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The Dublin cardiac arrest registry: temporal improvement in survival from out-of-hospital cardiac arrest reflects improved pre-hospital emergency care

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Aims

Out-of-hospital cardiac arrest (OOHCA) survival remains poor, estimated at 3–7%. We aim to describe the incidence of OOHCA, survival from OOHCA, and the impact of improved pre-hospital care on survival from OOHCA.

Methods and results

A retrospective registry was established using multi-source information to assess survival from cardiac arrest following the introduction of several improvements in pre-hospital emergency medical care from 2003. Survival from OOHCA, from asystole/pulseless electrical activity, and from ventricular tachycardia/ventricular fibrillation was estimated. Adjusted per 100 000 population annual incidence rates from national population census data were calculated. Mean and median emergency medical services (EMS) response times to OOHCA calls were assessed. A total of 962 OOHCAs occurred from 1 January 2003 until 31 December 2008. Sixty-nine per cent (69%, $n = 664$) were male. Seventy-two per cent (72%, $n = 693$) occurred at home with 28% occurring in a public venue. Of these public venues, 33.9% (91 of 268) had an automated external defibrillator available. Bystander cardiopulmonary resuscitation (CPR) was in progress when emergency services arrived in 11% ($n = 106$) of the cases. Nineteen per cent (19.4%, $n = 187$) had a known prior cardiac history or chest pain prior to circulatory collapse. Overall survival to hospital discharge improved significantly from 2.6 to 11.3%, $P = 0.001$. Survival from ventricular fibrillation (VF) to hospital admission, rose from 28.6 to 86.3%, $P = 0.001$. Survival to hospital discharge from VF improved from 21.4 to 33%, $P = 0.007$. Mean EMS response times to the scene of arrest decreased from 9.18 to 8.34 min. Emergency medical services scene time, reflecting acute pre-hospital medical care, rose from 14.46 to 18.12 min. The adjusted incidence of OOHCA for our catchment population declined from 109.4 to 88.2 per 100 000 population between 2003 and 2008.

Conclusions

The incidence of OOHCA has declined but importantly, survival to hospital discharge has improved dramatically. Reduction in ambulance response time, resulting in earlier initiation of basic and advanced life support and earlier defibrillation, was associated with an increase in the proportion of victims found in VF rather than asystole and likely accounted for most of the improvement. Further improvements in response times and public education to improve bystander CPR rates should remain a priority.

Keywords Out-of-hospital cardiac arrest Sudden cardiac death • Pre-hospital emergency care • Resuscitation • Ventricular fibrillation • Automated-external defibrillators • Cardiopulmonary resuscitation

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Introduction

Cardiovascular disease is the leading cause of death in the developed world.[1] Approximately 50% of cardiac deaths occur suddenly in the pre-hospital setting and in about half of these victims; sudden death is the presenting manifestation of cardiovascular disease.[2,3]

Out-of-hospital cardiac arrest (OOHCA) is a devastating event that continues to portend a dismal prognosis.[4,5] It has a major societal impact, and sudden cardiac death (SCD) is a major public health issue.[6]

The published incidence of SCD ranges between 36 and 128 deaths per 100 000 population per annum.[7–13] Wide differences in data collection, and methodological interpretation of this data, have resulted in differences in the reported incidence of SCD. In Ireland, two previous publications have established the incidence of OOHCA to be between 51.2 and 88 per 100 000 population.[10,14]

Survival from OOHCA generally reflects the ability of the emergency medical services (EMS) and acute care hospital systems to implement the chain of survival, including early access to EMS, bystander cardiopulmonary resuscitation (CPR), and basic life support, early defibrillation, early advanced cardiac life support, and optimal post-hospitalization care. Since the initial rhythm for most OOHCA is ventricular fibrillation (VF) (65–85%), prompt bystander CPR, initiation of basic life support, quality of external chest compression, early EMS response, and early defibrillation are the greatest determinants of survival.[15,16]

Previous studies have shown little or marginal improvement in survival from OOCHA over the last two decades, despite targeted improvements in pre-hospital care.[15–17] The Swedish OOHCA registry has recently found improved survival rates to 1 month post-resuscitation over a 14-year period from 4.8 to 7.3%. This improvement has been attributed to increased bystander CPR and increased EMS-witnessed cardiac arrests.[17] There was no increase in the overall proportion of VF cases >14 years.[17]

Since 2003, targeted improvements in pre-hospital care have been introduced by the emergency ambulance medical service in the Dublin city region. These changes have resulted in advanced cardiac life support at the scene, telephone dispatcher-guided bystander CPR, automated external defibrillator (AED) on all emergency response vehicles, intubation at the scene, community CPR and AED training, and protocols for management of suspected acute myocardial infarction (AMI)/chest pain. The aim of the present study was to explore the impact of these pre-hospital care changes on survival from OOCHA at our institution since 2003.

Methods

Study population

This is a retrospective observational hospital-based study of OOHCA survival. Between 1 January 2003 and 31 December 2008, data were collected for all OOHCAs brought to our hospital emergency department. Data sources used included EMS patient report forms, emergency department case notes, and hospital in-patient chart review. In order to ensure complete case capture, the hospital mortuary and local coroner/medical examiner provided information on OOHCA cases in which death was confirmed without resuscitation, only if the patient was seen alive in the preceding 24 h. The study was limited to persons aged >15 years of age as the hospital does not provide acute paediatric emergency care.

Based on the national population statistics for 2006, our hospital provides immediate acute hospital care to an adult (>15 years) population of 170 000.[18] Emergency response vehicles are co-ordinated from a single dispatch centre.

Case definition

Cases were defined as sudden abrupt loss of consciousness with no recognizable signs of life requiring initiation of CPR and activation of the emergency pre-hospital care services.

Data collection

Data recorded included patient demographics, site of arrest, availability of bystander CPR, and availability of an AED, initial presenting rhythm, whether defibrillation was attempted, initial resuscitation success rates, and finally, rates of successful discharge from hospital. In those who survived, neurologic recovery was assessed. Neurologic recovery was graded according to previous published functional levels: level 1 (full or near full recovery), level 2 (major memory deficit, naming difficulty, co-ordination difficulty, requiring some help with activities of daily living), level 3 (patient alert and awake but with a major neurologic deficit, fully dependent on for activities of daily living), and level 4 (unresponsive and comatose).[19,20]

Pre-hospital emergency care

Since 2003, progressive annual improvements in emergency pre-hospital care have occurred within our patient catchment area.

In 2003, national pre-hospital emergency care guidelines and protocols were introduced. At the same time, the Dublin pre-hospital emergency care service, provided by Dublin Fire Brigade, initiated community CPR and defibrillation education programmes. In 2004–2005, suspected AMI/chest pain management protocols were introduced, along with a roll-out programme for provision of AEDs on all forms of emergency response vehicles (ambulance, and fire vehicles). Dispatcher-guided basic life support and CPR programmes were introduced from 2005. By 2006, all emergency vehicles were equipped with AEDs, and advanced cardiac life support protocols were introduced into routine practice. It is a mandatory protocol for all suspected cardiac arrest victims to be connected to an AED on scene arrival to allow for rhythm analysis and treatment if appropriate. Since 2007, intubation and advanced airway management in the field has been introduced.

Structure of emergency medical services services in Dublin

The Dublin fire brigade control centre receives 999/112 calls for the Dublin area. The emergency medical dispatcher in the control centre will ask the pertinent questions to enable him or her to code the incident and assign it a particular response depending on the acuity of the call. An Echo-coded call (cardiac/

respiratory arrest, choking) would have the highest priority simultaneously activating ambulance, fire appliance, and advanced paramedic vehicles and will get the following response.

- The nearest available emergency ambulance;
- The nearest available fire appliance;
- An advanced paramedic vehicle, when available.

In Dublin city, paramedics and advanced paramedics provide pre-hospital emergency medical care while rostered for emergency ambulance and for fire appliance duties. Fire brigade emergency ambulances attend ~70 000 emergency medical incidents annually and fire appliances attend ~11 000 emergency medical incidents annually. The majority of incidents where fire appliances attend involve life-threatening (Category A, Echo and Delta) cases. Calls for medical emergency assistance received by the Dublin fire brigade's Eastern Region Control Centre (ERCC) are processed and prioritized using the Advanced Medical Priority Dispatch System software programme, ProQA, from Priority Dispatch Corporation, Salt Lake City, Utah, 84111, USA. As an example, over a 6-month period, the ERCC responded to 223 cardiac arrest calls, with 134 (60%) treated by fire appliance-based personnel, 80 (34%) treated by ambulance personnel, and 9 cases (4%) treated by both services.

Dublin Fire Brigade has 12 strategically located fulltime fire stations from which 12 emergency ambulances and 19 paramedic first response fire appliances respond to medical emergencies. There are also two retained fire stations in the north county from which they dispatch two emergency first-response crews to medical emergencies.

In the case of telephone-assisted CPR, a standard set of pre-arrival instructions are in built to ProQA , depending on the age of the patient, the emergency medical dispatcher will give instruction in adult, child, or infant CPR. These guidelines are based on American Heart Association guidelines for CPR detailing to the caller how to check for breathing, provide ventilations, and provide chest compressions and how to use an AED if there is one available.

The Dublin Fire Brigade provided the authors with averaged response times for all coded echo calls within our hospital catchment area, including all actively resuscitated cases, cases in which death was recognized and no resuscitation was performed, and decomposition cases that would have been brought to city coroner's morgue.

The overall response times were further subdivided for the purposes of observing trends in pre-hospital care. The call handling time is the time from when a call reaches the central response centre until a dispatch alert is issued to a vehicle. The response time is the time from issuing the dispatch alert until the unit is in attendance with the victim. The overall response time is the sum of the call handling time and the response time.

The next intervals reported involve time from the scene to the hospital. Scene time is the total time spent on scene with the victim, and the time from scene to hospital reflects the duration of transport from the scene to arrival at the emergency department. Both of these summed together form the total on scene to hospital time.

The total of the call handling time, response time, scene time, and time to hospital arrival, is the total EMS response time. A further sub-analysis assessed response intervals between daytime (7am until 7pm) and night-time (7pm until 7am) to assess impact of city traffic congestion on EMS response times.

Statistical analysis

Annual incidence was calculated per 100 000 population per annum, based on the population catchment area of the hospital from the national population census, published in 2006 by the Central Statistics Office. Parametric data were expressed as mean ± standard deviation, while non-parametric data were expressed as median and ranges. Categorical data were expressed as frequencies and percentages. Statistical analysis was performed using SPSS version 15.1 (SPSS Inc., Chicago, IL, USA).

The mortality rate was calculated as the number of known deaths per population using similar calculations. The case-fatality rate was calculated as the number of known deaths divided by the total number of cases including any missing cases. The survival rate was calculated as the number of known survivors divided by the total number of cases.

Survival to discharge was defined as discharge alive from the hospital after the index OOHCA.

Results

Overall outcomes

A total of 962 OOHCA occurred from 1 January 2003 until 31 December 2008. Sixty-nine per cent (69%, $n = 664$) were male. Seventy-two per cent (72%, $n = 693$) occurred at home with 28% occurring in a public venue. Of these public venues, 33.9% (91/268) had an AED available. Bystander CPR was in progress when emergency services arrived in 11% ($n = 106$). Nineteen per cent (19.4%, $n = 187$) had a known prior cardiac history [prior percutaneous coronary intervention (PCI), coronary artery bypass grafting, angina, pacemaker, and atrial fibrillation] or reported chest pain prior to circulatory collapse; 11.7% ($n = 113$), reported chest pain prior to collapse; 7.7% ($n = 74$) had a prior cardiac history. There was no change in the proportion of cases with a prior cardiac history or antecedent chest pain over the period 2003 until 2008, $P = 0.577$. *Table 1* summarizes the overall case numbers annually during the course of the study.

Overall defibrillation was performed, either pre-hospital with a publically available AED or EMS AED or in the emergency department, for a shockable OOHCA rhythm in 23.7% ($n = 228$). Resuscitation was initially successful, with return of spontaneous circulation and admission to hospital, in 15.1% of cases ($n = 145$). Of this cohort, 52 survived to hospital discharge, representing an overall OOHCA survival rate to hospital discharge of 5.2% ($n = 52/962$). Of the survivors, 47 out of 52 presented with a shockable rhythm, while 5 out of 52 survivors presented with asystole or electromechanical dissociation. Overall survival to hospital discharge from a shockable rhythm ['VF/pulseless ventricular tachycardia (VT)'] was 20.6% (47 of 228) while survival to hospital discharge from a non-shockable rhythm ('asystole/electromechanical dissociation')
was 0.68% (5 of 734), $P = 0.0001$, odds ratio (OR) 36.4 [95% confidence interval (CI) 14.2–92.9].

Table 1 Annual numbers of out-of-hospital cardiac arrest

Year	Overall total	Dead, no active resuscitation	OOHCA, actively resuscitated	Shockable rhythm	Shockable rhythm % of OOHCA	Non-shockable
2003	208	22	186	28	15.1	158
2004	217	14	203	43	21.2	160
2005	196	63	133	25	18.8	108
2006	183	37	146	37	25.3	109
2007	178	34	144	44	30.5	100
2008	172	22	150	51	34	99
Total	1154	192	962	228	23.7	734

Neurologic function in survivors

Neurologic recovery was graded according to previous published functional levels.[19,20]

Five patients had a neurological grade IV brain injury with severe hypoxic encephalopathy. Six patients had moderate neurological impairment, graded as II–III. Forty-one (80.4%, 41 of 52) had full or near full recovery (neurologic grade I).

Emergency response times

The mean and median emergency response times are outlined in *Table 2* below, subdivided into the pre-determined response intervals as defined in the methods section. Over the period for which data are available, the emergency response vehicles arrived on the scene more rapidly, but spent more time at the scene, reflecting improved pre-hospital triage and care with on-scene intubation, initiation of advanced cardiac life support (ACLS), and defibrillation if appropriate. This has resulted in the total EMS to hospital time lengthening over the period of the study. It is interesting to note that the response times to the scene and back to the hospital did not significantly differ between day and night periods, with overall trend showing reduction in response times and transport back times both during the day and the night-time period, highlighting the lack of impact of city traffic congestion on response times. Therefore, lengthening scene times highlight improved medical care delivered on the scene, included attaching an AED and delivering a shock if appropriate, rather than increased transport time.

Improving survival outcomes

Over the course of the study period, survival to admission and to hospital discharge overall annually improved significantly, in particular, survival to discharge from a shockable rhythm. *Table 3* outlines the overall survival outcomes analysed according to the presentation rhythm.

Adjusted incidence and survival rates based on catchment population

Based on Central Statistics Office National Population Census 2006 results, the population aged >15 years served by our hospital emergency department is estimated at 170 000. Using this figure, adjusted incidence rates per 100 000 population were calculated for OOHCA, as shown in *Table 4*. Interestingly, over the time period of the study, the overall incidence of OOHCA, especially in males, has declined, with reductions in the case fatality rate, and improving survival to hospital discharge.

Impact of public automated external defibrillator facilities and bystander cardiopulmonary resuscitation on survival

Data were analysed to assess the impact of publically available AEDs on survival from OOHCA. The geographic catchment area of our institution includes a number of large sports and concert arenas, each of which are equipped with full resuscitation facilities and have AEDs available throughout the arenas.

Over the period of the study, the number of arrests occurring in these venues with AEDS available did not alter significantly, ranging from 20 cases in 2003 (10.7%), to 18 cases in 2008 (12%), $P = 0.35$ (see *Table 5*).

However, survival from cardiac arrest in a venue equipped with an AED was significantly better when compared with survival in locations without an AED, 29 of 91 (32%) vs. 23 of 873 (2.6%), P value $= 0.0001$, OR 8.5, 95% CI 6.1–11.9.

Bystander CPR rates did not significantly alter during the period of the study, ranging from 18 of 186 (9.7%) in 2003 to 21 of 150 (14%) in 2008, P value $= 0.38$.

Discussion

In this observational study, the incidence of OOHCA has declined over the 6-year period, and survival to discharge, most especially from 'shockable' rhythms has significantly improved, $P = 0.007$.

The European Society of Cardiology Task force on SCD estimates the incidence of SCD to be between 36 and 128 deaths per 100 000 population per year. Using these figures, we anticipated the number of SCD cases in our population catchment area to be in the range of 61–217.[21,22] This correlates well with our observed OOHCA arrest incidence, which ranged from 78.2 to 119.4 per 100 000 population. Previously published work from a Dutch group reported an annual rate of between 90 and 100 deaths per 100 000,[7] and prior work from Belfast, a similar urban environment to our catchment area, reported an annual rate of 88 per 100 000 population.[10] Other papers, from

Table 2 Mean and median emergency responses times

Time (min)	2003 (*n* = 186)	2004 (*n* = 203)	2005 (*n* = 133)	2006 (*n* = 146)	2007 (*n* = 144)	2008 (*n* = 150)
Call handling time						
Overall mean (median)	n/a	n/a	2.17 (1.54)	2.27 (2.06)	2.06 (1.43)	2.22 (1.46)
*Day-time (7am–7pm) mean (median)	n/a	n/a	2.13 (1.49)	2.24 (2.08)	2.04 (1.42)	2.27 (1.38)
*Night-time (7pm–7am) mean (median)	n/a	n/a	2.22 (2.0)	2.24 (2.0)	2.10 (1.49)	2.10 (1.51)
Response time						
Overall mean (median)	n/a	n/a	7.01 (6.24)	7.03 (5.53)	6.51 (6.18)	6.12 (5.14)
*Day-time mean (Median)	n/a	n/a	6.18 (6.0)	7.11 (5.53)	6.30 (5.3)	6.02 (5.08)
*Night-time mean (median)	n/a	n/a	8.03 (7.08)	6.35 (5.53)	7.36 (6.34)	6.22 (5.34)
Total response time						
Overall Mean (median)	n/a	n/a	9.18 (8.27)	9.3 (8.13)	8.57 (7.54)	8.34 (7.06)
*Day-time Mean (Median)	n/a	n/a	8.31 (7.59)	9.35 (8.12)	8.34 (7.34)	8.29 (6.58)
*Night-time mean (median)	n/a	n/a	10:25 (9.13)	8.59 (8.14)	9.46 (7.20)	8.32 (6.14)
Scene time						
Overall mean (median)	n/a	n/a	9.36 (7.57)	9.42 (7.58)	10.35 (9.18)	13.06 (12.16)
*Day-time mean (median)	n/a	n/a	10.2 (8.04)	8.58 (7.48)	11.24 (9.22)	13.31 (13.01)
*Night-time mean (median)	n/a	n/a	8.58 (7.48)	10.47 (8.45)	8.39 (8.56)	12.28 (11.18)
Time from scene to hospital						
Overall mean (median)	n/a	n/a	4.56 (4.39)	4.56 (5.45)	5.14 (4.29)	4.45 (4.37)
*Day-time mean (median)	n/a	n/a	5.27 (4.53)	5.57 (6.30)	5.20 (4.35)	4.41 (4.07)
*Night-time mean (median)	n/a	n/a	5.07 (4.35)	3.36 (2.46)	5.22 (4.38)	4.54 (5.28)
Total scene to hospital time						
Overall mean (median)	n/a	n/a	14.32 (12.36)	14.38 (13.43)	15.49 (13.47)	17.51 (16.53)
*Day-time mean (median)	n/a	n/a	15.47 (12.57)	14.55 (14.18)	16.44 (13.57)	18.12 (17.09)
*Night-time mean (median)	n/a	n/a	14.05 (12.23)	14.23 (11.31)	14.01 (13.34)	17.22 (16.46)
Overall total EMS contact to hospital arrival time						
Overall mean (median)	n/a	n/a	24.15 (22.07)	24.11 (22.56)	25.08 (24.09)	27.15 (25:45)
*Day-time mean (median)			24.18 (20.56)	24.3 (22.30)	25.18 (21.31)	26.41 (24.07)
*Night-time mean (median)			24.30 (21.36)	23.22 (19.45)	24.47 (20.54)	25.54 (23)

*Day-time = 7am until 7pm; night-time = 7pm until 7am.

Table 3 Survival based on presenting rhythm

	2003 (*n* = 186)	2004 (*n* = 203)	2005 (*n* = 133)	2006 (*n* = 146)	2007 (*n* = 144)	2008 (*n* = 150)	*P* value
Shockable cases (%)	28 (15.1)	43 (21.2)	25 (18.8)	37 (25.3)	44 (30.6)	51 (34)	0.001
Non-shockable cases (%)	158 (84.9)	160 (78.8)	108 (81.2)	109 (74.7)	100 (69.4)	99 (66)	0.001
Initial survival to admission (%)	9 (4.8)	28 (13.7)	18 (13.5)	16 (10.9)	30 (20.8)	44 (29.3)	0.0001
Initial survival shockable rhythm to admission (%)	8 (28.6)	15 (34.8)	11 (44)	12 (32.4)	27 (61.4)	43 (86.3)	0.001
Initial survival non-shock to admission (%)	1 (0.6%)	13 (8.1%)	7 (6.4)	4 (3.7)	3 (3)	1 (1)	NS
Survival to discharge shockable rhythm (%)	6 (21.4)	6 (13.9)	3 (12%)	6 (16.2)	9 (20.5)	17 (33)	0.007
Survival to discharge non-shockable rhythm (%)	1 (0.6)	2 (1.2)	1 (0.9)	1 (0.9)	0 (0)	0 (0)	NS
Overall survival to discharge (%)	7 (3.7)	8 (3.9)	4 (3)	7 (4.8)	9 (6.25)	17 (11.3)	0.007

Oregon, USA and Galway, Ireland, reported rates of 53 and 51.2, respectively.[9,14] This marked difference reflects the rural nature of both of these areas, with low population densities and longer EMS response times.

The incidence adjusted per 100 000 population has declined markedly over the 6 years of the study, most markedly, the incidence in males. If we extrapolate our incidence figures to the national population census figures provided by the Central Statistics Office,[18] we estimated the total number of expected OOHCA cases in Ireland in 2003 at 4285 [109.4 of 170 000 × 3 917 203 (CSO 2002 population census)] reducing to 3739 in 2008 [88.2 of 170 000 × 4 239 848 (CSO 2006 population census)], an approximate reduction of 13% in the annual incidence of OOHCA >6 years.

Previous work has shown a dramatic decline in overall cardiovascular morbidity and mortality, although, no prior work has ever demonstrated an impact on the incidence of OOHCA.[23–26] This decline that we have observed may reflect improved primary prevention of cardiovascular risk factors and secondary prevention of cardiovascular events in patients with established cardiovascular disease.[23–26] Both beta-blockers and statins have been previously shown to decrease arrhythmic deaths in patients with established cardiovascular disease.[27–30] In our study, the proportion of patients with known cardiovascular disease or reported cardiac symptoms at the time of collapse remained unchanged throughout the 6 years of the study, however. Improvements in patient and general public education regarding cardiovascular symptoms and reducing delays in contacting emergency services for symptoms of chest pain, may also have impacted in the overall delay in seeking medical care for AMI, reducing the rate of infarction-related ventricular fibrillation.

Survival to both hospital admission and eventual discharge, has also significantly improved over the 6 years of the study. In 2003, survival to admission was 4.8%, rising year-on-year, to 29.3% in 2008, $P = 0.0001$. Survival to eventual discharge rose from 3.7 to 11.3%, $P = 0.007$. This improvement in survival was driven primarily by increases in the proportion of cases presenting with a shockable rhythm, which rose from 15.1 to 34%, $P = 0.001$. This is in contrast to previously published work from the Swedish Cardiac Arrest Registry, which has shown a decline in the proportion of VF cases, attributed to decreases in the incidence of coronary artery disease, and improvements in management of patients with established disease.[17] We hypothesize that the rise in 'shockable' rhythm reflects reducing EMS time to scene arrival, reduced from 7.01 to 6.12 min, so that effective early basic and advanced life support with placement of an AED and defibrillation before the rhythm has degenerated into asystole can occur. The proportion of OOHCA cases occurring in a venue with an AED or who received bystander CPR did not significantly alter. The proportion of 'non-shockable' cases has reduced, and we suggest that this is due to improved response times, resulting in patients being assessed and resuscitated more promptly before VT/VF may have degenerated into agonal/asystolic rhythms. One potential confounder of this hypothesis is whether EMS personnel have improved the diagnosis of death and therefore no longer commence CPR in patients who are found down after significant periods arises. In order to control for this, we identified cases notified to the area coroner or brought to the hospital mortuary after being found dead at home within 24 h of being last seen well. Over the 6 years, this number remained constant (see *Table 1*), meaning that the reduction in the number of non-shockable cases reflects a true reduction. In addition, the impact of city traffic congestion could alter either response times to the scene or similarly, transport times from the scene to the hospital. As outlined in *Table 2*, the response times in both directions have declined over the study period both during the daytime period, when traffic congestion would be expected to peak, and at night-time, when traffic volumes are at their lowest, indicating that the reduced response times are independent of the influence of traffic congestion.

Table 4 Adjusted rates per 100 000 population

	2003	2004	2005	2006	2007	2008
Adjusted incidence per 100 000	109.4	119.4	78.2	85.8	84.7	88.2
Adjusted mortality per 100 000	105.8	115.8	76.5	82.4	79.4	77.1
Adjusted male incidence per 100 000	147.1	166.6	104.6	120.7	103.4	120.7
Adjusted female incidence per 100 000	69.8	69.8	50.6	50.6	63.8	54.2
Case fatality rate %	96.8	97	97.7	95.9	93.8	87.3
Survival rate %	3.2	3	2.25	4.1	6.2	12.6

Table 5 Impact of automated external defibrillator availability and bystander cardiopulmonary resuscitation on survival from out-of-hospital cardiac arrest

n, %	2003 (*n* = 186)	2004 (*n* = 203)	2005 (*n* = 133)	2006 (*n* = 146)	2007 (*n* = 144)	2008 (*n* = 150)	*P* value
Bystander CPR	18/186 9.6%	23/203 11.3%	9/133 6.7%	16/146 10.9%	19/144 13.2%	21/150 14%	0.38
AED	20 (10.7%)	16 (7.8%)	7 (5.3%)	16 (10.9%)	14 (9.7%)	18 (12%)	0.35
Survival	7 (3.7%)	8 (3.9%)	4 (3%)	7 (4.8%)	9 (6.25%)	17 (11.3%)	0.007

Survival to both hospital admission and eventually, discharge, has dramatically improved over the 6 years of our study, and this is driven by improved survival from shockable rhythms. Survival to hospital admission from a shockable rhythm rose from 28.6 to 86.3% between 2003 and 2008, respectively, $P = 0.001$. Survival to eventual discharge, improved significantly from 21.4 to 33%, $P = 0.007$. This improved survival from shockable rhythm is influenced by improved pre-hospital emergency care. The total response time from emergency service call to EMS unit arriving on scene has declined from 9.18 min in 2005 to 8.34 min in 2008 (see *Table 2*). This results in prompt initiation of both basic and advanced life support and earlier defibrillation for those with a shockable rhythm, and it is well established from prior work, that earlier defibrillation in combination with effective life support and chest compressions can dramatically improve cardiac arrest outcomes.[19] As described earlier in the methods section, it is now mandatory since 2006 to attach an AED and analyse the initial rhythm of any victim suspected of suffering an out-of-hospital cardiac arrest. When the EMS service arrives, in addition to prompt early defibrillation where appropriate, the quality of emergency care provided has also improved over the 6-year period—with intubation at the scene, intravenous drug administration, AMI protocols, and ACLS care provision. This is reflected by the increased time spent at the scene after arrival, which has increased from 9.36 to 13.06 min. It is important to emphasize that this scene time interval reflects nothing else except patient assessment and acute medical care delivered on scene. Therefore, overall, the EMS service arrives more rapidly, crucial for early basic and advanced life support and early defibrillation, and provides higher-quality care on scene, reflected in longer scene times, which we suggest has resulted in marked improvements in survival to hospital discharge.

Bystander CPR can double or triple survival rates from OOHCA.[31–33] The proportion of witnessed arrests who receive bystander CPR has not significantly changed over the 6-year period, while the number of cases occurring in a venue with a public AED has also remained static. However, cardiac arrest in venue with a public AED as opposed to the home environment or location without an AED significantly influenced the chance of survival, 32 vs. 2.6%, $P = 0.0001$.

The impact of post-resuscitation in-hospital care on survival to hospital discharge also affects outcomes.[34–36] While whole body cooling was not performed during the course of this study, 24 h primary PCI, intra-aortic balloon pump placement, mechanical circulatory support, and general supportive intensive care unit care are available. Combined with prompt basic and advanced life support and early defibrillation, these in-hospital measures have resulted in good neurological outcomes for our cohort of cardiac arrest survivors.

While improvements in pre-hospital care have impacted survival in the last 6 years, future improvements in overall survival from OOCHA will have to focus on improving education of the public at large about recognizing and responding appropriately to signs of cardiac arrest. This would undoubtedly result in further reductions in the time interval to defibrillation, and improve the levels of bystander CPR. In the Swedish experience, education regarding CPR resulted in improvements of bystander CPR from 31 to 50% >14 years. This improved bystander CPR along with increases in witnessed arrest cases, were the two factors responsible for improved survival in the Swedish national cardiac arrest registry.[17]

A recent multicentre USA and Canadian prospective cohort study has published controversial findings regarding survival from cardiac arrest in public vs. home locations.[37] In this study, VF was identified less often during sudden cardiac arrest in the home vs. public locations, even for witnessed events. The authors hypothesized that this may reflect age, coexistent illness, and underlying disease severity. Additionally, outcomes were poorer with AED use in the home vs. public locations. The authors concluded that perhaps AEDs should be reserved for public locations and that CPR and basic life support should be widely trained throughout society to help survival from cardiac arrest at home. In our study, the proportion of cases with a shockable rhythm rose annually from 15.1% in 2003 to 34% in 2008. The proportion of arrests occurring in a public location with or without an AED did not alter significantly. We identify, in contrast to this prospective study, that EMS response times have shortened year-on-year during the study and we hypothesize that this has resulted in earlier defibrillation of shockable rhythms, and thus, improved cardiac arrest survival rates. In addition, prior work has established that more prompt response times will increase the proportion of cases with a potential shockable rhythm.[38] In our study, we conclude that more rapid EMS response has resulted in earlier detection and treatment of shockable rhythms. Our data do not report the time from last seen well to collapse or EMS activation. This time interval, which is also not available in the most recent prospective study, is vital to understanding whether the poor outcomes from non-shockable rhythm cardiac arrest reflects poorer recognition of cardiac arrest by the public and therefore longer times to activate EMS services, allowing shockable rhythms to degenerate into asystole. As suggested by the accompanying editorial with the recent Resuscitation Outcomes Consortium paper, improving general public awareness of cardiac arrest so that earlier activation of EMS and more prompt defibrillation can occur may improve survival from OOHCA rather than focusing exclusively on CPR education.[39] Additionally, in our study the total time spent on scene has increased, which we hypothesize reflects improved quality of care such as attachment of an AED, intravenous access and medication administration, airway management, and ACLS performance. However, the data regarding the exact frequency of use of each of these measures are not available for a definitive conclusion to be drawn on the impact of each of these measures on survival.

Study limitations

This is an observational prospective study and as with any observational study is open to potential selection and ascertainment biases. However, we have endeavoured to overcome this by ensuring case capture not only from EMS reports, but also from hospital emergency department records, mortuary records, and the coroner's case notifications. As with all publications in this area, case definition proves problematic, and so for the purposes of outcomes analysis, only patients who had resuscitation at least attempted by EMS personnel were included in the analysis.

Hospital catchment population is based on geographic population estimates from the 2006 national population census, and while all cardiac arrest calls are dispatched from one central call centre, it does not necessarily follow that all cases are brought solely to our emergency department. Some patients may have been transferred to other city centre hospital emergency departments.

The EMS service introduced a digital call monitoring service from 2005; therefore, mean and median response times for the first two years of the study are not available. Witnessed loss of circulation by EMS personnel was not reliably recorded on EMS report forms; therefore, the incidence of EMS-witnessed cardiac arrest could not be estimated.

While standardized improvements in quality of pre-hospital emergency care have been introduced and are now mandatory, such as AED attachment and shock delivery if appropriate, we do not have data on the time to AED shock delivery, or the proportion of cases in whom an advanced airway was placed, an intravenous line started, or an intravenous medication administered, and whether this has changed over the period of the study. Similarly, while we have highlighted the improved survival from arrest in locations with an AED, we do not have data to confirm whether the device was successfully used by the public rather than emergency personnel on scene arrival or whether, as a result of awareness or education, the device was used more frequently or earlier at the end of the 6-year period compared to the start.

The influence of city traffic congestion has been addressed with the individual reporting of both the response time and transport to hospital time, both during daylight hours and night-time hours. Both time intervals overall declined in the study and did not appear to be influenced by any day (when city congestion is highest) or night differences. This highlights our study finding that earlier EMS arrival and improved on scene care such as AED attachment has improved cardiac arrest survival.

Conclusions

Out-of-hospital cardiac arrest appears to have declined in incidence, and survival to hospital discharge from cardiac arrest, especially from 'shockable' rhythm cardiac arrest, has significantly improved over 6 years. These improvements in survival from OOHCA were most likely due to reduced time to arrival on the scene of an arrest, reduced time to defibrillation and implementation of the pre-hospital policies outlined above. The overall reduction in ambulance response times/time to initiation of basic and advanced life support and defibrillation was associated with an increase in the proportion of victims found in VF rather than asystole and likely accounts for most of the improvement in survival. Further attempts to improve response times, access to AED devices, and public education regarding recognition of cardiac arrest, basic life support, and bystander CPR should remain a societal priority.

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