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Title	Out-of-hospital cardiac arrest attended by ambulance services in Ireland: first 2 years' results from a nationwide registry
Author(s)	Masterson, Siobhán; Cullinan, John; McNally, Bryan; Deasy, Conor; Murphy, Andrew; Wright, Peter; O'Reilly, Martin; Vellinga, Akke
Publication Date	2016-10-20
Publication Information	Masterson, Siobhán, Cullinan, John, McNally, Bryan, Deasy, Conor, Murphy, Andrew, Wright, Peter, O'Reilly, Martin, Vellinga, Akke. (2016). Out-of-hospital cardiac arrest attended by ambulance services in Ireland: first 2 years' results from a nationwide registry. Emergency Medicine Journal, 33(11), 776-781. doi: 10.1136/emermed-2015-205107
Publisher	BMJ Publishing Group
Link to publisher's version	http://dx.doi.org/10.1136/emermed-2015-205107
Item record	http://hdl.handle.net/10379/6607
DOI	http://dx.doi.org/10.1136/emermed-2015-205107

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Title: Out-of-Hospital Cardiac Arrest Attended by Ambulance Services in Ireland: First Two Year Results from a Nationwide Registry.

Corresponding Author: Ms. Siobhán Masterson, Discipline of General Practice, Distillery Road, National University of Ireland Galway, Galway, Co. Galway.
Email: siobhan.masterson@hse.ie
Tel: 00 353 87 2773912
Fax: None

Co-Authors:
- Dr. John Cullinan, School of Business and Economics, National University of Ireland Galway, Galway, Ireland
- A/Prof. Bryan McNally, School of Medicine, Emory University, Atlanta, United States
- A/Prof. Conor Deasy, Medical Directorate, National Ambulance Service, Naas, Ireland and Department of Emergency Medicine, Cork University Hospital, Cork, Ireland
- Prof. Andrew Murphy, School of Medicine, National University of Ireland Galway, Galway, Ireland
- Dr. Peter Wright, Department of Public Health Medicine, Health Service Executive, Ballyshannon, Ireland
- Mr. Martin O'Reilly, EMS Support Unit, Dublin Fire Brigade, Dublin, Ireland
- Dr. Akke Vellinga, School of Medicine, National University of Ireland Galway, Galway, Ireland.

Keywords:
Prehospital care, resuscitation, cardiac arrest

Word Count: 3,241.

Contributorship
S Masterson performed data analysis and drafted the text of the manuscript. J Cullinan co-supervised SM writing and read and reviewed manuscript drafts. C Deasy contributed to the introduction and discussion text. M O'Reilly contributed to the methods section. P Wright contributed to the discussion section. A Murphy contributed to the discussion and conclusion sections. B McNally reviewed text and advised on data analysis. A Vellinga co-supervised SM drafting of text, contributed to manuscript text, instructed on data analysis plan and checked results.

Funding
S Masterson is funded by the Health Professionals Fellowship Award from the Health Research Board, Ireland (HPF-2014-609).

Competing Interests
None to declare. Dr. McNally reports grants from American Red Cross, the American Heart Association, Medtronic Philanthropy and Zoll Corporation, outside the submitted work.

Abstract

Background: National data collection provides information on out-of-hospital cardiac arrest (OHCA) incidence, management and outcomes that may not be generalisable from smaller studies. This retrospective cohort study describes the first two years' results from the Irish National Out-of-Hospital Cardiac Arrest Register (OHCAR).
Methods: Data on OHCAs attended by Emergency Medical Services where resuscitation was attempted (EMS-treated) was collected from ambulance services and entered onto OHCAR. Descriptive analysis of the study population was performed, and regression analysis was performed on the subgroup of adult patients with a bystander-witnessed event of presumed cardiac aetiology and an initial shockable rhythm (Utstein Group).
Results: 3,701 EMS-treated OHCAs were recorded for the study period (01/01/2012 – 31/12/2013). Incidence was 39/100,000 population per year. In the Utstein Group (n=577), compared to the overall group, there was a higher proportion of male patients, public event location, bystander cardiopulmonary resuscitation and early defibrillation. Median EMS call-response interval was similar in both groups. A higher proportion of patients in the Utstein Group achieved return of spontaneous circulation (ROSC) (35% vs. 17%) and survival to hospital discharge (22% vs. 6%). After multivariate adjustment for the Utstein Group, the following variables were found to be independent predictors of the outcome survival to hospital discharge: public event location (OR 3.1 (95%CI 1.9-5.0)); Bystander CPR (2.4 (95% CI 1.2-4.9)); EMS response of eight minutes or less (2.2 (95%CI 1.3-3.6)).
Conclusion: This study highlights the role of nationwide registries in quantifying, monitoring and benchmarking OHCA incidence and outcome, providing baseline data upon which service improvement effects can be measured.

What is already known on this subject?

1. Data from OHCA studies that are carried out in small populations or single communities may not be generalisable to entire countries.
2. Comprehensive national data collection is required for monitoring of nationwide OHCA incidence management and outcomes

What this study adds

Our study describes Irish OHCA incidence and outcomes and shows that nationwide OHCA data collection in a population of 4.6million is feasible and sustainable.

Introduction

While studies of single communities provide data on out-of-hospital cardiac arrest (OHCA) outcome, nationally representative data is essential in monitoring national trends in OHCA survival (1). In Europe and North America, over 575,000 cases of OHCA occur annually and the clinical and societal impact of OHCA is such that the American Heart Association has recommended that it be classified as a reportable disease (2). In the absence of rapid recognition, good quality cardiopulmonary resuscitation (CPR) and early defibrillation, there is a negligible prospect of survival from OHCA (3).

Reported incidence of and outcomes from OHCA vary widely internationally. The reasons for this variation include: variation in age and gender distribution; levels of urbanisation; bystander cardiopulmonary resuscitation; availability of community defibrillators; and configuration of Emergency Medical Services (EMS) (4-6). Inter-country differences are affected by these factors but are also complicated by variation in study sample definition and denominator (7). This is despite the widespread acceptance and use of the Utstein criteria for OHCA data collection (8).

The Irish National Out-of-Hospital Cardiac Arrest Register (OHCAR) was established in 2007 to provide data to estimate the incidence and survival of OHCA in Ireland with the aspiration of improving it. OHCAR is funded by the National Ambulance Service and Prehospital Emergency Care Council. It is administered and academically supported by the National University of Ireland, Galway and hosted by the Department of Public Health Medicine in the National Health Service Executive (HSE). In 2012, OHCAR achieved comprehensive national data collection (9).

Within this context, the aim of this paper is to provide an overview of the first two years of comprehensive Irish data collection and describe the incidence, key interventions and survival outcomes for OHCA attended by ambulance services where resuscitation was attempted (EMS treated OHCA) in the Republic of Ireland. In line with the Utstein Guidelines and as recommended by Chamberlain and Eisenberg, we focus our analysis on the subgroup of adult patients, with presumed cardiac aetiology, with a bystander-witnessed event and an initial shockable rhythm (Utstein Group) (10).

Methods

In Ireland, 62% of the total population of 4.6 million lives on 2.4% of the total land area (11). The remaining population are dispersed in low density settlements across the country. In Dublin city and county the National Ambulance Service (NAS) and the Dublin Fire Brigade (DFB) provide the statutory EMS response while throughout the rest of the country statutory ambulance services are solely provided by the NAS. All pre-hospital emergency practitioners who work for statutory ambulance services must be registered with the Pre-Hospital Emergency Care Council (PHECC). Practitioners use Clinical Practice Guidelines (CPGs) to inform decisions not to resuscitate or cease resuscitation (12). Emergency Medical Technicians (EMTs) and Emergency First Responders (EFRs) are trained in basic life support including automated external defibrillator (AED) use. Paramedics can perform supraglottic airway placement and Advanced Paramedics are additionally trained to intubate in cardiac arrest situations, attempt manual defibrillation and administer cardiac resuscitation drugs. All ambulance vehicles are staffed with Paramedics and/or Advanced Paramedics. For cardiac arrest calls the DFB also deploy practitioners on fire engines. Community response to OHCA in Ireland varies. In some areas, the community response depends on the training and willingness of people to perform basic life support and the opportunistic availability of AEDs in the vicinity of the event. In other areas the level of response is highly organised and coordinated by voluntary Community First Responder (CFR) programs. Irish general practitioners, primarily in some rural areas and some county fire services also respond to OHCA at the request of the NAS (13).

Statutory ambulance services in Ireland use a standardised Patient Care Report (PCR) which includes an 'OHCA' section for Utstein required data. For incidents attended by the DFB, all PCRs are received at a central location where PCRs for OHCAR incidents are manually identified. Data from each OHCAR incident is entered onto a Microsoft Access® database. Each incident is electronically linked to corresponding dispatch data and completed records are sent to OHCAR on a quarterly basis. Data is then checked to ensure compliance with OHCAR definitions as well as to avoid double entries.

In the rest of the country, immediately after attending an OHCA incident, NAS practitioners put completed PCRs for OHCAR incidents in specially provided envelopes. These PCRs are digitally processed at a central location and then electronically forwarded to OHCAR for case-by-case validation. Dispatch data is then added to all cases. In order to identify cases that may not have been placed in envelopes, missing case searches are performed in the NAS digital PCR archive. Outcome data is also obtained for patients brought to hospital.

Data for this study was anonymised and extracted from the OHCAR database for the study period.

Ethical Approval

Ethical approval for research using non-identifiable OHCAR data was obtained from the Research Ethics Committee, National University of Ireland, Galway.

Statistical Analysis

This is a retrospective cohort study of incidence, interventions and outcomes of EMS-treated OHCA in Ireland during 2012 and 2013. The reported population for 2012 and 2013 is described. To allow international comparisons and be in line with Utstein recommendations, a subgroup of patients was extracted which includes only adult patients with a bystander-witnessed OHCA, of presumed cardiac aetiology and an initial shockable rhythm (Utstein Group) (8). To ensure our data can be compared to data from other national registries, incidences per 100,000 population per year for the total group and the Utstein subgroup were age and sex standardised using the 2013 EUROSTAT population projections. In order to describe the difference in OHCA incidence according to age, age-adjusted incidence for the total group and Utstein subgroup is graphically presented. The key outcomes from our analysis are to calculate survival to discharge for the overall group and for the Utstein Group, and to determine predictors of survival in the Utstein Group.

An overview of differences between the total group and the Utstein group is presented. A variable was derived to represent the availability of early defibrillation using the following rule: (defibrillation attempted = yes AND (EMS response interval of five minutes or less OR defibrillation attempted before EMS arrival)). Analysis of predictors of survival was limited to the Utstein Group only.

Logistic regression analysis was performed to identify predictors of the main outcome of interest i.e. survival to hospital discharge. Variables were entered into the model based on: at least moderate univariate associations (p-value <0.15); validation of significance in previous literature; clinical relevance to support inclusion. Continuous variables i.e. age and ambulance response times were categorised for regression analysis. Calibration of the model was assessed using the Hosmer and Lemeshow χ^2 statistic ($p>0.05$). In order to assess the potential effect of loss to follow up, two potential scenarios were created: (i) assumed all missing cases had survived to hospital discharge (ii) assume all missing cases had died. Logistic regression analysis was repeated for both scenarios. Description and analysis of all cases of non-traumatic aetiology was also performed (see Tables S1 and S2 in the Supplementary Appendix).

Results

A total of 3,701 EMS-treated OHCAs were recorded for the study period (1,798 in 2012 and 1,903 in 2013). The overall incidence of EMS-treated OHCA was 39/100,000 population per year. The Utstein Group had an incidence of 6/100,000 population per year. Age-adjusted incidence was highest for overall cases in the 85+ age group, but peaked in the 70-74 year age category for the Utstein Group (Figure One).

Table 1: Overview of the differences in descriptive variables and outcome between All Cases and the Utstein Group

Characteristic	All Cases (n=3701)	Utstein Group (n=577)	Missing Variables
	(Median (IQR))	*(Median (IQR))*	*n (%)*
Age in years	67 (52-78)	65 (55-75)	107 (2.9)
EMS call-response interval*	12 (8-20)	12 (8-18)	235 (7.0)
	n (%)	*n (%)*	
Under 65 years	1602 (45)	278 (48)	107 (2.7)
Male	2479 (67)	453 (79)	4 (0.1)
Presumed Cardiac Aetiology	3199 (86)	577 (100)	0 (0.0)
Urban Setting	2306 (64)	321 (57)	92 (2.5)
Public Location	812 (22)	239 (42)	28 (0.8)
Initial Shockable Rhythm	850 (24)	577 (100)	86 (2.3)
Bystander witnessed	1934 (54)	577 (100)	144 (3.9)
EMS witnessed	213 (6)	0 (0)	144 (3.9)
Bystander witnessed and Bystander CPR**	1316 (70)	453 (80)	41 (2.1)
Defibrillation attempted	1302 (36)	575 (98)	104 (2.8)
Early defibrillation attempted***	297 (23)	180 (31)	0 (0.0)
EMS CRI eight minutes or less*	949 (27)	175 (32)	235 (7.0)
Outcome			
ROSC at any stage (n (%))	814 (23)	245 (44)	156 (4.2)
ROSC on arrival at hospital (n (%))	575 (17)	189 (35)	221 (6.0)
Survival to Hospital Discharge	216 (6)	124 (22)	30 (0.8)

*Excludes EMS witnessed cases. All cases (n=3488); Utstein Group (n=577)
**Includes only cases where the collapse was bystander-witnessed. All cases (n=1934); Utstein Group (n=577)
***Patients were defined as having received early defibrillation if defibrillation was attempted by a bystander or if the EMS call-response interval was five minutes or less. Includes only cases where defibrillation reported as attempted. All cases (n=1302); Utstein Group (n=575)
†Chi Square p value not ascertained for Utstein Group criteria
Abbreviations: EMS, emergency medical services; CPR, cardiopulmonary resuscitation; CRI, call-response interval; ROSC, return of spontaneous circulation.

For the overall group, 855 cases were missing one or more descriptive variables (23%) including 30 patients were lost to follow-up. In the Utstein group, nine patients were lost to follow-up. As shown in Table 1, 6% of all patients survived to hospital discharge, compared to 22% of patients in the Utstein group. Median age for all cases was 67 years (IQR 52-78 years), with the majority of patients aged over 65 years. Over half of patients (54%) had a bystander-witnessed arrest, and 70% of these patients received bystander CPR. Most cases were presumed to be of a cardiac

aetiology (86%). Trauma (including self harm and road traffic accidents) accounted for 7% of cases. Other causes included submersion and drug or alcohol overdose. The Utstein group comprised 15% of all cases (n=577). Patients in this subgroup were similar in age and gender to the overall group, but had higher percentage survival to discharge (22%) and better secondary outcomes i.e. Return of Spontaneous Circulation than the overall group. The Utstein Group also had higher proportions of publicly located events, bystander CPR, defibrillation attempted and a higher percentage of EMS call response within eight minutes.

Table 2: Regression Analysis for Utstein Group for the Outcome Survival to Discharge

	Outcome			
Variable	**Survived (n=106)**	**Died (n=396)**	**Model 1[a] (95% CI)**	**Model 2[b] (95% CI)**
Under 65 years	63	175	1.8 (1.2-2.9)*	1.6 (1.0-2.6)
Male	88	305	1.5 (0.8-2.6)	1.2 (0.6-2.2)
Urban Setting	71	219	1.6 (1.0-2.6)*	1.4 (0.9-2.3)
Public Location	70	131	3.9 (2.5-6.2)*	3.1 (1.9-5.0)*
Bystander CPR	95	310	2.4 (1.2-4.7)*	2.4 (1.2-4.9)*
Was shock delivered[c]	106	0	NA	NA
Early defibrillation attempted[d]	48	112	2.1 (1.4-3.3)*	1.4 (0.9-2.3)
EMS CRI eight minutes or less	47	104	2.2 (1.4-3.5)*	2.2 (1.3-3.6)*

[a]Univariate Analysis
[b]Multivariate Analysis
[c]The variable "Was shock delivered" was omitted from analysis as it is a constant i.e. shock delivered to all cases included in the analysis
[d]Patients were defined as having received early defibrillation if defibrillation was attempted by a bystander or if EMS defibrillation was attempted and the call-response interval was five minutes or less.
*Statistically significant
Abbreviations: CPR, cardiopulmonary resuscitation; EMS, emergency medical services; CRI, call-response interval

As shown in Figure Three, complete data was available for 502 of the 577 patients in the Utstein Group. Age under 65, collapse in an urban setting, collapse in a public location, bystander CPR, early defibrillation attempted, and an EMS response of eight minutes or less were all associated with patients' survival to discharge in the univariate analysis (Model 1). In the logistic regression model (Model 2)**,** public location of the OHCA incident (OR 3.1 (1.9-5.0)); bystander CPR (OR 2.4 (95%CI 1.2-5.0)) and EMS response time of eight minutes or less (OR 2.2 (1.3-3.6)) remained significant predictors of survival to discharge. Interactions between variables were not significant and omitted from the model. Data on outcome was missing for nine patients in the Utstein Group. The analysis was repeated using the assumption that (1) all missing cases had survived or (2) all missing cases had died. In both models, adjusted odds ratios for all variables remained similar.

Discussion:

Ireland is one of the few countries in Europe where nationwide reporting of OHCA is currently possible and a system has been developed that allows routinely collected data to be used to build a national register of OHCA capable of providing meaningful risk adjusted quality indicators. This paper provides a description of EMS-treated OHCA patients and their outcome in the Republic of Ireland during 2012 and 2013.

Our paper highlights the value of quality registries in describing, benchmarking and highlighting where challenges arise in care delivery and solutions hypothesised.

The incidence of OHCAR was 39/100,000 population/year. There is wide variation internationally in the reported incidence of OHCA varies from 19 to 141 per 100,000 population/year (7) suggesting variation in the threshold to commence CPR. The total number of incidents was similar in 2012 and 2013, suggesting internal consistency in case identification and incidence. The proportion of incidents that occurred in urban areas reflects the proportion of the Irish population that resides in urban areas. The age and gender profile of patients was very similar to other large studies of OHCA, as was the difference in median male and female ages (4, 15). The proportion of patients presumed to have suffered an arrest of cardiac aetiology is similar to North American data but high compared to other population-based studies of EMS-treated OHCA (15). This may be explained by the fact that in Ireland cardiac aetiology is presumed in the absence of documented evidence of any other probable cause and may be considered analogous to 'unknown cause'.

While the proportion of patients in our study with an initial shockable rhythm was 24%, there is significant variation in population-based studies, from 8.7% in Japan to 36% in North America (15,16).

Reported percentage survival to discharge globally varies from 0.8% to 25% in OHCA attended by ambulance services. At 6%, percentage survival in Ireland is low, but many other studies are region specific and do not reflect national survival. While there is considerable heterogeneity in the overall group, the Utstein subgroup includes patients who have been proven to benefit most from a resuscitation attempt i.e. adults, cardiac cause, bystander witnessed, initial shockable rhythm (8). Survival in the Utstein subgroup was 22% which is substantially lower than in other population-based studies where percentage survival of up to 52% has been achieved (17,18). Opportunities to strengthen the chain of survival in Ireland are being vigorously pursued.

In this study, we found that collapse in a public location, provision of bystander CPR and an EMS CRI of eight minutes or less were independent predictors of survival to hospital discharge. Our finding that collapse in a public location accounted for a three-fold increase in survival is not surprising and has been reported in other large scale registry-based studies (19,20).

The proportion of bystander CPR provided in bystander witnessed cases was high at 70% and even more impressive in the Utstein subgroup where bystander CPR was an independent predictor of survival. The proportion of bystander CPR provided is similar to countries and regions where percentage survival is higher than in Ireland (21, 22). Reliability of bystander CPR measurement is an issue for all OHCA registers but we believe the nationwide introduction of dispatch assisted CPR may help account for the high levels of bystander CPR observed in our study. Wissenberg *et al* observed an association between improved OHCA survival in Denmark and increased bystander CPR rates following national initiatives to increase bystander interventions (21). Our results indicate willingness amongst the Irish population to

attempt CPR and suggest that further extension of training initiatives may contribute to improved survival rates in Ireland.

An EMS CRI of eight minutes or less was also an independent predictor of survival. Identifying ways in which to minimise this interval are essential to improving Irish OHCA outcomes. In 2015 the NAS introduced 'ONELIFE', an extensive programme to improve OHCA outcomes within the NAS (23). As part of ONELIFE, dynamic deployment of EMS vehicles has been implemented and strategies to improve dispatcher OHCA recognition, incident location are currently being introduced.

For this study we derived a variable to represent early defibrillation and found that a minority of patients had access to early defibrillation. We had expected that early defibrillation would be a significant predictor of survival in multivariate analysis. Lack of significance may be because the derived variable overestimated the availability of early defibrillation, as we assumed that all defibrillation attempts before EMS arrival were made within minutes of collapse. This may not have been the case, particularly in more rural areas where travel times, even for first responders may be prolonged. Blom et al described how AED use was an independent predictor of survival in the Netherlands (24). In their study area AED use was tripled as a result of policy measures including: introduction of AED programmes for police teams (together with existing fire service response); implementation of a "6-minute time zone" and the introduction of a text alert system for registered volunteers. Structured AED programmes also have the advantage of efficiency as described by Ringh et al (22). They reported similar percentage survival as a result of 74 deployments from 5,016 public AEDs compared to 53 deployments out of a possible 135 first responder AEDs, suggesting that coordinated support of first responder programmes would be more cost efficient than mass implementation of public AEDs. In Ireland, voluntary groups, general practitioners and county fire services already provide a community response to OHCA. Extension and support of such schemes is considered an important way in which to reduce time to defibrillation.

Limitations

A substantial percentage of data was missing for the overall group, most notably resulting in 75 cases being omitted from the logistic regression analysis.In order to assess the impact of missing data, missing data imputation was performed for all cases and logistic regression analysis was repeated for the Utstein Group. The pooled results from regression analysis using imputed data did not differ significantly from the results found using original data (see Supplementary Table S3).

Thirty patients were lost to follow up. Most of these patients could not be traced due to unavailability of patient identification or poor legibility of PCRs. In our study, loss to follow up did not significantly affect results, but it remains an issue for OHCAR.

We presumed a cardiac cause in over 86% of OHCAR cases. This presumption may have led to misclassification bias (25). Classification of cases as ‘presumed cardiac’ was originally proposed by the Utstein Committee to create ‘case equivalency’, however such classification can be highly subjective (8) Reporting of EMS-treated cases of non-traumatic aetiology is a suggested way in which to decrease subjectivity and improve comparability of registries worldwide (please see supplementary data).

Conclusions

This study provides a nationwide description of EMS-treated OHCA in the Republic of Ireland. The incidence and demography of OHCA is similar to other population based studies. Initiatives to increase public education in CPR, support further implementation of community first responder programmes and continued quality improvement in the EMS are keys to improving OHCA outcomes. This nationwide profile provides the dashboard by which improvements can be measured.

Acknowledgements
The authors wish to thank National Ambulance Service and Dublin Fire Brigade personnel who provide the clinical and dispatch data that has made this study possible.

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Figure Legend

Figure One: Age and Sex Adjusted Incidence per 100,000 population per year (EUROSTAT, 2013)

*Figure Two: Cumulative percentage of cases responded to at each EMS Call-Response Interval**

*Time in minutes from call pick-up in ambulance control centre to first EMS vehicle arrival at scene. EMS witnessed cases excluded