

## Using a Cardiac Arrest Registry to Measure the Quality of Emergency Medical Service Care Decade of Findings From the Victorian Ambulance Cardiac Arrest Registry

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**Background**—Although the value of clinical registries has been well recognized in developed countries, their use for measuring the quality of emergency medical service care remains relatively unknown. We report the methodology and findings of a statewide emergency medical service surveillance initiative, which is used to measure the quality of systems of care for patients with out-of-hospital cardiac arrest.

**Methods and Results**—Between July 1, 2002, and June 30, 2012, data for adult out-of-hospital cardiac arrest cases of presumed cardiac cause occurring in the Australian Southeastern state of Victoria were extracted from the Victorian Ambulance Cardiac Arrest Registry. Regional and temporal trends in bystander cardiopulmonary resuscitation, event survival, and survival to hospital discharge were analyzed using logistic regression and multilevel modeling. A total of 32 097 out-of-hospital cardiac arrest cases were identified, of whom 14 083 (43.9%) received treatment by the emergency medical service. The risk-adjusted odds of receiving bystander cardiopulmonary resuscitation (odds ratio [OR], 2.96; 95% confidence interval, 2.62–3.33), event survival (OR, 1.55; 95% confidence interval, 1.30–1.85), and survival to hospital discharge (OR, 2.81; 95% confidence interval, 2.07–3.82) were significantly improved by 2011 to 2012 compared with baseline. Significant variation in rates of bystander cardiopulmonary resuscitation and survival were observed across regions, with arrests in rural regions less likely to survive to hospital discharge. The median OR for interhospital variability in survival to hospital discharge outcome was 70% (median OR, 1.70).

**Conclusions**—Between 2002 and 2012, there have been significant improvements in bystander cardiopulmonary resuscitation and survival outcome for out-of-hospital cardiac arrest patients in Victoria, Australia. However, regional survival disparities and interhospital variability in outcomes pose significant challenges for future improvements in care. (*Circ Cardiovasc Qual Outcomes*. 2015;8:56-66. DOI: 10.1161/CIRCOUTCOMES.114.001185.)

**Key Words:** cardiopulmonary resuscitation ■ death, sudden ■ emergency medical services ■ heart arrest

Although case fatality rates from cardiovascular diseases have improved significantly during the past 3 decades, globally reported case fatality rates from out-of-hospital cardiac arrest (OHCA) are not declining.<sup>1</sup> In fact, it is estimated that 5 million people worldwide will experience an OHCA every year, of which only 7% will survive.<sup>2</sup>

Prognosis after OHCA is largely determined by the quality and timeliness of prehospital interventions. Despite the discovery of new in-hospital postresuscitation therapies, OHCA survival remains almost entirely dependent on the attainment of return of spontaneous circulation in the field by emergency rescuers.<sup>1</sup> Thus, it is no surprise that the American Heart

Association recommends that the monitoring of treatment of OHCA by EMS be the sentinel measure of quality of EMS care in the community.<sup>3</sup> With some EMS jurisdictions reporting deteriorating outcomes after OHCA,<sup>4</sup> the urgency of these monitoring activities is greater than ever before.

Although the value of clinical registries has been well recognized in developed countries, their use for measuring the quality of EMS care remains relatively unexplored. For instance, of the 28 clinical registries operating in Australia in 2009, only 1 was identified as an EMS surveillance initiative.<sup>5</sup> Despite a growing number of EMS agencies contributing OHCA data to clinical registries across North America,<sup>6</sup>

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### WHAT IS KNOWN

- Although the value of clinical registries has been well recognized in developed countries, their use for measuring the quality of emergency medical service care remains relatively unknown.

### WHAT THE STUDY ADDS

- Monitoring of treatment of out-of-hospital cardiac arrest by emergency medical service has demonstrated significant improvements in bystander cardiopulmonary resuscitation, event survival, and survival to hospital discharge during a 10-year period.
- Significant variation in rates of bystander cardiopulmonary resuscitation and survival were observed across rural and metropolitan regions.
- For patients transported from the scene, significant interhospital variation in survival outcome was observed after adjustment for patient-level factors.
- Regional standardization of care, across both prehospital and in-hospital settings, and strategies to reduce emergency medical service response times could provide future gains in survival in optimized emergency medical service systems.

Asia,<sup>7</sup> and Europe,<sup>8,9</sup> the scope for a national OHCA registry in Australia remains in its infancy.<sup>10</sup> In fact, only 2 of the 8 Australian EMS organizations have reported previously registry-based methods of data capture and follow-up,<sup>11,12</sup> of which only the Victorian Ambulance Cardiac Arrest Registry (VACAR) operates statewide.<sup>11</sup>

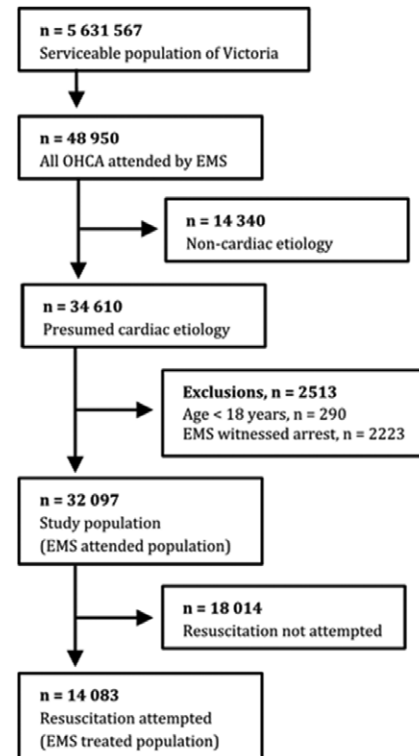
In this study, we sought to report the methodology of the VACAR and the findings of 10 years of surveillance in the Australian Southeastern state of Victoria for patients with OHCA of presumed cardiac pathogenesis. The objectives of this study were to analyze trends in bystander cardiopulmonary resuscitation (CPR), event survival, and survival to hospital discharge outcomes across the 10-year study period, with particular reference to outcome variability across major regions and receiving hospitals.

### Methods

The state of Victoria, Australia, has a population of ≈5.6 million people, of whom 4 million reside in the city of Melbourne. This report presents data for adult (aged ≥18 years or missing age) OHCA cases of presumed cardiac pathogenesis occurring in Victoria between July 1, 2002, and June 30, 2012 (Figure 1). Arrests witnessed by EMS personnel were excluded.

### Emergency Medical Service

Victoria operates a single statewide EMS system (Ambulance Victoria) using ≈2500 advanced life support paramedics and 500 intensive care paramedics. Access to emergency services is provided through a single nationwide telephone number (ie, 000), and telephone-assisted CPR instruction is provided to bystanders by trained emergency call-takers.<sup>13</sup> The EMS system is funded largely by the Victorian State Government, although one third of its funding is generated through a membership subscription scheme and transport fees. Funding from the State Government provides universal ambulance



**Figure 1.** Patient selection between July 1, 2002, and June 30, 2012, in Victoria, Australia. EMS indicates emergency medical service; and OHCA, out-of-hospital cardiac arrest.

coverage to people receiving government entitlements, including elderly, disability, and low-income pensioners. The funding provides free EMS treatment and transport to ≈50% of its emergency case load every year.

The EMS system provides a 3-tiered response to suspected cardiac arrest events in the community: (1) advanced life support paramedics capable of laryngeal mask airway insertion and intravenous adrenaline, (2) intensive care paramedics capable of endotracheal intubation and a wider scope for medications, and (3) first responders with basic life support skills in metropolitan Melbourne and selected rural communities.<sup>14</sup> Cardiac arrest treatment protocols follow the recommendations of the Australian Resuscitation Council ([www.resus.org.au](http://www.resus.org.au)). Prehospital postarrest treatment guidelines involve blood pressure maintenance, induction of therapeutic hypothermia for selected patients, and transport to the nearest appropriate medical facility. Paramedics are authorized to withhold resuscitation in adult patients if the following is present: evidence of irreversible death or injuries incompatible with life, a Refusal of Treatment Certificate for a precipitating condition is in place, or where the initial cardiac rhythm is asystole and the downtime exceeds 10 minutes, and there are no compelling reasons to commence resuscitation (eg, hypothermia).

### Case Ascertainment and Data Sources

The VACAR records details of all OHCA events where EMSs are in attendance. A statewide framework to identify OHCA cases has been developed for Victoria and includes the identification of cases from electronic and paper-based treatment records. Since 2006, treatment records have been recorded electronically using a computer tablet and synchronized daily to a clinical database.<sup>15</sup> A highly sensitive electronic search algorithm is used to identify potential cardiac arrest cases from treatment records, which is supplemented by a review of computer-aided dispatch records, emergency call logs, and paper-based treatment records. Paramedics are also required to report cardiac arrest cases and submit ECG recordings. Hospital outcome data are obtained from hospital medical records in ≈99% of transported

**Table 1. Patient and Arrest Characteristics of EMS-Treated Adult Patients With OHCA of Presumed Cardiac Pathogenesis in Victoria, Australia, 2002 to 2012**

	Overall	2002/2003	2003/2004	2004/2005	2005/2006
Population					
n (percentage of EMS attended)	14 083 (43.9)	1454 (43.0)	1396 (43.5)	1368 (45.8)	1296 (42.4)
Proportion of EMS caseload	0.21	0.26	0.25	0.24	0.21
Crude incidence, per 100 000 population	34.9	39.0	37.0	35.7	33.3
Age-sex-adjusted incidence, per 100 000 population	33.0	37.9	35.7	34.1	31.7
Age, median (IQR), y	70.0 (22.0)	71.0 (19.0)	71.0 (20.0)	71.0 (20.0)	71.0 (21.0)
Age, n (%), y					
18–30	274 (1.9)	26 (1.8)	23 (1.7)	15 (1.1)	11 (0.8)
31–45	1013 (7.2)	85 (5.9)	80 (5.7)	97 (7.1)	96 (7.4)
46–60	2822 (20.1)	267 (18.4)	278 (20.0)	260 (19.0)	250 (19.3)
61–75	4745 (33.7)	550 (38.0)	511 (36.7)	491 (35.9)	453 (35.0)
>75	5209 (37.0)	520 (35.9)	501 (36.0)	503 (36.8)	486 (37.5)
Male sex, n (%)	9889 (70.2)	981 (67.5)	1004 (72.0)	947 (69.2)	951 (73.4)
EMS response time, median (IQR), min	8.0 (4.4)	7.0 (4.0)	7.0 (4.0)	7.8 (4.0)	8.0 (4.0)
Metropolitan region, n (%)	10 660 (75.7)	1123 (77.2)	1054 (75.6)	1064 (77.8)	997 (76.9)
Location of arrest, n (%)					
Private residence	9615 (68.3)	1023 (70.4)	981 (70.3)	925 (67.6)	897 (69.2)
Aged care facility	1084 (7.7)	122 (8.4)	78 (5.6)	97 (7.1)	76 (5.9)
Public place	2931 (20.8)	267 (18.4)	301 (21.6)	306 (22.4)	277 (21.4)
Other	453 (3.2)	42 (2.9)	36 (2.6)	40 (2.9)	46 (3.5)
First monitored rhythm, n (%)					
Shockable	5561 (39.8)	559 (38.5)	598 (43.0)	565 (41.4)	542 (42.1)
Asystole	5367 (38.4)	503 (34.7)	465 (33.4)	451 (33.0)	453 (35.2)
Pulseless electric activity	2945 (21.1)	373 (25.7)	301 (21.6)	345 (25.3)	282 (21.9)
Not shockable	99 (0.7)	16 (1.1)	28 (2.0)	5 (0.4)	11 (0.9)
Time to defibrillation, median (IQR), min†	11.0 (4.0)	9.0 (4.0)	10.0 (4.0)	10.0 (4.0)	10.0 (4.0)
Bystander witnessed, n (%)	8540 (61.1)	858 (60.7)	914 (66.3)	828 (60.7)	832 (64.5)
Bystander CPR, n (%)	7019 (49.8)	592 (40.7)	608 (43.6)	537 (39.3)	508 (39.2)
Scene outcomes, n (%)					
Efforts ceased at scene	8737 (62.1)	899 (61.9)	870 (62.4)	877 (64.2)	821 (63.3)
Transport with ROSC	4164 (29.6)	356 (24.5)	393 (28.2)	325 (23.8)	354 (27.3)
Transport with CPR ongoing	1175 (8.3)	198 (13.6)	131 (9.4)	165 (12.1)	121 (9.3)
ROSC at any time, n (%)	4977 (35.3)	433 (29.8)	468 (33.5)	396 (28.9)	402 (31.0)
Survived event, n (%)	4178 (29.9)	364 (25.1)	384 (27.7)	325 (24.0)	346 (27.0)
Discharged alive, n (%)	1372 (9.9)	78 (5.5)	104 (7.6)	113 (8.4)	125 (9.8)
Discharge direction, n (%)					
Home	1077 (80.1)	53 (73.6)	77 (77.8)	73 (68.9)	95 (77.9)
Rehabilitation facility	225 (16.7)	13 (18.1)	18 (18.2)	30 (28.3)	22 (18.0)
Nursing home	42 (3.1)	6 (8.3)	4 (4.0)	3 (2.8)	5 (4.1)

Proportions exclude missing (unknown) data. CPR indicates cardiopulmonary resuscitation; EMS, emergency medical services; IQR, interquartile range; and ROSC, return of spontaneous circulation.

\*Not applicable.

†Cases with a shockable rhythm on arrival only.

‡A total of 768 cases (5.5) with unknown bystander activity were recorded as no bystander CPR.

cases. Hospital outcome data are validated against death records from the Victorian Registry of Births, Deaths, and Marriages.

A key function of the VACAR database is its transactional relationship with the organization's clinical database, which results in registry fields being populated automatically with standardized treatment

data. This process eliminates the need for case report forms and has improved both the lag-time to case ascertainment and the levels of missing data. Data quality control is facilitated by (1) clinical audits of defibrillated cases (~55% of the EMS-treated sample) are conducted to verify the initial cardiac rhythm, time of defibrillation,

Table 1. continued

2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012	P Value	Missing, n (%)
1360 (43.6)	1385 (43.7)	1503 (41.3)	1410 (43.2)	1397 (46.0)	1514 (46.7)	0.029	...*
0.20	0.20	0.21	0.19	0.18	0.18	<0.001	...*
34.2	34.1	36.1	33.3	32.4	34.5	<0.001	...*
32.3	31.9	33.7	31.0	29.9	31.6	<0.001	20 (0.1)
70.0 (22.0)	71.0 (22.0)	70.0 (23.0)	70.0 (22.0)	69.0 (23.0)	70.0 (24.0)	0.391	20 (0.1)
25 (1.8)	40 (2.9)	32 (2.1)	36 (2.6)	35 (2.5)	31 (2.1)	0.003	
107 (7.9)	106 (7.7)	111 (7.4)	110 (7.8)	105 (7.5)	116 (7.7)	0.010	
280 (20.6)	252 (18.2)	320 (21.3)	281 (19.9)	319 (22.9)	315 (20.8)	0.009	20 (0.1)
433 (31.9)	435 (31.4)	474 (31.6)	466 (33.0)	452 (32.4)	480 (31.7)	<0.001	
514 (37.8)	551 (39.8)	564 (37.6)	517 (36.7)	483 (34.6)	570 (37.7)	0.695	
967 (71.2)	981 (70.8)	1039 (69.1)	963 (68.3)	1001 (71.7)	1055 (69.8)	0.938	4 (<0.1)
8.0 (4.0)	8.0 (4.2)	8.0 (4.5)	8.1 (4.5)	8.1 (4.6)	8.5 (5.4)	<0.001	91 (0.6)
1034 (76.0)	1085 (78.3)	1144 (76.1)	1047 (74.3)	1026 (73.4)	1086 (71.8)	<0.001	4 (<0.1)
932 (68.5)	932 (67.3)	1020 (67.9)	950 (67.4)	952 (68.1)	1003 (66.2)	0.008	
106 (7.8)	116 (8.4)	130 (8.6)	144 (10.2)	93 (6.7)	122 (8.1)	0.028	0 (0.0)
280 (20.6)	295 (21.3)	298 (19.8)	257 (18.2)	315 (22.5)	335 (22.1)	0.369	
42 (3.1)	42 (3.0)	55 (3.7)	59 (4.2)	37 (2.6)	54 (3.6)	0.114	
501 (37.2)	522 (38.1)	562 (37.7)	528 (37.8)	569 (41.2)	615 (41.3)	0.505	111 (0.8)
502 (37.3)	587 (42.8)	638 (42.8)	634 (45.4)	532 (38.5)	602 (40.4)	<0.001	
328 (24.4)	257 (18.8)	292 (19.6)	234 (16.8)	265 (19.2)	268 (18.0)	<0.001	
11 (0.9)	4 (0.3)	0 (0.0)	0 (0.0)	16 (1.2)	4 (0.3)	<0.001	
10.0 (5.0)	11.0 (5.0)	11.0 (5.0)	12.0 (5.0)	12.0 (5.0)	12.0 (6.0)	<0.001	331 (6.0)
796 (58.7)	803 (58.3)	949 (63.6)	868 (61.6)	778 (55.9)	914 (60.7)	0.004	108 (0.8)
584 (42.9)	670 (48.4)	821 (54.6)	798 (56.6)	859 (61.5)	1042 (68.8)	<0.001	...‡
847 (62.3)	874 (63.2)	875 (58.3)	843 (59.8)	876 (62.7)	955 (63.1)	0.336	
381 (28.0)	405 (29.3)	505 (33.6)	472 (33.5)	458 (32.8)	515 (34.0)	<0.001	7 (<0.0)
131 (9.6)	105 (7.6)	122 (8.1)	95 (6.7)	63 (4.5)	44 (2.9)	<0.001	
459 (33.8)	464 (33.5)	608 (40.5)	576 (40.9)	552 (39.5)	619 (40.9)	<0.001	0 (0.0)
377 (28.0)	394 (28.8)	531 (35.5)	489 (34.8)	463 (33.2)	505 (33.4)	<0.001	91 (0.6)
103 (7.8)	142 (10.5)	165 (11.3)	170 (12.3)	169 (12.2)	203 (13.5)	<0.001	233 (1.7)
74 (72.5)	113 (80.1)	141 (85.5)	148 (87.1)	135 (81.3)	168 (83.6)	<0.001	
24 (23.5)	26 (18.4)	17 (10.3)	17 (10.0)	29 (17.5)	29 (14.4)	0.005	28 (2.0)
4 (3.9)	2 (1.4)	7 (4.2)	5 (2.9)	2 (1.2)	4 (2.0)	0.017	

and clinical practice variations, (2) a random audit of 10% of newly entered cases are conducted monthly, and (3) data range and validity checks are incorporated into the database using electronic algorithms. Incomplete or erroneous fields, including negative times, are dealt with by substituting data manually from treatment records or

contacting EMS personnel for clarification. Although levels of missing data improved during the study period (eg, missing survival to hospital discharge reduced from 1.8% in 2002 to 2003 to 0.9% by 2011 to 2012), the proportion of EMS-treated cases with missing data remained relatively low for most years.

**Table 2. Logistic Regression Analyses of Factors Associated With Receiving Bystander CPR in the EMS-Attended Population, and Event Survival and Survival to Hospital Discharge in the EMS-Treated Population in Victoria, Australia, 2002 to 2012**

	Bystander CPR (n=31 483)			
	Crude % (95% CI)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)	Crude % (95% CI)
Age/y	*	0.98 (0.98–0.98)†	0.98 (0.98–0.99)†	*
Male sex	29.1 (28.5–29.7)	1.39 (1.32–1.47)†	1.06 (1.00–1.13)	29.9 (29.1–30.9)
EMS response time/min	*	§	§	*
Public location	59.2 (57.5–60.8)	4.92 (4.58–5.29)†	3.04 (2.80–3.30)†	41.8 (40.0–43.6)
Shockable rhythm	*	§	§	44.6 (43.3–46.0)
Bystander witnessed	49.4 (48.4–50.3)	5.03 (4.77–5.30)†	4.52 (4.27–4.79)†	37.1 (36.1–38.2)
Bystander CPR	*	§	§	33.8 (32.7–34.9)
Bystander CPR by shockable rhythm	*	§	§	48.0 (46.3–49.6)
Region of Victoria				
Metropolitan region 1	27.9 (27.0–28.8)	Reference	Reference	33.5 (32.2–34.9)
Metropolitan region 2	28.3 (27.1–29.5)	1.02 (0.95–1.10)	1.17 (1.07–1.27)†	33.2 (31.4–35.1)
Metropolitan region 3	28.2 (27.2–29.2)	1.02 (0.95–1.09)	1.11 (1.03–1.19)‡	32.4 (30.9–34.0)
Rural region 1	24.8 (23.1–26.6)	0.85 (0.77–0.95)‡	0.90 (0.80–1.01)	22.3 (19.6–25.3)
Rural region 2	23.6 (21.5–25.8)	0.80 (0.70–0.91)‡	0.87 (0.76–1.01)	20.7 (17.4–24.5)
Rural region 3	23.2 (21.4–25.1)	0.78 (0.70–0.87)†	0.80 (0.71–0.91)†	17.0 (14.5–19.9)
Rural region 4	26.8 (24.7–29.0)	0.95 (0.84–1.07)	0.95 (0.83–1.08)	17.7 (14.9–20.9)
Rural region 5	22.0 (20.2–23.9)	0.73 (0.65–0.82)†	0.78 (0.69–0.89)†	20.5 (17.7–23.7)
Year of arrest				
2002/2003	21.4 (20.1–22.8)	Reference	Reference	25.1 (23.0–27.4)
2003/2004	22.8 (21.4–24.3)	1.09 (0.97–1.22)	1.02 (0.89–1.16)	27.7 (25.4–30.1)
2004/2005	21.2 (19.8–22.7)	0.99 (0.88–1.11)	0.93 (0.81–1.06)	24.0 (21.8–26.4)
2005/2006	19.5 (18.2–21.0)	0.89 (0.79–1.01)	0.85 (0.75–0.98)‡	27.0 (24.7–29.5)
2006/2007	21.9 (20.5–23.4)	1.03 (0.92–1.16)	1.05 (0.92–1.19)	28.0 (25.7–30.5)
2007/2008	25.5 (24.0–27.0)	1.25 (1.12–1.41)†	1.28 (1.12–1.45)†	28.8 (26.5–31.3)
2008/2009	27.9 (26.5–29.4)	1.42 (1.27–1.59)†	1.53 (1.35–1.73)†	35.5 (33.1–37.9)
2009/2010	30.9 (29.3–31.5)	1.64 (1.47–1.83)†	1.75 (1.55–1.98)†	34.8 (32.3–37.3)
2010/2011	35.3 (33.6–37.0)	2.00 (1.79–2.23)†	2.26 (2.00–2.56)†	33.2 (30.8–35.8)
2011/2012	41.3 (39.7–43.0)	2.58 (2.32–2.88)†	2.96 (2.62–3.33)†	33.4 (31.1–35.8)

CI indicates confidence interval; CPR, cardiopulmonary resuscitation; EMS, emergency medical services; and OR, odds ratio.

\*Crude proportion not applicable.

†Statistically significant  $P<0.05$ .‡Statistically significant  $P<0.001$ .

§Variable not included in model.

|| Interaction term represents bystander CPR=1 and shockable rhythm=1.

## Data Elements and Definitions

Definitions used in this report follow the recommendations of the Utstein reporting template.<sup>16</sup> The VACAR collects >150 standardized data elements containing patient demographic, treatment, and operational data, including the Utstein-style descriptors and definitions. Cardiac arrest is defined as the cessation of cardiac mechanical activity as 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 cases who receive emergency treatment and those who are declared deceased on EMS arrival. The EMS-treated population is defined as cases which receive any attempt at CPR or defibrillation.<sup>16</sup> Cardiac arrest pathogenesis is identified from the paramedic treatment record and is presumed to be of cardiac cause in the absence of a known precipitator. The variable EMS response time is defined as the time from emergency call to arrival of the first emergency

medical response team to the scene (ie, ambulance or first responder). EMS response time represents the largest component of the time to defibrillation, which includes the time from emergency call to the delivery of the first defibrillation in cases with a shockable rhythm on EMS arrival. Bystander CPR is defined as any attempt at chest compressions, with or without ventilations, and was assumed to be absent if not stated ( $n=768$  or 5.5%). Event survival (binary outcome) denotes evidence of sustained return of spontaneous circulation on the treatment record on arrival at hospital. Survival to hospital discharge (binary outcome) was defined as discharge from acute hospital care.

## Data Analysis

Data analyses for this study were performed using IBM SPSS Statistics 20. All analyses were evaluated using a 2-sided significance level of 0.05. Baseline characteristics and survival outcomes are reported using descriptive statistics and stratified by fiscal year



Table 2. continued

Event Survival (n=13 680)		Survival to Hospital Discharge (n=13 541)		
Unadjusted OR (95% CI)	Adjusted OR (95% CI)	Crude % (95% CI)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
0.99 (0.99–1.00)†	1.00 (0.99–1.00)‡	*	0.97 (0.97–0.97)†	0.97 (0.97–0.98)†
1.01 (0.94–1.10)	0.74 (0.67–0.81)†	11.2 (10.5–11.8)	1.67 (1.46–1.91)†	0.86 (0.73–1.00)
0.95 (0.95–0.96)†	0.96 (0.96–0.97)†	*	0.91 (0.90–0.93)†	0.91 (0.90–0.93)†
1.97 (1.81–2.15)†	1.26 (1.14–1.39)†	22.2 (20.7–23.7)	3.94 (3.51–4.42)†	1.77 (1.55–2.03)†
3.23 (2.99–3.48)†	2.38 (2.11–2.69)†	21.5 (20.4–22.6)	11.78 (10.05–13.79)§	5.07 (4.02–6.39)†
2.58 (2.38–2.80)†	2.10 (1.92–2.29)†	13.6 (12.9–14.4)	3.67 (3.17–4.26)†	2.11 (1.79–2.49)‡
1.46 (1.36–1.57)†	0.93 (0.83–1.05)	13.5 (12.7–14.4)	2.32 (2.06–2.61)†	0.62 (0.45–0.84)†
2.93 (2.70–3.18)†	1.34 (1.14–1.57)†	25.6 (24.1–27.1)	6.76 (6.01–7.62)†	2.57 (1.82–3.62)†
Reference	Reference	11.7 (10.8–12.7)	Reference	Reference
0.99 (0.89–1.09)	1.02 (0.92–1.14)	11.1 (9.9–12.3)	0.94 (0.80–1.09)	1.05 (0.88–1.25)
0.95 (0.87–1.05)	0.94 (0.85–1.04)	10.8 (9.9–11.9)	0.91 (0.79–1.05)	0.92 (0.79–1.08)
0.57 (0.48–0.68)†	0.54 (0.44–0.65)†	6.5 (5.0–8.4)	0.53 (0.39–0.70)†	0.49 (0.35–0.67)†
0.52 (0.41–0.65)†	0.55 (0.43–0.69)†	5.9 (4.2–8.4)	0.47 (0.32–0.69)†	0.51 (0.33–0.78)‡
0.41 (0.33–0.50)†	0.39 (0.32–0.49)†	4.4 (3.1–6.1)	0.34 (0.24–0.49)†	0.34 (0.23–0.51)†
0.43 (0.34–0.53)†	0.40 (0.32–0.51)†	4.3 (3.0–6.2)	0.34 (0.23–0.51)†	0.32 (0.21–0.48)†
0.51 (0.42–0.62)†	0.47 (0.38–0.58)†	6.3 (4.7–8.5)	0.51 (0.36–0.70)†	0.46 (0.31–0.67)†
Reference	Reference	5.5 (4.4–6.8)	Reference	Reference
1.13 (0.97–1.31)	1.06 (0.88–1.26)	7.6 (6.3–9.1)	1.41 (1.04–1.92)‡	1.29 (0.93–1.80)
1.02 (0.87–1.19)	0.91 (0.75–1.09)	8.4 (7.0–10.0)	1.59 (1.18–2.14)‡	1.59 (1.15–2.20)‡
1.06 (0.91–1.21)	1.05 (0.87–1.26)	9.8 (8.3–11.6)	1.88 (1.40–2.52)†	1.76 (1.28–2.43)‡
1.14 (0.98–1.33)	1.25 (1.05–1.50)‡	7.8 (6.5–9.4)	1.46 (1.08–1.98)‡	1.57 (1.13–2.20)‡
1.18 (1.02–1.38)‡	1.25 (1.04–1.49)‡	10.5 (8.9–12.2)	2.02 (1.52–2.69)†	2.11 (1.53–2.89)†
1.42 (1.23–1.63)†	1.73 (1.45–2.05)†	11.3 (9.7–13.0)	2.20 (1.66–2.90)†	2.42 (1.77–3.30)†
1.46 (1.26–1.69)†	1.72 (1.45–2.05)†	12.3 (10.7–14.1)	2.42 (1.83–3.20)†	2.75 (2.01–3.75)†
1.49 (1.29–1.73)†	1.64 (1.37–1.96)†	12.2 (10.6–14.0)	2.40 (1.81–3.17)†	2.65 (1.94–3.61)†
1.53 (1.32–1.77)†	1.55 (1.30–1.85)†	13.5 (11.9–15.4)	2.71 (2.06–3.56)†	2.81 (2.07–3.82)†

(Table 1). Annual crude and age-sex-adjusted incidence were calculated using population figures from the Australian Bureau of Statistics with an Australian Standard Population as at June 30, 2001 ([www.abs.gov.au](http://www.abs.gov.au)). The Mantel-Haenszel  $\chi^2$  test was used to assess the significance of temporal trends in baseline characteristics across ordinal year categories. Yearly differences in the median age, response time, and time to defibrillation of cases were assessed using the Kruskal-Wallis test. We used Joinpoint Regression Program v4.0.4 (National Cancer Institute) to assess whether there were any statistically significant inflection points in trend for bystander CPR and survival.

To examine factors associated with event survival and survival to hospital discharge in the EMS-treated population, we calculated odds ratios (ORs) with 95% confidence intervals (CIs) using ordinary logistic regression (Table 2). Patient-level factors known to predict survival, including age, sex, public location, bystander witnessed,

bystander CPR, EMS response time, and shockable rhythm on arrival, were included in our models.<sup>11</sup> In addition, we included a categorical variable in our analyses to classify cases according to 8 Victorian health regions ([health.vic.gov.au/regions](http://health.vic.gov.au/regions)). Fiscal year, a categorical variable, was used to describe temporal trends in outcomes outside of the patient-level factors. The main effect model was tested for relevant interactions between baseline factors (eg, bystander CPR and rhythm on arrival), as well as interactions between year and region with other baseline variables (eg, bystander CPR and year). Factors associated with bystander CPR were assessed in the EMS-attended population using the same approach, without adjusting for EMS response time and shockable rhythm on arrival.

In a subgroup analysis of cases transported from the scene, we constructed a multilevel (2-level) logistic regression model to assess the impact of receiving hospital on survival to hospital discharge outcome (Table 3). Multilevel models were used because of

**Table 3. Multilevel Logistic Regression Analysis of Factors Associated With Survival to Hospital Discharge in a Subgroup of 4668 Transported Patients Attending 18 Hospitals in Victoria, Australia, 2002 to 2012**

	Odds Ratio	95% CI	P Value
Age/y	0.97	0.97–0.97	<0.001
Male sex	1.08	0.91–1.30	0.380
EMS response time/min	0.95	0.93–0.97	<0.001
Public location	1.40	1.19–1.65	<0.001
Shockable rhythm	3.15	2.44–4.07	<0.001
Bystander witnessed	1.49	1.23–1.80	<0.001
Bystander CPR	0.55	0.39–0.78	0.001
Bystander CPR by shockable rhythm*	4.86	3.83–6.17	<0.001
Year of arrest			
2002/2003	Reference	...	...
2003/2004	1.35	0.93–1.97	0.114
2004/2005	1.85	1.27–2.68	0.001
2005/2006	2.03	1.40–2.94	<0.001
2006/2007	1.57	1.08–2.29	0.019
2007/2008	2.15	1.50–3.10	<0.001
2008/2009	2.20	1.54–3.13	<0.001
2009/2010	2.43	1.70–3.48	<0.001
2010/2011	2.59	1.80–3.72	<0.001
2011/2012	2.69	1.88–3.84	<0.001
Random intercept (hospital site)			
MOR	1.70†	‡	...

CI indicates confidence interval; CPR, cardiopulmonary resuscitation; EMS, emergency medical services; and MOR, median odds ratio.

\*Interaction term represents bystander CPR=1 and shockable rhythm=1.

†MOR for interhospital variability in survival to hospital discharge outcome.

‡No confidence interval for MOR.

the potential for nonindependence or clustering of outcomes at the hospital level.<sup>17,18</sup> We included patient-level factors and fiscal year as fixed-effects while allowing for hospital site as a random intercept. Fixed-effects are presented as ORs and 95% CIs. Because the interpretation of random intercepts in multilevel models can be difficult, we calculated the median OR as a measure of interhospital variation in survival.<sup>17</sup> The median OR can be interpreted as the median of a set of ORs that could be obtained by comparing survival outcomes for 2 patients with identical patient-level characteristics across 2 randomly selected hospitals. The analysis was restricted to 18 hospitals comprising 4668 (87.4%) transported patients, each receiving ≥50 patients during the study period.

### Patient Consent and Ethical Review

The use and collection of data for the VACAR are approved by the Department of Health Human Research Ethics Committee as a quality assurance initiative. This study has ethical approval from the Monash University Human Research Ethics Committee.

### Results

During the 10-year surveillance period, 32 097 EMS-attended OHCA cases met the inclusion criteria, of which 14 083 (43.9%) cases received an attempted resuscitation by EMS (EMS-treated population; Figure 1). Baseline characteristics stratified by fiscal year are presented in Table 1 for the EMS-treated population.

The annual crude and age-sex-adjusted incidence of EMS-attended cases decreased significantly during the study period from 89.3 to 73.7 per 100 000 persons and from 86.5 to 66.7 per 100 000 persons, respectively ( $P<0.001$ ). Although the proportion of EMS-treated cases increased over time, annual crude and age-sex-adjusted incidence declined significantly (Table 1). The median EMS response time, the median time to defibrillation, and the proportion of asystolic events also increased over time.

### Unadjusted Trends in Bystander CPR and Survival

Unadjusted trends in bystander CPR and survival for the EMS-treated population are presented in Figure 2. The largest 10-year trend was observed in the proportion of cases receiving bystander CPR, which rose from 40.7% (95% CI, 38.2%–43.3%) in 2002 to 2003 to 68.8% (95% CI, 66.4%–71.1%) in 2011 to 2012 (or from 21.4% to 41.3% in the EMS-attended population). Unadjusted event survival rose from 25.1% (95% CI, 22.9%–27.4%) at baseline to 33.4% (95% CI, 31.0%–35.8%;  $P<0.001$ ) by 2011 to 2012, whereas survival to hospital discharge rose from 5.5% (95% CI, 4.3%–6.6%) to 13.5% (95% CI, 11.8%–15.3%;  $P<0.001$ ). Increases in survival to hospital discharge were largely influenced by improved outcomes for cases with shockable rhythms, which rose from 10.3% (95% CI, 7.8%–12.9%) in 2002 to 2003 to 30.0% (95% CI, 26.3%–33.6%) in 2011 to 2012 ( $P<0.001$ ). The proportion of patients being discharged home also increased over time ( $P<0.001$ ).

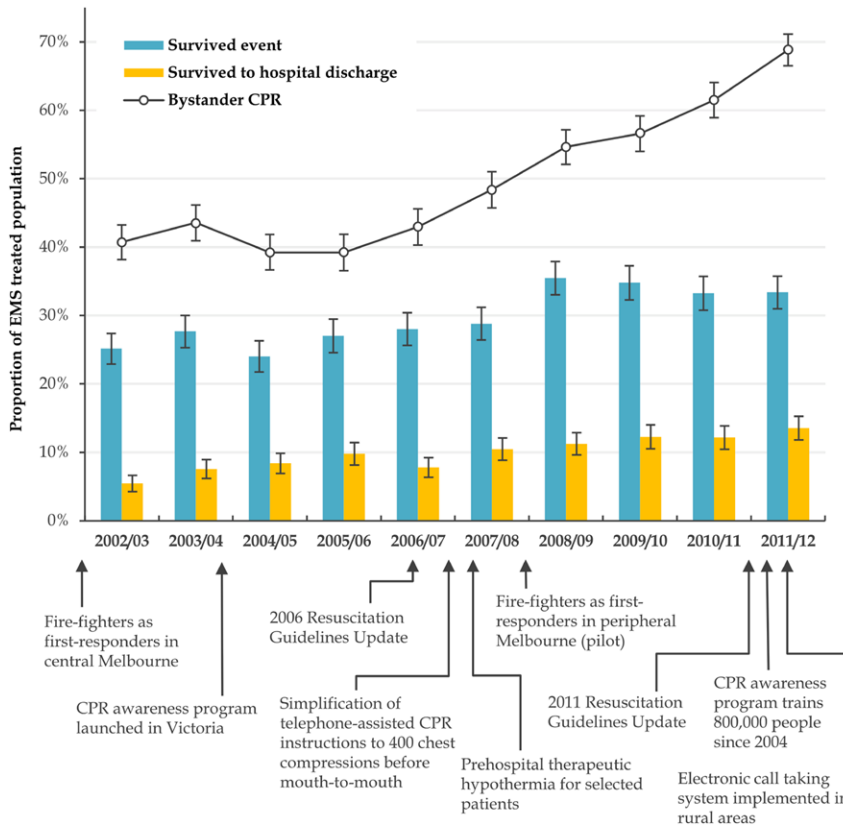
For the joinpoint analysis, a single inflection point in 2005 to 2006 was associated with a significant change in trend for bystander CPR ( $P<0.001$ ). No single point changes in trend were observed for event survival ( $P=0.595$ ) or survival to hospital discharge ( $P=0.688$ ).

### Adjusted Trends in Bystander CPR

After adjusting for patient-level factors, the risk-adjusted odds of receiving bystander CPR in the EMS-attended population was 2.96 (95% CI, 2.62–3.33) in 2011 to 2012 compared with 2002 to 2003, with significant improvements seen in each year after 2006 to 2007 (Table 2). Significant regional variability in bystander CPR was observed across both metropolitan and rural regions.

### Adjusted Trends in Survival

After adjustment for patient-level factors, the risk-adjusted odds of event survival were significantly improved after 2005 to 2006 (Table 2). Similarly, survival to hospital discharge improved markedly, and in 2011 to 2012 was ≈3× greater than 2002 to 2003 (OR, 2.81; 95% CI, 2.07–3.82). Survival outcomes varied regionally, with rural cases demonstrating significantly poorer survival when compared with metropolitan cases. A single interaction term between bystander CPR and shockable rhythm on arrival remained significant for both event survival and survival to hospital discharge. The finding suggests that bystander CPR improves the risk-adjusted odds of survival to hospital discharge by 2.57 (95% CI, 1.82–3.62) when the rhythm on arrival was shockable but did not improve survival for nonshockable rhythms (OR, 0.62; 95% CI, 0.45–0.84). A similar effect was observed for event survival.



**Figure 2.** Ten-year unadjusted trends in bystander cardiopulmonary resuscitation (CPR) and survival in the emergency medical service (EMS)-treated adult presumed cardiac out-of-hospital cardiac arrest population in Victoria, Australia, 2002 to 2012 ( $P$  trend  $<0.001$  for all). Error bars represent 95% confidence intervals for proportions.

### Interhospital Variability in Survival

There was a substantial amount of interhospital variation in survival to hospital discharge for transported patients (Table 3). The median OR for hospital effect was 1.70, which suggests a median 70% difference in the odds of survival to hospital discharge for 2 patients with identical characteristics who are treated at 2 randomly selected hospitals. With the exception of an initial shockable rhythm, the median OR for interhospital variation in survival outcome was higher than most patient-level predictors.

### Discussion

During the 10-year surveillance period, data from the VACAR have demonstrated significant improvement in survival after OHCA in Victoria, Australia. In particular, survival to hospital discharge was associated with a  $\approx 3$ -fold increase since 2002 to 2003. This increase in survival occurred despite unprecedented community demand for EMS,<sup>19,20</sup> and increasing EMS response times to OHCA events. Although similar improvements in survival have been demonstrated internationally by EMS agencies in King County,<sup>21</sup> London,<sup>22</sup> and Denmark,<sup>8</sup> our reported survival increase differs from those reported elsewhere in Australia.<sup>4</sup>

Several targeted initiatives established during the past decade may help explain the improvement in survival outcome observed in our community and internationally. Surveillance data from Denmark demonstrated that a substantial increase in bystander-initiated CPR may have been a key factor driving growth in survival during the past decade.<sup>8</sup> Other authors have attributed improvements in survival to several other changes

in their jurisdictions, including a reduction in EMS response time,<sup>23</sup> improved telephone-assisted CPR instructions for bystanders,<sup>22</sup> and changes to resuscitation guidelines.<sup>21</sup> In Sweden, a doubling in the crude 30-day survival rate from OHCA has been attributed to widespread improvements to the chain of survival, including shorter delays to activating EMS, improved participation rates in bystander CPR, shorter time-to-defibrillation intervals, and greater access to postresuscitation strategies.<sup>24</sup>

In Victoria, the evaluation of targeted initiatives on OHCA outcome has received significant attention by the VACAR. After changes to resuscitation guidelines in 2005, a segmented interrupted time series analysis of OHCA data in Victoria revealed little improvement in favorable outcomes after adjusting for the prechange trend in survival.<sup>25</sup> Other system-based approaches implemented in Victoria during the same time period may offer clearer explanations for the improvement in survival. These initiatives include an early defibrillation program by first responders,<sup>14</sup> improved call-taker identification of OHCA events,<sup>26</sup> simplification of telephone-assisted CPR instructions,<sup>13</sup> and targeted postresuscitation strategies.<sup>27</sup> Importantly, the large increase in bystander CPR participation reported in our study may have offset the impact of longer EMS response times<sup>11</sup> and may help explain the reported variation in incidence of shockable rhythms and survival outcomes across Victoria and other regions of Australia.<sup>4</sup> Furthermore, although the VACAR is not directly responsible for improving outcomes for OHCA patients, its clinical audit and feedback processes create a powerful mechanism for the evaluation of EMS performance, which is not easily



measurable but may have significantly improved outcomes in our population. The impact of registry feedback processes have also been highlighted by other international OHCA registries as a useful mechanism for the continuous evaluation of EMS performance.<sup>24</sup>

Although survival from OHCA is improving in Victoria, several opportunities to advance care still exist. Bystander CPR and survival outcomes in designated rural regions of Victoria were worse than their metropolitan counterparts. In particular, rural areas were associated with significantly poorer survival to hospital discharge outcomes after adjustment for patient and arrest-level factors. The crude difference in survival rates represents  $\approx 200$  excess deaths in rural regions during the 10-year study period.

Reports from Japan, North America, and Australia have recognized that regional differences in OHCA survival could be related to the cardiovascular risk profiles of regional populations and their access to primary prevention strategies.<sup>7,28,29</sup> In addition, several system-level factors also differed across our regions and may be responsible for the variation in outcomes. For instance, regional differences in the participation rate of bystander CPR can be partly attributed to delays in implementing an electronic call-taking procedure in rural emergency call centres. Its statewide expansion occurred by the conclusion of 2011 and was associated with both an increased identification of cardiac arrest in the call and an increase in dispatcher-assisted bystander CPR.<sup>26</sup> In addition, paramedics in our rural regions are exposed to significantly fewer resuscitation attempts than their metropolitan counterparts,<sup>26</sup> and it is not clear what effect this would have on adherence to optimal resuscitation practices or postresuscitation care.<sup>30</sup> Although postresuscitation protocols in our EMS system include aggressive blood pressure maintenance, a report from our region shows that post-return of spontaneous circulation patients in rural regions of Victoria were significantly more likely to experience hypotension on arrival at hospital and this was associated with increased mortality.<sup>31</sup> The periodic training of paramedics in resuscitation practices is not yet formalized in our EMS system but could help to standardize the quality of EMS care across our state.

Access to standardized postresuscitation strategies has generated significant interest in the scientific literature.<sup>32,33</sup> Both targeted temperature management<sup>27,34,35</sup> and early access to percutaneous coronary intervention<sup>36</sup> could help standardize in-hospital care and reduce early mortality after OHCA. In addition to optimal postresuscitation therapies, hospital characteristics such as bed capacity, case exposure, and trauma center designation could be associated with a superior system-based approach to care and warrants further evaluation.<sup>37,38</sup> Our study suggests that interhospital variation in survival outcomes could vary by 70%, and this may indicate inconsistencies with a range of hospital-based factors not currently measured by the VACAR. Future efforts to identify these factors may help to provide uniform standards of postresuscitation care and improve survival outcomes for patients with OHCA.

This study has several limitations. Although the VACAR has a small amount of missing survival data (1.7%), definitions such as presumed arrest pathogenesis were not

verified using hospital medical records or autopsy findings. The VACAR is also limited predominantly to prehospital data variables, and other hospital-based treatment factors were not collected. Thus, the variation in outcomes across hospitals and regions of Victoria may be explained by other factors not measured in our multivariable analyses. Finally, the VACAR does not capture cases where an out-of-hospital death occurs and EMSs are not called to attend (eg, expected deaths). As these cases would not receive an attempted resuscitation they would not affect our reported survival outcomes.

Despite these limitations, this study highlights the potential role of EMS agencies in lessening the health burden associated with acute cardiovascular disease in the community. During a 10-year surveillance period, the monitoring of EMS systems of care for OHCA has demonstrated favorable survival outcomes in our region, with a near 3-fold increase in the odds of survival to hospital discharge by 2011 to 2012. Our study contributes to the growing international literature demonstrating that increases in survival from OHCA are possible through improvements in EMS systems of care and the continuous monitoring of OHCA. Importantly, our study offers several opportunities to improve outcomes for patients with OHCA, both locally and internationally. Regional and interhospital variability in outcomes are responsible for a significant number of excess deaths from OHCA, which could be avoided through the standardization of care across both prehospital and in-hospital settings. Finally, EMS response times have a profound impact on OHCA survival, which could be improved with more efficient mobilization of EMS.

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## Disclosures

None.

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