Available online at www.sciencedirect.com

Resuscitation Plus

journal homepage: www.elsevier.com/locate/resuscitation-plus

Clinical paper

Out-of-Hospital Cardiac Arrest in Ireland 2012 to 2020: Bystander CPR, bystander defibrillation and survival in the Utstein comparator group

Tomás Barry[a,], Garrett Green[b], Martin Quinn[c], Conor Deasy[d], Gerard Bury[e], Siobhan Masterson[f], Andrew W Murphy[g], on behalf of the Out-of-Hospital Cardiac Arrest Registry Steering Group*

Abstract

Background: The Irish Out-of-Hospital Cardiac Arrest registry (OHCAR) collects data based on the internationally recognised Utstein template. The Utstein comparator group (bystander witnessed and initial shockable rhythm) has specific relevance in benchmarking out-of-hospital cardiac arrest (OHCA) health system performance.

Aims: To describe OHCA in the Utstein comparator group during 2012 to 2020 in Ireland. To explore predictors of bystander CPR, defibrillation, and survival to hospital discharge.

Methods: National level OHCA registry data were interrogated. The subset of patients in the Utstein comparator group were identified and explored. Multivariable logistic regression was used to model outcome predictors.

Results: There were 3,092 cases of OHCA in the Utstein comparator group during 2012 to 2020. Overall survival to hospital discharge was 27%. On average there were yearly improvements in bystander CPR, bystander defibrillation, and survival. Bystander CPR was associated with a 57% increase, while bystander defibrillation was associated with a 78% increase in the adjusted odds of survival to hospital discharge. The adjusted odds of both bystander CPR and defibrillation were higher in rural areas, despite decreased survival in these communities when compared to urban. OHCA that occurred at home was associated with decreased odds of bystander CPR, bystander defibrillation, and survival to hospital discharge.

Conclusions: Bystander CPR, bystander defibrillation and survival to hospital discharge have increased in the Utstein comparator group during 2012–2020 in Ireland. Bystander CPR and defibrillation remain key modifiable health systems targets to increase overall OHCA survival.

Keywords: Resuscitation, Out-of-Hospital Cardiac Arrest, Cardiopulmonary Resuscitation, Utstein comparator subgroup, Registry Data, Statistical Models, Public Health

Introduction

Ireland's population stands at more than 5.1 million people[1] with approximately 3000 annual Out-of-Hospital Cardiac Arrest (OHCA) resuscitation attempts and 8% survival to hospital discharge.[2] The Irish Out-of-Hospital Cardiac Arrest Register (OHCAR) has collected national level data on the experience of OHCA resuscitation in Ireland since 2012.[3] Previous OHCAR research has considered public access defibrillation, geographical disparities, the role of first responders, and outcomes in key age cohorts.[4–10] This current research is part of a large OHCAR project which seeks to explore predictors of OHCA survival at population level in Ireland.[3] Previous elements of the project have considered the chain of survival at overall population level. The outputs have in turn highlighted the heterogenous nature of the issue of OHCA at population level and the importance of studying key OHCA subgroups.[11] The Utstein Comparator subgroup (bystander witnessed and initial shockable rhythm) is of key importance in understanding health system efficacy and benchmarking performance of OHCA care.[12] The EuReCa two study demonstrated that the Utstein Comparator subgroup represented 13% of OHCA cases across Europe (range 6%–27%) with survival to hospital discharge/

* Corresponding author at: School of Medicine, University College Dublin, Belfield, Dublin 4, Ireland.
E-mail address: tomas.barry@ucd.ie (T. Barry).

https://doi.org/10.1016/j.resplu.2024.100851
Received 29 October 2024; Received in revised form 16 December 2024; Accepted 17 December 2024

thirty days of 28% (range 0–53%).[13] The Irish health system has undergone several OHCA developments since 2010, whose impacts would be expected to be reflected in Utstein comparator group outcomes. These developments include OHCA public education programmes, community first responder recruitment campaigns and quality improvement initiatives. These are summarised in supplementary figure 1 and have been previously described in detail.[3] The year 2020 was notable in terms of the COVID-19 pandemic.[3] During this period widespread public health measures were introduced[14] and COVID-19 has been associated with disruption of OHCA care processes and outcomes across various international jurisdictions.[15,16] Notably, in Ireland community first responder activity was paused during 2020.

The aim of this study was to interrogate OHCAR data from the period 2012 to 2020 inclusive focusing on the Utstein comparator group, to describe characteristics of this group and then model predictors of bystander CPR, bystander defibrillation and survival to hospital discharge.

Methods

OHCA care in Ireland

The National Ambulance Service (NAS) provide OHCA EMS (emergency medical services) care throughout Ireland. In Ireland's capital city Dublin there is also a fire based EMS system provided by Dublin Fire Brigade.[17] In addition to statutory EMS OHCA care, Ireland also has a well-developed national voluntary network of community first responders (CFRs) that aim to provide CPR and defibrillation before EMS arrival.[17] CFRs are alerted by SMS message from EMS dispatch, are trained in basic life support, and are equipped with automatic external defibrillators (AEDs).[17] Telephone/ Dispatcher Assisted CPR is an established standard of care in terms of EMS call centres. EMS clinical emergency care is delivered by paramedics and advanced paramedics whose scope of practice is determined by national guidelines.[18] These guidelines reflect the International Liaison Committee on Resuscitation (ILCOR) approach to OHCA resuscitation.[19]

OHCAR data collection

OHCAR includes all patients who suffer OHCA, are attended by emergency services, and have resuscitation attempted. OHCAR employs the international Utstein standarised approach to data collection.[20] Missing case identification is undertaken on a quarterly basis by the registry co-ordinator and cases are validated before being entered onto the registry database. The primary sources of OHCAR data are EMS dispatch and patient care records. Survival and neurological outcome data are provided by receiving hospitals.[3]

Study population

The population for this study were OHCAR patients of all ages, who suffered bystander witnessed OHCA, of any presumed aetiology, with an initial shockable rhythm (recorded on any device – bystander/EMS), during the period 2012 – 2020 in Ireland. All study data were obtained from the Irish Out-of-Hospital Cardiac Arrest Register (OHCAR).

Variable selection and modification

This research is a subcomponent of a larger project which sought to explore overall predictors of OHCA survival in Ireland.[3] A number of key OHCAR variables were identified as those of primary concern at the project planning phase.[3] These variables were chosen because their relevance had already been demonstrated in the international scientific literature and because the variables were known to have high levels of data capture in the Irish Out-of-Hospital Cardiac Arrest Registry.[21] In terms of this current component, individual variable selection was further informed by the output of earlier stages of the project.[11] The variables that were considered for this current research exercise are shown in supplementary table 1. Variables 1–11 were obtained from OHCAR. Variable 12 was created using the 'year' variable with 2020 representing the 'COVID period.' This variable was included because COVID-19 has been associated with an international disruption of OHCA survival outcomes and because preceding work by our group demonstrated that at overall population level COVID-19 was associated with decreased OHCA survival in Ireland.[15,16,22] The 'incident location' variable had multiple associated categories and thus was collapsed (as shown in supplementary table 1) to avoid decreased statistical power from analysis of an excessive number of potentially sparse categories. The 'year' variable was treated as a continuous variable to conserve degrees of freedom and statistical power. Variable 3 (call response interval) represented the time in minutes from the initiation of the EMS call and the first EMS arrival on scene. Variable 10 (urban or rural) was based on the Irish Central Statistics Office classification of urban or rural. Bystander CPR represented CPR performed prior to EMS arrival to scene. Bystander defibrillation represented shock(s) delivered prior to EMS arrival to scene. In each of these circumstances' bystanders may have represented opportunistic bystanders who were, or arrived at scene by chance or community responders who were alerted by EMS dispatch.

Statistical analysis

All analysis were performed using IBM SPSS Statistics V.27 and Microsoft Excel for Microsoft 365 MSO V. 2308. Categorical variables were explored by considering frequency and percentage, continuous variables were explored by considering mean, standard deviation, median and interquartile range. Binary logistic regression was performed to consider predictors of bystander CPR, bystander defibrillation, and survival to hospital discharge. Initially univariate unadjusted analysis was performed, this was then followed by multivariable adjusted analysis. Each independent variable was assessed for multicollinearity using the collinearity diagnostics function in SPSS to assess tolerance and variance inflation factors. Model fit was evaluated by inspecting the outputs of the Omnibus Tests of Model Coefficients and Hosmer-Lemeshow Goodness of Fit (GOF) test. The proportions of missing data for each variable were documented and evaluated. Sensitivity analyses were conducted using multiple imputation via fully conditional specification in SPSS with five imputations derived. Results from complete case and multiple imputation analysis were compared.

Ethical approval

The National University of Ireland Galway, Research Ethics Committee provided ethical approval for this study in advance of data processing and analysis (Reference 2020.01.012; Amend 2106).

Results

A total of 18,177 (non-EMS witnessed) OHCAR cases were available over the period 2012–2020 (Supplementary Fig. 2). Of these 10,056

were known to be bystander witnessed, 3,092 of which were known to have had an initial shockable rhythm. This subgroup i.e. the 'Utstein comparator' represented 17.0% of valid cases (3,092/18,141) over the period. Fig. 1 summarises the Utstein comparator group in terms of absolute number and proportion of all OHCA cases over time. It demonstrates that while the absolute number of patients in the Utstein comparator group trended upward over time, the relative proportion of all OHCAR patients that this represented trended downward. The Utstein comparator group was the lowest proportion of OHCA in 2020 (15.1%). Fig. 2 summarises

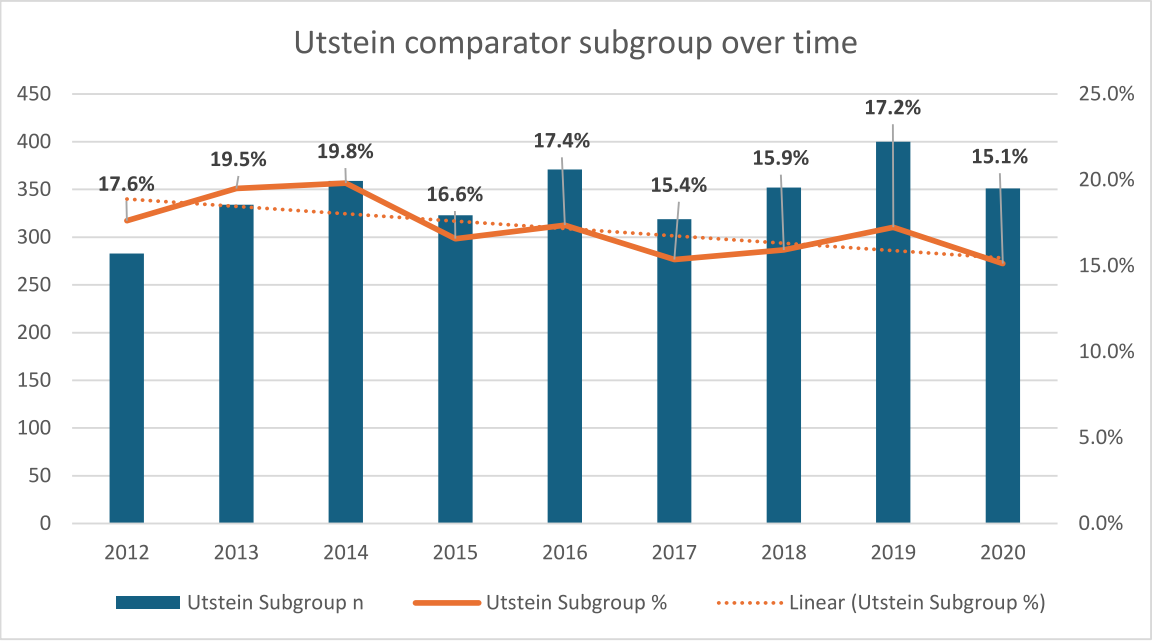

Fig. 1 – Utstein Comparator Group 2012–2020: absolute number(s), and proportion of all cases over time (EMS Witnessed OHCA excluded).

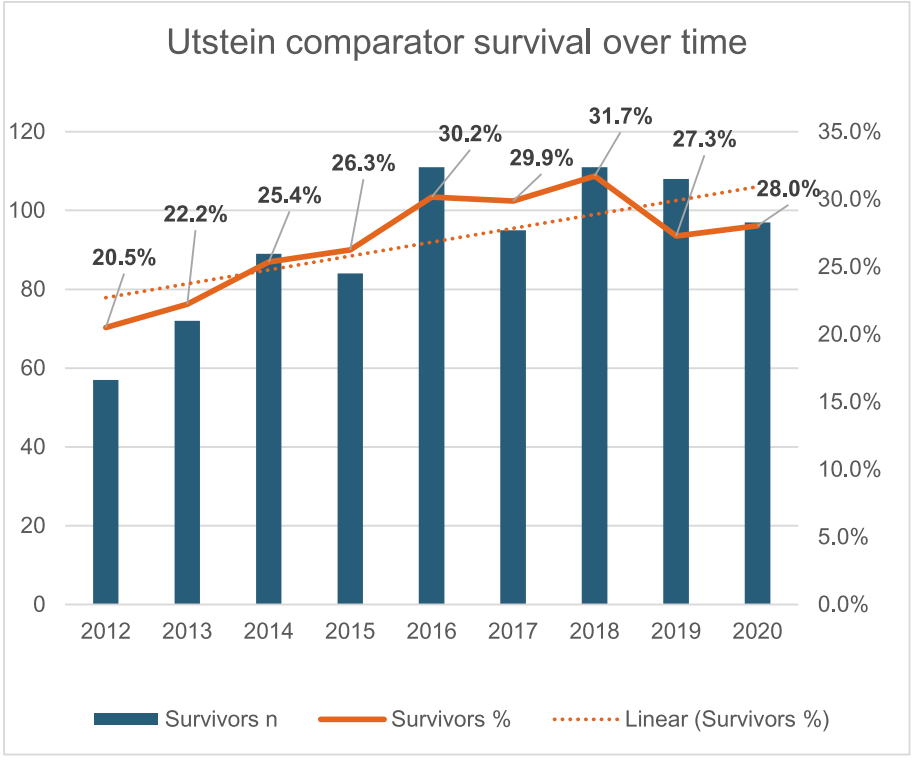

Fig. 2 – *Utstein Comparator Group 2012–2020:* Survival – absolute number(s), and proportion(s) over time.

Table 1a – Utstein Comparator Group 2012–2020: Summary of categorical variables.

Variable	Missing		Categories			Outcome Available	Survival to discharge		Outcome Available	Bystander CPR		Outcome Available	Bystander Defibrillation	
	n	%		n	%	n	n	%	n	n	%	n	n	%
Survived to Hospital Discharge	41	1.3	Did not Survive	2227	73.0%									
			Survived	824	27.0%									
			Total	3051	100.0%									
Chest Compressions Started By	33	1.1	EMS initiated CPR	372	12.16%	363	61	16.8						
			Bystander CPR	2687	87.84%	2658	752	28.3						
			Total	3059	100.00%									
First Shock Delivered By	26	0.8	EMS Defibrillation	2091	68.2%	2060	469	22.8						
			Bystander Defibrillation	926	30.2%	917	344	37.5						
			Not Applicable*	49	1.6%	48	4	8.3						
			Total	3066	100.0%									
Sex	3	0.1	Male	2487	80.5%	2455	685	27.9	2462	2176	88.4%	2437	777	31.9%
			Female	602	19.5%	595	139	23.4	594	509	85.7%	577	148	25.6%
			Total	3089	100.00%									
Incident location	17	0.5	Other Location	1442	46.89%	1412	520	36.8	1428	1313	91.9%	1409	654	46.4%
			Home Location	1633	53.11%	1623	301	18.5	1614	1359	84.2%	1591	269	16.9%
			Total	3075	100.00%									
Time of Day	0	0	Other (07.00–22:59 h)	2595	83.9%	2557	709	27.7	2567	2252	87.7%	2553	828	32.4%
			Night (23:00–6:59 h)	497	16.1%	494	115	23.3	492	435	88.4%	484	98	20.2%
			Total	3092	100.0%									
Urban or Rural	144	4.7	Urban Location	1978	67.1%	1947	575	29.5	1954	1673	85.6%	1925	499	25.9%
			Rural Location	970	32.9%	965	199	20.6	961	884	92.0%	951	373	39.2%
			Total	2948	100.0%									
Weekday or Weekend	0	0	Weekday	2137	69.1%	2108	583	27.7	2115	1853	87.6%	2084	661	31.7%
			Weekend	955	30.9%	943	241	25.6	944	834	88.3%	933	265	28.4%
			Total	3092	100.0%									
Covid Period	0	0	Other	2741	88.6%	2705	727	26.9	2709	2360	87.1%	2673	800	29.9%
			Covid Period (2020)	351	11.4%	346	97	28.0	350	327	93.4%	344	126	36.6%
			Total	3092	100.0%									

Table 1b – Utstein Comparator Group Survival 2012–2020: Summary of continuous variables.

Variable	Available Cases	Missing		**Mean**	**SD**	Available Cases	Missing		**Mean**	**SD**	Available Cases	Missing		**Mean**	**SD**
		n	%	*Median*	*IQR*		*n*	*%*	*Median*	*IQR*		*n*	*%*	*Median*	*IQR*
	All					**Survivors**					**Non– Survivors**				
	3054	38	1.2%	**63.3**	**15.5**	818	6	0.7%	**58.1**	**15.6**	2202	25	1.1%	**65.3**	**14.9**
Age (Years)				*65.0*	*54.0–75.0*				*59.0*	*49.8–69.0*				*67.0*	*56.0–77.0*
Call Response (Mins)	3014	78	2.5%	**14.0**	**8.0**	797	27	3.3%	**12**	**8.0**	2178	49	2.2%	**14.0**	**8.0**
				12.0	*8.0–18.0*				*10.0*	*7.0–15.0*				*13.0*	*8.0–19.0*
Shocks Delivered	2895	197	6.4%	**4.8**	**4.1**	788	36	4.4%	**3.1**	**2.5**	2070	157	7.0%	**5.4**	**4.5**
				4.0	*2.0–7.0*				*2.0*	*1.0–4.0*				*4.0*	*2.0–7.3*
						Bystander CPR					**EMS Initiated CPR**				
Age (Years)						2655	32	1.2%	**63.3**	**15.4**	367	5	1.3%	**63.3**	**15.9**
									65.0	*54.0–75.0*				*65.0*	*53.0–75.0*
Call Response (Mins)						2631	56	2.1%	**14**	**9.0**	352	20	5.4%	**11.0**	**8.0**
									12.0	*8.0–19.0*				*9.0*	*7.0–13.0*
						Bystander Defibrillation					**EMS Initiated Defibrillation**				
Age (Years)						921	5	0.5%	**63.0**	**15.7**	2059	32	1.5%	**63.3**	**15.4**
									64.0	*54.0–75.0*				*65.0*	*53.0–75.0*
Call Response (Mins)															
						901	25	2.7%	**16**	**9.0**	2039	52	2.5%	**12.0**	**8.0**
									15.0	*9.0–22.0*				*11.0*	*7.0–16.0*

the absolute number and proportion of survivors to hospital discharge in the Utstein comparator group over time. It demonstrates that both the absolute number and proportion of survivors in this group trended upwards over time. Table 1a summarises the categorical predictor variables considered in this study, while Table 1b summaries continuous variables. The proportion of missing data across each variable is provided and ranged from 0.0% across a number of variables to 6.4% in the variable 'number of shocks delivered'. Tables 1a and 1b also provide a comparison of the bystander CPR, bystander defibrillation and survival proportions across different variable categories and a comparison of continuous variable summary statistics for these outcomes. Of note, in the variable 'first shock delivered by', 49 cases were coded as 'not applicable'. As it was not clear why this was the case, these 49 cases were treated as missing data for the purposes of the regression analysis.

Most cases were male (80.5%, 2487/3089) and over two thirds (67.1%, 1,978/2,948) occurred in an urban location. Just over half of events occurred at home (53.1%, 1633/3075). Most cases had bystander CPR (87.8%, 2687/3059) and 30.2% had bystander defibrillation (926/3066). Of 923 patients know to have had bystander defibrillation, 918 (99.5%) also had bystander CPR. (Complete data on both bystander CPR and defibrillation available for 2992 patients. The overall median age was 65.0 years (IQR 54.0 – 75.0 years) while the median call response interval was 12.0 min (IQR 8.0–18.0 min). The median number of shocks delivered was 4.0 (IQR 2.0–7.0). In total 27.0% of all valid cases (824/3051) survived to hospital discharge.

Table 2. demonstrates the results of the Utstein Comparator Group logistic regression analysis of survival to discharge. In univariate analysis most of the thirteen predictor variables were associated with statistically significant p-values. The exceptions were 'weekday or weekend', and the 'COVID period'. In multivariable analysis eight of the independent variables in the model were significantly associated with survival (or non-survival) to hospital discharge. These were age in years (AOR 0.97, 95% CI 0.96, 0.98), home location (AOR 0.55, 95%CI 0.44 0.68), rural location (AOR 0.73, 95%CI 0.58, 0.92), bystander CPR (AOR 1.57, 95%CI 1.11, 2.22), bystander defibrillation (AOR 1.78, 95%CI 1.42, 2.24), call response interval (AOR 0.97, 95%CI 0.94, 0.98), total number of shocks (AOR 0.81, 95%CI 0.78, 0.84), and advancing year (AOR 1.05, 95%CI 1.00, 1.10). Table 2. also illustrates that the results of multivariable complete case and multiple imputation analysis demonstrated similar results.

Table 3 demonstrates the results of the Utstein Comparator Group logistic regression analysis of bystander CPR. In univariate analysis five of the nine predictor variables were associated with statistically significant p-values. The exceptions were 'age', 'sex' 'weekday or weekend', and 'time of day'. In multivariable analysis four of the independent variable predictors in the model were significantly associated with bystander CPR. These were home location (AOR 0.42, 95% CI 0.32, 0.54), rural location (AOR 1.65, 95%CI 1.23 2.23), call response interval (AOR 1.04, 95%CI 1.02, 1.06), and year (AOR 1.23, 95%CI 1.16, 1.30). Table 3 illustrates that the results of multivariable complete case and multiple imputation analysis demonstrated similar results.

Table 4. demonstrates the results of the Utstein Comparator Group logistic regression analysis of bystander defibrillation. In univariate analysis seven of the nine predictor variables were associated with statistically significant p-values. The exceptions were age and 'weekday or weekend'. In multivariable analysis four of the independent variable predictors in the model were significantly associated with bystander defibrillation. These were home location (AOR 0.17, 95% CI 0.14, 0.21), rural location (AOR 1.59, 95%CI 1.30 1.95), call response interval (AOR 1.06, 95%CI 1.05, 1.08), and year (AOR 1.17, 95%CI 1.12, 1.23). Table 4 illustrates that the results of multivariable complete case and multiple imputation analysis demonstrated similar results with the exception of weekend (AOR 0.80, 95%CI 0.66, 0.97) which was significantly associated with the outcome in sensitivity analysis.

Discussion

The aim of this study was to describe the Utstein comparator group in Ireland over 2012–2020 and to model predictors of key OHCA outcomes (bystander CPR, bystander defibrillation and survival to hos-

Table 2 – Utstein Comparator Group Survival 2012–2020: Logistic regression analysis.

	Univariate Analysis				Multiple Logistic Regression							
					Complete Case Analysis				*Multiple Imputation*			
	Odds Ratio	95% Confidence Intervals		p-value	Odds Ratio	95% Confidence Intervals		p-value	Odds Ratio	95% Confidence Intervals		p-value
Age	0.971	0.965	0.976	<0.001	0.970	0.964	0.976	<0.001	0.969	0.964	0.975	<0.001
Female	0.788	0.639	0.971	0.025	0.858	0.667	1.104	0.233	0.836	0.663	1.054	0.131
Home Location	0.391	0.331	0.461	<0.001	0.548	0.442	0.679	<0.001	0.527	0.434	0.641	<0.001
Rural Location	0.620	0.516	0.745	<0.001	0.733	0.584	0.921	0.008	0.760	0.613	0.943	0.013
Bystander CPR	1.953	1.465	2.605	<0.001	1.570	1.113	2.215	0.010	1.651	1.189	2.293	0.003
Bystander Defibrillation	2.037	1.720	2.411	<0.001	1.779	1.415	2.237	<0.001	1.768	1.433	2.180	<0.001
Call Response Interval	0.965	0.953	0.976	<0.001	0.965	0.942	0.976	<0.001	0.965	0.953	0.976	<0.001
Total Number of Shocks	0.813	0.788	0.839	<0.001	0.810	0.782	0.840	<0.001	0.819	0.793	0.847	<0.001
Weekend	0.898	0.754	1.069	0.227	0.945	0.766	1.167	0.601	0.938	0.773	1.138	0.514
Night (23:00–6:59 h)	0.791	0.631	0.991	0.042	0.914	0.695	1.202	0.521	0.898	0.696	1.159	0.408
Year	1.051	1.018	1.084	0.002	1.050	1.002	1.099	0.040	1.043	1.000	1.088	0.049
Covid Period (2020)	1.060	0.826	1.360	0.648	0.827	0.579	1.181	0.295	0.882	0.637	1.223	0.452

Table 3 – Utstein Comparator Group 2012–2020: Logistic regression bystander CPR.

	Univariate Analysis				Multiple Logistic Regression							
					Complete Case				*Multiple Imputation*			
	Odds Ratio	95% Confidence Intervals		p-value	Odds Ratio	95% Confidence Intervals		p-value	Odds Ratio	95% Confidence Intervals		p-value
Age	1.000	0.993	1.007	0.972	1.002	0.994	1.010	0.624	1.001	0.994	1.008	0.795
Female	0.787	0.606	1.021	0.072	0.889	0.669	1.182	0.418	0.930	0.708	1.223	0.605
Home Location	0.467	0.37	0.589	<0.001	0.418	0.322	0.542	<0.001	0.386	0.300	0.497	<0.001
Rural Location	1.928	1.479	2.513	<0.001	1.654	1.225	2.232	0.001	1.673	1.250	2.237	<0.001
Call Response Interval	1.049	1.030	1.062	<0.001	1.043	1.024	1.055	<0.001	1.043	1.024	1.062	<0.001
Weekend	1.072	0.846	1.359	0.566	1.027	0.792	1.330	0.842	1.042	0.816	1.331	0.741
Night (23:00–6:59 h)	1.067	0.791	1.441	0.67	1.339	0.960	1.868	0.086	1.347	0.981	1.848	0.065
Year	1.204	1.152	1.259	<0.001	1.229	1.163	1.298	<0.001	1.231	1.168	1.298	<0.001
Covid Period (2020)	2.102	1.357	3.256	<0.001	0.805	0.472	1.371	0.424	0.856	0.510	1.435	0.555

Table 4 – Utstein Comparator Group 2012–2020: Logistic regression bystander defibrillation.

	Univariate Analysis				Multiple Logistic Regression							
					Complete Case				*Multiple Imputation*			
	Odds Ratio	95% Confidence Intervals		p-value	Odds Ratio	95% Confidence Intervals		p-value	Odds Ratio	95% Confidence Intervals		p-value
Age	0.999	0.994	1.004	0.638	1.000	0.994	1.006	0.895	1.001	0.995	1.007	0.750
Female	0.737	0.600	0.905	0.004	0.927	0.728	1.180	0.539	0.951	0.758	1.192	0.660
Home Location	0.235	0.199	0.278	<0.001	0.172	0.141	0.210	<0.001	0.185	0.153	0.224	<0.001
Rural Location	1.844	1.563	2.176	<0.001	1.593	1.303	1.946	<0.001	1.628	1.340	1.977	<0.001
Call Response Interval	1.049	1.043	1.062	<0.001	1.062	1.049	1.075	<0.001	1.062	1.062	1.062	<0.001
Weekend	0.854	0.721	1.012	0.068	0.844	0.691	1.031	0.097	0.800	0.658	0.972	0.025
Night (23:00–6:59 h)	0.523	0.413	0.662	<0.001	0.824	0.628	1.082	0.165	0.771	0.590	1.007	0.056
Year	1.106	1.073	1.141	<0.001	1.173	1.123	1.226	<0.001	1.164	1.117	1.214	<0.001
Covid Period (2020)	1.353	1.07	1.711	0.011	0.899	0.648	1.248	0.525	0.873	0.640	1.192	0.394

pital discharge) in this group. The research incorporated nine years of national out-of-hospital cardiac arrest registry data and included 3,092 cases representing the Utstein comparator group. In turn this group represented 17% of all OHCA after excluding EMS witnessed cases. Notably the proportion of OHCA representing the Utstein comparator group appears to be declining over time in Ireland. As the Utstein comparator is the group most likely to survive OHCA, this has implications for how overall OHCA survival at population level is considered. Indeed, reported proportions of initial shockable OHCA have declined worldwide.[23]

During this current study period survival in the Utstein comparator group was 27.0% and both the absolute number and proportion of survivors in the group increased over time. Over the period 87.8% of Utstein comparator group patients had bystander CPR and 30.2% had bystander defibrillation. Logistic regression analysis demonstrated average yearly improvements in bystander CPR, defibrillation, and survival. In turn bystander CPR was associated with a 57% increase, while bystander defibrillation was associated with a 78% increase in the adjusted odds of survival to hospital discharge. It is important to highlight both the high proportion of Utstein comparator group bystander CPR in Ireland, and in addition the observation that most patients who received bystander defibrillation also received bystander CPR. Thus, the effect estimates for bystander defibrillation can be interpreted as an additional benefit of defibrillation in those already receiving CPR. Ultimately the results support the assertion that the efficiency of the OHCA care system in Ireland has improved over time with notable increases in bystander CPR and defibrillation in a critical group of patients who are most likely to benefit from these treatments. Furthermore, the results suggest that system developments and care process improvements have translated to improved patient outcomes in the Utstein comparator group.

International OHCA guidelines have previously suggested that bystander CPR can triple survival.[24] The Utstein comparator group studied in this research is likely to have been a group who were sensitive to the positive effects of bystander CPR. Thus, while bystander CPR remains vitally important, it may be that its independent real effect is somewhat more modest than has been previously suggested. The analysis in this current research is however based on a limited binary concept of bystander CPR as the available data captured only whether bystander CPR was performed and not who performed it or any measure of its quality. At national level Ireland

already has high levels of bystander CPR and thus in future the issue of the timeliness of bystander CPR commencement and whether some assessment of the quality of bystander CPR can be made warrant consideration.[13] Beyond this point, the study results highlight that bystander defibrillation is one of the strongest independent predictors of survival to hospital discharge. Thus, increasing the overall level of bystander defibrillation should remain a principal component of the Irish strategy to increase OHCA survival. Previously, a national public access defibrillation (PAD) programme was proposed in Ireland. However, a cost effectiveness analysis commissioned by the health ministry at the time did not support its roll out.[4] The analysis did however suggest that targeted AED deployment coupled with public education and a national EMS linked AED registry could render a future PAD programme cost effective.[4] A national level EMS linked AED registry is now in development. Scientific evidence suggests that community first response initiatives can increase bystander CPR and defibrillation and further demonstrates how modern smart phone alerting technology can contribute to 'crowd sourced' CPR and defibrillation.[24–26] Although community first response schemes are already well established in Ireland, further expansion possibly including crowd sourced elements should now be considered, while in parallel integrating smart technology which can increase the efficiency of response systems.[17,24] Any such developments must be underpinned by a robust national AED registry.

In this study the adjusted odds of both bystander CPR and defibrillation were higher in rural areas, despite decreased survival in these communities when compared to urban areas. Furthermore, OHCA that occurred at home was associated with decreased odds of bystander CPR, bystander defibrillation and survival to hospital discharge. These observations raise several issues. Over half of all OHCA in this study occurred at home. A previous systematic review found that prearrest comorbidity was generally associated with reduced survival following OHCA.[27] Home location may have been associated with increased comorbidity versus OHCA in other locations thus possibly explaining some of the disparity in survival outcome. Information concerning patient comorbidities is not available via OHCAR currently and thus further research is needed to explore whether a relationship between home location and a higher burden of comorbidity exists. Even if such a relationship exists though, the chances of bystander CPR and defibrillation remain lower at home locations in Ireland. Thus, any initiative which could increase bystander CPR and defibrillation when OHCA occurs at home holds the promise of increasing OHCA survival in Ireland. The observation that rural location was associated with a reduction in the adjusted odds of survival in this study is in keeping with a recent systematic review that concluded that OHCA survival was lower in rural areas.[28] Exceptions to this observation have however been reported.[29] Our previous research that looked at predictors of survival at overall OHCA population level also found an urban–rural discrepancy.[11] One third of all patients in the Utstein comparator group had their OHCA in a rural area and thus it is important to explore the factors that are driving this survival disparity. In contrast though, in Ireland the chances of receiving bystander CPR and bystander defibrillation are lower in urban areas even after adjusting for other relevant factors including EMS response time. This is true both at overall OHCA population level and for the Utstein comparator subgroup. Increasing bystander CPR and defibrillation for patients with witnessed OHCA and initial shockable rhythms in urban areas should be an immediate priority as it is highly likely that this could yield a further increase in OHCA survival in Ireland.

Conclusions

Bystander CPR, bystander defibrillation and survival to hospital discharge have increased in the Utstein comparator group during 2012–2020 in Ireland. Bystander CPR and defibrillation remain key modifiable health systems targets to increase overall OHCA survival.

CRediT authorship contribution statement

Tomás Barry: Writing – review & editing, Writing – original draft, Validation, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Garrett Green:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis. **Martin Quinn:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Conor Deasy:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis. **Gerard Bury:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis. **Siobhan Masterson:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Andrew W Murphy:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation.

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.

Acknowledgements

TB acknowledges funding support from the Health Research Board (CSF-2020-006)

AWM acknowledges funding support from the National Ambulance Service.

The authors acknowledge the assistance of colleagues from the National Ambulance Service and Irish Heart Foundation who assisted the study team in ensuring a comprehensive understanding of relevant health system developments pertinent to OHCA care over this study's period of concern.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resplu.2024.100851.

Author details

on behalf of the Out-of-Hospital Cardiac Arrest Registry Steering Group [a]*School of Medicine, University College Dublin, Ireland* [b]*School of Mathematics and Statistics, University College Dublin, Dublin, Ireland* [c]*Out-of-Hospital Cardiac Arrest Register, National Ambulance Service, Health Services Executive* [d]*Professor of Emergency Medicine, School of Medicine, University College Cork, Cork, Ireland* [e]*Emeritus Professor of General Practice, University College Dublin, Ireland* [f]*Clinical Strategy and Evaluation,*

Health Services Executive, National Ambulance Service, Ireland[g] *Foundation Professor of General Practice, Discipline of General Practice, University of Galway, Galway, Ireland*

REFERENCES

1. CSO. Census of Population 2022 - Summary Results 2023 [cited 2023 13/07/2023]. Available from: https://www.cso.ie/en/statistics/population/censusofpopulation2022/censusofpopulation2022-summaryresults/.
2. OHCAR. National Ambulance Service, Out-of-Hospital Cardiac Arrest Register, 16th Annual Report 2023. 2024.
3. Barry T, Kasemiire A, Quinn M, et al. Outcomes of out-of-hospital cardiac arrest in Ireland 2012-2020: Protocol for an observational study. HRB Open Research. 2023;6:17.
4. Moran PS, Teljeur C, Masterson S, O'Neill M, Harrington P, Ryan M. Cost-effectiveness of a national public access defibrillation programme. Resuscitation 2015;91:48–55.
5. Masterson S, Teljeur C, Cullinan J, Murphy AW, Deasy C, Vellinga A. Out-of-hospital cardiac arrest in the home: Can area characteristics identify at-risk communities in the Republic of Ireland? Int J Health Geogr 2018;17(1):6.
6. Masterson S, Wright P, O'Donnell C, et al. Urban and rural differences in out-of-hospital cardiac arrest in Ireland. Resuscitation 2015;91:42–7.
7. Barry T, Conroy N, Headon M, et al. The MERIT 3 project: Alerting general practitioners to cardiac arrest in the community. Resuscitation 2017;121:141–6.
8. Barry T, Headon M, Quinn M, et al. General practice and cardiac arrest community first response in Ireland. Resuscitation Plus 2021;6:100127.
9. Tanner R, Masterson S, Galvin J, et al. Out-of-hospital cardiac arrests in the young population; a 6-year review of the Irish out-of-hospital cardiac arrest register. Postgrad Med J 2021;97 (1147):280–5.
10. Tanner R, Masterson S, Jensen M, et al. Out-of-hospital cardiac arrests in the older population in Ireland. Emerg Med J 2017;34 (10):659–64.
11. Barry T, Kasemiire A, Quinn M, et al. Resuscitation for out-of-hospital cardiac arrest in Ireland 2012–2020: Modelling national temporal developments and survival predictors. Resusc Plus 2024;18:100641.
12. Perkins GD, Jacobs IG, Nadkarni VM, et al. Cardiac Arrest and Cardiopulmonary Resuscitation Outcome Reports: Update of the Utstein Resuscitation Registry Templates for Out-of-Hospital Cardiac Arrest A Statement for Healthcare Professionals From a Task Force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian and New Zealand Council on Resuscitation, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Southern Africa, Resuscitation Council of Asia); and the American Heart Association Emergency Cardiovascular Care Committee and the Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. Circulation 2015;132(13):1286–300.
13. Gräsner JT, Wnent J, Herlitz J, et al. Survival after out-of-hospital cardiac arrest in Europe - Results of the EuReCa TWO study. Resuscitation 2020;148:218–26.
14. Heffernan E, Keegan D, Clarke B, et al. Quality improvement in a crisis: a qualitative study of experiences and lessons learned from the Irish National Ambulance Service response to the COVID-19 pandemic. BMJ Open 2022;12(1)e057162.
15. Scquizzato T, D'Amico F, Rocchi M, et al. Impact of COVID-19 Pandemic on Out-of-Hospital Cardiac Arrest System-of-Care: A Systematic Review and Meta-Analysis. In: Prehospital Emergency Care : Official Journal of the National Association of EMS Physicians and the National Association of State EMS Directors. p. 1–12.
16. Teoh SE, Masuda Y, Tan DJH, et al. Impact of the COVID-19 pandemic on the epidemiology of out-of-hospital cardiac arrest: a systematic review and meta-analysis. Ann Intensive Care 2021;11 (1).
17. Barry T, Gonzalez A, Conroy N, et al. Mapping the potential of community first responders to increase cardiac arrest survival. 2018.
18. PHECC. Pre-Hospital Emergency Care Council; What We Do 2021 [Available from: https://www.phecit.ie/PHECC/What_we_do/PHECC/What_we_do/What_we_do.aspx?hkey=ad21b38b-ae2b-4bf4-85da-9e0abecde29f.
19. PHECC. Clinical Practice Guidelines, Advanced Paramedic. Kildare; 2021 August 2021.
20. Jacobs I, Nadkarni V, Bahr J, et al. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries. Resuscitation 2004;63(3):233–49.
21. Nolan JP, Maconochie I, Soar J, et al. Executive summary: 2020 international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Circulation 2020;142(16_suppl_1):S2–S27.
22. Barry T. Resuscitation for out-of- hospital cardiac arrest in Ireland 2012 -2020: Modelling national temporal developments and survival predictors. Resusc Plus 2024.
23. Hulleman M, Zijlstra JA, Beesems SG, et al. Causes for the declining proportion of ventricular fibrillation in out-of-hospital cardiac arrest. Resuscitation 2015;96:23–9.
24. Semeraro F, Greif R, Böttiger BW, et al. European resuscitation council guidelines 2021: systems saving lives. Resuscitation 2021;161:80–97.
25. Barry T, Doheny MC, Masterson S, et al. Community first responders for out-of-hospital cardiac arrest in adults and children. Cochrane Database Syst Rev 2019;7:Cd012764.
26. Scquizzato T, Belloni O, Semeraro F, et al. Dispatching citizens as first responders to out-of-hospital cardiac arrests: a systematic review and meta-analysis. Eur J Emerg Med 2022;29(3):163–72.
27. Majewski D, Ball S, Finn J. Systematic review of the relationship between comorbidity and out-of-hospital cardiac arrest outcomes. BMJ Open 2019;9(11)e031655.
28. Smith A, Masters S, Ball S, Finn J. The incidence and outcomes of out-of-hospital cardiac arrest in metropolitan versus rural locations: A systematic review and meta-analysis. Resuscitation 2023;185:109655.
29. Ringgren KB, Kragholm KH, Lindgren FL, et al. Out-of-hospital cardiac arrest: Does rurality decrease chances of survival? Resusc Plus 2022;9:100208.