

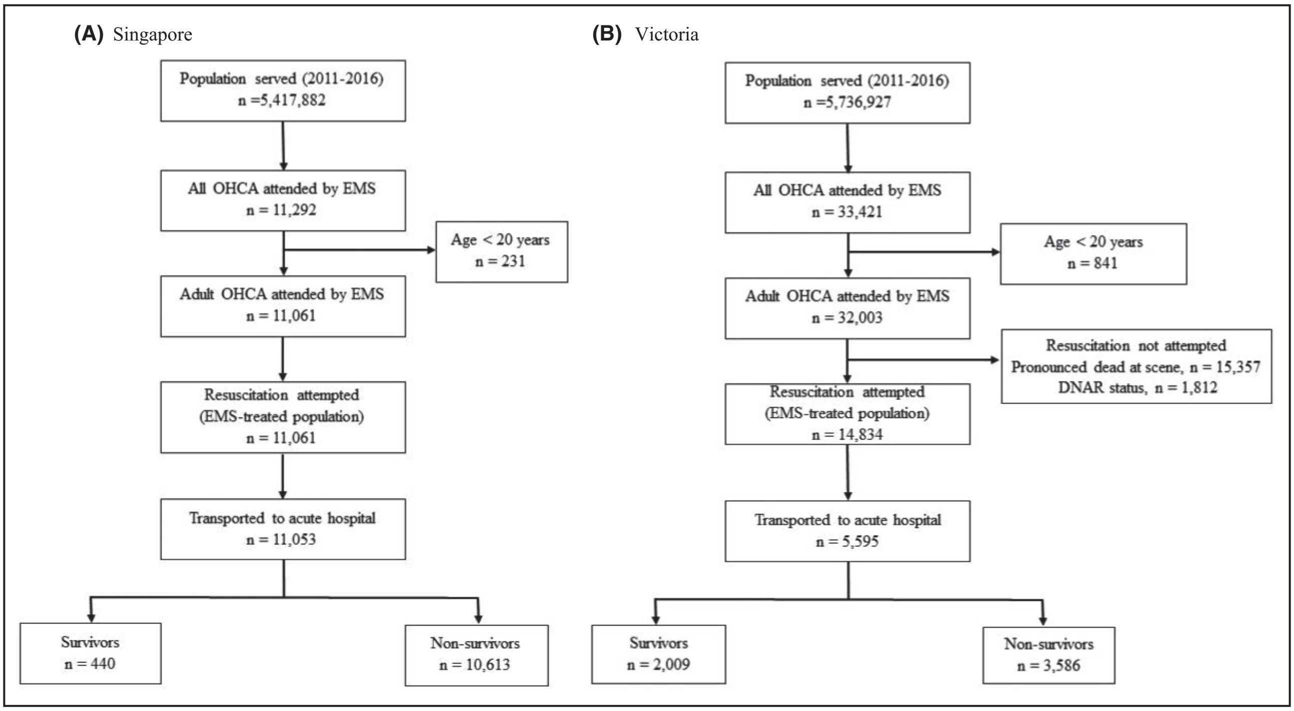

Figure 1. Patient selection between January 1, 2011 to December 31, 2016.
A, Singapore; **B**, Victoria. DNAR indicates do not attempt resuscitation; EMS, emergency medical services; and OHCA, out-of-hospital cardiac arrest.

were built into the data entry system, and data verification checks were implemented to ensure data integrity. Only data from Singapore were used in this comparison study.

The VACAR (Victorian Ambulance Cardiac Arrest Registry) is a statewide, prospective OHCA registry that records details of all OHCA events in Victoria attended by EMS personnel. Its methodology, including data capture and data quality control, have been described previously.[13] Using a multisource identification framework for OHCA, cases are identified primarily from electronic treatment records and supplemented by a review of computer-aided dispatch records, emergency call logs, paper-based treatment records, and paramedics' reports of OHCA cases. In transported cases, hospital outcome data are obtained from hospital medical records and validated against death records from the Victorian Registry of Births, Deaths, and Marriages.

Data Elements and Definitions

Data definitions for both registries are in accordance with Utstein definitions.[17] Core Utstein variables collected by both registries were selected for comparison. Recoding of each variable was done to improve uniformity in the data collected.

Cardiac arrest is defined as the cessation of cardiac mechanical activity confirmed by the absence of signs of circulation at any time as documented on the EMS treatment record. The EMS-attended population represents all OHCA cases attended by the EMS and includes both patients who receive emergency treatment and those who are declared deceased on EMS arrival. The EMS-treated population is defined as people who receive any attempt at cardiopulmonary resuscitation or external defibrillation. The etiology of cardiac arrest is identified from the paramedic treatment record and is presumed to be of cardiac cause in the absence of a known cause. Bystander CPR is defined as any attempt at chest compressions, with or without ventilation, and is assumed to be absent if not stated. The EMS response time (in minutes) is the interval between the time the call was received by the dispatch center and the time of arrival at scene of either the ambulance or a rapid responder dispatched via the same dispatch center.

Survival (no/yes) refers to discharge from acute hospital care. The Utstein comparator group is defined as OHCA cases that were witnessed by bystander, had resuscitation attempted and an initial shockable rhythm (ventricular fibrillation or pulseless ventricular tachycardia or unknown shockable rhythm).

Statistical Analysis

Data analysis was performed on EMS-treated OHCA population. Depending on their nature, the data were presented as mean±SD or frequency (%) and exploratory analyses were performed with Mann–Whitney *U* test, chi-square test, and trend tests. The direct method for age-adjustment of incidence and survival rates was based on the World Health Organization) population data. However, age and sex-adjustment could not be performed as there was no relevant information. The survival analysis was carried out with multiple logistic regression (logit), with goodness of fit ascertained with the Hosmer-Lemeshow test. The factors considered included age (years), sex (female/male), location of arrest (nonpublic/public area), etiology of arrest (noncardiac/cardiac), initial cardiac arrest rhythm (shockable: ventricular fibrillation, pulseless ventricular tachycardia and unknown shockable rhythm/non-shockable: asystole, pulseless electrical activity, and unknown non-shockable rhythm), witnessed OHCA (unwitnessed/witnessed arrests: bystander, first responder, or EMS provider), prehospital defibrillation (no/yes: bystander or EMS use of automated external defibrillator [AED]), bystander CPR (no/yes), and mean response time (minutes).

The model selection began with the bivariate results, with the significant predictors considered in the preliminary model. Based on a removal probability of >0.05 a backward elimination procedure was carried out to identify the final model. To ascertain the models' predictive accuracy the sample was randomly divided into the training (80%) and validation (20%) subsamples. The auxiliary models were built with the training subsample and the predicted results were compared with that of the validation subsample. The receiver operating characteristics curves were generated for ascertaining out-sample predictive accuracy. Using Stata MP V14 (Stata Corp, TX, USA), all analyses were performed at 5% level of significance.

Ethical Considerations

The Centralised Institutional Review Board and Domain Specific Review Board granted approval for Singapore PAROS. VACAR is approved as a quality assurance initiative by the Victorian Department of Health Human Research Ethics Committee, and the collection of patient outcomes is approved by the ethics committees of participating Victorian hospitals. Waiver of patient consent was granted in both states. All data were de-identified.

RESULTS

Patient and Arrest Characteristics

The total number of observations involved in analysis from 2011 (reference year) to 2016 was 25 895. The characteristics of EMS-treated OHCA population are depicted in Table 1. The 2 communities were significantly different in terms of patient and event characteristics as well as prehospital interventions received. Patients experiencing OHCA who were treated by EMS in Singapore were older (66.7±16.5 versus 64.6±17.7, *P*<0.001) and the proportion of female patients was higher in Singapore (35.0% versus 30.8%, *P*<0.001). In both communities, the majority of OHCA took place at home and were of a presumed cardiac origin. The proportion of those who presented with an initial shockable rhythm in Victoria was almost doubled that of Singapore (30.3% versus 17.7%, *P*<0.001).

EMS Systems

Table 2 describes the characteristics of EMS systems in Singapore and Victoria. The SCDF provided a single-tiered EMS during the study period; each OHCA case was attended by a paramedic and 2 emergency medical technicians, with 1 as the ambulance driver. Where necessary, motorcycle-based fast response paramedics are dispatched ahead of ambulances. Ambulance Victoria delivers a primarily 2-tiered EMS; each OHCA case is attended by 2 advanced life support and 2 intensive care paramedics, where possible. There are basic life support responders who mostly operate on a voluntary basis in rural areas. Firefighters also provide first response in select areas of Melbourne and rural communities.

Prehospital Interventions

Both bystander CPR rates and prehospital defibrillation rates were lower in Singapore when compared with Victoria (45.7% versus 58.5%, *P*<0.001 and 26.4% versus 41.1%, *P*<0.001).

Mean EMS response time and time taken to arrive at patient's side were longer in Victoria than Singapore, with greater variability noted (*P*<0.001). Paramedics spent more time at scene in Victoria compared with Singapore, as reflected by time to ambulance departure (in minutes) for the subset of patients who were eventually transported to hospital (61.7±26.7 versus 27.3±7.7, *P*<0.001).

Outcomes

Almost all of the resuscitation-attempted OHCAs were transported to an acute care hospital in Singapore, and less than half (99.9% versus 37.7%, *P*<0.001) were transported to a hospital in Victoria. Overall outcomes were better in Victoria, with 33.1% having sustained return of spontaneous circulation on arrival at the emergency department and 13.6% surviving to discharge, compared with 7.3% and 4.0% in Singapore respectively (*P*<0.001 for both). Survival for the Utstein comparator group was also higher in Victoria (32.9% versus 15.4%; *P*<0.001).

Temporal Trends

During the study period, both states saw an increase in the demand for emergency services,

Table 1. Baseline Characteristics of Patients Experiencing OHCA Who Were Treated by EMS

	Singapore N=11 061	Victoria N=14 834	*P* Value[‡]
Demographics			
Age, y	66.7±16.5	64.6±17.7	<0.001
Sex, male	7186 (65.0)	10 260 (69.2)	<0.001
Event information			
Arrest location			<0.001
Private residence	7994 (72.3)	9927 (66.9)	
Aged care	412 (3.7)	1000 (6.7)	
Public area	1908 (17.2)	2913 (19.7)	
Other	747 (6.8)	993 (6.7)	
Etiology of arrest			<0.001
Cardiac	7710 (69.8)	11 094 (74.8)	
Trauma	361 (3.3)	1058 (7.1)	
Respiratory/medical	602 (5.4)	569 (3.8)	
Others	2381 (21.5)	2113 (14.3)	
Initial rhythm			<0.001
Ventricular fibrillation/tachycardia, shockable	1961 (17.7)	4499 (30.3)	
Pulseless electrical activity/asystole, nonshockable	9056 (81.9)	10 229 (69.0)	
Unknown	44 (0.4)	106 (0.7)	
Witnessed arrest			<0.001
Bystander witnessed	5813 (52.6)	6695 (45.5)	
EMS witnessed	968 (8.7)	2407 (16.3)	
Not witnessed	4280 (38.7)	5627 (38.2)	
Prehospital resuscitation			
Bystander cardiopulmonary resuscitation	5059 (45.7)	8676 (58.5)	<0.001
Prehospital defibrillation			<0.001
No shock	8141 (73.6)	8734 (58.9)	
Bystander automated external defibrillator	139 (1.3)	371 (2.5)	
Defibrillation by EMS	2781 (25.1)	5729 (38.6)	
EMS response times			
Time intervals, min			
At scene	9.0±3.8	10.6±10.4	<0.001
At patient	11.5±4.8	12.3±11.2	<0.001
Depart scene*	27.3±7.7	61.7±26.7	<0.001
At hospital*	37.2±8.9	81.6±34.9	<0.001
Time to defibrillation, min[†]	14.0±6.0	17.1±18.7	<0.001
Patient outcomes			
Transported	11 054 (99.9)	5595 (37.7)	<0.001
Prehospital return of spontaneous circulation	807 (7.3)	4908 (33.1)	<0.001
Discharged alive	440 (4.0)	2009 (13.6)	<0.001
Utstein survival	208 (15.4)	959 (32.9)	<0.001

Numbers are n (%) for categorical variables and mean±SD for continuous variables. *P* is for differences between the groups by X_2 test for categorical variables and Wilcoxon sum rank test for continuous variables. EMS indicates emergency medical services; OHCA, out-of-hospital cardiac arrest.

*Valid for patients who were transported (Singapore 11 053; Victoria 5595).

[†]Valid for patients VF/VT or unknown shockable rhythm (Singapore 1677; Victoria 4352).

[‡]Statistically significant at 5%.

reflected in the overall and emergency call volumes (*P*<0.001) (Figure S1). The EMS response times were higher in Victoria with improvements over time (*P*=0.02) (Figure 2). Although the rates of community interventions (bystander CPR and AED) were lower in Singapore, there were significant upward trends during the study period (*P*=0.002 for bystander CPR and *P*<0.001 for bystander AED) (Figure 3A and 3B).

Table 2. EMS Characteristics in Singapore and Victoria

	Singapore	Victoria
Dispatch systems		
Call number	Single	Single
Dispatch CPR instructions	Yes	Yes
Computer-aided dispatch	Yes	Yes
Ambulance systems		
Single/multi-tier	Single-tier	Multitier
Ambulance personnel	2 EMTs 1 paramedic (EMT-intermediate equivalent)	2 ALS paramedics 2 intensive care paramedics
Qualifications	EMT will undergo 5 weeks of training. Paramedics will undergo a 15-month training program.	Paramedics undergo a 3-year bachelor degree in paramedicine followed by a supervised in-field graduate year. In addition to this training, intensive care paramedics complete a postgraduate diploma in emergency health.
Resuscitation interventions	EMT: 1. Basic life support certified 2. Defibrillation Paramedics (in addition to above): 1. Administration of drugs such as dextrose, adrenaline, salbutamol, and sublingual glyceryl trinitrate 2. Insertion of laryngeal mask airway 3. IO drug administration	ALS paramedics: 1. ALS certified 2. Defibrillation 3. Insertion of supraglottic airway 4. Administer intravenous adrenaline Intensive care paramedics (in addition to above): 1. Rapid sequence intubation 2. IO drug administration 3. Administration of amiodarone 4. Mechanical CPR
Dispatch/first responder	Fire response specialists—EMTs on fire bikes are deployed for life-threatening emergencies. Each bike is equipped with medical drugs, oxygen cylinders, AED set, and diagnostic equipment.	Firefighters and community emergency response teams provide a first response with AEDs in select areas of Melbourne and rural communities.
Protocols		
Withholding resuscitation	No signs of life and one of: 1. Decapitation 2. Rigor mortis 3. Dependent lividity 4. An adult or a child with a Do Not Attempt Resuscitation order	No signs of life and one of: 1. Clear evidence of prolonged cardiac arrest (with specific definitions of this such as rigor mortis or asystole and downtime >10 min) 2. Injuries incompatible with life 3. Death declared by a doctor who is or has been at scene 4. An adult with an advanced care directive or refusal of treatment certificate; or 5. A child with a valid Emergency Treatment Plan to not commence resuscitation
Termination of resuscitation	None*	Resuscitation can be terminated in adults who, after 30–45 mins of ALS resuscitation has not achieved return of spontaneous circulation, has no signs of life including pupil reaction and agonal/gasping respiration and there are no compelling reasons to continue (such as suspected hypothermia, suspected drug overdose, a child, a family member requests continued effort, any signs of life observed including pupil reaction or agonal/ineffective gasping respiration or patient inventricular fibrillation/tachycardia).

AED indicates automated external defibrillation; ALS, advanced life support; CPR, cardiopulmonary resuscitation; EMS, emergency medical services; EMT, emergency medical technician; O, intraosseous.

*No termination of resuscitation protocol existed at time of study. A protocol for termination of resuscitation has been instituted in Singapore since January 2019.

Over the years, there was a significant upward trend in age-adjusted incidence of OHCA in Singapore ($P<0.001$; Figure 4A). This was accompanied by a significant rising trend in the survival rates ($P=0.009$; Figure 4B). Both the incidence and survival rates were stable for Victoria, with age-adjusted incidence of OHCA and survival hovering around 90 per 100 000 population ($P=0.405$) and 6.4 per 100 000 population ($P=0.933$), respectively (Figure 4A and 4B).

Survival

All the predictors were significant in analyzing survival (Table 1). The subsequent analyses with logistic regression found that the same set of predictors were significant in explaining the outcome (Table 3). Sex was nonsignificant in both analyses and was omitted from the final models.

The odds of survival increased significantly with public location of arrest, initial shockable rhythm,

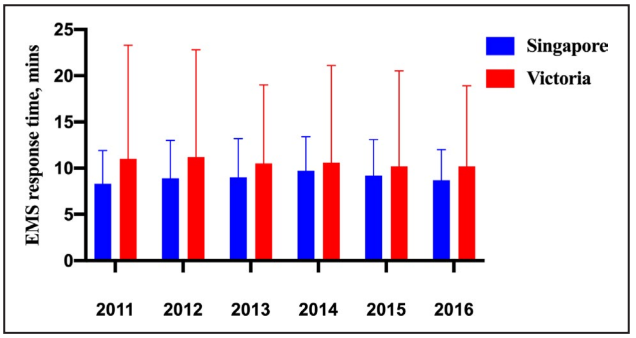

Figure 2. Temporal trends in EMS response times. Temporal trends in EMS response times during the study period (January 2011 to December 2016). Error bars represent SD. EMS indicates emergency medical services.

witnessed arrest, bystander CPR, and bystander defibrillation but decreased significantly with EMS response time and age (Table 3).

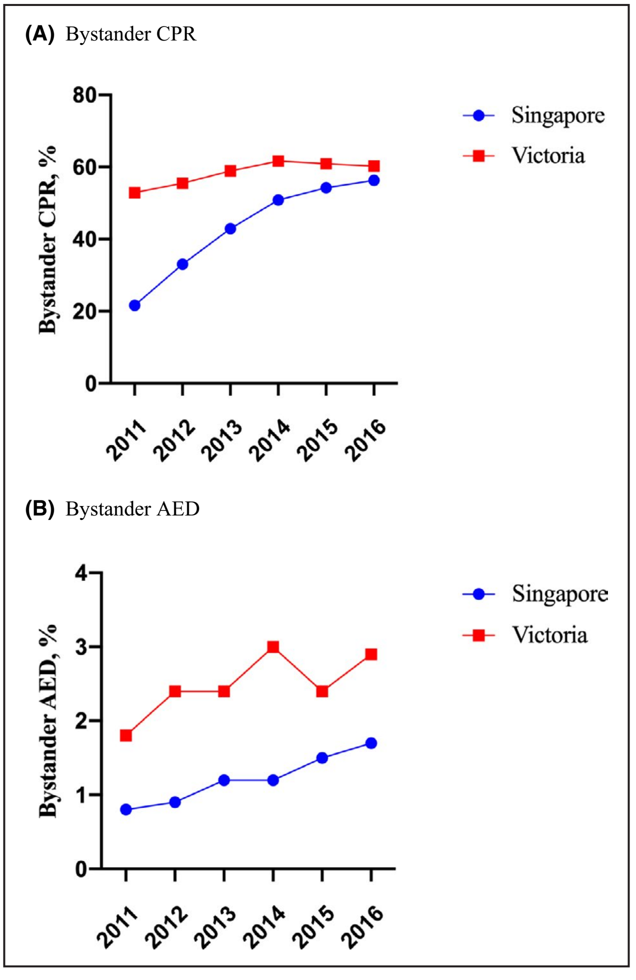

Figure 3. Temporal trends in community interventions. Temporal trends of bystander (**A**) CPR and (**B**) AED rates during the study period (January 2011 to December 2016). AED indicates automated external defibrillation; and CPR, cardiopulmonary resuscitation.

The odds of survival could be raised by more than 2 times with witnessed OHCA. When located at public areas, the odds could increase by 1.58 times for patients in Singapore, and nearly 2 times in Victoria. The odds were also increased with bystander CPR: 1.75 times in Singapore and 1.20 times in Victoria. A similar observation was made for bystander defibrillation, with the odds almost doubled in Victoria and raised by 2.30 times in Singapore. Initial shockable rhythm, in comparison, had the strongest effect as the odds were raised by more than 8 times in Victoria and more than 10 times in Singapore.

Age reduced the odds of survival; the patients from both states were expected to have their odds lowered by about 2% to 3% with a year older in age. Last but not least, the effects of EMS response time were also nearly identical in both states: the odds could be reduced by almost 9% with an extra minute in response time.

Cardiac etiology was retained in the final model given its near-significance in the Singapore cohort (P=0.059) and clear significance in the Victoria cohort (P=0.001). The odds of survival were increased by nearly 1.5 times for patients with presumed cardiac etiology in Victoria. However, the odds were reduced for patients in Singapore.

The models for both states were found to be satisfactory in explaining the outcome (Hosmer-Lemeshow test P>0.05). The c-statistics based on receiver operating characteristics were 0.83 for Singapore and 0.85 for Victoria, thus suggesting that the models were valid externally (Figure S2A and S2B). Note that the coefficients of the auxiliary models based on the reduced training subsample were similar to those based on the full sample reported previously.

DISCUSSION

This comprehensive comparison study of adult OHCA revealed significant variations in incidence, patient characteristics, EMS systems, community interventions, and survival outcomes. Factors influencing survival were similar in both states except etiology of arrest; whereas age and EMS response time decreased the odds of survival, public location of arrest, witnessed arrest, an initial shockable rhythm, bystander CPR, and bystander AED increased the odds of survival. However, these traditional Utstein factors did not completely explain the variations in outcomes. Our study extends the findings of prior studies[2–9] by providing a comparison across distinct geographical and sociocultural borders and included a comparison of EMS agencies serving these states.

The differences in EMS practices between Singapore and Victoria are noteworthy. All patients

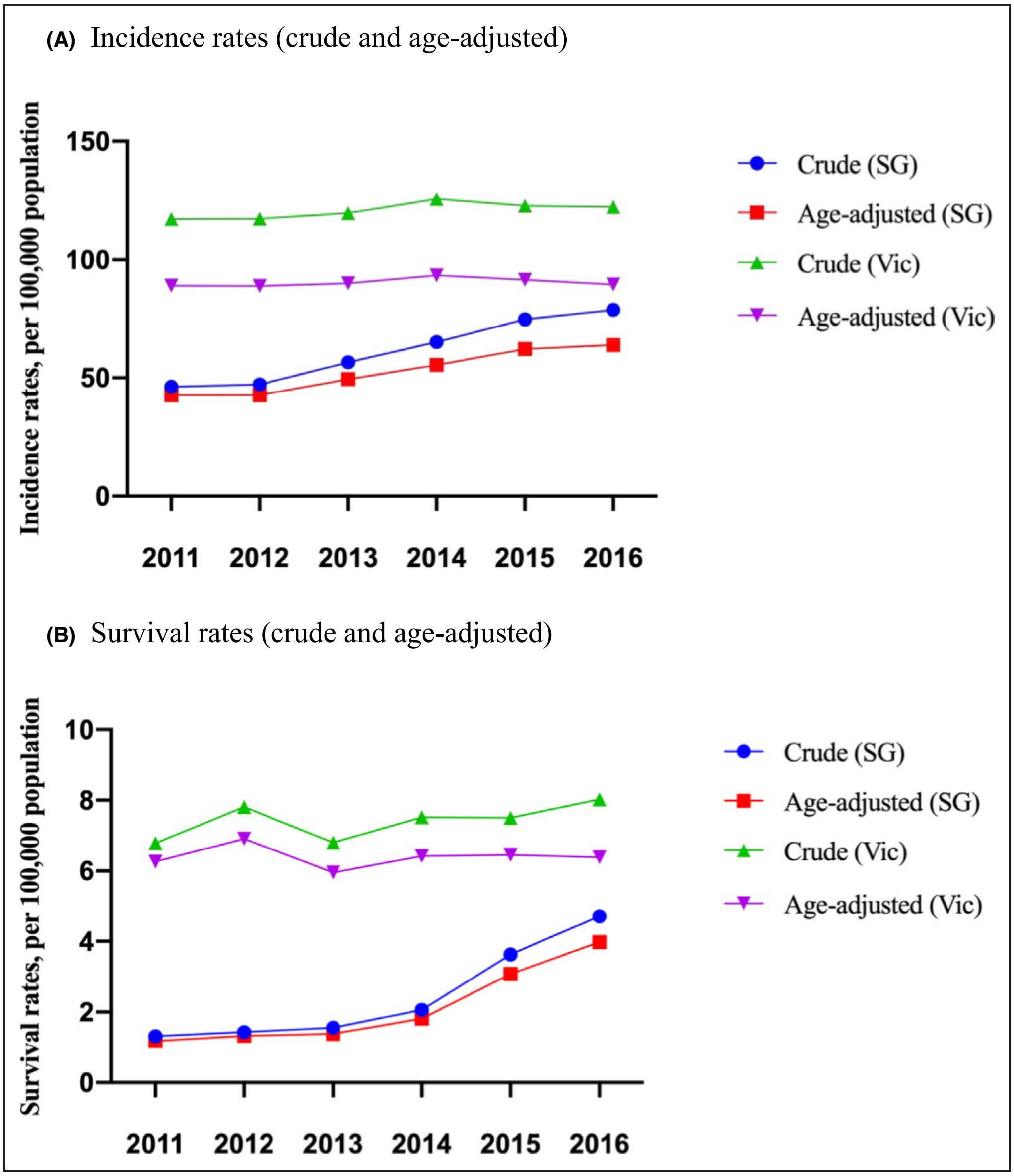

Figure 4. Temporal trends of EMS-attended OHCA from 2011 to 2016.
Temporal trends of (**A**) incidence and (**B**) survival during the study period (January 2011 to December 2016). Adjustment for age performed using direct method, based on World Health Organization population data. EMS indicates emergency medical services; OHCA, out-of-hospital cardiac arrest; SG, Singapore; and Vic, Victoria.

experiencing OHCA in Singapore received treatment at scene and almost all were transported after a brief period of resuscitation, most with ongoing CPR. In contrast, Ambulance Victoria paramedics resuscitated less than half of EMS-attended cases and transported only half of these EMS-treated cases after a longer period of resuscitation. This patient selection possibly reflects the maturity of the system, paramedics' skill set as well as cultural differences between communities. A significant proportion of EMS-attended OHCA cases in Victoria had Do Not Attempt Resuscitation orders or were clearly deceased at time of ambulance arrival; these cases had no chance of survival even if resuscitation was attempted. Such cases were rarely seen in Singapore, implying there were cultural differences in community use of ambulance services. Notwithstanding that, SCDF had a lower threshold for initiating resuscitation and no termination of resuscitation protocol at time of study. A high percentage of EMS-treated OHCA has been shown to be negatively associated with survival.[2] Prehospital return of spontaneous circulation is a key predictor of survival from OHCA,[18] whereas transport to hospital with ongoing CPR has been associated with poor outcomes.[19,20]

Table 3. Factors Influencing Survival in Resuscitated Patients Experiencing OHCA*

	Singapore (n=10 006)		Victoria (n=12 270)	
	Adjusted OR (95% CI)	*P* Value	Adjusted OR (95% CI)	*P* Value
Age (every year increase)	0.98 (0.98–0.99)	<0.001	0.97 (0.97–0.97)	<0.001
Arrest location, public	1.58 (1.22–2.04)	0.001	1.97 (1.71–2.27)	<0.001
Cardiac etiology	0.74 (0.54–1.01)	0.059	1.48 (1.18–1.86)	0.001
Initial shockable rhythm	10.67 (8.31–13.70)	<0.001	8.84 (7.48–10.44)	<0.001
Witnessed arrest	2.08 (1.54–2.81)	<0.001	2.36 (1.99–2.79)	<0.001
Bystander cardiopulmonary resuscitation	1.75 (1.35–2.28)	<0.001	1.20 (1.01–1.43)	0.034
Bystander automated external defibrillator	2.30 (1.48–3.56)	<0.001	1.97 (1.55–2.52)	<0.001
EMS response time	0.91 (0.87–0.94)	<0.001	0.91 (0.89–0.93)	<0.001

EMS indicates emergency medical services; OHCA, out-of-hospital cardiac arrest; and OR, odds ratio.
*Excludes EMS-witnessed patients experiencing OHCA.

This may explain why only 7.3% of transported patients in Singapore had a pulse on arrival at hospital despite transporting almost all patients with OHCA treated by EMS. It is conceivable that many of these futile transports could be avoided in Singapore had there been a termination of resuscitation protocol in place. Recognizing the need for patient selection, SCDF instituted a termination of resuscitation protocol in January 2019.

The mean EMS response times in Singapore and Victoria exceeded the internationally accepted 8-minute benchmark for life-threatening events,[21] with greater variability noted in Victoria. Geographical factors may be partly accountable, with delays resulting from traffic congestion in urban areas and large distances between ambulances and patients experiencing OHCA in rural areas. The increase in demand for emergency services during the study period also added pressure on response times. Much has been done in both states to improve the response times—increase in number of paramedics and vehicles in tandem with population growth, introduction of a clinical response framework to triage and prioritize emergency calls, and the use of technology in dispatch protocols.[11,22,23] In Singapore, fire rescue specialists on motorbikes are dispatched ahead of ambulances in times of bad traffic. Since April 2019, as part of the tiered response to OHCA, fire medical vehicles are also dispatched. These vehicles are staffed by emergency medical technicians and crew members are trained in high-performance CPR. Although the economic burden of maintaining an 8-minute response time is significant, our study found improved odds of survival with shorter EMS response time, thus supporting ongoing efforts to improve EMS response times.

Our bystander CPR rates during the study period were comparable to that reported in other developed countries.[8,24] However, the same period saw bystander defibrillation occurring in only 1.3% and 2.5% of EMS-treated OHCA in Singapore and Victoria respectively despite 17.7% and 30.3% of them presenting with an initial shockable rhythm. The challenges to increasing bystander AED use go beyond the economic burden of installation and dissemination of public AEDs.[25] We need to increase public awareness and link willing, trained lay responders to these public AEDs. Programs integrating community CPR+AED training with increased access to AEDs in North Carolina and Japan successfully increased the proportion of patients receiving bystander CPR and defibrillation, with corresponding improvements in outcomes.[26–28] A similar program, Dispatcher-Assisted first Responder program, was started in 2014 in Singapore; this was intentionally kept simple, that is, focusing on compression-only CPR and AED use in order to increase community penetration.[29] Additionally, Singapore and Victoria have started using technology to enhance community efforts: the SCDF myResponder and the GoodSAM (smartphone activated medics) are mobile phone applications introduced to connect trained people to nearby OHCA cases to provide bystander interventions before the arrival of EMS.[22,29]

During the study period, Singapore reported lower incidence rates of adult EMS-attended OHCA compared with Victoria; these rates increased over the years to approximate that in developed nations. These temporal trends underscored the shift of globalcardiovascular disease burden, the largest contributor of OHCA, from developed Western nations to rapidly developing Asian countries, including Singapore.[30] Outcomes were poorer in Singapore, in terms of overall survival and Utstein survival. The lower survival rates in Singapore could be partly accounted for by high percentage of attempted resuscitation resulting in an EMS-treated population who were older and less likely to have an initial shockable rhythm and received bystander interventions, compared with the more selected EMS-treated population in Victoria.

Both crude and age-adjusted survival rates improved over the study period in Singapore. Though these were partly accounted by improvements in bystander interventions, the marked improvements in survival rates from 2014 suggested the additional contribution of other factors. Improvements in postresuscitation care is one possibility; unfortunately, the data were not available for this study. These improvements in survival are reassuring given the rising incidence rates of OHCA and encourage continued efforts to strengthen the various links in the chain of survival, in order to improve OHCA outcomes.

We know that survival rates vary according to the choice of denominator, and meaningful comparisons across communities can be made only when definitions of numerators and denominators are standardized.[31,32] The target population in our analysis (and hence denominator chosen) was patients experiencing OHCA who were resuscitated by EMS, as this is a common benchmark used by EMS services. EMS services may be activated for cases who are already deceased (rigor mortis, dependent lividity, decapitation) or have Do Not Attempt Resuscitation status. Using EMS-attended OHCA as a denominator would include patients who, a priori, could not be resuscitated. In order to remove the confounding by clearly deceased cases in the denominator, we chose to analyze the cases who were EMS resuscitated, as a surrogate for cases that were not deceased. However, we do recognize that different EMS agencies do have different resuscitation protocols. At the time of the study, unlike Victoria, Singapore EMS did not have a termination of resuscitation protocol. If the denominator were changed to all cases attended, the overall survival for Victoria would be 6.3% instead of 13.6% whereas the figure would remain the same for Singapore. Additionally, we presented survival rates using the Utstein comparator group and overall population served as denominators. The former is in accordance with International Liaison Committee on Resuscitation guidelines and reflects system efficacy,[17] and the latter is more representative of the "population experience."

The Utstein factors considered in our study accounted for more than 80% of survival in both states, despite the different survival rates, implying that part of the variation in survival could be accounted for by the differences in favorable Utstein factors between the states. Yet, these factors did not fully predict survival, indicating the presence of other factors that were unaccounted for. Patient factors such as comorbidities and socioeconomic factors are possible confounders. Comorbidity is associated with long- and short-term outcomes following OHCA[33] and shown to be the most powerful predictor of survival from OHCA with an initial shockable rhythm.[34] Similarly, socioeconomic status is an important predictor of survival; areas of low socioeconomic status consistently have the lowest rates of bystander CPR and defibrillation compared with areas of high socioeconomic status.[35,36] Other than patient factors, some of the disparities may be explained by variations in postresuscitation care such as access to emergency cardiovascular care, targeted temperature management, and local practices on neuroprognostication and withdrawal of care. Last but not least, we lack information on the quality of prehospital resuscitation, an important modifiable factor influencing survival.[37]

Our findings have implications for prehospital management of OHCA, particularly in Singapore. Adopting the practice of patient selection both for attempted resuscitation as well as subsequent transport to hospital may improve overall OHCA outcomes. This allows for rationalization of limited resources (both prehospital and in emergency department) and focusing efforts on those with higher likelihood of survival. Resources should be channeled into strengthening the capabilities and performance of EMS system. As high-quality CPR is one of the basic elements of good resuscitation practices, CPR performance metrics should be monitored. Both sites should continue to foster a culture of public awareness and action as community interventions are crucial to OHCA outcomes.

The strengths of our study include the large sample size, population-based design of registry with uniform data collection based on Utstein definitions for reporting cardiac arrest, and the capture of all EMS-attended OHCA cases in both states. Both registries use multiple methods to identify OHCA cases and have in-built quality control measures therefore ensuring data quality and integrity.

Our study should be interpreted in the context of the following limitations. The observational nature of the study rendered it susceptible to confounding. As both registries collected mainly essential prehospital data variables, we lacked information on comorbidities, socioeconomic factors, hospital-based management, and functional outcomes. This may have contributed to the observed differences, for which we could not control. There were varying amounts of missing data for all OHCA cases, albeit a small proportion (<2%). Finally, as with all epidemiological studies, data integrity, validity, ascertainment bias, and misclassifications were potential limitations.

CONCLUSIONS

Singapore reported increasing OHCA incidence and survival rates during the study period, compared with stable, albeit higher, rates in Victoria. Differences in survival might be related to the differences in EMS practices including patient selection for resuscitation and transport. Refinement of prehospital management, through patient selection for resuscitation and strengthening the capabilities of EMS system, may improve OHCA survival, particularly in Singapore.

ARTICLE INFORMATION

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Supplementary Material

Figures S1–S2

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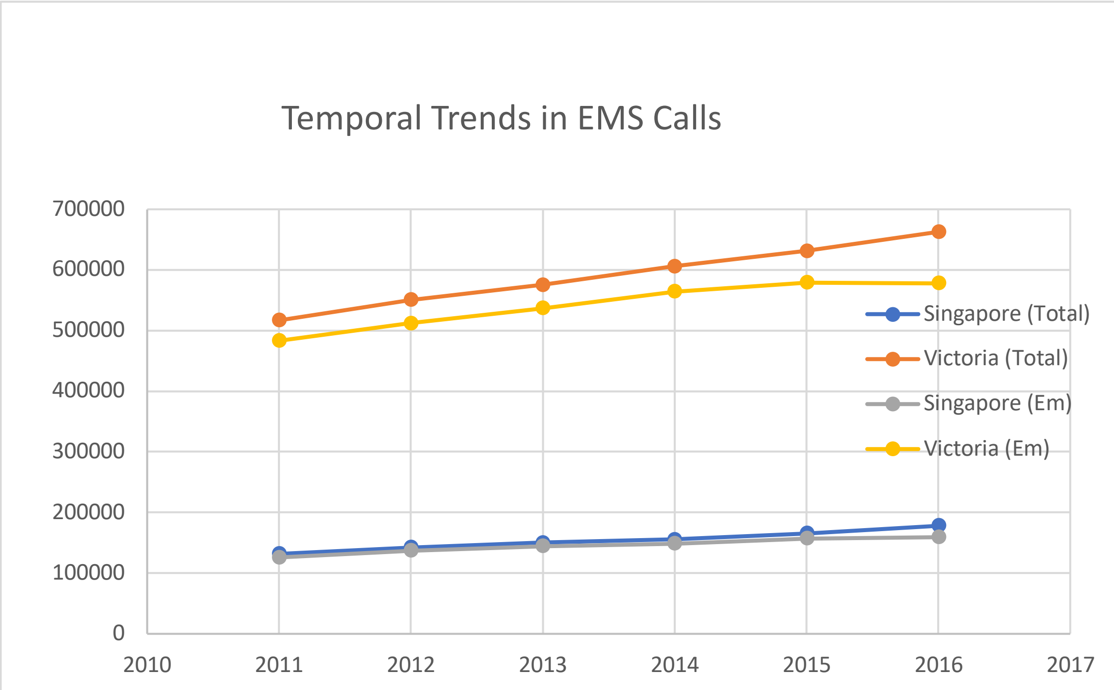
SUPPLEMENTAL MATERIAL

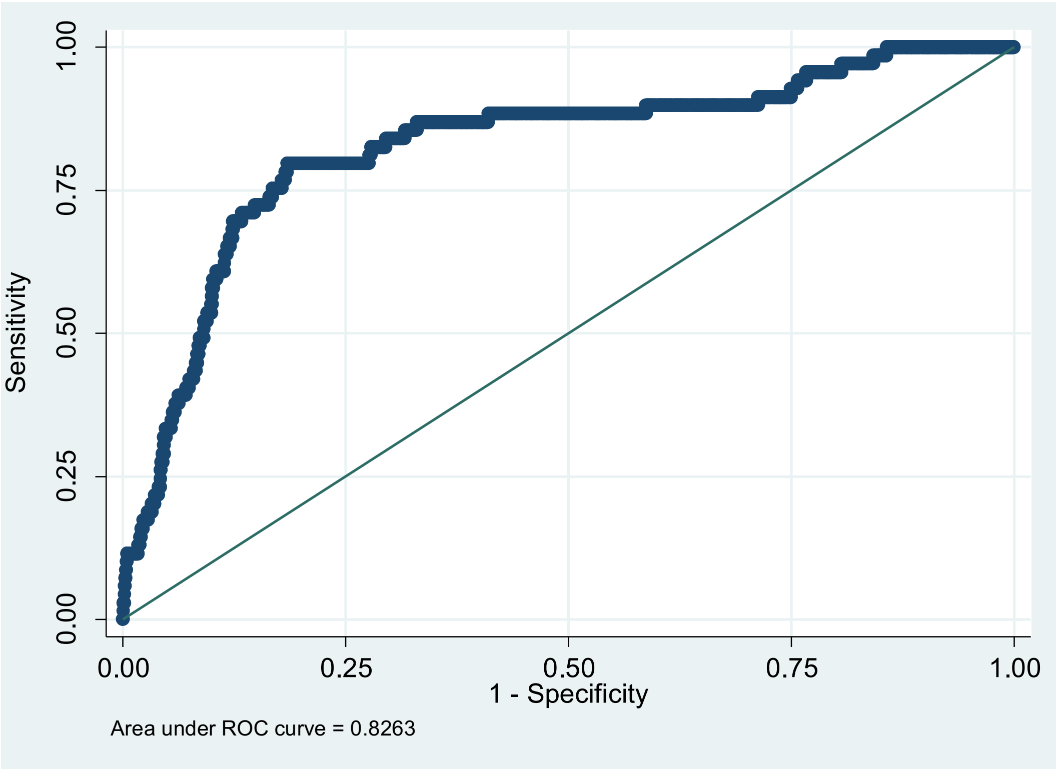
Figure S1. Temporal trends in EMS calls



EMS, emergency medical services; Em, emergency

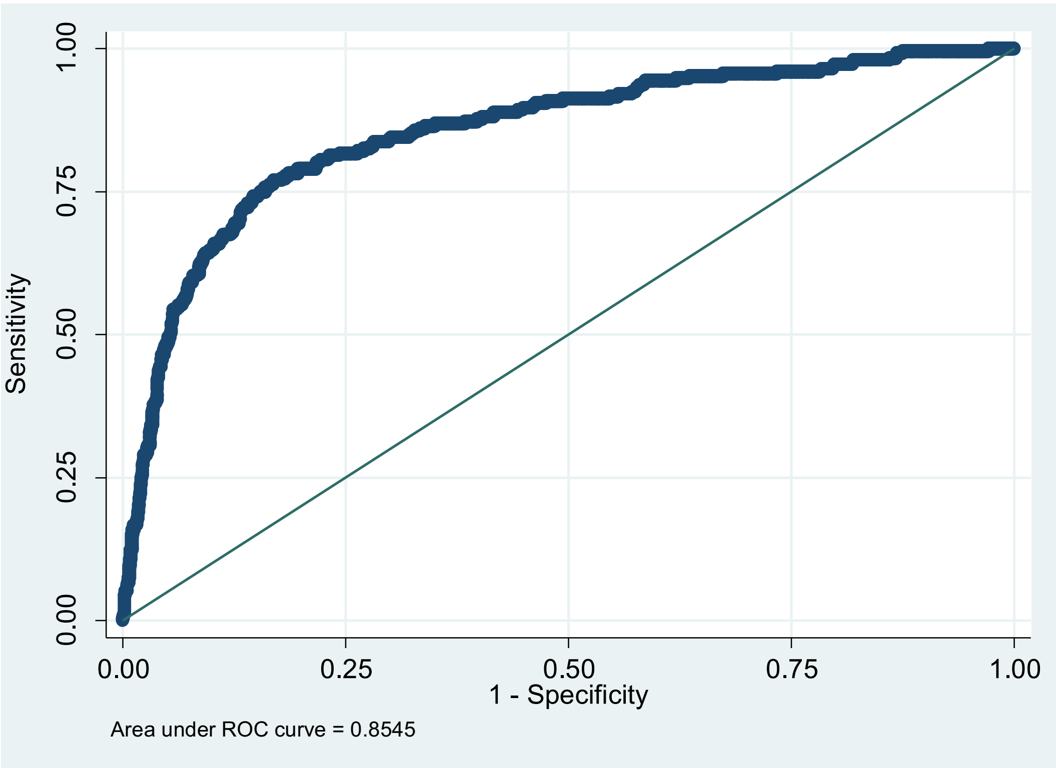
Figure S2. Receiver operating curve for the Utstein elements from the model of survival

(a) Singapore



Area under curve: 0.8263, Wald 95% confidence interval: 0.7710 – 0.8817

(b) Victoria



Area under curve: 0.8545, Wald 95% confidence interval: 0.8277 – 0.8813

ROC, receiving operating characteristic