Original research

One-year quality-of-life outcomes of cardiac arrest survivors by initial defibrillation provider

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ABSTRACT

Objective To assess the long-term functional and health-related quality-of-life (HRQoL) outcomes for out-of-hospital cardiac arrest (OHCA) survivors stratified by initial defibrillation provider.

Methods This retrospective study included adult non-traumatic OHCA with initial shockable rhythms between 2010 and 2019. Survivors at 12 months after arrest were invited to participate in structured telephone interviews. Outcomes were identified using the Glasgow Outcome Scale-Extended (GOS-E), EuroQol-5 Dimension (EQ-5D), 12-Item Short Form Health Survey and living and work status-related questions.

Results 6050 patients had initial shockable rhythms, 3211 (53.1%) had a pulse on hospital arrival, while 1879 (31.1%) were discharged alive. Bystander defibrillation using the closest automated external defibrillator had the highest survival rate (52.8%), followed by dispatched first responders (36.7%) and paramedics (27.9%). 1802 (29.8%) patients survived to 12-month postarrest; of these 1520 (84.4%) were interviewed. 1088 (71.6%) were initially shocked by paramedics, 271 (17.8%) by first responders and 161 (10.6%) by bystanders. Bystander-shocked survivors reported higher rates of living at home without care (87.5%, 75.2%, 77.0%, p<0.001), upper good recovery (GOS-E=8) (41.7%, 30.4%, 30.6%, p=0.002) and EQ-5D visual analogue scale (VAS) ≥80 (64.9%, 55.9%, 52.9%, p=0.003) compared with first responder and paramedics, respectively. After adjustment, initial bystander defibrillation was associated with higher odds of EQ-5D VAS ≥80 (adjusted OR (AOR) 1.56, 95% CI 1.15–2.10; p=0.004), good functional recovery (GOS-E ≥7) (AOR 1.53, 95% CI 1.12–2.11; p=0.009), living at home without care (AOR 1.77, 95% CI 1.16–2.71; p=0.009) and returning to work (AOR 1.72, 95% CI 1.05–2.81; p=0.031) compared with paramedic defibrillation.

Conclusion Survivors receiving initial bystander defibrillation reported better functional and HRQoL outcomes at 12 months after arrest compared with those initially defibrillated by paramedics.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Bystander defibrillation using the closest automated external defibrillator (AED) increases survival from out-of-hospital cardiac arrest and improves the odds of a good functional recovery and health-related quality-of-life (HRQoL) outcomes at hospital discharge, and at 30 days after arrest.

WHAT THIS STUDY ADDS

⇒ This study investigates the functional recovery and HRQoL outcomes at 12 months after arrest for out-of-hospital cardiac arrest survivors stratified by the initial provider of defibrillation. After adjustment, we found that survivors receiving bystander defibrillation had 77% higher odds of living at home without care, 72% higher odds of returning to work and 56% and 53% higher odds of EuroQol-5 Dimension ≥80 and Glasgow Outcome Scale-Extended ≥7, respectively, at 12 months after arrest compared with those initially defibrillated by paramedics. The only increase in the adjusted odds for dispatched first responder defibrillation was an 84% increase in the odds of returning to work at 12 months after arrest, when compared with initial paramedic defibrillation.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Additional strategies to increase bystander defibrillation, such as equipping smartphone-alerted volunteer responders with AEDs, and increasing the availability of 24-hour accessible AEDs in residential neighbourhoods, may help increase survival and better the odds of a good functional recovery and HRQoL outcomes at 12 months after arrest.

INTRODUCTION

Out-of-hospital cardiac arrest (OHCA) remains one of the leading causes of mortality and morbidity globally, with approximately 10% surviving to hospital discharge.[1] Although immediate cardiopulmonary resuscitation (CPR) is crucial to maintain perfusion of vital organs,[2] early defibrillation while the heart remains in a shockable rhythm[3] has been shown to be a major determinant of survival from OHCA.[4]

To facilitate early defibrillation prior to paramedic arrival, many emergency medical service (EMS) systems dispatch first responders, such as firefighters or police officers, equipped with automated external defibrillators (AED). In addition, some systems alert volunteer responders of nearby OHCA using smartphone apps, while directing other bystanders on scene to start CPR and retrieve the closest AED.[5] Defibrillation by dispatched first

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responders has been shown to increase survival from OHCA; however, the greatest increase in survival has been reported for bystander defibrillation.[6]

Better quality-of-life outcomes for OHCA survivors at 12 months after arrest have previously been associated with early bystander CPR.[7] With the proliferation of dispatched first responder and public access defibrillator programmes, it is important to also understand the impact early defibrillation has on long-term functional recovery and health-related quality-of-life (HRQoL) outcomes for OHCA survivors.[8] A number of studies have reported favourable functional and neurological status on hospital discharge,[9 10] and 30 days after arrest[11 12] for survivors receiving bystander defibrillation. One Danish study reported neurological outcomes at 12 months after arrest for bystander CPR and defibrillation. They found significantly lower risks of brain damage for survivors who received bystander resuscitation compared with those who had not.[13]

To better understand the impact of dispatched first responder and public access defibrillator programmes on the long-term outcomes for survivors, we have compared the 12-month functional recovery, HRQoL and return to work outcomes for OHCA survivors, stratified by the initial defibrillation provider in Victoria, Australia.

METHODS

Design and setting

We performed a retrospective analysis of adult OHCA survivors who were initially shocked by bystanders (including smartphone-alerted volunteers), dispatched first responders or paramedics between 1 January 2010 and 31 December 2019 as recorded by the Victorian Ambulance Cardiac Arrest Registry (VACAR). Traumatic cardiac arrests, initial non-shockable rhythms, EMS witnessed arrests, patients <18 years of age and those located in aged care facilities were excluded (figure 1).

The state of Victoria in Australia has a population of approximately 6.5 million and covers an area of 227 444 km^2.[14] Ambulance Victoria is the single state-wide EMS provider. Triple Zero (000) call takers provide telephone CPR instructions once an OHCA is suspected. A three-tiered response is dispatched concurrently, including first responders (firefighters in metropolitan Melbourne and parts of rural Victoria), advanced life support and intensive care paramedics.[15] Ambulance Victoria cardiac arrest treatment guidelines follow recommendations from the Australian Resuscitation Council.[16]

In 2018, the 'GoodSAM' smartphone volunteer responder app was introduced in Victoria.[17] When available, nearby GoodSAM responders are automatically alerted to attend an arrest and provide bystander CPR. The call taker simultaneously instructs bystanders on scene how to start CPR and retrieve the nearest available AED.

For dispatched first responders and EMS personnel the time to first defibrillation was measured from the initial emergency call to first defibrillation as recorded in the emergency call logs. For bystanders it was measured using the emergency call logs in the vast majority of cases, or by using the best available chronology from emergency call logs and patient care records.

Data sources

Data for this study were obtained from the VACAR, a state-wide population-based registry of OHCA attended by EMS in the state of Victoria, Australia. The data collection and registry processes of VACAR have been described previously.[18] In brief,

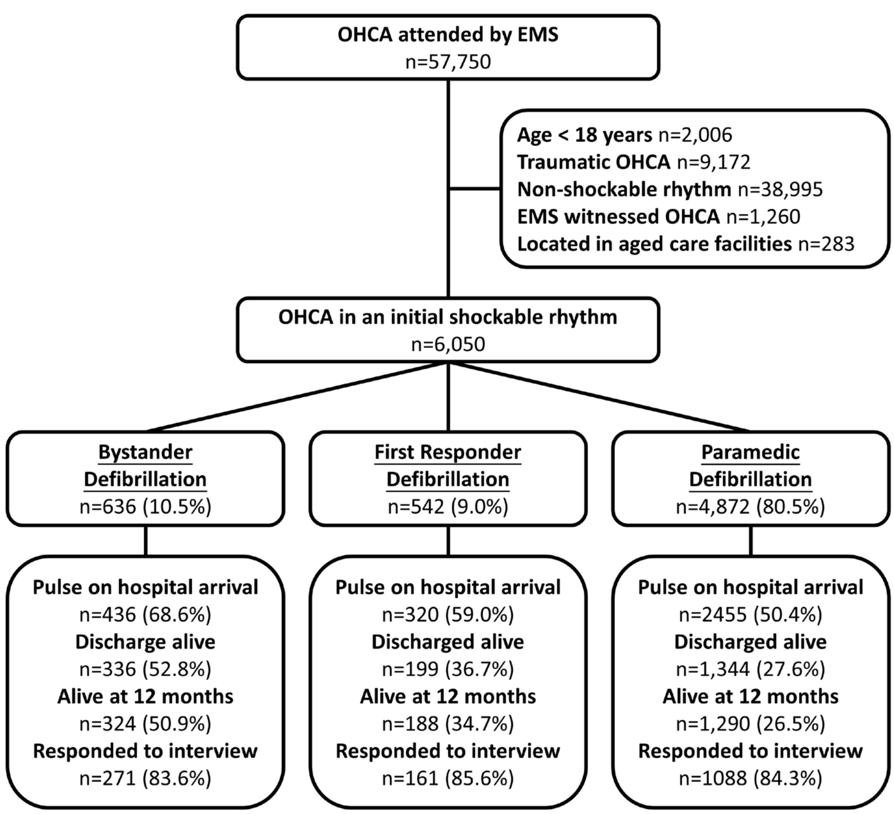

Figure 1 Patient selection flow chart for out-of-hospital cardiac arrest (OHCA) in initial shockable rhythms by shock provider shows OHCA in initial shockable rhythms stratified by initial shock provider. Cases were excluded if the patient was less than 18 years old, had suffered a traumatic cardiac arrest, was not in an initial shockable rhythm, was witnessed by the emergency medical services (EMS) or was located in an aged care facility.

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Table 1 Characteristics of survivors invited to participate in 12-month telephone interview

	No response n=282	Patient and proxy response n=1520	Patient and proxy response to 12-month interview: Bystander n=271	Dispatched first responder n=161	Paramedic n=1088	P value
Age in years, median (IQR)	57 (49, 66)	60 (50, 69)	61 (52, 70)	59 (49, 69)	60 (50, 69)	0.459
Male sex, n (%)	222 (78.7)	1267 (83.4)	238 (87.8)	136 (84.5)	893 (82.1)	0.070
Presumed cardiac aetiology, n (%)	281 (99.7)	1500 (98.7)	268 (98.9)	160 (99.4)	1072 (98.5)	0.641
Witnessed, n (%)	245 (86.9)	1314 (86.4)	256 (94.5)	142 (88.2)	916 (84.2)	<0.001
Bystander CPR, n (%)	251 (89.0)	1354 (89.1)	267 (98.5)	148 (91.9)	939 (86.3)	<0.001
Arrest location, n (%)						
Private residence	125 (44.3)	623 (41.0)	4 (1.5)	68 (42.2)	551 (50.6)	<0.001
Public location	146 (51.8)	835 (54.9)	227 (83.8)	92 (57.1)	516 (47.4)	<0.001
Medical clinic	10 (3.6)	61 (4.0)	39 (14.4)	1 (0.6)	21 (1.9)	<0.001
Custodial facility	1 (0.4)	1 (0.1)	1 (0.4)	0	0	NA
Urban region, n (%)	212 (75.2)	1161 (76.4)	204 (75.3)	151 (93.8)	806 (74.1)	<0.001
Time intervals (min), median (IQR)						
Call to EMS arrival	7 (6, 9)	7 (6, 9)	7 (6, 10)	6 (5, 8)	7 (6, 9)	<0.001
Call to first shock	9 (7, 12)	9 (7, 11)	5 (3, 7)	9 (7, 11)	10 (8, 12)	<0.001
Discharge direction, n (%)						
Home	239 (84.8)	1300 (85.5)	248 (91.5)	138 (85.7)	914 (84.0)	0.012
Rehabilitation	30 (10.6)	194 (12.8)	21 (7.7)	21 (13.0)	152 (14.0)	0.021
Aged care facility	2 (0.7)	13 (0.9)	1 (0.4)	1 (0.6)	11 (1.0)	0.552
Missing	1 (0.4)	13 (0.9)	1 (0.4)	1 (0.6)	11 (1.0)	
Responder type at 12 months, n (%)						
Patient	NA	1249 (82.2)	244 (90.0)	131 (81.4)	874 (80.3)	0.001
Proxy	NA	270 (17.8)	27 (10.0)	29 (18.0)	214 (19.7)	0.001
Highest level of education, n (%)						
Primary/elementary school or less	NA	49 (3.2)	6 (2.2)	5 (3.1)	38 (3.5)	0.483
High school	NA	558 (36.7)	90 (33.2)	53 (32.9)	415 (38.1)	0.049
College or university	NA	802 (52.8)	167 (61.6)	94 (58.4)	541 (49.7)	0.009
Missing	NA	111 (7.3)	8 (3.0)	9 (5.6)	94 (8.6)	
EQ-5D VAS						
VAS prior to arrest, median (IQR)	NA	85 (75–95)	90 (72–93)	90 (75–95)	85 (75–95)	0.296
VAS prior to arrest ≥80, n (%)	NA	1024 (67.4)	186 (68.6)	112 (69.6)	726 (66.7)	0.500
Missing	NA	68 (4.5)	6 (2.2)	11 (6.8)	51 (4.7)	
Work status, n (%)						
Working prior to arrest	NA	889 (58.5)	169 (62.4)	96 (59.6)	624 (57.4)	0.335
Missing	NA	5 (0.3)	0	1 (0.6)	4 (0.4)	

Proportions exclude missing data.
CPR, cardiopulmonary resuscitation; EMS, emergency medical service; EQ-5D, EuroQol-5 Dimension; NA, not available; VAS, visual analogue scale.

all potential cardiac arrests recorded in electronic patient care records are identified daily by search algorithms, they are then screened and audited by registry staff capturing over 150 data points.[18 19] For all EMS-transported patients, VACAR collects hospital discharge outcomes by reviewing hospital medical records and cross-validating data with the Victorian Registry of Births, Deaths and Marriages. This study uses data definitions as recommended by the Utstein guidelines.[19] Cardiac arrest aetiology is presumed to be of cardiac origin if no obvious precipitating factor is recorded.

Patient and public involvement

Patients who previously had an OHCA and their families were not involved in setting the research question or the outcome measures. A letter invited patients (or a proxy) to participate in the telephone interview using validated HRQoL assessment instruments and additional questions relating to living and work status. VACAR staff make multiple attempts to contact each patient or proxy who agrees to participate. Since January 2010, all adult (>18 years of age) OHCA survivors have been invited to participate in a structured telephone interview at 12 months after arrest. Screening of death records is conducted prior to contact to identify any patients who have died.

Outcome measures

The primary outcome of this study was good functional recovery in survivors at 12 months after arrest, as measured by the Glasgow Outcome Scale-Extended (GOS-E). Secondary outcomes at 12 months after arrest included return to work, living at home without care, a EuroQol-5 Dimension (EQ-5D) index score of 1, an EQ-5D visual analogue scale (VAS) ≥80 and a score ≥50 in the 12-Item Short Form Health Survey (SF-12) for both mental and physical components. All the HRQoL assessment instruments have previously been used for reporting outcomes in OHCA survivors.[20] A proxy response is considered suitable for both the GOS-E and EQ-5D

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Table 2 Functional recovery and HRQoL outcomes for 12-month responders

	Patient and proxy response n=1520	Patient and proxy response to 12-month interview			
		Bystander n=271	Dispatched first responder n=161	Paramedic n=1088	P value
Glasgow Outcome Scale-Extended, n (%)					
Upper good recovery	495 (32.6)	113 (41.7)	49 (30.4)	333 (30.6)	0.002
Lower good recovery	491 (32.3)	89 (32.8)	52 (32.3)	350 (32.2)	0.980
Upper moderate recovery	236 (15.5)	35 (12.9)	32 (19.9)	169 (15.5)	0.151
Lower moderate recovery	131 (8.6)	15 (5.5)	16 (9.9)	100 (9.2)	0.128
Upper severe disability	73 (4.8)	9 (3.3)	6 (3.7)	58 (5.3)	0.305
Lower severe disability	86 (5.7)	9 (3.3)	5 (3.1)	72 (6.6)	0.037
Vegetative state	1 (0.1)	0	0	1 (0.1)	NA
Missing	7 (0.5)	1 (0.4)	1 (0.6)	5 (0.5)	
Residential status, n (%)					
Living at home without care	1196 (78.7)	237 (87.5)	121 (75.2)	838 (77.0)	<0.001
Living at home with care	274 (18.0)	26 (9.6)	36 (22.4)	212 (19.5)	<0.001
Not living at home	37 (2.4)	6 (2.2)	2 (1.2)	29 (2.7)	0.535
Missing	13 (0.9)	2 (0.7)	2 (1.2)	9 (0.8)	
Work status, n (%)					
Returned to work, if working prior	658 (74.0)	137 (81.1)	78 (81.3)	443 (71.0)	0.002
Missing	19 (1.3)	6 (2.2)	2 (1.2)	11 (1.0)	
EQ-5D index score, n (%)					
1.00	656 (43.2)	138 (50.9)	67 (41.6)	451 (41.5)	0.021
0.80–0.99	368 (24.2)	60 (22.1)	44 (27.3)	264 (24.3)	0.498
0.60–0.79	332 (21.9)	52 (19.2)	40 (24.8)	241 (22.2)	0.370
<0.60	120 (7.9)	15 (5.5)	8 (5.0)	97 (8.9)	0.053
Missing	43 (2.8)	6 (2.2)	2 (1.2)	35 (3.2)	
EQ-5D VAS					
VAS current, median (IQR)	80 (70–90)	80 (70–90)	80 (70–90)	80 (70–90)	0.017
VAS current ≥80, n (%)	842 (55.4)	176 (64.9)	90 (55.9)	576 (52.9)	0.003
Missing	52 (3.4)	6 (2.2)	9 (5.6)	37 (3.4)	
EQ-5D domains, n (%)					
Problems with mobility	440 (28.9)	63 (23.2)	44 (27.3)	333 (30.6)	0.050
Problems with self-care	144 (9.5)	14 (5.2)	16 (9.9)	114 (10.5)	0.027
Problems with usual activities	460 (30.3)	69 (25.5)	52 (32.3)	339 (31.2)	0.150
Problems with pain/discomfort	334 (22.0)	56 (20.7)	36 (22.4)	242 (22.2)	0.827
Problems with anxiety/depression	416 (27.4)	61 (22.5)	37 (23.0)	318 (29.2)	0.030

Proportions exclude missing data.
EQ-5D, EuroQol-5 Dimension; HRQoL, health-related quality-of-life; NA, not available; VAS, visual analogue scale.

assessments; however, the SF-12 assessment is only suitable for patient responders.

- *GOS-E*. GOS-E uses an 8-point scale, a score of 1 equates to 'death' and 8 to 'upper good recovery'.[21]
- *EQ-5D health survey*. An EQ-5D score of 0 indicates a 'state equivalent to death' and 1 indicates 'perfect health'. The EQ-5D VAS provides an assessment of the patient's self-rated health status on a scale from 0 to 100.[22]
- *SF-12*. SF-12 scores range from 0 to 100, with scores ≥50 indicating no disability, 40–49 indicating mild disability and ≤30 indicating severe disability.[23]
- *SF-6D domains*. SF-6D domains are calculated from questions within the SF-12 survey.[24 25] We report the percentage of patients with problems in each domain.
- *Work-related factors*. Return to work status after arrest is established by confirming that the survivor is working with the same employer and in the same role after arrest.
- *Residential status*. The patient's residential status and use of support services is self-reported during the 12-month interview.

Data analyses

Statistical analyses were undertaken using IBM SPSS Statistics V.25. Tests were two sided and p values <0.05 were considered statistically significant. Descriptive statistics for categorical data are presented as frequencies and proportions, and for continuous data as mean (SD) or median (IQR), as appropriate. Comparisons of baseline characteristics and unadjusted outcome data, stratified by shock provider, were performed using the χ^2 test, one-way analysis of variance or Kruskal-Wallis test, as appropriate. To assess the association between time to first shock and unadjusted outcome data, we categorised the time to first shock into 5 min increments. The χ^2 linear-by-linear association test was used to assess trends for emergency call time to shock for unadjusted outcomes.

Multivariable logistic regression models were employed to assess the impact of initial bystander and dispatched first responder defibrillation compared with initial paramedic defibrillation for 12-month good functional recovery (GOS-E≥7), living at home without care, an EQ-5D index score

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of 1, an EQ-5D VAS ≥80, return to work and SF-12 mental and physical component summaries ≥50. The initial logistic regression models were adjusted for age, sex, arrest aetiology, witness status, bystander CPR, public location, urban/rural location, EMS response time and shock provider. In addition to logistic regression models, we replaced EMS response time with emergency call time to shock to assess the impact of 'time to initial defibrillation' on outcomes. We also adjusted for a prior EQ-5D VAS ≥80 to assess the impact of 'health status prior to collapse' on outcomes. Results from the logistic regression models are presented as adjusted ORs (AOR) with 95% CIs.

RESULTS

Patient population

Between 2010 and 2019, we identified 57 750 OHCAs attended by EMS, of which 6050 cases were included in the study. Of these, 636 (10.5%) were initially defibrillated by bystanders, 542 (9.0%) by dispatched first responders and 4872 (80.5%) by paramedics (figure 1). In total, 3211 (53.1%) cases had a pulse on hospital arrival, the highest rate was for initial bystander defibrillation (68.6%), followed by first responders (59.0%) and paramedics (50.4%). Of the 1879 (31.1%) patients who survived to hospital discharge, the highest survival rate was for initial bystander defibrillation (52.8%), followed by first responders (36.7%) and paramedics (27.9%). Seventy-seven patients died within 1-year postarrest, leaving 1802 alive at 12 months. Of these, 1520 (84.4%) responded to the telephone interview. The response rates were similar for bystander, first responder and paramedic-shocked survivors (83.6% vs 85.6% vs 84.3%, respectively).

Patient characteristics

Table 1 details the baseline characteristics for the OHCA survivors who were invited to participate in the 12-month survey. A higher proportion of bystander-shocked survivors had witnessed arrests, were located in public, received bystander CPR and had shorter emergency call to first shock times, compared with dispatched first responder or paramedic-shocked survivors (all p<0.001). Survivors who received bystander defibrillation were more likely to be discharged home (p=0.012) and less likely to be discharged to a rehabilitation facility (p=0.021), compared with those initially shocked by first responders or paramedics.

HRQoL outcomes

The unadjusted functional recovery and HRQoL outcomes for the 12-month patient and proxy responders are shown in table 2. Survivors shocked by bystanders were most likely to report a 'GOS-E upper good recovery' (41.7% vs 30.4% for first responder-defibrillated vs 30.6% for paramedic-defibrillated survivors, p=0.002), living at home without care (87.5% vs 75.2% for first responder defibrillated vs 77.0% for paramedic defibrillated, p<0.001) and an EQ-5D index score of 1 indicating perfect health (50.9% vs 41.6% for first responder defibrillated vs 41.5% paramedic defibrillated, p=0.021). Furthermore, a greater percentage of bystander and dispatched first responder-defibrillated survivors returned to work at 12 months after arrest compared with paramedic-shocked survivors (81.1% vs 81.3% vs 71.0%, respectively, p=0.002) (table 2 and figure 2).

The unadjusted SF-12 mental and physical component summaries along with the SF-6D domains for the 12-month patient responders are shown in table 3. No survivors defibrillated by bystanders reported an SF-12 mental component summary score <30 (indicating severe disability), compared with 0.8% for dispatched first responders and 2.9% for paramedic-shocked survivors (p=0.011). There were no other significant differences in outcomes according to initial shock provider.

Changes in HRQoL outcomes according to time from emergency call to initial shock

Figure 3 presents functional recovery and HRQoL outcomes according to the time between emergency call and initial defibrillation. For all outcomes, there was a significant decreasing trend in favourable outcome as the time between emergency call and initial defibrillation increase.

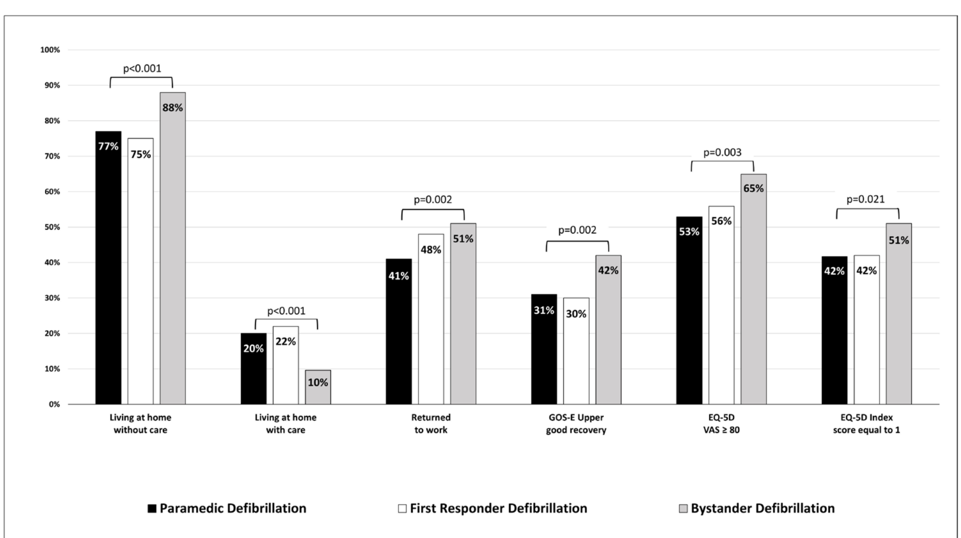

Figure 2 Functional and health-related quality-of-life (HRQoL) outcomes stratified by the provider of initial defibrillation. Returned to work indicates that the survivor has returned to the same employer and fulfils the same roles as they did before the cardiac arrest. EuroQol-5 Dimension visual analogue scale (EQ-5D VAS) ≥80 is the patient's self-rated health status on a scale from 0 to 100. An EQ-5D health survey index score of 1 equates to perfect health. GOS-E, Glasgow Outcome Scale-Extended.

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Table 3 HRQoL outcomes for 12-month patient responders

		Patient response to 12-month interview			
	Patient response n=1249	Bystander n=244	Dispatched first responder n=131	Paramedic n=874	P value
SF-12 mental component summary					
Median (IQR)	57 (52–59)	57 (52–59)	57 (52–58)	57 (52–59)	0.702
≥50, n (%)	989 (79.2)	198 (81.1)	106 (80.9)	685 (78.4)	0.806
40–49, n (%)	140 (11.2)	34 (13.9)	16 (12.2)	90 (10.3)	0.296
30–39, n (%)	72 (5.8)	10 (4.1)	7 (5.3)	55 (6.3)	0.393
<30, n (%)	26 (2.1)	0	1 (0.8)	25 (2.9)	0.011
Missing	22 (1.8)	2 (0.8)	1 (0.8)	19 (2.2)	
SF-12 physical component summary					
Median (IQR)	52 (41–56)	53 (44–57)	51 (39–55)	51 (41–56)	0.077
≥50, n (%)	699 (56.0)	151 (61.9)	70 (53.4)	478 (54.7)	0.148
40–49, n (%)	269 (21.5)	51 (20.9)	27 (20.6)	191 (21.9)	0.865
30–39, n (%)	158 (12.7)	22 (9.0)	21 (16.0)	115 (13.2)	0.101
<30, n (%)	101 (8.1)	18 (7.4)	12 (9.2)	71 (8.1)	0.827
Missing	22 (1.8)	2 (0.8)	1 (0.8)	19 (2.2)	
SF-6D domains, n (%)					
Problems with physical function	412 (33.0)	66 (27.0)	47 (35.9)	299 (34.2)	0.050
Problems with mental health	587 (47.0)	117 (48.0)	66 (50.4)	404 (46.2)	0.453
Problems with role limitation	454 (36.3)	76 (31.1)	49 (37.4)	329 (37.6)	0.112
Problems with social functioning	356 (28.5)	59 (24.2)	42 (32.1)	255 (29.2)	0.120
Problems with vitality	1073 (85.9)	216 (88.5)	113 (86.3)	744 (85.1)	0.253
Problems with pain	342 (27.4)	63 (25.8)	34 (26.0)	245 (28.0)	0.721

Proportions exclude missing data.
HRQoL, health-related quality-of-life; SF-12, 12-Item Short Form Health Survey.

Adjusted functional and HRQoL outcomes

The AORs for the effect of initial bystander or dispatched first responder defibrillation compared with initial paramedic defibrillation are shown in table 4. At 12 months after arrest, survivors receiving bystander defibrillation had higher odds of having an EQ-5D VAS ≥80 (AOR 1.56, 95% CI 1.15–2.10; p=0.004), a good functional recovery (GOS-E≥7) (AOR 1.53, 95% CI 1.12–2.11; p=0.009), living at home without care (AOR 1.77, 95% CI 1.16–2.71; p=0.009) and returning to work (AOR 1.72, 95% CI 1.05, 2.81; p=0.031), when compared with initial paramedic defibrillation. The only outcome affected when initial defibrillation was provided by dispatched first responders was higher odds of returning to work (AOR 1.84, 95% CI 1.02–3.32; p=0.041) when compared with paramedic defibrillation.

The additional logistic regression models replacing 'EMS response time' with 'emergency call time to shock' slightly

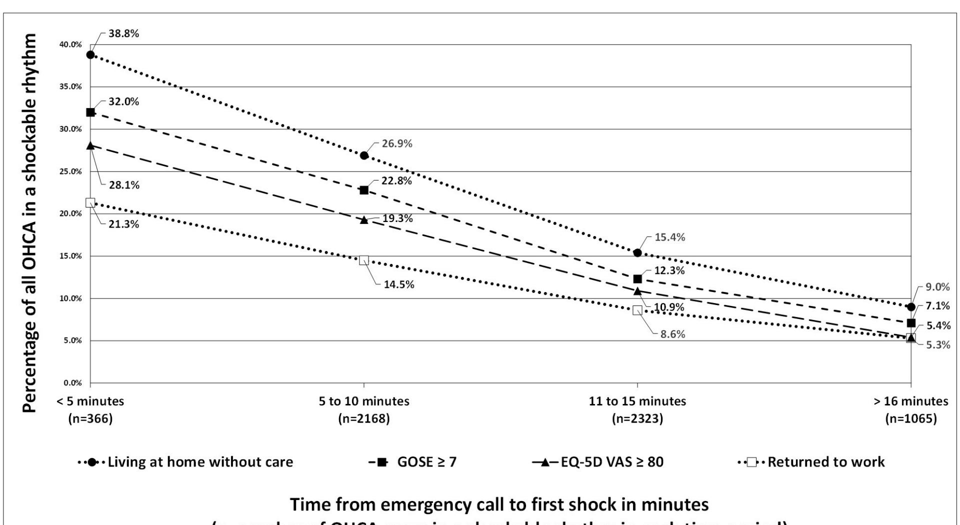

Figure 3 Functional and health-related quality-of-life outcomes of out-of-hospital cardiac arrest (OHCA) survivor at 12 months after arrest as a percentage of all OHCAs in a shockable rhythm from 2010 to 2019, stratified in 5 min time intervals from emergency call to initial shock. Glasgow Outcome Scale-Extended (GOS-E) ≥7 includes 'upper good recovery' and 'lower good recovery'. EuroQol-5 Dimension visual analogue scale (EQ-5D VAS) ≥80 is the patient's self-rated health status on a scale from 0 to 100. Returned to work indicates that the survivor has returned to the same employer and fulfils the same role as they did before their cardiac arrest. The time to first shock was unavailable in 128 cases.

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Table 4 Adjusted ORs (95% CI) for association between defibrillation provider and 12-month outcomes

	Bystander defibrillation		Dispatched first responder defibrillation	
Reference—paramedic defibrillation	AOR (95% CI)	P value	AOR (95% CI)	P value
Good functional recovery (GOS-E≥7)	1.53 (1.12, 2.11)	0.009	0.97 (0.68, 1.38)	0.852
Living at home without care	1.77 (1.16, 2.71)	0.009	0.82 (0.54, 1.24)	0.353
EQ-5D index score equal to 1	1.16 (0.86, 1.55)	0.327	0.88 (0.62, 1.24)	0.453
EQ-5D VAS≥80	1.56 (1.15, 2.10)	0.004	1.13 (0.79, 1.61)	0.498
Returned to work*	1.72 (1.05, 2.81)	0.031	1.84 (1.02, 3.32)	0.041
SF-12 mental component ≥50†	1.06 (0.72, 1.57)	0.770	1.21 (0.75, 1.96)	0.433
SF-12 physical component ≥50†	1.21 (0.88, 1.66)	0.253	0.86 (0.59, 1.27)	0.456

Models adjusted for age, sex, arrest aetiology, witness status, bystander CPR, public location, urban region, EMS response time and defibrillation providers.
*For cases working prior to cardiac arrest.
†For 12-month patient responders only.
AOR, adjusted OR; CPR, cardiopulmonary resuscitation; EMS, emergency medical service; EQ-5D, EuroQol-5 Dimension; GOS-E, Glasgow Outcome Scale-Extended; SF-12, 12-Item Short Form Health Survey; VAS, visual analogue scale.

attenuated the effect of bystander defibrillation; however, all four outcomes remained statistically significant. 'Return to work', the single affected outcome for dispatched first responder defibrillation, also remained significant in this model (table 5). Further logistic regression models adjusting for EQ-5D VAS ≥80 prior to arrest also slightly attenuated the effect of bystander defibrillation for the four statistically significant outcomes. However, 'Return to work', the single affected outcome for dispatched first responder defibrillation, was no longer statistically significant in this model (data not shown).

DISCUSSION

Our study assessed the 12-month functional recovery and HRQoL outcomes for OHCA survivors stratified by shock provider. We found that after adjustment for known confounder variables, bystander defibrillation increased the chances of living at home without care by 77%, returning to work by 72%, having a good functional recovery (GOS-E≥7) by 53% and an EQ-5D VAS ≥80 by 56%, at 12 months after arrest when compared with initial paramedic defibrillation. The only effect observed for initial defibrillation by dispatched first responders was an 84% increase in the adjusted odds of returning to work at 12 months after arrest compared with paramedic-shocked survivors.

While bystander defibrillation has been previously associated with higher survival rates,[6 9] our findings show that it is also associated with better long-term outcomes, as 87% of bystander-defibrillated survivors reported an upper moderate recovery or better, compared with 83% and 78% of dispatched first responder and paramedic-shocked survivors, respectively. The median time from the emergency call to first shock was 5 min faster for bystander defibrillation compared with paramedic defibrillation, which is similar to the time reduction previously identified for use of on-site AEDs compared with EMS defibrillation.[26] After adjustment, our results show that bystander defibrillation was associated with more favourable long-term outcomes. Our trend analysis shows that early defibrillation in <5 min offers a greater chance of long-term favourable outcomes for survivors. These findings provide support for the theory that the time from collapse to defibrillation is a major contributing factor in determining long-term outcomes for survivors.

Our findings of favourable recovery and HRQoL outcomes at 1 year after arrest for survivors receiving bystander defibrillation support previous research showing better neurological status on hospital discharge,[9 10] at 30 days after arrest[11 12] and 1 year after arrest.[13] Of the survivors working prior to their cardiac arrest, a higher proportion who received bystander or dispatched first responder defibrillation returned to work compared with those receiving paramedic defibrillation (81.1%, 81.3% and 71%, respectively). These findings are consistent with results from another VACAR study which reported that 83% of bystander-defibrillated survivors and 73% of all OHCAs in Victoria, Australia, returned to work.[27] These higher rates of functional recovery and ability to return to work point towards the economic viability of increasing AED availability.

Table 5 Adjusted ORs (95% CI) for association between defibrillation provider and 12-month outcomes adjusted for 'Emergency Call to Shock Time'

	Bystander defibrillation		Dispatched first responder defibrillation	
Reference—paramedic defibrillation	AOR (95% CI)	P value	AOR (95% CI)	P value
Good functional recovery (GOS-E≥7)	1.52 (1.09, 2.13)	0.015	0.97 (0.67, 1.40)	0.860
Living at home without care	1.69 (1.09, 2.62)	0.020	0.79 (0.51, 1.21)	0.280
EQ-5D index score equal to 1	1.16 (0.85, 1.58)	0.360	0.90 (0.63, 1.30)	0.586
EQ-5D VAS≥80	1.48 (1.08, 2.04)	0.016	1.14 (0.79, 1.65)	0.490
Returned to work*	1.74 (1.04, 2.91)	0.035	1.93 (1.03, 3.59)	0.039
SF-12 mental component ≥50†	0.96 (0.64, 1.44)	0.833	1.30 (0.78, 2.17)	0.322
SF-12 physical component ≥50†	1.19 (0.84, 1.69)	0.330	0.88 (0.59, 1.32)	0.531

Models adjusted for age, sex, arrest aetiology, witness status, bystander CPR, public location, urban region, EMS call to first shock and defibrillation providers.
*For cases working prior to cardiac arrest.
†For 12-month patient responders only.
AOR, adjusted OR; CPR, cardiopulmonary resuscitation; EMS, emergency medical service; EQ-5D, EuroQol-5 Dimension; GOS-E, Glasgow Outcome Scale-Extended; SF-12, 12-Item Short Form Health Survey; VAS, visual analogue scale.

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In our study, less than 1% of survivors who had a cardiac arrest in a private residence received bystander defibrillation, while 11% were initially shocked by dispatched first responders and 88% by paramedics. A recent Dutch study by Stieglis *et al* showed that directing two-thirds of text message-alerted lay responders to an AED first reduced the time to first defibrillation and increased bystander CPR and the overall survival for patients in residences found in a shockable rhythm.[28] As the long-term functional and HRQoL outcomes were more favourable for bystander and first responder defibrillation, strategies to increase defibrillation prior to paramedic arrival, including smartphone-activated responders, may prove a wise use of resources to improve both survival rates and long-term outcomes for OHCA.

Limitations

Our study has a number of limitations, 282 (15.6%) patients did not participate in the 12-month telephone interviews; however, they were evenly distributed between shock providers. Paramedic-shocked survivors reported lower prior heath status, this may indicate increased comorbidities which have previously been associated with poorer HRQoL outcomes.[29] This study used the EQ-5D as an assessment tool which does not include an assessment of cognitive function; therefore, we could not directly assess the effect the initial defibrillation provider had on changes in cognitive function.[30] The limited observed improvement in outcome for survivors shocked by first responders compared with paramedics may be due to the relatively low numbers of survivors receiving first responder defibrillation. The telephone interviews collected data to assess functional outcomes and HRQoL at 12 months. As there were no further follow-up interviews we were unable to evaluate changes in outcomes over a longer time frame. No adjustment was made for hospital-based treatments or postarrest rehabilitation factors, which may have an effect on the patient's long-term recovery. Although we adjusted for favourable factors, we could not adjust for potential differences in comorbidities across cohorts.

CONCLUSION

Our study reinforces the importance of defibrillation prior to paramedic arrival for OHCA. Bystander-defibrillated patients reported better functional recovery and higher rates of both returning to work and living at home without care, while defibrillation by first responders had higher rates of returning to work at 12 months after arrest when compared with paramedic defibrillation.

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Contributors BH conceived the study. BH, ZN and EA contributed to data collection. BH, ZN, EA, SB, PC and KS were responsible for data analysis and interpretation of results. BH drafted the manuscript and all authors made edits to the manuscript for important intellectual property. All authors approved the final manuscript. BH is responsible for the overall content as guarantor.

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Competing interests BH is an unpaid member of the Medical Board of Advisers for DefibsPlus.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by the Monash University Human Research Ethics Committee (Project ID: 12758). The VACAR maintains independent ethics approval from the Monash University Human Research Ethics Committee, Melbourne, Australia (Project ID: 21046) and site-specific governance approval for over 100 participating hospitals for the collection of outcome data. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

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