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Extended Research Article

Optimisation of the deployment of automated external defibrillators in public places in England

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Scientific summary

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Scientific summary

Background

Annually, English ambulance services treat over 30,000 people who have sustained an out-of-hospital cardiac arrest (OHCA), about 25% of whom achieve a return of spontaneous circulation by the time of hospital handover and 8.5% survive to 30 days. The chain of survival shows the essential elements required in an emergency care system to improve outcomes from an OHCA. The first two links – early recognition and early cardiopulmonary resuscitation – can buy time for the OHCA patient but are not definitive treatments in themselves. The key and most effective treatment for an OHCA is defibrillation. Prompt treatment with an automated external defibrillator (AED), within 3–5 minutes of collapse, can lead to survival rates in excess of 50%. Public-access defibrillation (PAD) refers to the use of AEDs by members of the public. PAD programmes allow the community access to this life-saving intervention while waiting for ambulances to arrive. The importance of PAD is growing given the increasing demands on ambulance services that are making reaching OHCAs in a timely manner challenging. However, at present, only a small proportion of patients are treated by PAD (5%).

A fundamental, structural barrier, which limits opportunity for the use of AEDs, is their location in the community. There has been no clear strategy in the UK on where AEDs should be placed; the choice of where to install them in public places has been driven mainly by local ad hoc initiatives. This approach is limited and there is a call for an evidence-based strategy, and a requirement to identify the optimal location for an AED to improve OHCA coverage, to improve the chances of survival.

Objectives

The primary objective of this study was to optimise the placement of public-access AEDs in England, using mathematical modelling techniques, to maximise the likelihood that an individual sustaining an OHCA will have access to PAD, improving their chances of survival. The secondary objective was to assess the cost-effectiveness of optimised public-access AED placement compared to current and alternative-placement strategies.

Methods

Ethics and regulatory approvals

Following Health Research Authority guidelines, the study did not require formal NHS Research Ethics Committee approval. The study was approved by the University of Warwick's Biomedical and Scientific Research Ethics Committee (BSREC 118/18-19). The project was co-sponsored by the University Hospitals Birmingham NHS Foundation Trust and the University of Warwick. The Out-of-Hospital Cardiac Arrest Outcomes (OHCAO) registry has approval from the Confidentiality Advisory Group to collect and process identifiable patient information where it is not practical to obtain consent (22CAG0072 and 22CAG0087). Ethics approval for the OHCAO registry was gained from the National Research Ethics Committee South Central (13/SC/0361).

Design

This was a secondary analysis of data that were collected by the OHCAO registry on historical OHCAs, data held by ambulance services on the location of AEDs registered with them, and locations of points of interest (POIs) available from Ordnance Survey. Also, data were obtained on the census neighbourhood characteristics of areas of England.

The study was divided into four work packages (WPs): (1) exploration of the characteristics and coverage of current locations of AEDs relative to the location of historical OHCAs; (2) comparison of the OHCA coverage of various AED deployment strategies (POIs and grid-based) and an optimisation model with the current coverage; (3) determination of the cost-effectiveness of the strategies in WP2 compared to current placement (CP); and (4) development of a national consensus of the optimal location for public-access AEDs.

Statistical analysis

Descriptive statistics were used to analyse for any differences in neighbourhood characteristics where OHCAs occurred and registered AEDs were located.

Using geographical information system software, we calculated the walking distance between OHCA locations and locations of registered AEDS and POIs designated as potential sites for AED (e.g. pubs, places of worship, schools, halls and community centres, and cash machines). Assumed coverage was calculated as the proportion of OHCAs within 500 m of a registered AED or POI, assuming the latter were accessible 24 hours a day, 7 days a week. Actual coverage was calculated based on when the OHCA occurred and the working hours of the AED locations. Using these definitions, we then calculated coverage loss as assumed coverage minus actual coverage divided by assumed coverage. Coverage efficiency was calculated as the number of OHCAs covered divided by the number of POIs.

For the optimisation part of the study, mathematical models for maximal coverage location problem were adapted. These mathematical models were based on seminal literature in operational research, specifically within the area of facility location optimisation (maximal covering location problem). The model took in information for historical OHCAs, as well as locations of existing AEDs and candidate future AED locations. It then determined the optimal locations for future AED placement so that OHCA coverage was maximised and the number of AEDs required to maximise coverage.

For the cost-effectiveness analysis a de novo decision-analytic model was developed and used as a vehicle for assessing the costs and benefits of deployment strategies at POIs compared to current AED placement. The model was developed in line with recommended ‘good practice’ guidelines and, where relevant and possible, in accordance with requirements for economic evaluation aiming to inform decision-making in the UK.

A stakeholder meeting was convened towards the end of the study that brought together groups interested in AED deployment. Results of the study were presented and discussed. Then three groups were organised to discuss: (1) what strategies should be used to increase the distribution of AEDs in communities; (2) what guidance should be provided for where to place AEDs in communities; and (3) what further research would be required.

Patient and public involvement

The project was designed to ensure meaningful patient and public involvement (PPI) was embedded throughout the study. The PPI co-applicant was involved from the conception of the study and made valuable contribution to the development of the proposal, and reviewed and commented on work at various stages of the project. Presentations were made to the National Institute for Health and Care Research (NIHR) Clinical Research Ambassadors Group, based at the University Hospital Birmingham NHS Foundation Trust. There were two PPI representatives on the Steering Committee, and at the stakeholder meeting there were representatives of two charities.

Results

The study looked at the location of 147,278 historical OHCAs (2014–9) and 32,491 AEDs, and 14 potential POIs.

Current coverage

Historical OHCAs were observed to occur in more urban areas with a high population density. These areas had a larger proportion of workers in routine jobs or unemployed and people from non-white ethnic groups, and a great degree of deprivation. In contrast, AEDs were placed in more affluent areas that had lower proportions of people from non-white ethnic groups. About 43.4% of the areas (the lower-level super output area) were found to not have a single AED located within their boundary. The average OHCA–AED distance was 1014 m (median 638 m). The number of OHCAs occurring within 100 m of an AED was 7965 (5.4%) and within 500 m was 57,225 (38.9%).

Alternative coverage: points of interest

The numbers (percentages) of OHCAs that were covered by each POI, ignoring the currently registered AEDs, varied greatly, from 7.4% by state secondary schools to 55.1% by cash machines. Similarly, of those OHCAs not covered by a currently registered AED, the proportion then covered by one of the POIs ranged from 5.5% by state secondary schools to 46.0% by cash machines. The proportion of OHCAs that were covered by a registered AED or a POI also ranged significantly, from 42.2% by state secondary schools to 67.0% by cash machines.

Coverage loss for cash machines, care homes and community halls was assumed to be zero because the AEDs at these locations were presumed to be accessible all the time. Loss was greatest for state schools, if we assume that all the OHCAs that occur outside of normal state school opening times there will be no access to an AED.

Coverage efficiency also varied significantly and ranged, based on assumed coverage, from about 150% in pubs to just under 450% in post offices, chemists, dentists, general practitioner surgeries and supermarkets.

Alternative coverage: 1 km^2 grids and census output areas

If the country was divided up into 1 km^2 grids, coverage of OHCAs would be significantly greater if we were to deploy an AED at the centre of each grid: 116,016 (78.8%). If we were also to consider the location of existing registered AEDs, the coverage would be 133,901 (90.9%). Alternatively, if we were to place an AED at the centroid of every census output area the coverage would be 57,134 (38.8%), and 97,718 (66.3%) if we included the location of existing AEDs.

Alternative coverage: optimisation model

The optimisation model was observed to show that if AEDs were placed in each POI location, OHCA coverage levels would not reach that of optimisation-based placement. For example, if an AED were placed in every pub in the West Midlands (n = 3573), it would result in additional coverage of 17.8% above that provided by existing registered AEDs. However, the same amount of added OHCA coverage could be achieved with only 250 optimised grid points spaced 1 km apart. The coverage efficiency provided by the optimised grid points was unmatched by any POI in any region.

Cost-effectiveness

Compared to current AED placement, all of the alternative deployments assessed were associated with a greater expected total cost per OHCA for a small increase in quality-adjusted life-years (QALYs) and life-years gained (LYGs). The most cost-effective option was halls and community centres. Compared to CP, this deployment option resulted in higher costs [£223, 95% confidence interval (CI) generated from probabilistic sensitivity analysis (PSA) distribution: £148 to £330], a higher number of QALYs (0.007, 95% CI generated from PSA distribution: 0.004 to 0.011) and an incremental cost-effectiveness ratio (ICER) of £32,418 per QALY (£18,893 per LYG). This value is above the upper bound of the £20,000–30,000 per QALY range that is often seen as a maximum ICER considered for decision-making in health care.

Stakeholder meeting

The meeting agreed that the current distribution of registered publicly accessible AEDs was suboptimal and that there was a disparity in their location in respect of deprivation and other health inequalities.

Conclusions

Automated external defibrillators are potentially life-saving devices for people who sustain an OHCA. AEDs need to be placed intelligently in public settings so that they are likely to be used by bystanders. We have developed a data-driven framework to support public-access AED location decisions, using optimisation and statistical models. We applied the methodology to real data from England. Results have demonstrated that optimising AED locations can result in substantial improvement in coverage compared to the current approach to AED deployment.

We developed a de novo decision-analytic model to determine the costs and benefits associated with AED placement strategies in each of the different POIs and compared these against current AED placement. Results of the economic analysis showed that all of the alternative placements considered were associated with ICERs above £30,000 per additional QALY.

Study registration

This study is registered as researchregistry5121.

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