**Epidemiology and outcomes from out-of-hospital cardiac arrests in England**

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Abstract word count: 216

Main text word count: 3041

Keywords: Cardiac arrest, Emergency Medical Services, Out-of-hospital cardiac arrest, Pre-hospital care, Resuscitation

**Abstract:**

**Introduction:** This study reports the epidemiology and outcomes from out-of-hospital cardiac arrest (OHCA) in England during 2014.

**Methods:** Prospective observational study from the national OHCA registry. The incidence, demographic and outcomes of patients who were treated for an OHCA between 1st January, 2014 and 31st December 2014 in 10 English ambulance service (EMS) regions, serving a population almost 54 million, are reported in accordance with Utstein recommendations.

**Results:** 28,729 OHCA cases of EMS treated cardiac arrests were reported (53 per 100,000 of resident population). The mean age was 68.6 (SD=19.6) years and 41.3% were female. Most (83%) occurred in a place of residence, 52.7% were witnessed by either the EMS or a bystander. In non-EMS witnessed cases, 55.2% received bystander CPR whilst public access defibrillation was used rarely (2.3%). Cardiac aetiology was the leading cause of cardiac arrest (60.9%). The initial rhythm was asystole in 42.4% of all cases and was shockable (VF or pVT) in 20.6%. Return of spontaneous circulation at hospital transfer was evident in 25.8% (n= 6302) and survival to hospital discharge was 7.9%.

**Conclusion:** Cardiac arrest is an important cause of death in England. With less than one in ten patients surviving, there is scope to improve outcomes. Survival rates were highest amongst those who received bystander CPR and public access defibrillation.

**Introduction:**

Each year 60,000 people sustain an out-of-hospital cardiac arrest (OHCA) in England, [1,2] for whom resuscitation is attempted in less than half.[3] Internationally, cardiac arrest survival rates vary widely from 0.6% to 25%,[4,5] and in the United Kingdom (UK) are much worse than in the best performing Emergency Medical Services (EMS) systems. Doubling the reported UK survival rates to a level comparable with the best performing systems could save 1,000 lives a year.[6]

Improving links in the cardiac arrest chain of survival can improve outcomes,[7] particularly the early links in this chain. Interventions known to improve survival include, improving early recognition and calling for help from EMS (link 1), bystander cardiopulmonary resuscitation (CPR) (link 2) and the use of public access defibrillation (link 3).[8] By definition, these interventions mean increasing the proportion of the population with skills to provide them. The impact of such interventions with regional, or even national populations occurs incrementally over time and can occur in different locations at different times, depending on who is organising and delivering improvement strategies e.g. voluntary sector or public sector organisations, and the level of national or local policy support. Demonstrating the scale and rate of improvement warrants baseline measurement as well as measurement over time of both the proportions of OHCA patients experiencing process outcomes (such as bystander CPR) and clinical outcomes (such as survival). Comprehensive measurement nationally, using clearly defined outcome measures enables evaluation of the impact of both national and local initiatives. Comparison with systems outside the UK is also possible.

Other regional and national OHCA registries have successfully provided such measurement data.[9] They have been used to evaluate national initiatives (e.g. Denmark,[10] Sweden[11] and USA[12]) demonstrating the value of regional and national interventions to improve outcome from cardiac arrest (e.g. mandating CPR training in schools and for people taking a driving test).

Beyond OHCA survival outcomes in England[13], little is known about patient demographics, event characteristics, process variables and treatments administered. The Out of Hospital Cardiac Arrest Outcomes (OHCAO) project aimed to establish a national registry including detailed process and clinical outcomes relevant to all links in the chain of survival, to facilitate research and quality improvement in OHCA.[14]

This study reports the 2014 data from England as a baseline for future reference, summarising patient characteristics, processes and outcomes for OHCA.

## Methods

*Setting and population*

This analysis is based on OHCA events that occurred between 1st January, 2014 and 31st December 2014 in 10 English ambulance service (EMS) regions, which together serve a population of approximately 54 million in England. One small service providing emergency care for an island (Isle of Wight, population 139,105 inhabitants) did not submit data. The registry covered 99.74% of the 2014 population of England and 83.87% of the UK population. [15] OHCA patients of all ages with resuscitation commenced or continued by EMS personnel were included. Patients who had a 'Do Not Attempt Resuscitation' (DNAR) decision in place, or achieved ROSC before the arrival of EMS, were excluded.

*Ethical approval*

The University of Warwick hosts the OHCAO project. The registry is structured and maintained in accordance with the Utstein guideline for resuscitation registries.[16] Details of the registry have been summarised previously.[14] The National Research Ethics Service granted ethics approval, reference number 13/SC/036. The Confidential Advisory Group (CAG), reference number ECC8-04(C)/2013, granted approval to use identifiable patient information where it is not practical to obtain consent.

*Description of EMS:*

EMS are provided by the National Health Service (NHS). Emergency dispatch centres are alerted through a national emergency services number (999 or 112). Dispatchers use the protocolised Medical Priority Dispatch system or NHS Pathways to triage calls. Cases identified as a cardiac arrest are assigned the highest priority response. EMS are commissioned to reach 75% of these cases with a defibrillator capable response within eight minutes and to have an ambulance on scene within 19 minutes in 95% of cases. The nearest available resource(s) which may be a community responder, car, ambulance, motorbike or helicopter is dispatched to the scene.

Paramedics or emergency medical technicians, either or both of which may be assigned to a cardiac arrest case, staff ambulance vehicles. Paramedics can deliver advanced life support interventions (including advanced airway management and intravenous drugs). Technicians, and many community responders dispatched by the NHS ambulance service, can deliver CPR and defibrillation, and some use supraglottic airways.

Upon arrival at a cardiac arrest, EMS personnel assess the viability of a full resuscitation attempt. Resuscitation may be withheld if there is unequivocal evidence of death (major traumatic injuries, putrefaction, rigor mortis, post mortem staining etc.), a DNAR decision is documented or if there is asystole, no bystander CPR and more than 15 minutes has elapsed from the time of collapse. When resuscitation is attempted, EMS

follow national Resuscitation Council (UK) guidelines or regional clinical guidelines derived from these national guidelines, which in turn, are derived from the European Resuscitation Council guidelines.[17] Resuscitation is continued until ROSC is achieved or further resuscitation is considered futile. Recognition of life extinct (ROLE) guidelines permit qualified EMS personnel to terminate resuscitation in the field if the patient remains in asystole despite 20 minutes of full resuscitation measures.[18]

*Data collection*

Participating EMS routinely collect source data from the 999 call to hospital transportation via Patient Report Forms (PRFs), as well as data related to survival status at hospital discharge. Each EMS region has their own methods for case ascertainment e.g. screening paper or electronic PRF databases for cardiac arrest case records, dispatch codes, or related clinical or treatment terms. Identified cases are entered into a cardiac arrest database, cleaned and verified by trained members of the EMS clinical audit team. If the patient is conveyed to hospital the EMS collect data on survival at hospital discharge status directly from hospital Emergency Departments if data sharing protocols are in place. The data are uploaded by each service to the OHCAO server, transformed using service-specific rules and securely stored in the OHCAO registry at the University of Warwick.

*Definitions*

Age at date of OHCA was calculated from the patient's date of birth. If age was missing or out of a reasonable range (0-110 years), it was replaced by the EMS estimated age. EMS response time was defined as the duration in minutes between the start of the 999 call and EMS arrival on scene time, except for the EMS witnessed cardiac arrests, defined as zero minutes. A predefined upper limit of 90 minutes and above was applied to reduce potential data entry errors.

According to the updated Utstein definition,[19] unknown initial aetiology was recoded as a cardiac cause. For initial rhythm, ventricular fibrillation (VF) and pulseless ventricular

tachycardia (pVT) were defined as shockable rhythms, while asystole, pulseless electrical activity (PEA) and bradycardia were defined as non-shockable rhythms.

The incidence of cardiac arrest was defined as the total number of OHCA events, where resuscitation was commenced or continued by EMS, per 100,000 population served. The 2014 population data were estimated using the average of the 2013 and 2014 mid-year estimates published by the UK Office for National Statistics.[15,20] Survived event was defined as the total number of patients with ROSC at hospital handover, divided by the total number of EMS treated OHCA events. Similarly, survival rate was defined as the total number of patients surviving to hospital discharge, divided by the total number of EMS treated OHCA events. The bystander CPR rate was defined as the total number of patients receiving bystander CPR, divided by the total number of EMS treated OHCA events minus the EMS witnessed cardiac arrests. Events with missing or not available status were also included in the denominators.

*Statistical Analysis*

All rates were unadjusted and associated 95% confidence intervals calculated for incidence, survival and ROSC rates at the service level. Other data are presented as means. Data management and analysis was carried out using SAS v9.3 (SAS Institute Inc., Cary, NC, USA).[21]

## Results

Following removal of duplicates and ineligible cases, 28,729 OHCA cases with resuscitation commenced or continued by EMS were included in the 2014 analysis (Figure 1).

For all eligible cases (mean age 68.6 (SD=19.6) years; 58.7 % male), in cases with a known event location, one in four occurred outside of a place of residence. Over half (52.7%, n=15,153) the cases were witnessed by either the EMS or a bystander. In non-

EMS witnessed cases, 55.2%, n=11,145 received bystander CPR. Bystanders witnessed 35% of cases, and of those 61% received bystander CPR (n=8315, based on data from 8 services). In all cases, cardiac aetiology was the leading initial cause of cardiac arrest (60.9%, n=17,491). If the aetiology was reported unknown or unobtainable, cases were presumed to be of a cardiac cause and included, this figure is 79.5% (n=22,849). The initial rhythm was asystole in 42.4% (n=12,178) of all cases and was shockable (VF or pVT) in 20.6% (n=5,933).

*Figure 1: Utstein flowchart of 2014 OHCA events where resuscitation is commenced or continued by EMS in England*

The overall incidence of cardiac arrests was 53.2 per 100,000 of the population in England (figure 2 top graph). Marked variation in the incidence rates and case numbers were reported by the ten ambulance services (figure 2).

*Figure 2: Incidence of cardiac arrest where resuscitation was commenced or continued by EMS per 100,000 English population in 2014 at service and national level (top) and Number of cardiac arrest events (bottom) by service (total n=28,729)*

Apart from children under the age of five years, the OHCA incidence rate increased exponentially with age in both sexes, showing consistently higher rates among males (figure 3).

*Figure 3: Number (top) and incidence (bottom) of cardiac arrest where resuscitation is commenced or continued by EMS by age group and sex*

The majority of arrests occurred in the home (83.3%, n=17,466) and 2 in 5 (40%, n=10128) were witnessed by bystanders (fig 1, excluding missing, unknown or unobtainable data).

Public access defibrillator (PAD) use was reported in only 2.4% of the 16,811 non-EMS witnessed cases (missing data were excluded from the denominator). PAD was used more often in non-residential places than in places of residence (4.1% vs. 0.9%, respectively).

Information about airway management, vascular access and airway type was missing in 40% of cases reporting an initial rhythm. Basic airway use was reported in 8.1% (n=1878) cases, supraglottic airway in 17.5% (n=4055), and tracheal tube in 19.0% (n=4406), whereas 5.1% (n=1177) used more than one advanced airway. Intravenous access was reported in 38.8% (n=8991) of cases, intraosseous in 6.8% (n=1584) and both modalities in 9.1% (n=2116). Adrenaline and amiodarone were administered to 59.2% (n=13,705) and 5.8% (n=1354) of cases, respectively.

Overall, ROSC at hospital transfer was evident in 25.8% (n= 6302) and survival to hospital discharge was 7.9%, with some variation between services (figure 4). ROSC at hospital transfer in those presenting with an initial shockable rhythm was 43.6% (n=2522), and for those with a non-shockable rhythm was 18.8% (n=3222).

*Figure 4: Rate OHCA cases where resuscitation was commenced or continued by EMS with ROSC at hospital transfer (green) and of survival to hospital discharge (blue) of by service with 95% confidence interval. Note: Service 2 & 4 excluded due to incomplete ROSC at hospital transfer data and Service 2, 4 & 10 excluded due to incomplete survival to hospital discharge data.*

Figure 5 illustrates that patients who had their arrest witnessed by a bystander were more likely to be found in a shockable rhythm on EMS arrival and had a better chance of

survival if bystander CPR was provided and a PAD was used. Survival rates declined with longer EMS response times, but remained better than witnessed arrests where there was no bystander CPR or PAD use. For OHCA cases with a shockable rhythm the benefits of both CPR and PAD use show 35% surviving if EMS arrive within 2 minutes, declining to less than 15% where EMS arrive at between 14-16 minutes. The data presented are not modelled to demonstrate the relationship between the variables; rather rates are plotted against time and the line of best fit is shown here. Interpretation warrants some caution due to data quality in the subgroups. However, the data do indicate possible trends.

*Figure 5: Shockable rhythm in Utstein groups by EMS arrival time and survival to hospital discharge in Utstein groups by EMS arrival time.*

**Discussion**

We have established an OHCA registry in England, with 28,729 cases analysed for 2014. This figure is comparable with that reported in the NHS England Ambulance Quality Indicators (AQI) of just under 30,000 cases in the year 2013/14, but indicates our data completeness could be improved.[13]

Our initial interrogation of the data shows an incidence of OHCA of 53.2 per 100,000. ROSC at hospital transfer was 25.8% and a survival to hospital discharge rate of 7.9% (comparable to AQI figures of 26.1% and 8.7% respectively). Bystander CPR was given in 55% of cases not witnessed by EMS and public access defibrillation used in just 2.4%.

There is variation in the incidence of OHCA reported around the world.[22] The incidence of OHCA in England, of 53 per 100,000 was comparable to rates reported in populations from other western countries e.g. 56 in North America[23] and 62 per 100,000 in Denmark.[10]

Survival to hospital discharge of all EMS treated cases was 7.9% and while comparable to some other reported rates (CARES USA 9.6,[24], Korea 8.5%[25]) the best performing EMS report a survival rate of 21% (King County, USA 2013) [26] and in Norway, based only on cases where the aetiology is presumed cardiac, 25%.[11] The potential for doubling survival rate in England remains.[6]

Rates of bystander CPR by EMS varied between 39% and 57. Rates of bystander witnessed cases varied between 41.1% and 48.8%. A rate of 13.6% was noted for a site with 40% missing data. This indicates some of the regional variation observed may be due to data quality and/or may account for some variation in outcomes (figure 4).

Bystanders witnessed 35% of arrests in our registry and, of those, 61% received bystander CPR (n=8315 and is based on data from 8 services). In all non-EMS witnessed cases 55% received bystander CPR. Although bystander CPR rates compare well with some countries, e.g. 45% reported in Denmark for 2010, and 44% in North America (CARES),[24] the best performing EMS services report rates of 66%, (Netherlands),[27] 69% (King County, Seattle)[26], 68.8% (Victoria, Australia)[28] and 73% (Norway).[11]

The OHCA patients most likely to survive with early intervention were those whose arrest had a cardiac aetiology, was bystander witnessed and presented with an initial shockable rhythm (VT/VF). King County EMS, reported a survival rate of 69% in 2013, which has increased from 46% in 2009.[26] This increase was attributed to various initiatives including increasing access to and training for public automated external defibrillator (AED) use, public CPR training and the use of telephone CPR by EMS call handlers, and training EMS responders in high quality BLS and ALS. A study in the Netherlands demonstrated a 12% increase in survival with a favourable neurological

outcome from 29.1-41.4% between 2006 and 2012, and this was associated with an increase in AED use.[27]

PAD use in our data was 2.4% (30.5% missing data), which is similar to that previously reported in England (1.74% [29]and 2%[30]). Early defibrillation for OHCA patients presenting in an initial rhythm of VT or VF is an important link in the cardiac arrest chain of survival. Evidence from a US population-based cohort study found an almost two-fold (OR 1.75) increase in survival after OHCA when a PAD was successfully before arrival of EMS.[31] A recent population-based cohort study found that an increase in PAD use was associated with an increase in survival from OHCA.[27] While some improvement may be attributed to increase use of AEDs by EMS, fire fighters or police, AED use at the site of arrest increased from 5.4% to 10.6% between 2006-2012. The Dutch experience indicates that there is considerable room for improvement in PAD use in England.

Trends in the data showing a decline in rates of patients in a shockable rhythm on EMS arrival and in survival to hospital discharge the longer it takes the EMS to arrive, were observed (figure 5). O'Keefe et al. report a 24% (95% CI 4%-48%) improved odds of survival with a one minute reduction in response times. However, service changes required to achieve such reductions are unlikely to be cost effective for the NHS.[32]

Hospital care varies, and is known to impact myocardial infarction outcome.[33] Hospital care could account for some of the variation in survival to discharge observed across services in this study. Specialist cardiac arrest centres may improve survival[34] and further research is needed.

Strengths of the OHCAO registry are the collegiality shown amongst English NHS Ambulance Services to collaborate to produce national data on the epidemiology and

outcome of cardiac arrest. The use of a standard data dictionary based on the Utstein recommendations helped ensure consistency in approach between ambulance services.

Variation in case ascertainment methods has been reported elsewhere.[35,36] EMS returning data to our registry use locally determined case ascertainment and associated quality control methods. This could account for some regional variation. A team member (SBM) is investigating optimal methods of case identification in a linked study.

Like other registries,[36] data quality was problematic and led to the exclusion of some services for some process and outcome variables (e.g. ROSC at hospital transfer, bystander CPR and survival). Survival to hospital discharge data is particularly challenging for ambulance services to collect[37]. We are currently exploring the feasibility of linking with the Office for National Statistics (ONS) death registry, which may increase the proportion of patients in whom outcomes are known. On-going monitoring including comparison with case numbers reported to NHS England[13] and a new system of data quality checks at upload are intended to help improve data quality and completeness in future years.

Finally the data reported here have not been adjusted for case mix, so some of the variation seen between regions may reflect differences in patient epidemiology and service setting (urban versus rural).

**Conclusions**

Cardiac arrest is an important cause of death in England. With less than one in ten patients surviving, there is scope to improve outcomes. Survival rates were highest amongst those who received bystander CPR and public access defibrillation.

## Conflict of interest statement

Claire Hawkes, Scott Booth, Chen Ji, Samantha Brace-McDonnell, Terry Brown and Gavin Perkins are employed by the University of Warwick, which receives grants from the British Heart Foundation and the Resuscitation Council (UK) for the conduct of the OHCAO project.
Andrew Whittington reports grants from the British Heart Foundation, personal fees from West Midlands Ambulance Service Foundation Trust, outside the submitted work.
Matthew Cooke, Charles Deakin, Chris Gale, Rachael Fothergill, Jerry Nolan, James Mapstone, Nigel Rees and A. Niroshan Siriwardena report no conflicts of interest.
Jerry Nolan, Gavin Perkins and Jasmeet Soar are editors of the journal resuscitation.

## Funding

The study is supported by research grants from the British Heart Foundation and Resuscitation Council (UK). GDP is supported as NIHR Senior Investigator and Director of Research for the Intensive Care Foundation. Samantha Brace-McDonnell is supported by an NIHR Clinical Doctoral Fellowship

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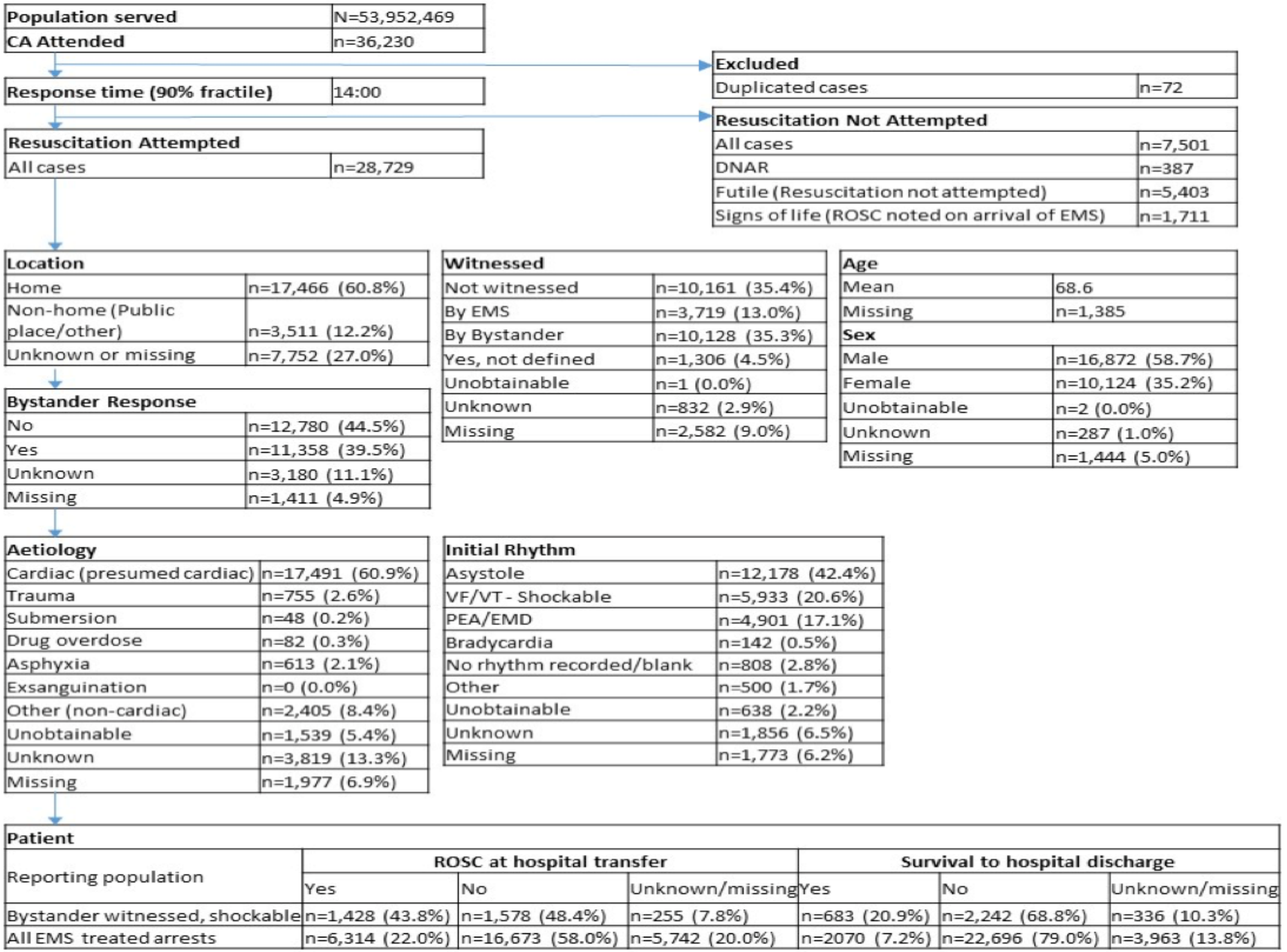
*Figure 1: Utstein flowchart of 2014 OHCA events treated by EMS in England*



| Population served | N=53,952,469 |
|---|---|
| CA Attended | n=36,230 |

| Excluded | |
|---|---|
| Duplicated cases | n=72 |

| Response time (90% fractile) | 14:00 |
|---|---|

| Resuscitation Not Attempted | |
|---|---|
| All cases | n=7,501 |
| DNAR | n=387 |
| Futile (Resuscitation not attempted) | n=5,403 |
| Signs of life (ROSC noted on arrival of EMS) | n=1,711 |

| Resuscitation Attempted | |
|---|---|
| All cases | n=28,729 |

| Location | |
|---|---|
| Home | n=17,466 (60.8%) |
| Non-home (Public place/other) | n=3,511 (12.2%) |
| Unknown or missing | n=7,752 (27.0%) |

| Witnessed | |
|---|---|
| Not witnessed | n=10,161 (35.4%) |
| By EMS | n=3,719 (13.0%) |
| By Bystander | n=10,128 (35.3%) |
| Yes, not defined | n=1,306 (4.5%) |
| Unobtainable | n=1 (0.0%) |
| Unknown | n=832 (2.9%) |
| Missing | n=2,582 (9.0%) |

| Age | |
|---|---|
| Mean | 68.6 |
| Missing | n=1,385 |
| **Sex** | |
| Male | n=16,872 (58.7%) |
| Female | n=10,124 (35.2%) |
| Unobtainable | n=2 (0.0%) |
| Unknown | n=287 (1.0%) |
| Missing | n=1,444 (5.0%) |

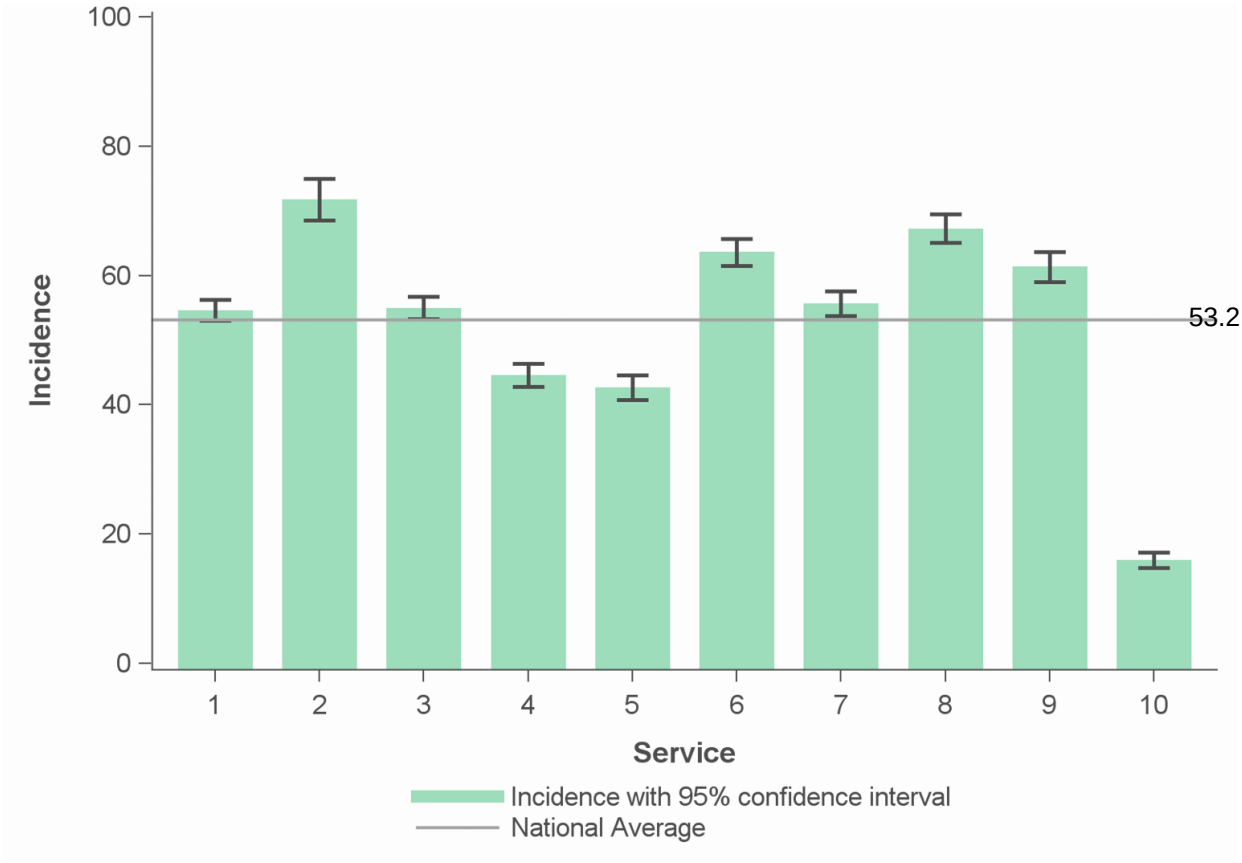
| Bystander Response | |
|---|---|
| No | n=12,780 (44.5%) |
| Yes | n=11,358 (39.5%) |
| Unknown | n=3,180 (11.1%) |
| Missing | n=1,411 (4.9%) |

| Aetiology | |
|---|---|
| Cardiac (presumed cardiac) | n=17,491 (60.9%) |
| Trauma | n=755 (2.6%) |
| Submersion | n=48 (0.2%) |
| Drug overdose | n=82 (0.3%) |
| Asphyxia | n=613 (2.1%) |
| Exsanguination | n=0 (0.0%) |
| Other (non-cardiac) | n=2,405 (8.4%) |
| Unobtainable | n=1,539 (5.4%) |
| Unknown | n=3,819 (13.3%) |
| Missing | n=1,977 (6.9%) |

| Initial Rhythm | |
|---|---|
| Asystole | n=12,178 (42.4%) |
| VF/VT - Shockable | n=5,933 (20.6%) |
| PEA/EMD | n=4,901 (17.1%) |
| Bradycardia | n=142 (0.5%) |
| No rhythm recorded/blank | n=808 (2.8%) |
| Other | n=500 (1.7%) |
| Unobtainable | n=638 (2.2%) |
| Unknown | n=1,856 (6.5%) |
| Missing | n=1,773 (6.2%) |

| Patient | | | | | | |
|---|---|---|---|---|---|---|
| Reporting population | ROSC at hospital transfer | | | Survival to hospital discharge | | |
| | Yes | No | Unknown/missing | Yes | No | Unknown/missing |
| Bystander witnessed, shockable | n=1,428 (43.8%) | n=1,578 (48.4%) | n=255 (7.8%) | n=683 (20.9%) | n=2,242 (68.8%) | n=336 (10.3%) |
| All EMS treated arrests | n=6,314 (22.0%) | n=16,673 (58.0%) | n=5,742 (20.0%) | n=2070 (7.2%) | n=22,696 (79.0%) | n=3,963 (13.8%) |

*Figure 2: Incidence of cardiac arrest where resuscitation is commenced or continued by EMS per 100,000 English population in 2014 at service and national level (top) and Number of cardiac arrest events (bottom) by service (total n=28,729)*



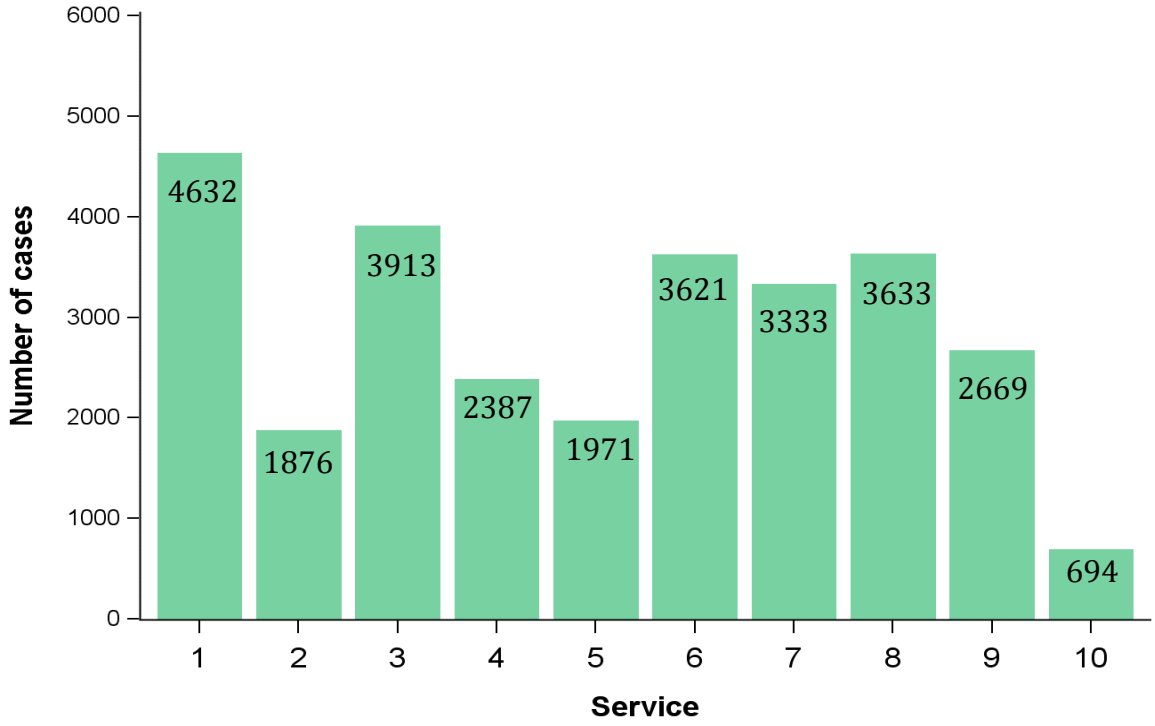
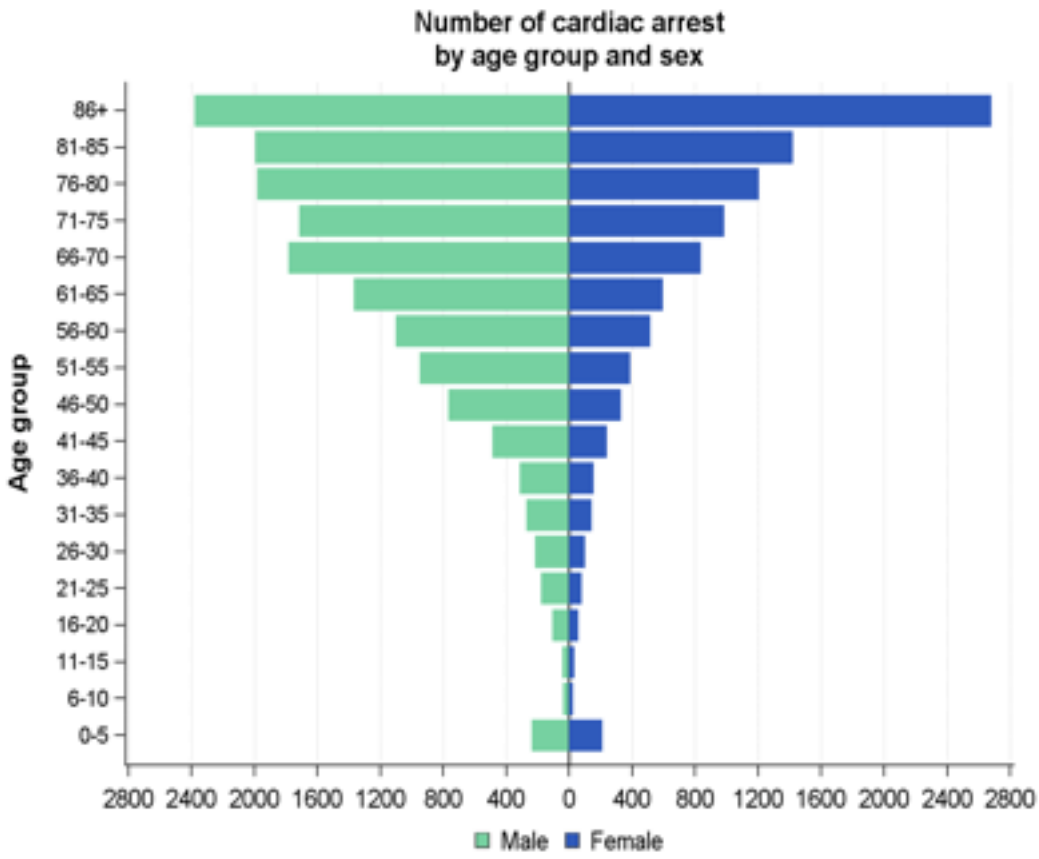



*Figure 3: Number (top) and incidence (bottom) of cardiac arrest with resuscitation commenced or continued by EMS by age group and sex*



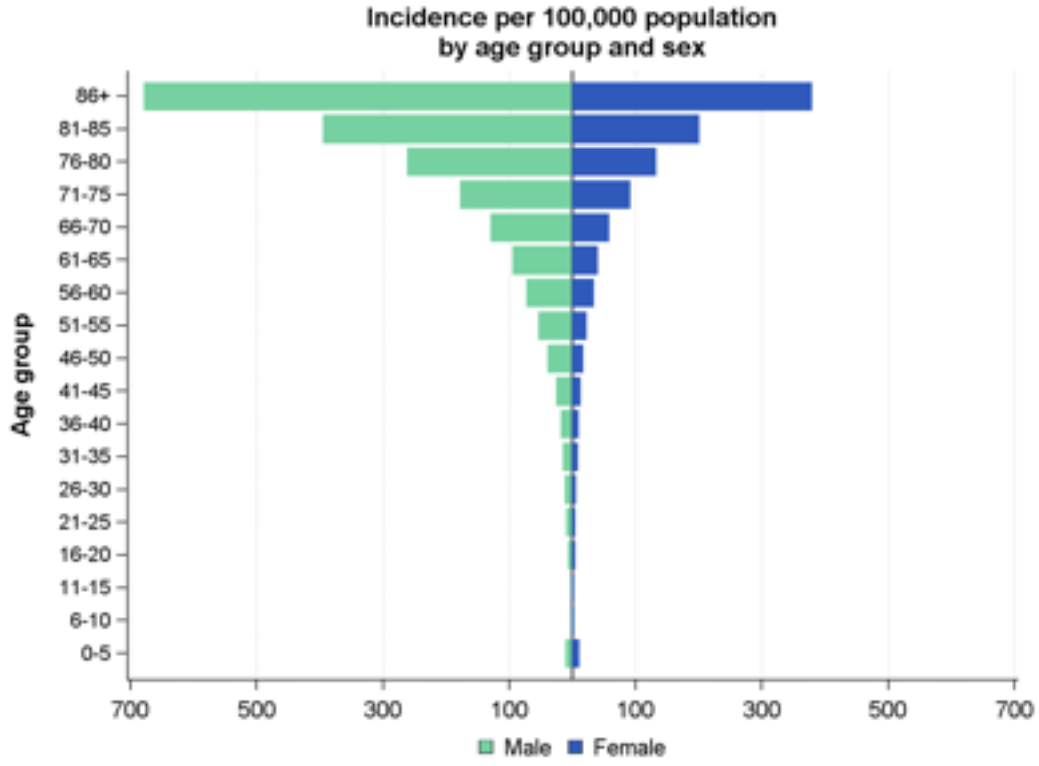



*Figure 4: Rate of OHCA cases where resuscitation was commenced or continued by EMS with ROSC at hospital transfer (green) and survival to hospital discharge (blue) by service with 95% confidence interval. Note: Service 2 & 4 excluded due to incomplete ROSC at hospital transfer data and Service 2, 4 & 10 excluded due to incomplete survival to hospital discharge data.*

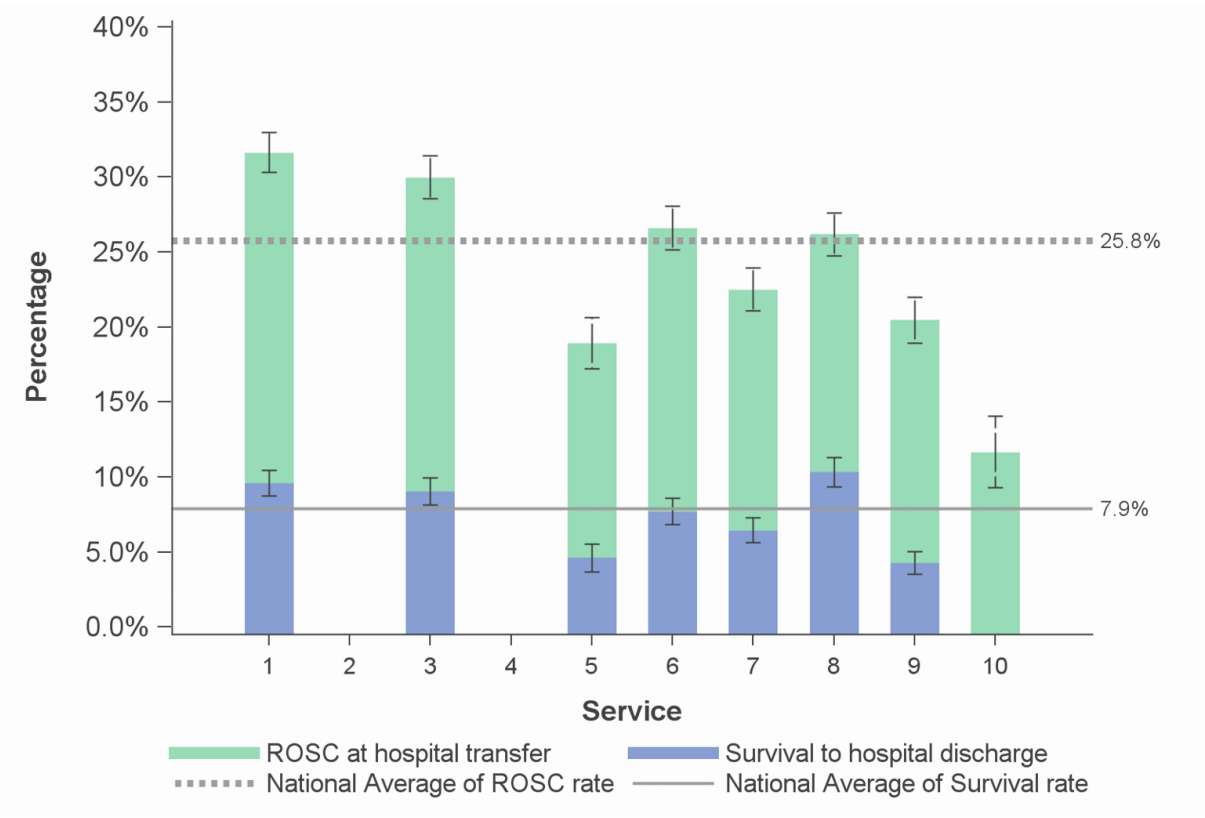


*Figure 5: Shockable rhythm in Utstein groups by EMS arrival time and survival to hospital discharge in Utstein groups by EMS arrival time.*