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Clinical paper

Out-of-hospital cardiac arrest outcomes in emergency departments

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Abstract

Background: The emergency department (ED) plays an important role in out-hospital-cardiac arrest (OHCA) management. However, ED outcomes are not widely reported. This study aimed to (1) describe OHCA ED outcomes and reasons for ED deaths, and (2) whether these differed between hospitals.

Methods: Data were obtained from the Victorian Ambulance Cardiac Arrest Registry and 12 hospitals for adult, non-traumatic OHCA cases transported to ED between 2014 and 2016. Multivariable logistic regression was used to examine the association of level of cardiac arrest centre on ED survival in a subset of cases (non-paramedic witnessed OHCA who were unconscious on ED arrival with ROSC).

Results: Of 1547 eligible OHCA cases, 81% (N = 1254) survived ED, varying between 57% to 88% between EDs. Among non-survivors, the majority had either: cessation of resuscitation after presenting with CPR in progress (27%); withdrawal of life-sustaining treatment for non-neurological (n = 65, 22%) or neurological (16%) reasons; or a unsuccessful resuscitation following a rearrested in ED (20%). These causes of ED deaths varied between the dierent levels of cardiac arrest centres, and in our subset of interest (n = 952) ED survival was associated with transportation to centres with high annual OHCA volumes and with 24-hour cardiac intervention capabilities (AOR = 3.43, 95% CI 1.89–6.21).

Conclusion: Our study found wide variation in survival between EDs, which was associated with hospital characteristics. Such data suggests the need for a detailed review of ED deaths, particularly in non-cardiac arrest centres, and potentially the need for monitoring ED survival as a measure of quality.

Keywords: Out-of-hospital cardiac arrest, Heart arrest, Emergency department, Registries

Introduction

Out-of-hospital cardiac arrest (OHCA) is a global health issue, with high incidence and low survival internationally.[1–3] For example, in Australia, there are approximately 25,000 OHCAs per year with only 12% surviving to hospital discharge.[4] OHCA outcomes are associated with patient demographics,[5–6] arrest characteristics,[7–8] prehospital management[9–11] and the availability and delivery of post-resuscitation care.[12–13] While prehospital and intensive care survival has been extensively studied, little is known about what occurs to these patients in the Emergency Department (ED).

The ED plays an important role in the early post-resuscitation intervention and stabilisation of OHCA patients. However, few stud-

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ies have reported ED patient outcomes. This may have occurred because ED survival is not currently listed in the Utstein OHCA template.[14] Two previous reports demonstrate wide variability in ED mortality (between 22 %[15] and 74 %[16]), although the data used in both of these studies is more than a decade old and the reasons for deaths in ED are currently unreported.

This study aims to fill these gaps by: (1) describing ED outcomes and causes of ED deaths overall and by status on arrival; and (2) examining whether ED survival and causes of ED death varies between hospital types. A detailed review of ED outcomes is important, as it may reveal factors which are unavoidable (e.g. death from a major catastrophic event) or preventable (e.g. neurological prognostication, undertaken too early), which when compared between hospitals may also contribute to understanding the survival variation seen between hospitals, as is seen in Australia[17–18] and internationally.[19–20]

Methods

Study design

We conducted a retrospective, multi-centre observational study of OHCA cases presenting by ambulance to 12 hospitals in the Australian state of Victoria between January 1st 2014 and December 31st 2016. Data were obtained from the Victorian Ambulance Cardiac Arrest Registry (VACAR) and 12 hospitals.[10] This study was approved by the Monash University Human Research Ethics Committee (#2020-21458-39719).

Study setting

The Australian state of Victoria covers 227,000 km^2 and has a population of approximately 6.6 million people. Ambulance Victoria (AV) is the sole Emergency Medical Service (EMS) provider for the state.

AV provides a three-tiered response to suspected OHCA including first-responders, advance life support (ALS) paramedics and intensive care paramedics. All EMS resuscitation protocols are in accordance with Australian Resuscitation Council (ARC) Guidelines.[21] AV paramedics are able to cease resuscitation in: adult patients in non-shockable rhythms who have received 30 minutes of ALS resuscitation with no compelling reason to continue; and adults in ventricular fibrillation (VF) who have received 45 minutes of ALS resuscitation, and there is no compelling reason (e.g. signs of life, periods of return of spontaneous circulation [ROSC], younger age, hypothermia and/or the absence of co-morbidities) to transport to ED with mechanical CPR or continue resuscitation efforts at scene. In OHCA with identified ST-elevation on 12 lead electrocardiogram, arrest with initial shockable rhythm, or presumed cardiac cause, current EMS guidelines recommend transport to the closest percutaneous coronary intervention (PCI) capable hospital.[22] In instances where distance or resources preclude travel to a PCI-capable centre, current guidelines recommend consideration of thrombolysis (if STEMI on 12 lead ECG) and transporting the patient to an interim health care facility, from which secondary transfer to a PCI facility will be co-ordinated. In suspected non-cardiac causes, EMS guidelines recommend transport of patients to the closest appropriate facility.

There are currently 40 public hospital EDs across the state of Victoria[23] which receive the majority (>99%) of OHCAs in Victoria. All EDs triage OHCA patients in accordance with the Australasian Triage Scale and hospital management was guided by existing (2010) recommendations from the ARC.[21] Due to limited funding we could not include all hospitals in this study. Hospitals participating in this study (n = 12): receive the majority of OHCA cases (~60% annually); had experienced data collectors available to collect data for this study; represent the different public hospital types in our region (large metropolitan n = 8, large regional n = 2, small rural n = 2); and different cardiac capabilities (24/7 PCI-capability n = 5, restricted PCI-capability n = 2, no PCI-capability n = 5).

Study population

We included OHCA cases that: occurred between January 1st 2014 and December 31st 2016; had a non-traumatic aetiology; were aged 18 years or older; and were admitted to a participating hospital. Patients were excluded if: the patient's identifying information was unknown or insufficient to find their hospital medical record; they were pronounced dead immediately on arrival to ED with no ED assessment or treatment provided; were admitted directly to hospital bypassing the ED (e.g. STEMIs directly admitted to catheterisation laboratory); or if the initial location of arrest occurred in a hospital facility (e.g. day procedure centre).

Variables and definitions

Re-identifiable pre-hospital and hospital outcome data was provided by the VACAR.[10] In brief, VACAR has comprehensive and standardised methods of collecting details of all EMS-attended OHCA cases in accordance with the Utstein recommendations.[14,24] For this specific project, hospital data were retrospectively collected[25] by trained data collectors (nurses or medical students) with additional ethics committee approval at each of the 12 participating hospitals. One person collected data for each hospital, and data was extracted from the patients' medical record (including ED record, hospital record, and pathology reports). Cause of ED death was determined by reviewing ED medical and nursing notes. The complete list of hospital variables and definitions are outlined in the Supplementary Materials (Supplementary Table 1). Data includes the relevant pre-hospital, hospital and outcome variables associated with OHCA.

Some variables were created from the available data for the purposes of analysis and reporting, these included: cardiac arrest centre status —high (>50 OHCA presentations/year and 24/7 PCI-capability) medium (25–50 OHCA presentations/year restricted PCI-capability) and low (<25 OHCA presentations and no PCI-capability)[17]; downtime (duration in minutes between time of first ROSC and time of emergency call) and systolic blood pressure (SBP) (<90 mmHg, 90 – 160 mmHg, >160 mmHg).[26] There were 22 different aetiologies of arrest recorded in the patients' hospital records and these were categorised into 13 groups using previous published methods.[27]

Data analysis

The primary outcome of the study was 'ED survival' defined as admission to hospital from ED alive (ROSC or extracorporeal membrane oxygenation [ECMO]). The secondary outcomes were 'ED discharge destination' and 'survival to hospital discharge'.

Continuous variables are summarised as means with standard deviations or medians with interquartile range (IQR); categorical variables were summarised as counts with percentages with comparisons between groups made using Pearson's chi-squared or Fisher's exact tests. To examine the impact of hospital type (i.e. cardiac arrest centre status), univariable and multivariable analyses were conducted for known and potential predictors of ED survival in a subset of patients: non-EMS witnessed OHCAs who were

Table 1 – Demographics and characteristics of adult non-traumatic OHCAs overall and by destination or status at ED discharge.

Characteristics	Overall	ICU	Ward	Died in ED	Transfer
	N = 1547	n = 985	n = 205	n = 293	n = 64
Female, n (%)	**393 (25)**	239 (24)	38 (19)	94 (32)	22 (34)
Male, n (%)	**1154 (75)**	746 (76)	167 (81)	199 (68)	42 (66)
Age, years, mean (SD)	**64 (16)**	62 (15)	65 (15)	68 (17)	64 (15)
Country of Birth, n (%)					
Australia	**895 (58)**	580 (59)	127 (62)	140 (48)	48 (75)
International	**497 (32)**	334 (34)	68 (33)	87 (30)	8 (13)
Not stated	**155 (10)**	71 (7)	10 (5)	66 (23)	8 (13)
Co-morbid conditions, n (%)					
Hypertension	**756 (49)**	499 (51)	106 (52)	119 (41)	32 (50)
Congestive heart failure	**184 (12)**	106 (11)	22 (11)	49 (17)	7 (11)
Ischaemic Heart Disease	**457 (30)**	308 (31)	54 (26)	75 (26)	20 (31)
Diabetes Mellitus	**362 (23)**	244 (25)	34 (17)	72 (25)	12 (19)
COPD	**218 (14)**	138 (14)	18 (9)	57 (19)	5 (8)
AICD	**42 (3)**	27 (3)	4 (2)	8 (3)	3 (5)
Stroke	**103 (7)**	68 (7)	13 (6)	21 (7)	1 (2)
Substance use	**385 (25)**	275 (28)	57 (28)	43 (15)	10 (16)
Previous arrest	**74 (5)**	48 (5)	12 (6)	11 (4)	3 (5)
Pre-arrest DNR, n (%)	**35 (2)**	11 (1)	6 (3)	18 (6)	0 (0)
Pre-arrest CPC, n (%)					
CPC 1	**1341 (87)**	863 (88)	180 (88)	239 (82)	59 (92)
CPC 2	**156 (10)**	98 (10)	17 (8)	37 (13)	4 (6)
CPC 3	**49 (3)**	24 (2)	8 (4)	16 (5)	1 (2)
CPC 4	**1 (0)**	0 (0)	0 (0)	1 (0)	0 (0)
Location, n (%)					
Health care facility/ambulance	**454 (29)**	189 (19)	126 (61)	114 (39)	25 (23)
Public	**398 (26)**	295 (30)	49 (24)	42 (14)	12 (19)
Private	**695 (45)**	501 (51)	30 (15)	137 (47)	27 (58)
Residence, n (%)					
Private	**1466 (95)**	941 (96)	197 (96)	267 (91)	61 (95)
Hostel	**32 (2)**	19 (2)	4 (2)	8 (3)	1 (2)
Aged care facility	**49 (3)**	25 (3)	4 (2)	18 (6)	2 (3)
Initial Rhythm, n (%)					
Non-shockable	**659 (43)**	403 (41)	31 (15)	202 (69)	23 (14)
Shockable	**886 (57)**	581 (59)	174 (85)	90 (31)	41 (2)
Missing	**2 (0)**	1 (0)	0 (0)	1 (0)	0 (0)
EMS Response Time, min, (IQR)	**7 (5.88–9.48)**	7 (5.89–9.40)	7 (5.43–8.79)	8 (6.10–9.82)	7 (6.25–9.40)
Downtime*, min, (IQR)	**20 (11–32)**	22 (15–32)	4 (2–12)	30 (18–47)	15 (6–26.5)
Witness, n (%)					
Bystander	**901 (58)**	639 (65)	79 (39)	148 (51)	35 (55)
Paramedic witness	**388 (25)**	153 (16)	117 (57)	96 (33)	22 (34)
No Witness	**258 (17)**	193 (20)	9 (4)	49 (17)	7 (11)
Bystander CPR#, n (%)					
Yes	**901 (78)**	654 (79)	79 (90)	135 (69)	33 (79)
No	**258 (22)**	178 (21)	9 (10)	62 (31)	9 (21)
Witness/CPR, n (%)					
Unwitnessed/No CPR	**83 (5)**	57 (6)	0 (0)	25 (9)	1 (2)
Unwitnessed/CPR	**175 (11)**	136 (14)	9 (4)	24 (8)	6 (9)
Witnessed/No CPR	**175 (11)**	121 (12)	9 (4)	37 (13)	8 (13)
Witnessed/CPR	**726 (47)**	518 (53)	70 (34)	111 (38)	27 (42)
Paramedic/CPR	**388 (25)**	153 (16)	117 (57)	96 (33)	22 (34)

Table 1 – (continued)

Characteristics	Overall	ICU	Ward	Died in ED	Transfer
	N = 1547	n = 985	n = 205	n = 293	n = 64
Aetiology, n (%)					
Cardiac	**895 (58)**	573 (58)	175 (85)	113 (39)	34 (53)
Respiratory	**147 (10)**	100 (10)	8 (4)	31 (11)	8 (13)
Distributive shock	**30 (2)**	22 (2)	2 (1)	6 (2)	0 (0)
Pulmonary embolism	**35 (2)**	21 (2)	0 (0)	13 (4)	1 (2)
Metabolic	**5 (0)**	4 (0)	0 (0)	0 (0)	1 (2)
Neurological	**49 (3)**	40 (4)	1 (0)	3 (1)	5 (8)
Toxicological	**29 (2)**	25 (3)	2 (1)	2 (1)	0 (0)
Electrolyte	**21 (1)**	17 (2)	1 (0)	2 (1)	1 (2)
Non-traumatic exsanguination	**18 (1)**	4 (0)	1 (0)	12 (4)	1 (2)
Other medical	**38 (2)**	15 (2)	4 (2)	18 (6)	1 (2)
Multiple	**3 (0)**	2 (0)	0 (0)	1 (0)	0 (0)
Missing	**5 (0)**	1 (0)	0 (0)	4 (1)	0 (0)
Unknown	**272 (18)**	161 (16)	11 (5)	88 (30)	12 (19)
Any prehospital ROSC, n (%)	**1464 (95)**	963 (98)	204 (100)	233 (80)	64 (100)
Status on Arrival, n (%)					
Conscious	**270 (17)**	53 (5)	187 (91)	11 (4)	20 (31)
Unconscious w/ ROSC	**1139 (74)**	896 (91)	16 (8)	182 (62)	45 (70)
Unconscious w/ Ongoing-CPR	**138 (9)**	36 (4)	2 (1)	100 (34)	0 (0)
Survival to discharge, n (%)	**658 (43)**	412 (42)	188 (92)	0 (0)	58 (91)

COPD: Chronic obstructive pulmonary disease, AICD: Automatic Implantable Cardioverter Defibrillator, DNR: do not resuscitate, CPC: Cerebral Performance Category.
* non-EMS witnessed cases only.
# patients with ROSC.

unconscious on ED arrival with prehospital return of spontaneous circulation (ROSC). This group was chosen because unconscious and non-EMS witnessed patients are less likely to survive and have different predictors of survival,[28] and ambulance transport policies for patients without ROSC vary in our region (e.g. patients in some regions are transported with mechanical CPR to ECMO centres).[29] The associations between ED survival and potential predictors are presented as odds ratios with 95% confidence intervals (95% CI). Variables with a $p < 0.2$ on univariate analyses and those known to be clinically relevant were included in a multivariable, logistic regression model to identify the independent predictors of ED survival in our subset of interest. In variables that were highly correlated (e.g. downtime and serum lactate) we included in the models the variable with either the least missing data or the variable deemed more clinically important. We chose not to include the underlying cause of the arrest in the model, as there was a high proportion of cases of unknown aetiology (17%). A sensitivity analysis with this variable included (coded as cardiac, respiratory, neurological, other and unknown) did not change the direction or statistical significance of any variable (data not shown). We also conducted a sensitivity analysis, repeating the model excluding 63 patients transferred from ED to other hospitals, this modelling also did not change the direction or statistical significance of any variable (data not shown). All tests were two-tailed and significance was assessed at the 5% level.

Results

Patient demographics and characteristics are described in Table 1. Between January 2014 and December 2016, there were 2673 adult non-traumatic OHCA patients transported to hospital in Victoria. Of these, 1674 (63%) were transported to a hospital participating in this study and 1547 (92%) were included in this study (Fig. 1).

The median age of the 1547 included cases was 65 years (IQR = 53–76), 75% were male (n = 1154), and the first monitored rhythm in 57% of cases (n = 886) was shockable (Table 1). Excluding EMS-witnessed cases, the majority of arrests (n = 901, 78%) were witnessed by a bystander, and of these cases 81% (n = 726) received bystander-CPR and the median ambulance response time was 7.3 (IQR 5.9–9.5) minutes. The majority of cases (95%) achieved at least one episode of pre-hospital ROSC, with a median downtime of 20 minutes to first ROSC (IQR = 11–32).

Overall, 1271 patients (82%) had an identified cause of their arrest documented in their medical record. There were 22 different aetiologies identified, with cardiac aetiologies accounting for 58% of all cases (n = 895).

ED outcomes overall

Overall survival of patients from the ED was 81% (n = 1254) and survival to hospital discharge was 43% (n = 658) (Fig. 1). In the ED, 'do not resuscitate' (DNR) orders were made for 219 (14%) patients, of whom 76% (n = 167) died in ED. Of those who survived the ED, 64% went to ICU (n = 985), 13% (n = 205) were admitted to a medical ward and 6% were transferred to another hospital (n = 64). No patients were discharged to their usual residence from ED. Demographics, aetiology of arrest, known predictors of OHCA survival and status on ED arrival varied between patients admitted to the ward and ICU, and in those transferred and who died in the ED (Table 1).

Among non-survivors (n = 293), the majority had either: cessation of resuscitation after presenting with CPR in progress (n = 79, 27%); withdrawal of life-sustaining treatment (WLST) for non-neurological

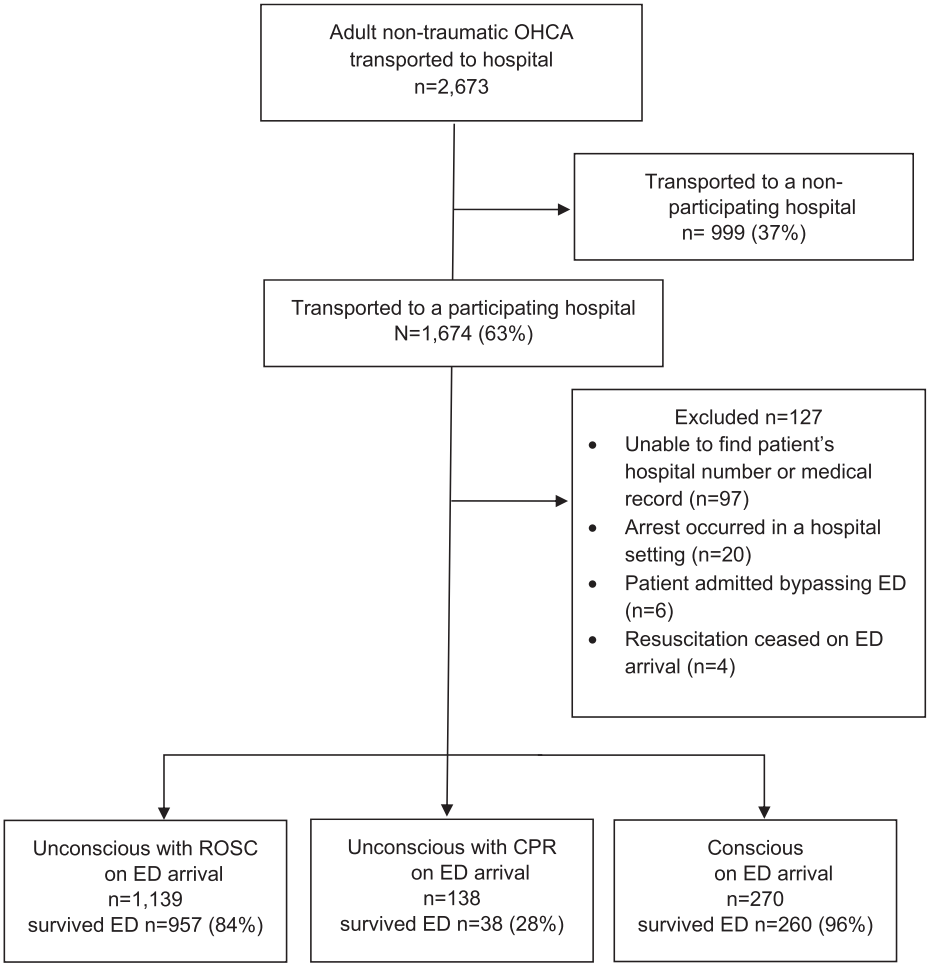

Fig. 1 – Flowchart of study.

(n = 65, 22%) or neurological (n = 46, 16%) reasons; or a unsuccessful resuscitation following a rearrested in ED (n = 59, 20%) (Table 2). Reasons for WLST for non-neurological included unsupportable circulation on maximum treatment, and terminal or extensive co-morbidities. Whereas, most of the WLST for neurological reasons in the ED had documented suspected hypoxic brain injury (e.g. documentation of unresponsive with fixed dilated pupils).

Of the 46 patients with WLST in ED for neurological reasons, only 6% had a neurological aetiology. The majority of these cases had aetiologies that were unknown (37%), cardiac (30%) or respiratory (15%). Similar aetiologies were seen in the 65 patients who had WLST for non-neurological reasons (cardiac = 38%, unknown = 18% and respiratory = 15%).

Table 2 – Reasons for emergency department death in OHCA patients overall and by status on arrival and hospital characteristics.

Cause of ED death, n(%)	Died in ED N = 293	Status on Arrival			Cardiac arrest centre status*		
		Conscious n = 11	Unconscious with ROSC n = 182	Ongoing CPR n = 100	Low n = 54	Medium n = 18	High n = 221
Ongoing CPR efforts ceased	79 (27)	0	0	78 (78)	6 (11)	4 (22)	69 (31)
Rearrest and unable to revive	59 (20)	4 (36)	47 (26)	9 (9)	8 (15)	6 (33)	45 (20)
Rearrest and DNR	29 (10)	0	28 (15)	1 (1)	6 (11)	1 (6)	22 (10)
WLST: neurological	46 (16)	0	41 (23)	5 (5)	13 (24)	0	33 (15)
WLST: non-neurological	65 (22)	5 (45)	54 (30)	6 (6)	18 (33)	4 (22)	43 (19)
Unknown	9 (3)	1 (9)	7 (4)	1 (1)	2 (4)	3 (17)	4 (2)
Other	6 (2)	1 (9)	5 (3)	0 (0)	1 (2)	0	5 (2)

DNR: do not resuscitate, WLST: withdrawal of life sustaining treatment.
* Cardiac arrest centre status: high (>50 OHCA presentations/year and 24/7 PCI-capability) medium (>25 OHCA presentations/year non-24/7 PCI-capability) and low (<25 OHCA presentations and no PCI-capability).

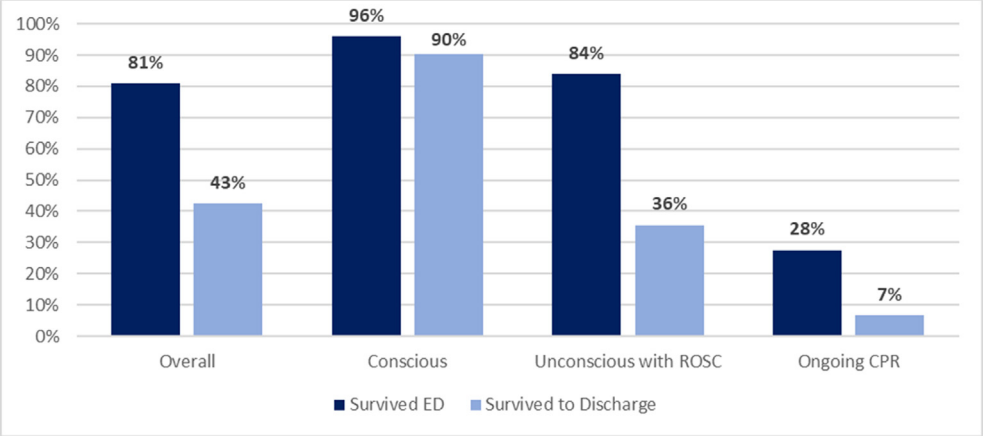

Fig. 2 – Unadjusted emergency department (ED) and hospital survival by status on arrival.

ED outcomes by status on arrival

Supplementary Table 2 provides the patient demographics, arrest characteristics and prehospital treatment by conscious and ROSC status on arrival at ED. Most patients (n = 1276, 83%) were unconscious on arrival at hospital. A high proportion of these patients were intubated by paramedics (88%), with 54% intubated following a supraglottal airway. ED and hospital outcomes varied by the patient's status on ED arrival (Fig. 2).

Of the 1547 cases, 74% of patients (n = 1139) arrived at hospital unconscious with ROSC. In these patients ED survival was 84% (n = 957) and varied significantly between hospitals (55–%, p < 0.001). The majority of these patients (94%) were admitted to ICU. Overall 64% of these patients died during their hospital admission, with the ED accounting for 25% of those deaths (n = 182). The majority of non-survivors in ED either: experienced a rearrest without successful resuscitation (n = 47); or had WLST for neurological (n = 41) or non-neurological (n = 54) reasons.

In patients who arrived in ED with ongoing CPR (n = 138, 9%), only a small number received intra-arrest ECMO (n = 15); of whom none survived to hospital discharge. Overall, ED survival in patients with ongoing CPR was 28% (n = 38) and varied between hospitals (0% to 43%). The majority of non-survivors in this group had cessation of resuscitation efforts in the ED (n = 78). Overall, 9 of these patients (of 138, 6.5%) survived to hospital discharge.

In patients who were conscious on arrival to hospital (n = 270), ED survival was high (96%, n = 260), with some variation seen between hospitals (88% to 100%). These patients were typically admitted to medical wards (72%, n = 187). Overall survival to discharge in this group of patients was 90% (n = 244).

ED outcomes by cardiac arrest centre status

Unadjusted ED and hospital discharge survival varied across the 12 hospitals (57% and 88%, and 27% and 56%, respectively). The majority of cases (84%, n = 1298) were admitted to a "high status" cardiac arrest centre (24/7 PCI-hospitals, 51–112 OHCA per year). These "high status" centres had significantly greater ED survival overall (Fig. 3). Some of the known predictors of survival (e.g. location of arrest, shockable rhythm, and aetiology) (Supplementary Table 3) and causes of ED death were noted to differ by cardiac arrest centre status (Table 3). While the numbers of death in cases transported to low status centres (i.e. hospitals with < 25 OHCA presentations and no PCI-capability) were small (n = 54), these sites had higher rates of WLST for neurological reasons (vs. all other cause of death, p < 0.04) (Table 2) and unknown underlying aetiology for their arrest (Supplementary Table 3). However, there also appears to be differences in cause of death between hospitals within our cardiac arrest centre groupings. For example in the four low status hospitals, one metropolitan hospital accounted for all the ED WLST for neurological reasons.

In patients who were unconscious with ROSC and not witnessed by EMS (n = 952), 822 (86%) survived ED. After adjusting for differences in baseline variables and known predictors, presentation to a high status centre was associated with significantly greater survival (adjusted OR = 3.43, 95% CI 1.89–6.21, p < 0.001) compared to a low status centre (Table 3).

Discussion

In this study, we set out to describe the outcomes of patients admitted to Emergency Departments following an OHCA, and to identify the factors associated with ED survival. Overall, ED mortality for non-traumatic adult OHCA patients was 19%, with the majority of non-survivors having cessation of resuscitation from their prehospital or re-arrest in the ED. The known predictors of ROSC and hospital survival were also associated with ED survival.[10] Smaller hospitals, without or with restricted PCI capabilities (e.g. during business hours), received a smaller proportion of OHCA patients (17%) and had lower survival after adjusting for known predictors. The EDs in these hospitals also had higher rates of withdrawal of life supporting treatment for neurological and non-neurological reasons.

Previous authors who have studied ED outcomes report some similar and some conflicting findings when compared to our results. Schober et al.[15] examined OHCA patients who were unconscious with ROSC admitted to a large cardiac arrest centre, and reported a similar ED mortality rate (22%) to the large cardiac arrest centres in our region. Johnson et al.[16] examined a large multi-centre administrative database, and included all non-traumatic arrests presenting to 933 EDs, and reported a significantly higher ED mortality (74%), which accounted for 90% of hospital deaths. By comparison, the ED deaths in our study only accounted for 33% of deaths. This large difference may reflect differences in the EMS resuscitation and transport protocols in place or the source of data, as large hospital administrative databases are not necessarily designed specifically for

Table 3 – Predictors of emergency department survival in non-paramedic witnessed, unconscious OHCAs with ROSC (n = 952).

Variable	Unadjusted OR (95% CI)	p-value	Adjusted OR (95 %CI)	p-value
Age group (years)				
18–44	Ref		Ref	
45–59	0.50 (0.14–1.78)	0.29	0.46 (0.12–1.71)	0.25
≥60	0.14 (0.04–0.44)	0.001	0.11 (0.03–0.38)	< 0.001
Male sex	1.66 (1.12–2.46)	0.01	1.28 (0.80–2.04)	0.31
CPC pre-arrest				
1	Ref		Ref	
2	0.51 (0.31–0.85)	0.009	0.59 (0.33–1.06)	0.08
3	0.26 (0.11–0.59)	0.001	0.31 (0.12–0.80)	0.02
Arrest in private residence	0.56 (0.37–0.85)	0.007	1.04 (0.63–1.72)	0.96
Hypertension*	1.05 (0.73–1.52)	0.80	1.77 (1.11–2.80)	0.02
Congested heart failure*	0.40 (0.26–0.63)	< 0.001	0.47 (0.27–0.80)	0.005
Diabetes*	0.73 (0.49–1.11)	0.14	1.03 (0.63–1.69)	0.91
Ischaemic heart disease*	0.99 (0.67–1.47)	0.96	-	
COPD*	0.48 (0.31–0.75)	0.001	0.73 (0.43–1.22)	0.23
Stroke*	0.85 (0.44–1.67)	0.64	-	
Witnessed & bystander CPR				
Unwitnessed & no CPR	Ref		Ref	
Unwitnessed & CPR	2.77 (1.37–5.61)	0.05	2.01 (0.90–4.51)	0.09
Witnessed & no CPR	1.73 (0.90–3.34)	0.10	1.91 (0.89–4.51)	0.10
Witnessed & CPR	3.10 (1.74–5.52)	< 0.001	2.21 (1.10–4.46)	0.03
Shockable rhythm	4.53 (3.00–6.84)	< 0.001	3.49 (2.15–5.67)	< 0.001
SBP on ED arrival (mmHg)				
0–89	0.30 (0.19–0.49)	< 0.001	0.29 (0.17–0.51)	< 0.001
90–160	Ref		Ref	-
>160	1.28 (0.70–2.32)	0.42	1.22 (0.64–2.36)	0.55
EMS response time (minute)	0.97 (0.93–1.01)	0.15	0.98 (0.93–1.03)	0.37
Downtime (minute)	0.98 (0.97–0.99)	< 0.001	0.98 (0.96–0.99)	< 0.001
ED arrival in business hours	1.43 (0.97–2.11)	0.07	1.41 (0.90–2.22)	0.14
Cardiac arrest centre status#				
Low	Ref		Ref	
Medium	2.13 (0.89–5.11)	0.09	2.19 (0.76–6.28)	0.14
High	3.07 (1.88–5.01)	< 0.001	3.43 (1.89–6.21)	< 0.001

OR: odds ratio, CPC: Cerebral Performance Category, COPD: Chronic obstructive pulmonary disease.

* Co-morbid conditions.

Cardiac arrest centre status: high (>50 OHCA presentations/year and 24/7 PCI-capability) medium (>25 OHCA presentations/year non-24/7 PCI-capability) and low (<25 OHCA presentations and no PCI-capability).

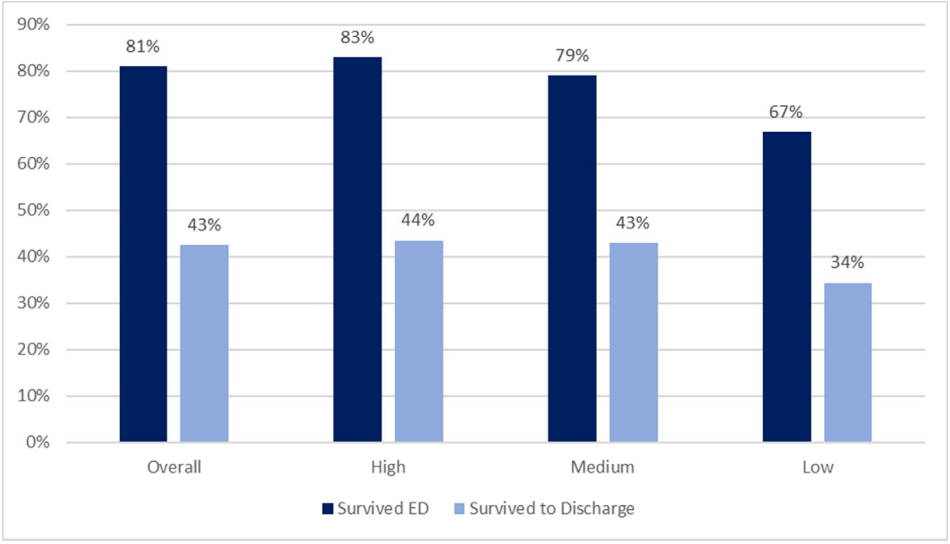

Fig. 3 – Unadjusted OHCA survival according to hospital characteristics*. # Cardiac arrest centre status: high (>50 OHCA presentations/year and 24/7 PCI-capability) medium (>25 OHCA presentations/year non-24/7 PCI-capability) and low (<25 OHCA presentations and no PCI-capability).

research purposes and usually limit the ability to adjust for known predictors of OHCA survival. There were also large differences in survival to hospital discharge between Johnson et al.[16] and our cohort, at 14.5% and 43%, respectively.

A recent systematic review shows wide variation between studies for the impact of hospital characteristics (e.g. OHCA volumes, bed-size, teaching and cardiac capabilities), although most studies consistently report the availability of 24 hour cardiac intervention as associated with good patient outcomes.[19] Some of the variation seen in outcomes is probably related to the different health care systems in these studies. For example, Johnson et al.[16] found a range of ED and hospital characteristics were associated with ED survival in the United States. However, in our mostly public funded health care setting hospital characteristics tend to overlap, with hospitals that have 24-hour cardiac capabilities are also the largest, with the most comprehensive ED and ICU care, and that receive the most OHCA cases annually. Therefore, unpicking the exact hospital factors associated with improved survival in these "cardiac arrest centres" is difficult to determine, and likely explains why an earlier study in our region found only PCI-capability as significant.[17] A similar overlap in hospital characteristics was also recently reported for cardiac arrest centres in the UK.[20]

However, our data does suggest a difference in the cause of ED deaths between hospitals types. Of interest a high proportion of deaths in the low status cardiac arrest centres had life support withdrawn for neurological reasons but did not have a underlying neurological pathology. All of these cases were treated in a single metropolitan hospital. Reasons for this remain unclear from the data available in our study, however early prognostication due to hypoxic brain injury is probable. The variation in cause of death generally may also be due to patient selection.[30] It is possible paramedics may have transported patients more likely to survive to higher status cardiac arrest centres. Although the available prehospital resuscitation care didn't appear to be different between patients transported to the different centres, and our model adjusted for known differences, there may be other factors not available in our dataset that were taken into consideration when deciding which hospital would be suitable. We suggest a detailed review is needed of all OHCA ED deaths, similar to our review in traumatic OHCA deaths[31] but preferably prospectively, including the paramedic's rationale for transport to a specific hospital, before any firm conclusions can be made.

Limitations

Our results are subject to a number of limitations. Firstly, we were unable to collect hospital data for all OHCA cases in Victoria transported to hospital. However, our participating hospitals included the majority (8 of 11) of large metropolitan hospitals, two large regional hospitals and two smaller rural hospitals. Also, our sample has similar patient demographics and arrest characteristics to previous reports from VACAR examining transported patients at earlier time periods.[17,26] Secondly, the medical record audit was performed retrospectively, and although we attempted to overcome the associated limitations by standardising data collection, there was significant missing data for some variables (e.g. ABG) and we were unable to include these variables in our statistical models. It is unclear whether these missing data were missing because these tests were not performed, alternates were used (e.g. a venous blood gas), or they were performed but not recorded in the medical record. Therefore, the results based on this information should be treated with caution. Thirdly, we were unable to examine compliance with the EMS transport protocol with the data in this study. Future research is needed to examine the impact of non-compliance with outcomes. Fourthly, we do not know whether patients in the receiving EDs were managed under a ED post-resuscitation care protocol or what treatment was provided in the ED outside what we have collected. There were likely other medical tests performed that we did not collect data for (e.g. computed tomography scans) and which may have informed ED medical decision-making (e.g. severe cerebral oedema or cerebral herniation). Our data suggest such data should be collected in future studies exploring ED outcomes. In spite of these limitations, the strength of this study is its inclusion of hospital data, and collection of the cause of death in ED for which we found no previous reports.

Conclusion

Our study of 1547 adult, non-traumatic OHCA patients found one-in-five OHCA patients transported to hospital die in the ED, with significantly higher ED survival seen in larger hospitals, with 24-hour cardiac capabilities that see higher volumes of OHCA cases. The association of 24-hour cardiac intervention services with ED survival adds to the evidence of improved patient outcomes at cardiac arrest centres in Australia, however a greater understanding of factors associated with ED deaths is needed.

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CRediT authorship contribution statement

Kalin Kempster: Conceptualization, Formal analysis, Writing - original draft, Writing - review & editing. **Stuart Howell:** Formal analysis, Supervision, Writing - original draft, Writing - review & editing. **Stephen Bernard:** Conceptualization, Funding acquisition, Investigation, Methodology, Writing - review & editing. **Karen Smith:** Conceptualization, Data curation, Funding acquisition, Investigation, Project administration, Resources, Writing - review & editing. **Peter Cameron:** Conceptualization, Funding acquisition, Writing - review & editing. **Judith Finn:** Conceptualization, Funding acquisition, Writing - review & editing. **Dion Stub:** Conceptualization, Funding acquisition, Writing - review & editing. **Peter Morley:** Supervision, Writing - review & editing. **Janet Bray:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing - original draft, Writing - review & editing

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resuscitation.2021.07.003.

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